A framework for processing and presenting parallel text corpora

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Abstract

This thesis describes an extensible framework for the processing and presentation of multi-modal, parallel text corpora. It can be used to load digital documents in many formats like for example pure text, XML or bit-mapped graphics, to structure these documents with a uniform markup and link them together. The structuring or tagging can be done with respect to formal, linguistic, semantic, historical and many other aspects. Different, parallel taggings are possible for a document and the documents marked up this way can be linked together with respect to any of these structures. Depending on the nature of the tagging and the scope of the linking, they can be performed automatically, semi-automatically or manually.

As a foundation of this work, XTE, a simple but powerful XML standoff annotation scheme has been developed and realized as a DTD and as an XML Schema. XTE is especially well suited for the encoding of multiple, overlapping hierarchies in multi-modal documents and for the cross linking of the elements of these encodings across several documents.

Together with XTE, elaborate editor and browser applications have been developed which allow the comfortable creation and presentation of XTE encoded documents. These applications have been realized as a configurable and extensible framework that makes it easy for others to extend, customize and adopt the system for their special needs. The combination of a classical textual synopsis with the supplementary options of dictionaries, encyclopedias, multi-media extensions and powerful tools opens a wide area of applicability for the system ranging from text analysis and language learning to the creation of critical editions and electronic publishing.

As a side effect of the main topic, different tools for program and software documentation have been developed and a new and innovative, multilingual user interface has been created. The documentation tools have been used to document the components of the framework while the new user interface has been built into the created applications.

Zusammenfassung

Diese Arbeit stellt ein erweiterbares System für die Bearbeitung und Präsentation von multi-modalen, parallelen Textkorpora vor. Es kann dazu verwendet werden um digitale Dokumente in vielerlei Formaten wie zum Beispiel einfache Textdateien, XML-Dateien oder Graphiken zu bearbeiten wobei bearbeiten in diesem Zusammenhang vor allem strukturieren und verlinken bedeutet. Diese Strukturierung nach einem neu entwickelten Kodierungschema kann zum Beispiel auf formalen, linguistischen, semantischen, historischen oder auch vielen anderen Gesichtspunkten beruhen. Die Dokumente können gleichzeitig mit beliebig vielen parallelen und sich möglicherweise auch überlappenden Strukturen versehen werden und bezüglich jeder dieser Strukturen auch miteinander verknüpft werden. Die unterschiedlichen Strukturen können je nach Art entweder automatisch oder halbautomatisch erzeugt werden oder sie können vom Benutzer manuell spezifiziert werden.

Als Grundlage des vorgestellten Systems dient XTE, ein einfaches aber zugleich mächtiges, externe Kodierungsschema das sowohl als eine XML DTD als auch als ein XML Schema verwirklicht wurde. XTE ist besonders zum Kodieren von vielen, sich gegenseitig überlappenden Hierarchien in multi-modalen Dokumenten und zum Verknüpfen dieser Strukturen über mehrere Dokumente hinweg, geeignet.

Zusammen mit XTE wurden zwei ausgereifte Anwendungen zum Betrachten und Bearbeiten von XTE-kodierten Dokumenten sowie zum komfortablen Arbeiten mit den so erstellten Ergebnisdokumenten geschaffen. Diese Anwendungen wurden als anpassbares und erweiterbares System konzipiert, das möglichst einfach für andere Einsatzgebiete und an neue Benutzerwünsche angepasst werden können soll. Die Kombination einer klassischen Synopse zusammen mit den vorhandenen Erweiterungsmöglichkeiten mittels Wörterbüchern, Lexika und Multi-Media Elementen die das System bietet, machen es zu einem Werkzeug das auf vielen Gebieten, angefangen von der Text-Analyse und dem Sprachenlernen über die Erstellung textkritischer Editionen bis hin zum elektronischen Publizieren, einsetzbar ist.

Neben diesem System sind als weitere Ergebnisse dieser Arbeit verschiedene Werkzeuge für die Softwaredokumentation entstanden und zur Dokumentation des Systems eingesetzt worden. Weiterhin wurde eine neuartige, mehrsprachige, graphische Benutzeroberfläche entwickelt, die unter anderem in dem hier beschriebenen System eingesetz wurde.

Contents

Chapter 1

Introduction

Although we live in the electronic age and electronic media is a natural component of our everyday live, written text is still the main means of storing and communicating information. It was the development of scripts that allowed it for the first time to make ideas that have been thought and expressed in natural language to be made persistent across time and space. It was the different writing systems which made it possible to communicate knowledge not only from man to man, but also from one generation to all the subsequent generations and thus directly led to the development of the human culture.

From the very beginning the results of writing became manifest in many different ways. It may have started with scribing into clay, carving into stone and wood or painting on walls. It developed further from writing on papyrus up to printing on paper and finally typing keys on a keyboard and storing the results on a magnetic or optical media the content of which can be displayed on a screen or printed on a printing device. This evolution finally led to a tremendous number of texts being available today in many different formats, languages and scripts.

Now, with the possibilities offered by the computer and information technology, we have the unique possibility to collect, edit and structure all these texts, no difference in which format, language or script they exist, such that they are available to everybody who has access to these new technologies.

This work will present an extensible framework that allows the processing, structuring, analyzing and finally the presentation of texts from arbitrary sources. Special emphasis will be placed on the comparative processing of related texts such as translations or synopses, linking these texts together and finally integrating other tools like for example dictionaries with the texts in order to increase the comprehension of the original versions. As the word "text" itself derives from the Latin *texere - to weave*, it seams natural to finally represent related texts in a form that makes it possible to "weave them together" in a sophisticated way.

1.1 Text encoding

The expression "text encoding" is sometimes misleading and overloaded with several different meanings in the area of text processing. Throughout this chapter we will use it as an expression that denotes the way in which single characters or ideographs are presented electronically on a computer system. It is not to be confused with markup schemas like for example the Text Encoding Initiative (see section 1.2.3) that are often also called "encodings".

1.1.1 History of text encoding

As we know today, there is no canonical way to convert spoken or thought language to text. Different cultures have developed different writing systems to record language.

The oldest scripts we know of consist of hieroglyphics, which may be thought of as iconic representations of the concept they intend to describe. Further on, some cultures developed ideographic scripts that also use graphic symbols to represent objects or ideas, but in some more abstract way than it is was done by the hieroglyphics. Other cultures developed alphabetic scripts, where each symbol represents a phoneme of the language. A sequence of these symbols, which together mimic the pronunciation of an object or an idea in the corresponding spoken language, must be used to represent it in textual form.

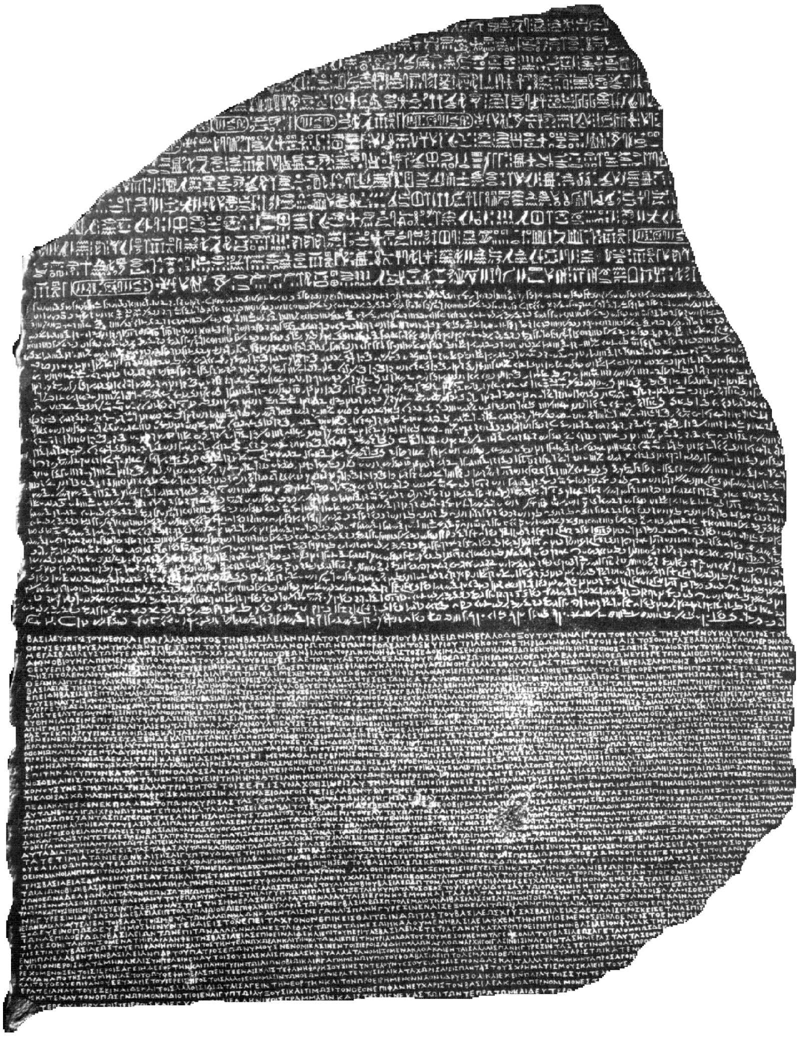


Figure 1.1: A picture of the famous "Rosetta Stone" [Park]. Dated back to 200 BC, it is not only an example of how characters have been engraved into stone, but also the first evidence of a synopsis. It contains the same text in two different languages written with three different scripts. The upper and the middle part both contain Egyptian versions written with a hieroglyphic and a demotic script respectively while the lower part contains the Greek version of the text.

Common to all these different approaches however was the fact that the resulting text consisted of a sequence of graphic symbols out of a fixed set of available symbols. We call each of these symbols a character [1].

In the early days of writing, creating textual representations of language has always been a manual task. And in order to make their texts understandable to others, writers had to adhere to certain "standards" concerning the shapes of the different characters. This however did not prevent them from turning writing into a highly creative and artistic process as can be seen for example when looking at calligraphic masterpieces of medieval writers.

The situation changed drastically after Johannes Gutenberg invented the printing press in the middle of the 15th century. Single letters were efficiently molded and casted from metal resulting in movable metal types with their lead base width varying according to the letter's size. Every page of a book could now be assembled easily from these types. And because the shape of a letter was exactly the same at every position on a page and everywhere in a book, this led to a perfect regular appearance.

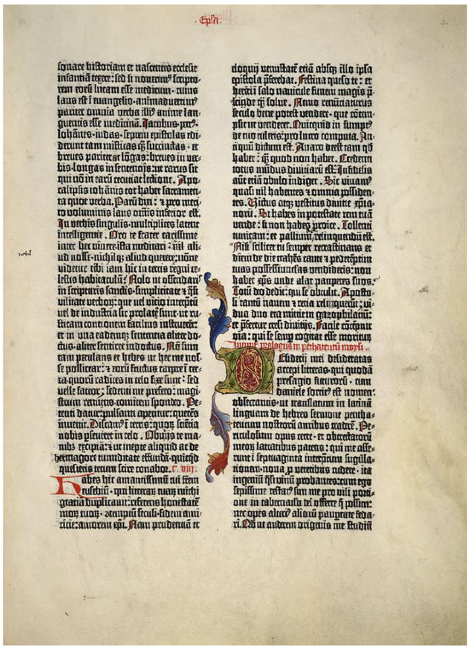


Figure 1.2: A page of the famous Gutenberg bible. The bible was printed using two columns where each of them contained 42 lines of black letters. The coloring was done later on manually, as well as the painting of the initials, for which place had been reserved already on the page. (Picture taken from [GJ].)

In the middle of the 19th century, the typewriter was invented. This was a mechanical machine, which had a built-in metal type for every letter of the Latin alphabet. This type was coupled with a key on the keyboard of the typewriter such that the user could print a letter by pressing the corresponding key. Because of physical constraints, a typewriter could not contain more than the amount of letters and numbers available in the Latin script. And in order to simplify the machinery, all the letter types had the same extent. So in fact the invention of the typewriter was at the same time the invention of mono-spaced fonts.

Because of the limited number and fixed size of their types, documents created with a typewriter did not look very impressive from a typographic point of view. Gutenberg for example not only used proportional types for the first printed bible [GJ], but also a typeset

[1] Following [MW] the word "character" is derived from the Greek *charaktEr* which itself derives from *charassein* and means as much as "to scratch" or "to engrave" which immediately leads us back to the very first text evidences we are aware of today and which have been scratched into clay or have been engraved into stone

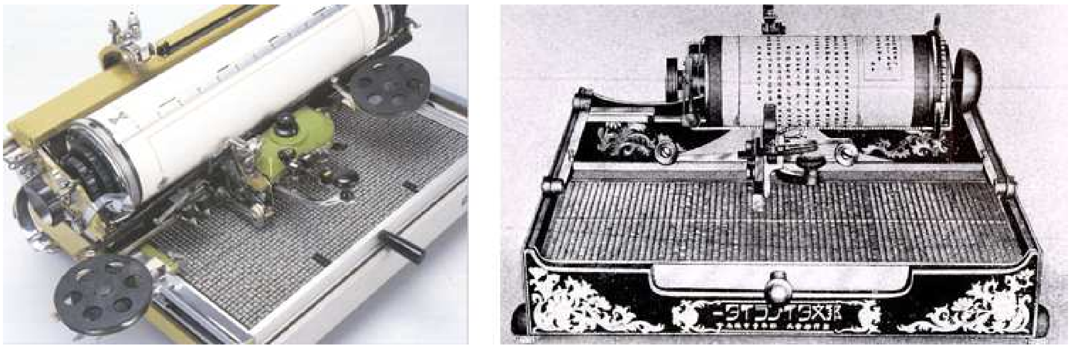


Figure 1.3: Even though the first typewriters where restricted to Latin characters, they have been quickly adopted to other scripts like Greek or Cyrillic. As these pictures show, even typewriters for Chinese and Japanese have been developed. They could handle between 2000 and 4000 ideographs, however at a moderate writing speed.

of about 290 different letters, which contained several, slightly varying sizes for each letter and a set of ligatures for common two and three letter combinations.

1.1.2 Electronic character encodings

After IBM invented the first electric typewriter in the 1960s, the 1970s brought us the first microcomputers. And one thing for which micro or personal computers have always been used ever since (besides playing and calculating) is writing. Here for the first time characters had to be encoded in binary form. And because memory was very precious at that time, programmers have been very conservative when they had to choose a coding scheme.

In 1960, R.W. Bemer described in a survey [BE60] the big number of different character encodings available at that time. This was the starting point for the creation of the ASCII (American Standard Code for Information Interchange) standard [BSW, BE63]. ASCII was still a 7-bit encoding, but with the help of escape sequences it was possible to express characters that did not fit in the set of the original 128 characters.

Later on, in the 1980s, the European Computer Manufacturer's Association (ECMA) [ECMA] created a 8-bit encoding family, which contained the ASCII characters as a subset and used the additional 128 code points to encode other alphabetic languages such as Cyrillic, Arabic, Greek, Hebrew and the various special characters needed for the European languages written with Latin characters. These encodings have been endorsed by the International Standards Organization (ISO) [ISO] as the ISO 8859 family of encodings.

But these encodings still had some drawbacks: they combined the standard Latin characters available in ASCII with just one single national character set. So for example ISO 8859-5 could be used to write texts that used Latin and Cyrillic characters and ISO 8859-1 could be used to write texts that contained German umlauts and French accented characters. However it was still not possible to use one of these standard encodings for writing texts which contained Cyrillic as well as special German and French characters. Another problem was that ideographic scripts with theirs thousands of symbols could not fit naturally within an 8-bit encoding. Therefore special escape sequences, which where unhandy because they required complicated parsing, had to be used in these cases. Additionally, the character represented by an arbitrary code point became ambiguous because it was depended from the characters and escape sequences that had been read just before it.

The Unicode Standard

All these problems led to the foundation of the UNICODE consortium [UNI] in 1991 with the goal to create a universal, efficient, uniform and unambiguous character encoding not only for all the written languages used today in the world but also for punctuation marks, mathematical and technical symbols and eventually for historic scripts. The Unicode consortium synchronizes its work with ISO such that the Unicode 3.0 standard [U30] is actually equivalent with the ISO 10646 standard.

Unfortunately Unicode is a 16-bit encoding, which by default can handle about 65.000 characters. This is still a tribute to memory requirements and was dictated by the widespread use of 16-bit computer architectures at the end of the 1990s. With the help of so called "surrogate pairs" however, it is possible to encode about one million different characters.

Although the Unicode standard is still under active development and more and more scripts get added as time goes by (Unicode 3.0 defines 49.194 different characters, symbols and ideographs), Unicode also reserved certain code areas for private use if there is a special need for characters not currently encoded by the standard.

But Unicode also does a lot more than just defining a code point for a given character. Because many scripts have special requirements like for example changing the writing direction or special obligatory ligatures and because in some scripts new characters can be built by combining two or more existing characters, the Unicode standard also provides support for normalization, decomposition, bidirectional behavior and efficient searching and sorting.

Meanwhile, the Unicode standard gained broad acceptance in virtually all areas of the computer industry. All modern operating systems as well as most of the modern programming languages and computer programs have support for Unicode today. Many new standards like for example XML and XHTML [XML, XHTML] depend on Unicode.

1.2 Text markup

From the beginning computers have been used for writing and text processing. Usual typewriters were used as printing devices to output the texts. Because of the deficiencies mentioned at the end of section 1.1.1, the visual appearance of these works was not very appealingly. For this reason text processing with computers was first used for administrative purpose only.

After the appearance of the first matrix printers (Epson claims to have introduced the first personal computer printer, the MX 80, in 1978) the situation changed. Now it became feasible to print not only different fonts in different sizes and styles, but also graphics and pictures. After Xerox finally invented the laser printer in 1978 and HP shipped the first laser printers for the mass market in 1984 and the first ink-jet printers in 1988, the output created with such devices became comparable with the one produced by traditional print offices. The time was ripe for the so-called "desktop publishing" era.

1.2.1 Text processing

The only remaining problem was the fact that the screen devices and graphics hardware could not keep up with the development of printing devices. For a long time they only supported the display of text in a fixed sized font, usually based on ASCII or an 8-bit encoding. So the first text processing programs defined special commands or macros that could be inserted into the running text. These commands had the only purpose to change the appearance of the text such as its size or style. Some programs like for example WordStar, one of the first word processing programs produced for microcomputers and released back in 1979, could use the bare printer escape sequences for this purpose.

One of the oldest text formatting programs is nroff/troff by J. F. Ossanna [Os76] from AT&T. Its origins can be traced back to a formatting program called runoff, written by J. E. Saltzer, which ran on MIT's CTSS operating system in the mid-sixties. Later on, troff was rewritten by Brian Kernighan [Ke78] in C and became a de facto standard on Unix machines [EP87]. It provided macros, arithmetic variables, operations, and conditional testing for complicated formatting tasks. Many macro packages have been written for the different *roff formatting programs, one of the most famous being the man macro package for the formatting of Unix manual pages.

Donald Knuth, one of the pioneers of computer science, invented his own typesetting program called TEX [Kn91] sometimes back in 1978. In fact TEX was a domain specific programming language dedicated to typesetting. It supported macros defined by the user. These macros took text as arguments and formatted it in a special way. Later on, Leslie Lamport extended TEX by a standard macro set called LATEX [La86]. This was a fundamental change from a purely visual or procedural markup towards a kind of structural or descriptive markup[2] . So instead of writing {\bf Section title} in order to set a section header in bold face, the user could write now \section{Section title} to declare a sentence as section header. By including a certain "style file" he could influence how a section header would be formatted. In fact, style files contained only implementations of the structural markup macros. However, because structure was separated from appearance, it became much easier to change the visual appearance of a whole document at once.

Another very old text processing system that is still in use and constantly revised today is TUSTEP [TU01, Ba95], the "Tübinger System of Text-processing Programs". In contrast to the two abovementioned programs, TUSTEP does a lot more than typesetting. It is also an extendable system of different tools that can be used to process the text in various ways, such as creating indices, annotations or apparatuses. Furthermore TUSTEP supports a lot of different, even ancient languages. It is primarily used to create critical editions, encyclopedias and reference books.

The development of TUSTEP started back in 1966, while the name TUSTEP was established in 1978. In the beginning TUSTEP also required a lot of formatting codes that had to be inserted right into the text in order to define the text layout. Today however, TUSTEP offers the possibility to use a custom markup for structuring texts. The markup can be bound to arbitrary visual formatting commands in order to produce printable or browsable output. This is a technique similar to the cascading style sheets used in HTML (see section 1.2.3). One interesting point is the fact that TUSTEP supports two different output modes: one that produces output in a mono-spaced font and one that produces high quality, postscript output. The first format is a reminiscence of the time when displays and printers supported only fixed sized fonts in one style.

1.2.2 General Markup Languages

In 1969, Charles Goldfarb, Edward Mosher and Raymond Lorie picked up an idea proposed already some time ago by William Tunnicliffe and Stanley Rice, and begun to develop a descriptive markup language called Generalized Markup Language (GML) [Go90]. However they not only generalized the generic coding ideas suggested so far but also introduced formally defined document types. The formal definitions that were derived from the BNF [Wir77] notation could be used to validate the markup of a document [Go81]. Their efforts finally led to the development of SGML, the Standard Generalized Markup Language.

[2] The concept of descriptive markup is also called *generic coding* by some authors.

SGML - The Standard Generalized Markup Language

In 1986 SGML was approved as an international standard by ISO [ISO] under the name ISO 8879. One important point about SGML is the fact that it is a generalized markup language not tied to any special content type, although it was strongly influenced by the needs of the publishing industry. Secondly, SGML does not define a particular markup syntax or special markup tags. Instead it provides authors with the possibility to create arbitrary document types by defining *document type definitions* (DTDs) and arbitrary markup conventions that are called *concrete syntax* in SGML.

Additionally, SGML defined several optional features, which can be used in an SGML document. For example one of these features is *CONCUR* which allows a document to contain different, maybe even overlapping, logical structures.

However this universality, which is one of the strength of SGML, also leads to many problems. It is quite hard to implement a conforming SGML system, that is a system that can process any standard conforming SGML document. Furthermore, an SGML document is in general much more verbose compared to a document which contains only procedural markup because the format of the latter is usually optimized to be as user friendly as possible and contains a lot of implicit information which has to made explicit in an SGML document. Therefore it is much harder for an author to manually create an SGML document and sophisticated tools are needed instead of simple text editors.

XML - The Extensible Markup Language

Sometime back in 1996 the World Wide Web Consortium (W3C) [WWW] formed a working group with the goal of bringing together the two powerful ideas of the Web and of descriptive markup. The intention was to develop a markup language that could be used easily on the Web while maintaining compatibility with SGML.

The result was the specification of XML, the Extensible Markup Language [XML], which was published as a W3C recommendation in 1998. Because of its simplicity - the initial specification consisted of 25 pages only - paired with its elegant design it was rapidly adopted by virtually all software vendors and became a de facto standard for data exchange.

The drawback of its simplicity is of course the fact that it cannot cover every desirable functionality. Therefore a big amount of accompanying specifications have been created in the last time in order to fill the gaps. But while XML itself is well established meanwhile, all the other auxiliary standards seem to suffer from the same problems like SGML did: they are difficult to understand and implement, often they are too specific to be of general interest and because they are developed by different working groups they often do not fit together very well. Section 2.1 will present some of the different XML related standards used throughout this work in more detail.

Publishing marked-up documents

Composing a document in a structured way is only the first step in the editing process. For publication, the document will usually have to be translated into another format. Depending on where it will be published, this may be HTML [HTML] for online publications or PS/PDF [PS, PDF] for printed ones. Another widely used possibility is to translate a marked-up document into one of the text processing systems described in section 1.2.1, like for example TEX or `troff` and let them produce the final output.

For documents defined in SGML or XML this transformation is usually done with a stylesheet language based on a stylesheet. The most common stylesheet languages in use today are the Document Style Semantics and Specification Language (DSSSL) for SGML documents which has been standardised by ISO [DSSSL], the Extensible Stylesheet Language (XSL) for XML which is a W3C recommendation [XSL] and finally Cascading Style Sheets (CSS) [CSS] which are a stylesheet language for HTML (see section 1.2.3).

Both, DSSSL and XSL define a vocabulary for specifying an abstract formatting description in the sense that the layout of a document may be specified in terms of typographic categories like paragraphs, flow objects, footnotes, headings, side marks and so on. While this so called style language is a part of the DSSSL standard, it is known under the separate name XSL Formatting Objects (XSL-FO) for XSL. Both style languages however leave the fine tuning of the typographic layout like for example line breaking and line balancing on a page to the formatter, whereby they are not yet tied to a special formatter.

One possibility to create the final, publishable document is by directly transforming the document description with the help of the DSSSL or XSL transformation languages[3] into the desired target format. The second possibility is to first transform to the abstract style language and then use a specific formatter (also called formatting engine) to create the final representation. The first path is often taken for online documentation published in the HTML format, while the second on is more common for high quality, printed output formats like PS or PDF.

1.2.3 Specialized Markup Languages for Text

HTML - The Hypertext Markup Language

The Hypertext Markup Language is the well-known lingua franca of the World Wide Web. Tim Berners-Lee and Robert Caillau developed it in 1989 at the Conseil Européen pour la Recherche Nucléaire (CERN), a high energy physics research center near Geneva. It was designed as a very simple markup language with a syntax based on SGML. It offered a minimalist set of tags, some style options and so called "hyperlinks" which could associate arbitrary HTML documents with each other. Like in the early text processing systems, structural markup was not strictly separated from visual markup.

Although it was primarily intended as a linked information system for high energy physicists it turned out to be extremely useful for making any kind of content available to others on a computer network. After the National Center for Supercomputer Applications (NCSA) at Urbana-Champaign encouraged Marc Andreessen and Eric Bina to develop Mosaic, a freely available, graphical HTML browser, the distribution of HTML grew exponentially, forming the corner stone of the World Wide Web, as we know it today.

Meanwhile, the development of HTML is controlled by the W3C. HTML has been revised and extended several times. The actual W3C recommendation is version 4.x [HTML]. In general however, HTML is moving towards XHTML [XHTML] that is a reformulation of HTML in XML syntax. It uses an own stylesheet language called Cascading Style Sheets (CSS) [CSS] to associate style information with the different elements.

DocBook

DocBook [WaMu] is a set of tags for describing books, articles and other prose documents, particularly about computer hardware and software, although it is not limited to these applications. It is defined as a native DTD for SGML as well as for XML.

It was started as a pure SGML DTD around 1991 in order to facilitate the exchange of Unix documentation by HaL Computer Systems and O'Reilly & Associates. Later on, many other computer companies have been involved in the further development and extension of DocBook. In 1998 finally, it became a technical committee of the Organization for the

[3] XSLT, the XSL Transformations Language is the second part of the XSL Specification. It is available as an own W3C recommendation [XSLT].

Advance of Structured Information Standards (OASIS) [OASIS]. Today both, SGML and XML versions are provided by OASIS [DocB].

There are two main ways to publish a DocBook document. The first one uses Jade [Jade], which is a free DSSSL processor and a DocBook style sheet to produce HTML, TeX, RTF [RTF] or MIF [MIF] output. The second way is to use an XSLT processor and produce either HTML output directly or XSL Formatting Objects that can in turn be processed by a formatting objects engine to produce PDF or TeX output.

Meanwhile DocBook is widely used for the documentation of software projects in the open source community, for example by the Linux Documentation Project [LDP].

<OeB> - Open eBook Publication Structure

The Open eBook Publication Structure [OeB] is a standard developed by major soft- and hardware companies which have joined in the Open eBook Forum [OeBF]. Its primarily intention is to facilitate and to advance the publication and representation of books in electronic form. The main target is to define a format in which content providers can publish their books such that they are readable on a variety of different reading systems no difference whether these systems are special hardware devices, special software or a combination of the two.

In order to simplify the transition from existing systems, OeB is based on several other, well-established standards. It is defined in XML and uses a subset of HTML 4.0 and CSS 1 for the description of content and appearance respectively. The Dublin Core meta-data language [DuCo] (also known as RFC 2413 [RFC2413]) is used to specify the bibliographic data and the Multipurpose Internet Mail Extensions (MIME) media types [RFC2046] are used to denote the type of embedded media objects.

TEI - The Text Encoding Initiative

TEI [SperBu] is a standard encoding scheme for the representation of all kinds of literary and linguistic texts. Like DocBook, it is in fact a set of tags defined in a DTD. TEI was launched in 1987 and has since than gained big acceptance especially in the linguistic and philological community. It is available as an SGML as well as an XML version.

While DocBook was designed in order to facilitate the writing of technical documentation, the main focus of TEI was the methodical markup of already existing documents to make them available electronically.

More than one hundred big projects which use the TEI encoding are registered at the TEI home page, most of them being digital libraries and text corpora. Although many of the documents encoded with TEI already exist in a printed version, there also exist various stylesheets that transform TEI-encoded documents to HTML, $\TeX$ or PDF. The main advantage of TEI for the humanities community however are the extended search capabilities offered by documents encoded in such a way, the possibility of easily generating statistics from them, and finally the possibility to easily interchange documents that are encoded in this format.

1.3 Scope and contribution

This thesis introduces a framework for structuring, analyzing and presenting texts in arbitrary languages and media formats. Although it can be used as a text processor or editor, the main application is not the support of the input and editing process of a text.

Instead, its main feature is the possibility to load digital documents in many formats (pure text, facsimile manuscripts, XML files), to structure these documents with a uniform markup and link them together. Structuring is used here in the sense of tagging a document with respect to formal, linguistic, semantic, historical or any other aspects. Different, parallel taggings are possible for a document and the documents marked up this way can be linked together with respect to any of these structures. Depending on the nature of the tagging and the scope of the linking, they can be performed automatically, semi-automatically or manually.

The documents processed this way can be combined with other tools like for example dictionaries or index generators and then be made available in a form in which they can be comfortably read, browsed, analyzed or transformed into other formats.

All this functionality is realized as a configurable and extensible framework where the word *framework* is used here in the sense of *software framework* as defined for example in [GHJV, Szy]. This makes it easy for others to extend, customize and adopt the system for their special needs where the target domains may be as different as for example text analysis, language learning, creation of critical and historical editions or electronic publishing. The framework is built around a new XML encoding scheme which is used as a standardized, persistent and media independent repository for all different kind of documents along with the different tagging and linking structures defined for them. The advantage of this format which is defined as an XML DTD and an XML Schema is the fact that the whole armada of XML-related tools can be used to process the documents, but also to easily transform them into other formats, exchange them or to use them independently of the framework.

As a side effect of the main topic, different tools for program and software documentation have been developed and a new and sophisticated, multilingual user interface has been created. The documentation tools have been used to document the components of the framework while the new user interface has been built into the created applications.

1.4 Structure of this work

The remainder of this thesis is organized as follows. The next chapter will describe XTE, a new XML markup scheme that can handle an arbitrary number of possibly overlapping hierarchies and which may be used not only with encoded texts but also with texts available in different media formats like graphics or sound.

Chapter 3 will then give a brief overview of the software architecture of the implemented system which consists of an extendable editor for the efficient and comfortable tagging and linking of texts with the new markup scheme (LanguageAnalyzer) and a viewer and browser application for displaying and working with these texts (LanguageExplorer).

Chapter 4 will give some implementation details and describe some general-purpose libraries that have been created during the development process. A new software documentation approach will be introduced which was used to document the system and a new and an innovative, multi-lingual user interface which is part of LanguageAnalyzer and LanguageExplorer will be presented.

Finally, the two applications LanguageExplorer and LanguageAnalyzer are described in full detail in chapter 5 and 6 respectively. A chapter containing references to related work, a discussion of the contributions of this thesis and an outlook on further research topics will conclude the work.

Chapter 2

A new markup scheme for text

Section 1.2 introduced some common text markup languages. This chapter will analyze the advantages and problems of the existing languages especially in the context of overlapping hierarchies. A new encoding scheme based on XML and some ideas of the Text Encoding Initiative [SperBu] will then be described which tries to eliminate the identified drawbacks of the other approaches. The new encoding will finally be formally defined as an XML DTD as well as an XML Schema.

2.1 A short introduction to XML

XML is a markup language developed by the W3C consortium [WWW] as a simple and general data interchange format for the World Wide Web. XML was intended to fill the gap between SGML and HTML, i.e. it should have a formal and concise design but at the same time it should be easy to create and process data in an XML format. The final specification defined a compatible subset of SGML on about 25 pages compared to the 500+ pages of the original SGML standard. The following description of XML does not pretend to completely and formally explain XML. Instead, it wants to give a short and simple introduction to the reader who is not familiar with XML in order to support the understanding of the following sections. For the complete specification refer to [XML].

An XML document is composed of markup and character data. The markup basically consists of opening, closing and empty tags and of comments and processing instructions. In order to distinguish markup from character data several special characters like `<`, `>`, `'`, `"` and `&` have to be escaped as `&lt;`, `&gt;`, `&apos;`, `&quot;` and `&amp;` when used in character data. A start tag is defined as <*tag-name*>, an end tag as </*tag-name*> and an empty tag as <*tag-name*/>. Start and empty tags may additionally contain an arbitrary number of attribute definitions of the form *key*='*value*' before the closing >. It is also possible to use double quotes instead of the single quotes. An element is either an empty tag or a composition of comments, processing instructions, tags and character data enclosed by a matching start and end tag, that is a start and an end tag with the same name.

A textual object is called a well-formed XML document if all the start and end tags are properly nested and matching and the whole document has a single root element. For illustration purpose a well-formed XML document can be imagined as a well-formed mathematical infix expression where operations, numbers and variables correspond to the XML character data and the different parentheses, brackets and curly braces correspond to the different XML tags respectively. Usually XML documents also contain an XML declaration of the form `<?xml version='1.0' encoding='utf8'>` as their first line which specifies the actual XML version and character encoding. The following listing shows a small XML file which illustrates the before mentioned properties:

Listing 2.1: A minimalist, well-formed XML example

```
<?xml version='1.0' encoding='utf-8'?>
<message style='bold'>
  Hello world!
</message>
```

As mentioned before, XML documents may also contain comments which are introduced by `<!--` and ended by `-->` and processing instructions which begin with `<?` and end with `?>`. While the meaning of comments needs no further explanation, processing instructions allow XML documents to contain instructions for the applications by which they will be processed. For convenience reasons, XML documents may also contain so called CDATA sections anywhere in the document where character data is allowed. CDATA sections are introduced by `<![CDATA[` and ended by `]]>`. They can contain arbitrary character data (except the character sequence `]]>`) which would have to be quoted elsewhere and can be used if a bigger part of text needs to be escaped because it would be recognized as markup otherwise. In order to specify characters not available in the current encoding, character references of the form `&#`*dec-number*`;` or `&#x`*hex-number*`;` can be used to refer to an arbitrary Unicode [U30] character code.

Document type definitions

So far we gave a coarse description of how an XML document looks like. However the XML standard also defines a possibility to restrict the structure of a document. The name and the nesting of elements and the name and type of the attributes allowed for each element can be defined inside the XML document or associated with it. Such a definition is called a document type definition (DTD) and an XML document that is well formed and fully complies with its DTD is called a valid document. XML parsers are not required to validate a document but they need to check at least if it is well formed. XML parsers which additionally check the validity of a document are called validating parsers. The document type of a document is given in its document type declaration that is located between the XML declaration and the root element and has the following form:

`<!DOCTYPE` *Name ExternalID*? [*intSubset*]? >

The optional *ExternalID* specifies the location of an external DTD while the optional *intSubset* defines the so-called internal subset of the DTD. In a valid document, the name given in the document type declaration has to match the name of the root element. Notice however, that neither an internal nor an external DTD must be available for a well-formed document. If both, the internal and an external DTD are present, they are merged together while internal definitions have precedence over external definitions with the same name. This fact can be used to customize a DTD as will be shown for example in section 2.4. Transforming the small XML example given above into a valid XML document could be done by adding an internal DTD as follows:

Listing 2.2: A minimalist, well-formed and valid XML example

```
<?xml version='1.0' encoding='utf-8'?>
<!DOCTYPE message [
  <!ELEMENT message (#PCDATA)>
  <!ATTLIST message style (normal|bold|italic) 'normal'>
]>
<message style='bold'>
```

Listing 2.2: A minimalist, well-formed and valid XML example (continued)

```
  Hello world!
</message>
```

The example shows how elements and attributes are defined with `ELEMENT` and `ATTLIST` statements respectively. The `ELEMENT` definition specifies the child elements which are allowed for an element with a notation similar to the regular expression syntax [Friedl] by using the meta-characters `(`, `)`, `,`, `|`, `?`, `*` for grouping, sequencing, alternation, option and repetition. The `ATTLIST` definition determines which attributes are allowed for an element and narrow their type.

Finally the document type definition can be used to define entities that will be expanded later on. Entities can be used for example to create abbreviations for frequently used text sequences to save the user from typing or to make a DTD itself customizable by defining certain parts of the DTD by means of entities. The first task can be solved with so called general entities which are defined in the DTD but which can be used only in the XML document. The second task may be accomplished with so called parameter entities that can be defined and used only inside the document type definition. The following lines show the format of general and parameter entities respectively:

`<!ENTITY` *Name* (*EntityValue*|*ExternalID*)`>`
`<!ENTITY %` *Name* (*EntityValue*|*ExternalID*)`>`

Notice that entity definitions can be used to include external files into a document type definition or into an XML file if the *ExternalID* declaration is present and references such a file. This functionality is comparable to the include mechanism available in C/C++ and many other programming languages. General entities are referenced as `&`*Name*`;` in the XML document while parameter entities have to be referenced as `%`*Name*`;` in the document type definition.

Although DTDs are widely used today to constrain the content of XML files and although there meanwhile exist a lot of quite complex XML vocabularies like DocBook and TEI [DocB, SperBu] that are defined as DTDs, the possibilities of DTDs are still quite restricted. It is not possible for example to constrain the ordering and number of child elements in an element with mixed content, that is an element which contains child elements as well as character content. The number of different attribute types is quite small and it is not possible to define new types. These problems led to the development of new and more sophisticated XML description languages. One of these languages called XML Schema Language has become a W3C recommendation in 2001 and will be introduced in section 2.1.2.

2.1.1 XML namespaces

One of the problems of document type definitions is the fact that they do not have a module concept and all the element and attribute definitions are located in a single global name space. This may lead to name clashes when bigger DTDs are developed or parts of a DTD should be reused.

These deficiencies led to the development of the XML namespace specification [XML-Na], which became a W3C recommendation in 1999. One of the important points about this specification is the fact that it does not change the underlying XML specification in any way but instead tries to define the namespace mechanism such that it remains fully compatible with the XML standard. This is achieved by giving the colon character '`:`' which is an ordinary character in XML a special meaning in name declarations. Following the namespace specification, XML names can be composed of a name prefix and a local name which are both separated by a colon. Such a name is called a qualified name. The namespace prefix can be bound to a namespace which is identified by a URI (Unique Resource Identifier) [URI] by using an attribute declaration of the form `xmlns:`*NSprefix*`='`*URI*`'`. This declaration binds the prefix *NSprefix* for the actual element and all other nested elements to the specified URI. In order to save the user from excessive typing in the case where most of the elements in a document belong to a single namespace, it is possible to declare a default namespace with the attribute `xmlns ='`*URI*`'`. After such a declaration all unprefixed elements are implicitly bound to belong to that default namespace. Namespaces apply equally well to attributes, that is attributes names can also be given as qualified names according to the XML namespace recommendation. It is essential to notice, that the prefix name can be chosen arbitrary. What counts is the associated URI, that is qualified names are bound to a URI corresponding to their actual prefix, not to the prefix itself.

Although XML namespaces are designed to fit smoothly into the XML specification without affecting it, this goal has not been fully achieved. One of the biggest problems is that DTDs are not namespace aware. Although it is possible to use qualified names in a DTD, the prefixes have no meaning. The consequence is that instance documents have to use exactly the same prefix as the DTD for a certain namespace. This is an anachronism however, because it leads to exactly the same problems that should be solved by namespaces. Although there exist some techniques as shown in section 2.4.1 and 2.4.3 to partially work around this problem the only real solution for the problem is to use another schema language instead of DTDs which is namespace aware.

2.1.2 XML schema languages

To overcome the deficiencies of document type definitions several new so called schema languages have been designed and developed [Relax, Trex]. Finally, the W3C consortium itself created a new schema language called XML Schema Language and made it a recommendation in 2001. One of the main features of XML Schema is the fact that the schemas themselves are completely written in XML and no additional syntax as for example the DTD syntax is required. XML Schema also supports namespaces and as such facilitates the modularization of schemas. It allows the definition of own simple and complex types and supports some object oriented features that allow type derivation and extension. Finally, the XML Schema language has a more flexible and powerful cross-document concept of keys and references than it is available in DTDs and allows a more fain grained constraining of the uniqueness of attribute and element values.

As an example of an XML Schema definition consider the following schema for the "Hello world!" example shown before:

Listing 2.3: An XML Schema for the "Hello world!"example that uses derivation by restriction.

```
<xsd:schema xmlns:xsd='http://www.w3.org/2001/XMLSchema'>
  <xsd:element name='message' type='messageType'/>

  <xsd:complexType name='messageType'>
    <xsd:simpleContent>
      <xsd:extension base='xsd:string'>
        <xsd:attribute name='style' type='styleType'/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:simpleType name='styleType'>
    <xsd:restriction base='xsd:string'>
```

Listing 2.3: An XML Schema for the ”Hello world!”example that uses derivation by restriction. (continued)

```
      <xsd:enumeration value='normal'/>
      <xsd:enumeration value='bold'/>
      <xsd:enumeration value='italic'/>
    </xsd:restriction>
  </xsd:simpleType>
</xsd:schema>
```

The XML Schema language is defined in two parts, namely XML Schema Structures [XMLSch1] and XML Schema Datatypes [XMLSch2]. Additionally, there exists a non-normative but a lot more readable document called XML Schema Primer [XMLSch2] that can be used as a simple introduction to the schema language. Finally notice that it is possible to automatically generate an XML Schema from an XML DTD although this transformation is not unique and that there exist several tools that accomplish this task [dtd2xsA, dtd2xsB].

2.1.3 XPath, XPointer and XLink

This section will describe some auxiliary XML standards which are of little use by themselves, but which are extensively used by other XML specifications. The first of these standards is XPath [XPath], a language for addressing the parts of an XML document. The need for such a language evolved during the development of XSL, the Extensible Stylesheet Language (see section 2.1.4) because XSL needed a transformation language and the transformation language in turn needed a possibility to somehow address the parts of the XML document which it processes. Because this functionality was considered of general use for other applications and standards as well, it became an own W3C recommendation in the end.

The XPath expressions for addressing the different parts of an XML document are defined using a simple, non-XML syntax in order to be more concise and to support XPath expressions as values of attributes. They operate on the abstract, logical structure of an XML document, which is comparable with the tree-like structure of the document object model (DOM) for example (see section 3.1.1).

Although any literal string or number can be a valid XPath expression, in general an expression will be a so called locations path where each location path may consist of several location steps separated by a / character. Every location step in turn consists of an axis specification, a node test and a predicate and has the following format: *axis*`::`*nodetest*`[`*predicate*`]`. Of these three parts only the node test is mandatory, the axis and the predicate parts are optional.

The *axis* part of a location step specifies which kind of nodes will be selected in the corresponding step. XPath defines several axes which can be used to navigate the XML tree from a given context node like for example `child::` for all the immediate child nodes, `parent::` for the parent node, `descendant::` for all the child nodes taken recursively, `ancestor::` for all the parent nodes taken recursively, `attribute::` for all the attribute nodes or `namespace::` for all the namespace nodes (for a complete list refer to [XPath, § 2.2]). If no explicit axis is given in a location step, the child axis will be taken as a default.

The *nodetest* part of the XPath expression specifies the name of the nodes that should be selected on the chosen axis while the asterisk character * can be used to select all the nodes on that axis. Finally, the *predicate* part can be used to further narrow down the selected node set. The XPath recommendation also defines a set of functions that can be used to further refine the results returned by an XPath expression.

Navigating an XML document with XPath can be compared with the navigation of a file system with the help of wildcards. The selection of the slash character as a location step separator in XPath has been chosen intentionally to encourage this association. The following code line shows an XPath expression that would select the string "Hello world" if applied to our small XML example previously shown in listing 2.2.

```
/descendant-or-self::node()/message[attribute::style='bold']/text()
```

The first location step `/descendant-or-self::node()` which could be abbreviated as // recursively selects all the child nodes of the root node. The second location step `message[attribute ::style='bold']` selects all element nodes with a style attribute set to bold and the last location step finally selects the text elements of the elements found in the previous step by applying the special `text()` node test.

XPointer

The initial XML Pointer Language (XPointer) has been factored out into the general XML Pointer Framework [XPoint] with simple, so called short hand fragment identifiers and three additional fragment identification schemes: the XPointer element() scheme for addressing elements by their position in the document tree, the XPointer xmlns() scheme for binding namespace prefixes to namespace names and the XPointer xpointer() scheme for full XPath-based addressing. The specification only covers the addressing of fragments in XML files although the syntax is open for extensions and could be adapted to other media types like for example simple text or certain graphic formats.

The XML Pointer Framework essentially defines a syntax for how to compose an XPointer from one or more schema parts and a semantics for how an XPointer processor, that is an application that claims to support the XPointer standard, should handle it. The simple short hand fragment identifiers defined by the standard roughly corresponds to the fragment identifiers in HTML.

While the xmlns() scheme is only intended to bind namespace prefixes for subsequent schemes and the element() scheme can only be used to select elements based on their position in the tree representation of an XML document, the xpointer() scheme allows for the full XPath standard to be used for the identification of certain fragments in an XML resource.

The XPointer framework is used in many other XML related standards like for example XLink [XLink] or XInclude [XInc].

XLink

The XLink specification, which became a W3C recommendation in 2001 generalizes the concept of simple, unidirectional hyperlinks known from HTML. In particular it provides complex links between more than two resources, it allows associating meta-data with a link and it allows links to be expressed independently from the resources that they reference. XLink may be used to address documents of arbitrary media types by using uniform resource identifiers [URI]. However if the target of the link is an XML document, the fragment identifier of the URI is interpreted as an XPointer.

XLink also provides the possibility of defining so called link bases, that is documents that contain third party and inbound links. If the source of a link is in a remote resource and the target points into the actual document, the link is called inbound, if both, the source and the target of a link are located in remote document, the link is called to be third party. Simple links as known from HTML are so called outbound links following the XLink specification. Link bases can be used to collect related links in a single place.

Notice that the XLink specification only defines a set of attributes. These attributes may be applied to arbitrary elements. Depending on the values of these attributes they make resources, locators or arcs out of the elements they have been applied to.

Besides HTML, many other hyper-media standards like HyTime [DeRoDu] and TEI [SperBu] have been influential for the XLink specification.

2.1.4 XSL - The Extensible Stylesheet Language

As pointed out before in section 2.1.3, the need for a stylesheet language for XML comparable in the functionality with DSSSL [DSSSL] for SGML arose already before the XML specification was approved as a W3C recommendation. This was the starting point for XSL, the Extensible Stylesheet Language. It quickly became clear however that the transformation language needed as a part of the stylesheet language was of broader interest because it could serve as a general tool for the transformation of XML documents written in different vocabularies. Therefore the specification was split into two parts: the XSL part which effectively only contains the formatting part of the specification which is also known under the name XSL Formatting Objects (XSL-FO) and XSL Transformations (XSLT) the transformation part of the specification.

XSL-FO and XSLT are both quite big and complicated specifications. While the first tries to define an XML vocabulary that covers every possible typographic aspect of publication the second one defines a full-blown, general-purpose transformation language for XML.

XSLT is based on a so-called template mechanism comparable with the one present in the AWK [AKW] programming language. XPath based patterns are used to choose an XSLT element and execute its body, that is output the elements not belonging to the XSLT vocabulary and processing the XSLT child elements. The processing of an XML document advances until no more matching templates can be found in the corresponding stylesheet. One of the biggest problems of XSLT is that it has no global variables, i.e. it is stateless. This makes it extremely hard and time consuming to achieve certain computations like for example creating page references or indices for a book based on an XML document in on pass.

2.1.5 The future of XML

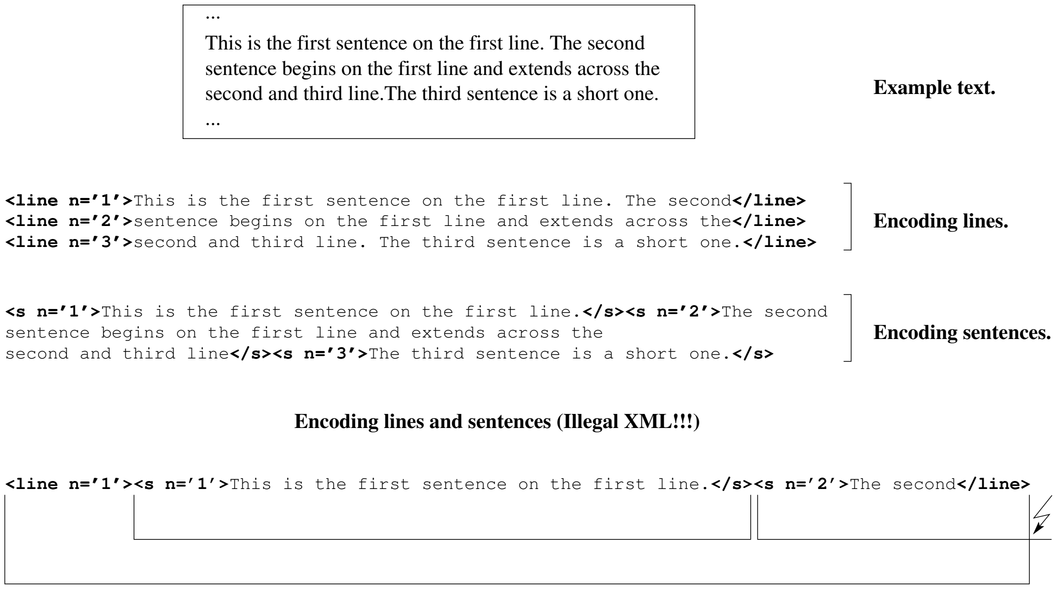
XML seems to be like a self-fulfilling prophecy. Since its introduction it quickly developed to a de-facto standard and proliferated into every single domain of information technology. Its initial strengths, conciseness and simplicity more and more become one of its biggest drawbacks. In fact, every feature dropped from SGML in order to keep XML simple gets reinvented by new XML related W3C recommendations. And because all these recommendations are prepared by different working groups and are mainly focused on their single, isolated topic, they can hardly be integrated without problems. Tool support, which has always been a problem for SGML and one of the biggest advantages of XML becomes a problem again because it will get continuously harder to find tools which will support the exact subset of needed recommendations out the unmanageable total number of existing ones.

While it looks like it will definitely survive as a standard for data exchange, it seems questionable if XML will provide the right basis for complex information systems in the future.

2.2 The problem of overlapping hierarchies

As already described in section 1.2.2, the development of the descriptive markup languages like for example SGML and XML was heavily influenced by the publishing industry. And although these languages are general in the sense that they are not tied to any specific application domain they are nevertheless somewhat biased towards document creation instead of document editing or marking of existing documents.

This fact leads to the phenomena that the creation of new SGML or XML vocabularies and the creation of new documents with these vocabularies is straightforward and easy.



...
This is the first sentence on the first line. The second sentence begins on the first line and extends across the second and third line.The third sentence is a short one.
...

Example text.

```
<line n='1'>This is the first sentence on the first line. The second</line>
<line n='2'>sentence begins on the first line and extends across the</line>
<line n='3'>second and third line. The third sentence is a short one.</line>
```

Encoding lines.

```
<s n='1'>This is the first sentence on the first line.</s><s n='2'>The second
sentence begins on the first line and extends across the
second and third line</s><s n='3'>The third sentence is a short one.</s>
```

Encoding sentences.

Encoding lines and sentences (Illegal XML!!!)

```
<line n='1'><s n='1'>This is the first sentence on the first line.</s><s n='2'>The second</line>
```

Figure 2.1: A demonstration of the problem of overlapping hierarchies (also known under the names "multiple hierarchies" or "concurrent hierarchies"). The text in the upper box is encoded twice, once line-wise and once sentence-wise. However, encoding both hierarchies simultaneously is impossible in XML because an opening tag of a given type cannot be followed by a closing tag of a different type.

However, as time goes by, vocabularies tend to grow in order to fulfill the needs and wishes of the different user groups of the vocabulary. At some point this leads to the problem of overlapping hierarchies, which is illustrated in figure 2.1. The problem arises because SGML documents as well as XML documents are in fact a kind of tree structure and not a general graph structure. But in a tree structure sub trees cannot overlap, they are disjoint by definition.

The problem of overlapping hierarchies arises if there is more than one way to structure a given text. It has been already extensively discussed by different authors [SpHu99, SpHu00, ReMyDu, DuOD01, DuOD02, ThMcK] and several solutions have been proposed. The TEI manual for example dedicates a whole chapter to the problem and describes several workarounds [SperBu, § 31].

2.3 Workarounds for the problem of overlapping hierarchies

Because the problem of overlapping hierarchies arises quite often in the area of humanities computing there exist several workarounds for it. They will be discussed in this section along with some examples.

2.3.1 The SGML CONCUR feature

SGML has an optional feature called CONCUR [Bryan, § 9]. It allows the markup of different concurrent hierarchies in one SGML document. Therefore more than one document type may be declared in the header of an SGML document. The first document type will be the base document type. Its elements may be used in the usual way throughout the document. But it will also be possible to use elements of the other document definitions at arbitrary places in the document no difference if they overlap with elements of the additional document definitions, as long as they are preceeded by a prefix that denotes the document type they belong to. This is demonstrated in listing 2.4, which uses the two document types `page-layout` and `structure` to encode the two hierarchies from figure 2.1.

Listing 2.4: An example of using the SGML CONCUR to encode overlapping hierarchies

```
<!SGML "ISO 8879-1986"
...
>
<!DOCTYPE page-layout [
  <!ELEMENT line - - #PCDATA>
  ...
]>
<!DOCTYPE structure [
  <!ELEMENT s - - #PCDATA>
  ...
]>

<line n= 1><(structure)s n='1'>This is the first sentence on the first line. </(structure)s>
<(structure)s n='2'>The second</line><line n= 2>sentence begins on the first line and extends
across the</line><line n= 3>second and third line. </(structure)s><(structure)s n='3'>The
third sentence is a short one.</(structure)s></line>
```

The SGML `CONCUR` feature is somewhat related with the XML namespaces [XML-Na] functionality with the difference that XML documents always have to be well formed, i.e. their elements always have to be properly nested, no difference which namespace they belong to. The `CONCUR` feature is an elegant method for the encoding of concurrent hierarchies. Unfortunately it is only an optional feature of SGML which has been seldom implemented and which has been dropped entirely in XML.

2.3.2 Milestone elements

One method suggested by TEI to avoid problems with concurrent hierarchies is the use of empty elements, so called milestone elements. Because they contain no content, they do not nest and thus they cannot overlap with other elements. The text from listing 2.4 could be encoded as follows in XML if the two empty elements `sb` for "sentence begin" and `se` for "sentence end" would be used instead of the `s` element:

Listing 2.5: Encoding the structure from listing 2.4 with milestone elements

```
<line n= 1><sb n='1'/>This is the first sentence on the first line. <se/>
<sb n='2'/>The second</line><line n= 2>sentence begins on the first line and extends
across the</line><line n= 3>second and third line. <se/><sb n='3'/>The
third sentence is a short one.<se/></line>
```

The advantage of this approach is simplicity. The problem is that the valid placement of the `sb` and `se` elements can not be validated by the XML parser, because in a document type definition there is no way to specify the fact that an `sb` tag must logically always be followed by an `se` tag. There is also a certain kind of unbalance between the main structure expressed by the `line` elements in this example and other auxiliary structures expressed by milestone elements.

2.3.3 Fragmentation

Another method, which can be used to avoid overlapping hierarchies is to break up the elements that cause the problems into smaller fragments that do not overlap with the other structures anymore. Listing 2.6 shows how the text from listing 2.4 could be encoded using this approach.

Listing 2.6: Encoding the structure from listing 2.4 by breaking elements into fragments

```
<line n= 1><s n='1'>This is the first sentence on the first line. </s>
<s n='2'>The second</s></line><line n= 2><s n='2'>sentence begins on the first line and extends
across the</s></line><line n= 3><s n='2'>second and third line. </s><s n='3'>The
third sentence is a short one.</s></line>
```

Besides its simplicity, this solution also has some drawbacks. Additional processing is needed for the reconstruction of the fragmented structure. Just as with the last approach the resulting encoding is biased towards the main, unfragmented structure. Finally fragmentation does not scale very well and has to be potentially further refined as new structures are being added to a document.

2.3.4 Virtual joins

The last method, which worked by segmenting the document can be improved by using so called "virtual joins" [SperBu, § 31]. They are special elements, that are used to express the logical relationship of otherwise structural unrelated elements as shown in listing 2.7. Notice the similarity of this approach with the XLink link base concept discussed in section 2.1.3.

Listing 2.7: Augmenting the structure from listing 2.6 with virtual join elements

```
<line n= 1><s n='1' id='s1'>This is the first sentence on the first line. </s><s n='2' id='s2'>
The second</s></line><line n= 2><s n='2' id='s3'>sentence begins on the first line and extends
across the</s></line><line n= 3><s n='2' id='s4'>second and third line. </s><s n='3' id='s5'>The
third sentence is a short one.</s></line>
<join targets='s2 s3 s4' result='s'/>
```

Another possibility to create virtual joins is to simply link the corresponding elements with each other as demonstrated in listing 2.8:

Listing 2.8: Augmenting the structure from listing 2.6 with virtual join elements

```
<line n= 1><s n='1' id='s1'>This is the first sentence on the first line. </s><s n='2' id='s2' next=
's3'>The second</s></line><line n= 2><s n='2' id='s3' prev='s2' next='s4'>sentence begins on the first
line and extends across the</s></line><line n= 3><s n='2' id='s4' prev='s3'>second and third line.
</s><s n='3' id='s5'>The third sentence is a short one.</s></line>
```

Although virtual joins make the fragmentation solution some more robust, this has to be paid with an increased complexity. On the other hand the same advantages discussed for the fragmentation solution also apply to virtual joins.

2.3.5 Multiple encodings

If it is likely that the text in question will not have to be modified, an alternative to the before mentioned solutions can be to encode the text multiple times. On the one hand, this procedure makes each of the encoded versions easier to process because it represents a single view of the document and is not disturbed by the other encodings. On the other hand the method needs more memory and there is always the risk of introducing redundant information into the individual encodings, which are hard to keep up to date and which can lead to inconsistencies between the different copies of the document.

2.3.6 Bottom up virtual hierarchies

In [DuOD01] Durusau and O'Donnell propose the use of a single encoding for every hierarchy in question and the automatic creation of a so-called base file that contains the collected information for every encoding. For this approach to work, the individual encodings have to use the same atomic level PCDATA[1], i.e. all the individual documents have to be built up from the same base elements. In their paper they use word segments as base level elements, however a finer segmentation based on syllables or even characters may be used.

In the base file each of these base elements contains an attribute for each of the individually marked up documents, which records its position in the corresponding hierarchy. The attributes are written as XPath [XPath] expressions that denote the exact position of the base element in the corresponding markup hierarchy. The authors argue that the base file can be constructed automatically from the different, individually encoded files and give some examples how the base file can be queried for information which requires the knowledge of several of the potentially overlapping hierarchies.

The approach is feasible, however as soon as a more fine-grained segmentation than world level segmentation is needed, the base file size grows significantly. Additionally, the base file size is not proportional to the complexity of the hierarchy but to the number of base elements. Even an imaginary hierarchy with just one element would add an additional attribute to every element in the base file.

2.3.7 Just in time trees

In [DuOD02] the same authors propose a new parsing model that honors just the element tags that are valid with reference to the current document type definition. All the other tags are discarded, while there PCDATA content is still processed. With this method, it is possible to attach custom encodings to a single document that may have potentially overlapping hierarchies.

In fact this is a rediscovery of the SGML `CONCUR` feature. In order to be feasible, the method would need to relax the XML well-formed constraint which is a key feature of XML documents. Despite its attractiveness, the new approach requires a new data and processing model that is not compatible with XML. It is therefore questionable if it will become widely accepted.

2.3.8 Standoff markup

Markup that is external to the content it describes in the sense that it does not wrap the tagged content but only references it is called external or standoff markup. In the year 1997 Thompson and McKelvie [ThMcK] introduced a system they called "standoff markup" which uses links to include parts of one or more other documents that are already tagged

[1] The term PCDATA derives historically from "parsed character data."It is widely used throughout the W3C Recommendations and denotes the actual character data of an XML document (i.e. all text that is not markup).

into a new hierarchy. Initially designed to add markup to read-only documents and to documents spread across different locations, the approach also solves the problem of overlapping hierarchies.

In their paper the authors assume a pipelined architecture where individual tools work on a stream of SGML/XML documents and augment, transform or modify them stepwise. The advantages of the system are evident: different editors can create different markup for the same document. The documents that are marked up do not even have to be available together or be editable. And finally, the markup can be distributed independently from the documents they describe.

The disadvantages are an increased processing complexity and the restriction on SGML/XML elements as targets for the links to the external markup structures.

The TEI consortium established a special working group dedicated to the area of standoff markup [TEISO]. It tries to elaborate guidelines for an external encoding which use the XML XInclude [XInc] and XPointer [XPoint] features to include content from external resources into a document based on the TEI encoding standards.

2.4 XTE - A new standoff markup scheme

After various workarounds for the realization of overlapping hierarchies have been discussed in the last sections a new standoff markup scheme called XTE (e*X*ternal *T*ext *E*ncoding) that solves the mentioned problems will be introduced.

In contrast to the before mentioned external markups, the main idea with XTE is not to have several files which contain a different markup of a reference document. Instead, in XTE, all the different markups are collected in a single file. This file effectively stores an arbitrary number of independent encodings of the same document, i.e. different tree structures referencing the same source document. The entire single tree structures are of course well formed, however, it is perfectly legal for elements from different trees to overlap with respect to the content that they reference in the source document.

Although it is possible for the different markups in XTE to reference content from external resources, this is not strictly necessary. XTE is designed in a way to allow the source content to be stored along with the different encodings[2] in the same file. Finally, XTE allows the user not only to combine an arbitrary number of encodings of the same document, but also to combine different source documents with an arbitrary number of encodings into a single XTE file.

In addition to the encoding of language in textual form, XTE also addresses the encoding of language given in various other formats like for example graphics (i.e. facsimile editions of a historic text) or sound formats.

The combination of different documents where each of them may be encoded by a number of different markups and available in different media formats and the ability to easily specify links between the different documents and encoding elements makes XTE especially useful for the encoding of parallel, multilingual and multi-modal text corpora.

While XTE is fully based on XML and a number of other XML related standards like XML Namespaces, XPath and XLink, it is nevertheless a quite complex markup scheme which makes it hard to work on with standard tools like simple word or even sophisticated XML editors. In order to take full advantage of its features a graphical editor and browser tool have been developed which will be introduced in chapter 6 and 5 respectively.

[2] Please note that the terms “encoding” and “markup” will be used interchangeably in this section with the meaning of “markup” as defined in section 1.2

2.4.1 The XTE DTD

XTE can be defined as an XML Document Type Definition (DTD) as well as an XML Schema. This section will introduce the XTE DTD while the following section is devoted to the XML Schema version of XTE.

In the definition of the XTE DTD so called customization layers (see for example [DocB, § 5] or [SperBu, § 29]) will be used in order to provide a simple and intuitive way for users to extend XTE with their own markup schemes or to adapt existing schemes to their needs. This technique is based on an XML/SGML feature that allows entity declarations to be repeated. If an entity is declared more than once, the first declaration will be used.

Together with external entities, which can be used to include data from other files into a DTD it becomes possible to declare every single encoding scheme in its own file while still using entities that have been defined in the main XTE DTD. Finally, the XTE DTD and the different encoding schemes, which are needed for a special document, can be combined in a customization layer. This customization layer will be the DTD which will be used by the XML processor to validate the content of a given instance document. The following listing shows the base XTE DTD:

Listing 2.9: The base XTE DTD

```
<!--
   XTE DTD version 0.1

   This DTD module is identified by the foll. PUBLIC and SYSTEM identifiers:

   PUBLIC "-//Language-Explorer//DTD XTE XML V0.1//EN">
   SYSTEM "http://www.language-explorer.org/XTE/dtd/XTE.dtd"
-->

<!ENTITY % xte.ns.suffix             ":xte">
<!ENTITY % xte.ns.prefix             "xte:">
<!ENTITY % namespace.xte             "xmlns%xte.ns.suffix;">
<!ENTITY % XTE                       "%xte.ns.prefix;XTE">
<!ENTITY % text                      "%xte.ns.prefix;text">
<!ENTITY % group                     "%xte.ns.prefix;group">
<!ENTITY % content                   "%xte.ns.prefix;content">
<!ENTITY % body                      "%xte.ns.prefix;body">
<!ENTITY % loadLinkBase              "%xte.ns.prefix;loadLinkBase">

<!ENTITY % xlink.ns.suffix           ":xlink">
<!ENTITY % xlink.ns.prefix           "xlink:">
<!ENTITY % namespace.xlink           "xmlns%xlink.ns.suffix;">

<!ELEMENT %XTE; (%text;)>
<!ATTLIST %XTE;
  %namespace.xte; CDATA #FIXED "http://www.language-explorer.org/XTE"
  %namespace.xlink; CDATA #FIXED "http://www.w3.org/1999/xlink"
  xmlns CDATA #IMPLIED
>

<Definition of the text and group elements - see Listing 2.10 on page 25>
```

Listing 2.9: The base XTE DTD (continued)

```
<Definition of the content element - see Listing 2.11 on page 25>

<Definition of the body element - see Listing 2.12 on page 25>

<Definition of the default attributes - see Listing 2.13 on page 26>

<Definition of the loadLinkBase element - see Listing 2.14 on page 26>
```

One of the problems we face is the fact that DTDs have no knowledge of namespaces. If we want to put the elements defined in XTE into their own namespace, we have to hard-code a namespace prefix into the DTD. As this would greatly reduce the profit of namespaces if not make it useless at all, we define the namespace prefix as a parameter entity as can be seen in the first two lines of listing 2.9. Subsequently, we define all the element names that will be defined in the XTE DTD by means of this parameter entity. This way, the user has the possibility to redefine the namespace prefix that will be used for the XTE elements in the internal subset of the DTD. An instance document that just references the XTE DTD has to use the qualified names with the default namespace prefix `xte`:

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE xte:XTE PUBLIC "-//Language-Explorer//DTD XTE XML V0.1//EN">
<xte:XTE>
  <xte:text>
    ...
</xte:XTE>
```

It is however possible to use another, arbitrary prefix as follows:

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE xteNS:XTE PUBLIC "-//Language-Explorer//DTD XTE XML V0.1//EN" [
    <!ENTITY % xte.ns.prefix "xteNS:">
    <!ENTITY % xte.ns.suffix ":xteNS">
  ]
>
<xteNS:XTE>
  <xteNS:text>
    ...
</xteNS:XTE>
```

It is even possible to let the XTE elements reside in the default namespace, by setting the parameter entities that define the XTE prefix to be the empty string:

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE XTE PUBLIC "-//Language-Explorer//DTD XTE XML V0.1//EN" [
    <!ENTITY % xte.ns.prefix "">
    <!ENTITY % xte.ns.suffix "">
  ]
>
<XTE>
  <text>
    ...
</XTE>
```

After the namespace prefix for the XTE namespace has been parameterized we do the same for the XLink namespace, because we will use some XLink attributes later on in the DTD.

Finally, we define the `XTE` element that will be the root element of the DTD. We bind the namespace prefixes to their corresponding fixed values for the `XTE` element and thus for the whole document. We also define an optional `xmlns` attribute for the XTE element to give the user the possibility to define his own default namespace on the root element if he would like to do so.

The `text` and the `group` elements

The `XTE` contains a single `text` element that in turn contains either a `group` element or an optional `loadLinkBase` element followed by one or more `content` elements and one or more `body` elements. The `loadLinkBase` element can be used to include an XLink link base and will be further specified in listing 2.14.

Listing 2.10: Definition of the `text` and `group` elements (Referenced in Listing 2.9 on page 23)

```
<!ELEMENT %text; (%group; | (%loadLinkBase;?, %content;+, %body;+))>
<!ATTLIST %text; nr    CDATA #IMPLIED
                 xmlns CDATA #IMPLIED>

<!ELEMENT %group; (%text;+)>
```

The `group` element is used for recursion only because it can contain one or more `text` elements. At the moment, an XTE document usually contains just a single `group` element, which in turn contains a sequence of all the different, parallel texts included in the document. But by using such a recursive encoding schema (see also [SperBu]), more sophisticated text structures can be realized in the future.

The `content` element

The `content` elements are used to store the text content of a document as a stream of unformatted characters. Usually all the content belonging to one document is kept in one `content` element. However, more than one `content` element may be useful to store out of band data like for example footnotes or user supplied annotations. Notice that the `content` element is the only element that contains character data (PCDATA in XML notation). All the other elements may well refer to a part of this content, however only through pointers (e.g. the `start` and `end` attributes defined in `default.attributes`).

Listing 2.11: Definition of the `content` element (Referenced in Listing 2.9 on page 23)

```
<!ELEMENT %content; (#PCDATA)>
<!ATTLIST %content; type CDATA #IMPLIED>
```

The `body` element

The `body` element is declared as a composition out of the elements declared in the parameter entity `local.encodings`, while the parameter entity itself, as declared in the XTE DTD, has an empty value. This parameter entity is the main extension point provided for a user of the XTE DTD. Listing 2.17 shows how it can be used to combine or plug in custom encodings into the general XTE framework and figure 2.2 shows a graphical overview of the XTE encoding scheme.

Listing 2.12: Definition of the body element (Referenced in Listing 2.9 on page 23)

```
<!ENTITY % local.encodings "EMPTY">

<!ELEMENT %body; %local.encodings;>
<!ATTLIST %body; encodingName CDATA #REQUIRED
                 type         (default|auxiliary) #REQUIRED
                 view         CDATA #REQUIRED
                 xmlns        CDATA #IMPLIED
>
```

Default attributes defined by XTE

Finally, the base XTE DTD also defines some parameter entities which are used in the XTE DTD itself but which are intended at the same time to simplify the creation of new XTE encodings by the user. An example for such a parameter entity is `default.attributes`, which defines the attributes that should be present on every internal, user created encoding element. The `start` and `end` attributes can be used for example to link the element to the content while the `link` element can be used to link an element to other elements in the same or even from other encodings in the same document. Notice that the format of these attributes is intentionally specified very loose as `CDATA` to get a maximum of flexibility. This allows simple solutions like for example plain numbers as references into the content for the `start` and `end` attributes, but also supports more complex and powerful solutions like for example XPath [XPath] or XPointer [XPoint] expressions as values for these attributes.

Listing 2.13: Definition of the default attributes (Referenced in Listing 2.9 on page 23)

```
<!ENTITY % default.attributes "start      CDATA #IMPLIED
                               end        CDATA #IMPLIED
                               link       CDATA #IMPLIED
                               n          CDATA #IMPLIED
                               viewClass  CDATA #IMPLIED
                               loadClass  CDATA #IMPLIED
                               saveClass  CDATA #IMPLIED
                               style      CDATA #IMPLIED
                               xmlns      CDATA #IMPLIED"
>
```

The various `*Class` attributes are intended as a hint for the processing application for how to handle elements of that specific type. They can contain for example Java class names that specify a special view class that should be used to optimally display the corresponding element. The precise process of loading and displaying XTE files is covered in section 3.2.

The `loadLinkBase` element

There was one part missing in listing 2.9, namely the definition of the `loadLinkBase`. This part is now appended in the following listing:

Listing 2.14: Definition of the `loadLinkBase` element (Referenced in Listing 2.9 on page 23)

```
<!ENTITY % src                "%xte.ns.prefix;src">
<!ENTITY % linkbase           "%xte.ns.prefix;linkbase">
<!ENTITY % load               "%xte.ns.prefix;load">
```

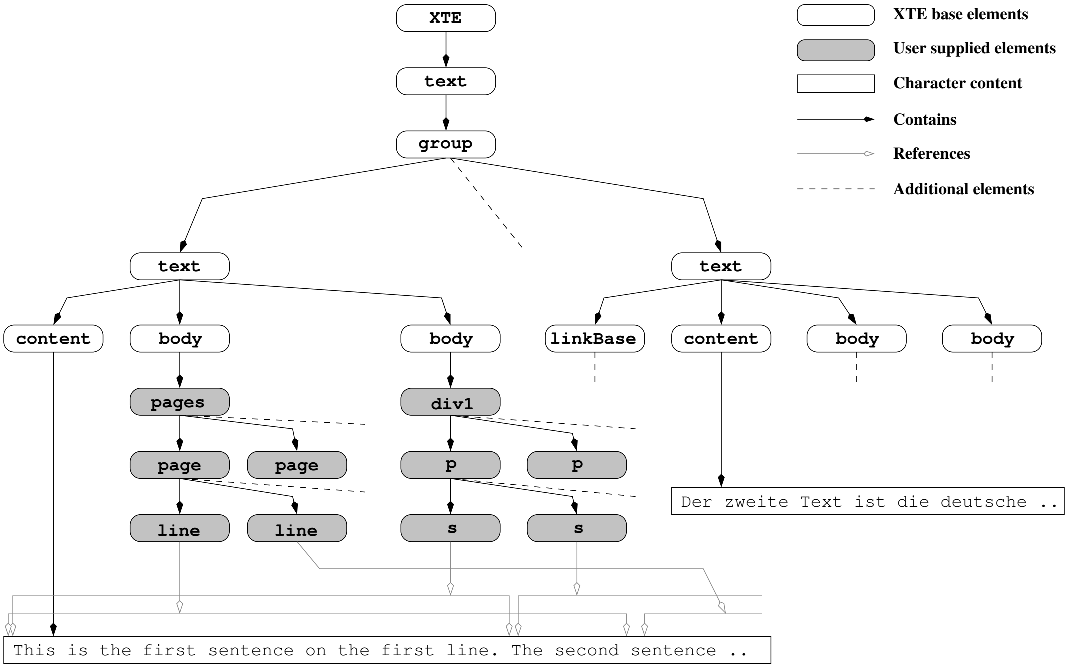


Figure 2.2: An example of how XTE could be used to encode the overlapping hierarchies used as an example in figure 2.1. Notice how the elements of the different encodings may well reference parts of the text that overlap (gray arrows) while the single encodings are still well formed. The various element attributes have been omitted for brevity.

```
<!ENTITY % xlinkType         "%xlink.ns.prefix;type">
<!ENTITY % xlinkHref         "%xlink.ns.prefix;href">
<!ENTITY % xlinkLabel        "%xlink.ns.prefix;label">
<!ENTITY % xlinkArcrole      "%xlink.ns.prefix;arcrole">
<!ENTITY % xlinkActuate      "%xlink.ns.prefix;actuate">
<!ENTITY % xlinkFrom         "%xlink.ns.prefix;from">
<!ENTITY % xlinkTo           "%xlink.ns.prefix;to">

<!ELEMENT %loadLinkBase; ((%src; | %linkbase; | %load;)*)>
<!ATTLIST %loadLinkBase; %xlinkType;   (extended)   #FIXED "extended">

<!ELEMENT %src; EMPTY>
<!ATTLIST %src;          %xlinkType;    (locator)    #FIXED "locator"
                         %xlinkHref;    CDATA        #REQUIRED
                         %xlinkLabel;   NMTOKEN      #IMPLIED>

<!ELEMENT %linkbase; EMPTY>
<!ATTLIST %linkbase;     %xlinkType;    (locator)    #FIXED "locator"
                         %xlinkHref;    CDATA        #REQUIRED
                         %xlinkLabel;   NMTOKEN      #IMPLIED>

<!ELEMENT %load; EMPTY>
<!ATTLIST %load;         %xlinkType;    (arc)        #FIXED "arc"
                         %xlinkArcrole; CDATA        #FIXED
```

Listing 2.14: Definition of the loadLinkBase element (continued)

```
  "http://www.w3.org/1999/xlink/properties/linkbase"
%xlinkActuate; (onLoad
               |onRequest
               |other
               |none)       #IMPLIED
%xlinkFrom;    NMTOKEN      #IMPLIED
%xlinkTo;      NMTOKEN      #IMPLIED>
```

The loadLinkBase element can contain child elements, which can be used to define an XLink link base. This can be used together with the link attribute specified in default.attributes or as an exclusive source of linking information for the corresponding encoding.

Defining custom encodings for XTE

As explained until now, the base XTE DTD is just a framework for other, separately defined encodings. The XTE DTD alone cannot be used to tag any documents. However XTE comes with some simple encodings, which can be plugged into the XTE base DTD in order to get a practically usable DTD. The following paragraphs will present two of these encodings and demonstrate how they can be merged into a new, customized DTD.

The following listing for example shows a DTD, which divides a text into sentences and paragraphs. Furthermore, there exist three additional elements, div1, div2 and div3, which can be used to structure the content on a higher level (e.g. divide it into sections, chapters and parts). The structuring level of these elements (e.g. chapter) can be declared with the help of the name attribute.

Listing 2.15: div1.dtd

```
<!--
  An external encoding which can be used with the XTE DTD version 0.1

  This encoding divides the text into up to three divisions (e.g. chapter,
  section, subsection) where each of these divisons contains paragraphs and
  the paragraphs contain sentences.
-->

<!ELEMENT div1 ((p | div2)+)>
<!ATTLIST div1 %default.attributes;
               name CDATA #IMPLIED >

<!ELEMENT div2 ((p | div3)+)>
<!ATTLIST div2 %default.attributes;
               name CDATA #IMPLIED>

<!ELEMENT div3 (p+)>
<!ATTLIST div3 %default.attributes;
               name CDATA #IMPLIED>

<!ELEMENT p (s+)>
<!ATTLIST p %default.attributes;>
```

Listing 2.15: div1.dtd (continued)

```
<!ENTITY % sentence.parts "EMPTY">

<!ELEMENT s %sentence.parts;>
<!ATTLIST s %default.attributes;>
```

Notice how the `sentence` element is declared as empty element. However, by doing this indirectly with the help of a parameter entity, the user of the encoding will have the possibility to further subdivide the `sentence` element if she needs to do so. Listing 2.17, which combines this encoding with another partial encoding and the base XTE DTD, shows how such an extension can be accomplished.

The next listing shows the second example of a partial encoding, which can be plugged into and used together with the base XTE DTD. It divides the underlying text into lines and pages according to an actual printed edition. The edition may be specified in the `edition` attribute of the `pages` element. The `hyphen` attribute indicates whether the last word of a line is hyphenated while the `para-pos` attribute specifies the position of a line in the paragraph. The last two attributes can be used as hints by view classes when they render these elements.

Listing 2.16: pages.dtd

```
<!--
   An external encoding which can be used with the XTE DTD version 0.1

   This encoding divides the text into pages and lines as present in a certain
   edition of a printed version of the text.
-->

<!ELEMENT pages (page+)>
<!ATTLIST pages %default.attributes;
                edition CDATA #IMPLIED>

<!ELEMENT page (line+)>
<!ATTLIST page %default.attributes;>

<!ELEMENT line EMPTY>
<!ATTLIST line %default.attributes;
               para-pos (begin | end | default) "default"
               hyphen   (true) #IMPLIED
>
```

Finally, listing 2.17 shows how the encodings defined in listing 2.15 and 2.16 can be combined and used together with the base XTE DTD. First of all, the parameter entity `local.encodings` is defined to be either `div1` or `pages`. This has to be done before the inclusion of the XTE DTD as an external entity in order to overwrite the empty definition of `local.encodings` their. Then the two partial encodings presented before are pulled into the file by declaring them as external entities respectively.

Notice how the `sentence` element which is declared as an empty element in listing 2.15 is extended to contain `latin` and `french` elements (which can denote Latin and French words in a text) by redefinition of the parameter entity `sentence.parts`. Also notice how the use of the standard element attributes defined in the main XTE DTD is only possible in the partial encodings shown in the listings 2.15 and 2.16, because the main XTE DTD is included before the partial encodings into the final DTD file.

Listing 2.17: div1pages.dtd

```
<!--
   A collection of external encodings which can be used with
   the XTE DTD version 0.1

   This collection combines the 'div1' and the 'pages' encoding.
-->

<!ENTITY % local.encodings "(div1 | pages)">

<!ENTITY % xte.dtd SYSTEM "XTE.dtd">
%xte.dtd;

<!ENTITY % sentence.parts "(latin | french)*">

<!ELEMENT latin EMPTY>
<!ATTLIST latin %default.attributes;>

<!ELEMENT french EMPTY>
<!ATTLIST french %default.attributes;>

<!ENTITY % div1 SYSTEM "div1.dtd">
%div1;
<!ENTITY % pages SYSTEM "pages.dtd">
%pages;
```

Finally, the newly created DTD can be used to validate an XML file, by including the following lines in the header of the corresponding file:

Listing 2.18: An example XML file which uses the DTD defined in listing 2.17

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE XTE SYSTEM "resources/div1pages.dtd"
    <!ENTITY % xte.ns.prefix "">
    <!ENTITY % xte.ns.suffix "">
  ]
>
<XTE>
 ...
</XTE>
```

As shown in this section, the XTE DTD is an easily extensible and easily configurable DTD, which allows users to define and use several, even overlapping encodings on several different documents and store all this information into a single XML file. Another approach, namely the implementation of XTE as an XML Schema, will be discussed in the next section.

2.4.2 XTE - Expressed as an XML Schema

As described in section 2.1, XML document type definitions have a number of serious drawbacks. But XTE is not tied to a DTD in any way. In particular it can also be expressed by means of a more general schema language (see 2.1.2). In this section XTE will be defined as a W3C XML Schema [XMLSch0, XMLSch1, XMLSch2].

Listing 2.19: XTE.xsd

```
<xsd:schema xmlns="http://www.language-explorer.org/XTE"
            xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            targetNamespace="http://www.language-explorer.org/XTE"
            elementFormDefault="qualified">

<xsd:annotation>
  <xsd:documentation xml:lang="en">
    XTE Schema version 0.1
    This Schema is available from the following Schema Location:
    http://www.language-explorer.org/XTE/schema/XTE.xsd
  </xsd:documentation>
</xsd:annotation>

<xsd:element name="XTE" type="XTE"/>

<xsd:complexType name="XTE">
  <xsd:sequence>
    <xsd:element name="text" type="text"/>
  </xsd:sequence>
</xsd:complexType>

<xsd:complexType name="text">
  <xsd:choice>
    <xsd:element name="group" type="group"/>
    <xsd:sequence>
      <xsd:element name="loadLinkBase" type="loadLinkBase" minOccurs="0"/>
      <xsd:element name="content" type="xsd:string" maxOccurs="unbounded"/>
      <xsd:element name="body" type="body" maxOccurs="unbounded"/>
    </xsd:sequence>
  </xsd:choice>
  <xsd:attribute name="nr"/>
</xsd:complexType>

<xsd:complexType name="group">
  <xsd:sequence>
    <xsd:element name="text" type="text" maxOccurs="unbounded"/>
  </xsd:sequence>
</xsd:complexType>

<Definition of the 'body' element and type - see Listing 2.20 on page 32>

<xsd:attributeGroup name="defaultAttributes">
  <xsd:attribute name="start"/>
  <xsd:attribute name="end"/>
... Some more attribute definitions ...
</xsd:attributeGroup>
```

Listing 2.19: XTE.xsd (continued)

```
... Definition of the loadLinkBase type. ...

</xsd:schema>
```

Listing 2.19 shows the XTE schema that conforms to the XTE DTD known from listing 2.9. First of all a global element XTE of type XTE is defined. Then the type XTE is defined to be a complex type that contains a single element of type text. Subsequently the complex type text is defined to contain either a group element of type group or a sequence of the optional loadLinkBase element and the two content and body elements that are of type string and body respectively. Finally, the group element is defined as a complex type that contains a single element of type text. While the XML Schema version is a little bit more verbose than the DTD version, until now we have a more or less one-to-one translation of the XTE DTD presented in the previous section which could also have been done automatically by means of a DTD to XML Schema translation tool. The extension and configuration capabilities of the DTD version however will be implemented by specific features, which are available only in the XML Schema language.

The XTE XML Schema realized with substitution groups

While customization layers have been used in the DTD version to make XTE easily extensible for users, two more convenient and intuitive possibilities are available to achieve the same result within XML Schema. The first one is to define a global, empty and abstract encoding element of type encoding which is contained in the body element as shown in listing 2.20.

Listing 2.20: XTE.xsd (Referenced in Listing 2.19 on page 31)

```
<xsd:complexType name="body">
   <xsd:sequence maxOccurs='unbounded'>
     <xsd:element ref="encoding"/>
  </xsd:sequence>
  <xsd:attribute name="encodingName" use="required"/>
  <xsd:attribute name="type" use="required">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="default"/>
        <xsd:enumeration value="auxiliary"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:attribute>
  <xsd:attribute name="view" use="required"/>
</xsd:complexType>

<xsd:element name="encoding" type="encoding" abstract="true"/>

<xsd:complexType name="encoding" abstract="true">
</xsd:complexType>
```

Users who want to define their own encodings can now easily do this by deriving the root element of their encoding from encoding and add that element to the substitution group for encoding as shown in listing 2.21.

Listing 2.21: div1.xsd (Referenced in Listing 2.22 on page 33)

```
<xsd:element name="div1" type="div1" substitutionGroup="xte:encoding"/>

<xsd:complexType name="div1">
  <xsd:complexContent>
    <xsd:extension base="xte:encoding">
      <xsd:choice maxOccurs='unbounded'>
        <xsd:element name="p" type="p"/>
        <xsd:element name="div2" type="div2"/>
      </xsd:choice>
      <xsd:attributeGroup ref="xte:defaultAttributes"/>
      <xsd:attribute name="name"/>
    </xsd:extension>
  </xsd:complexContent>
</xsd:complexType>
```

The crucial point in the previous schema definition is the fact that the element `div1` is being added to the substitution group `encoding` and the type of the `div1` element is derived from `encoding`.

Notice also how the attributes defined in the `defaultAttributes` attribute group in the file `XTE.xsd` are reused in the definition of the complex type `div1`. This is possible because the base XTE Schema was included into the schema file before the definition of the `div1` type (see listing 2.22).

Together with the XML Schema import mechanism, which is comparable with the external entities feature of DTDs, it becomes easy to create own encodings and combine them in a new XML Schema. Listing 2.22 shows the missing part of the XML Schema definition for a sentence-wise encoding which is equivalent to the sentence-wise encoding previously defined as a DTD in listing 2.15.

Listing 2.22: div1.xsd

```
<xsd:schema xmlns="http://www.language-explorer.org/XTE/div1"
            xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            xmlns:xte="http://www.language-explorer.org/XTE"
            targetNamespace="http://www.language-explorer.org/XTE/div1"
            elementFormDefault="qualified">

<xsd:import namespace="http://www.language-explorer.org/XTE"
            schemaLocation="XTE.xsd"/>

<xsd:annotation>
  <xsd:documentation xml:lang="en">
    An external encoding which can be used with the XTE Schema version 0.1
    This encoding divides the text into up to three divisions (e.g. chapter,
    section, subsection) where each of these divisons contains paragraphs and
    the paragraphs contain sentences.
  </xsd:documentation>
</xsd:annotation>

<Definition of the div1 element and type - see Listing 2.21 on page 32>
```

Listing 2.22: div1.xsd (continued)

```
<xsd:complexType name="div2">
  <xsd:choice maxOccurs='unbounded'>
    <xsd:element name="p" type="p"/>
    <xsd:element name="div3" type="div3"/>
  </xsd:choice>
  <xsd:attributeGroup ref="xte:defaultAttributes"/>
  <xsd:attribute name="name"/>
</xsd:complexType>

<xsd:complexType name="div3">
... Definition of div3 which contains paragraph elements p ...
</xsd:complexType>

<xsd:complexType name="p">
... Definition of p which contains sentence elements s ...
</xsd:complexType>

<xsd:complexType name="s">
  <xsd:attributeGroup ref="xte:defaultAttributes"/>
</xsd:complexType>

</xsd:schema>
```

The elements and types defined in the schema will not be discussed in depth here because they directly correspond to the elements with the same names in the corresponding DTD.

As a second example of constructing a custom XTE encoding, a schema definition for the line- and page-wise encoding, which has been previously presented as a DTD in listing 2.16, will be given in the next listing:

Listing 2.23: pages.xsd

```
<xsd:schema xmlns="http://www.language-explorer.org/XTE/pages"
            xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            xmlns:xte="http://www.language-explorer.org/XTE"
            targetNamespace="http://www.language-explorer.org/XTE/pages"
            elementFormDefault="qualified">

<xsd:import namespace="http://www.language-explorer.org/XTE"
            schemaLocation="XTE.xsd"/>

<xsd:annotation>
  <xsd:documentation xml:lang="en">
    An external encoding which can be used with the XTE Schema version 0.1
    This encoding divides the text into pages and lines as present in a
    certain edition of a printed version of the text.
  </xsd:documentation>
</xsd:annotation>

<xsd:element name="pages" type="pages" substitutionGroup="xte:encoding"/>
```

Listing 2.23: pages.xsd (continued)

```
<xsd:complexType name="pages">
  <xsd:complexContent>
    <xsd:extension base="xte:encoding">
      <xsd:sequence maxOccurs='unbounded'>
        <xsd:element name="page" type="page"/>
      </xsd:sequence>
      <xsd:attributeGroup ref="xte:defaultAttributes"/>
    </xsd:extension>
  </xsd:complexContent>
</xsd:complexType>

<xsd:complexType name="page">
  <xsd:sequence maxOccurs='unbounded'>
    <xsd:element name="line" type="line"/>
  </xsd:sequence>
  <xsd:attributeGroup ref="xte:defaultAttributes"/>
</xsd:complexType>

<xsd:complexType name="line">
  <xsd:attributeGroup ref="xte:defaultAttributes"/>
</xsd:complexType>

</xsd:schema>
```

Again, all the elements defined in this schema directly correspond to the elements with the same name in the DTD version of the encoding.

Finally, the two custom encodings defined in listing 2.22 and 2.23 respectively, can be combined and merged together with the base XTE Schema as shown in listing 2.24. In fact it is just a matter of importing the desired partial encodings into one schema file. The base XTE Schema has to be imported into the final schema file only because the `default.attributes` attribute group is used in the definition of the complex types `latin` and `french`. Otherwise this would not have to be done explicitly, because the base XTE schema is already imported into the partial encodings (see for example listing 2.23).

Listing 2.24: div1pages.xsd

```
<xsd:schema xmlns="http://www.language-explorer.org/XTE/div1pages"
            xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            xmlns:xte="http://www.language-explorer.org/XTE"
            xmlns:div1="http://www.language-explorer.org/XTE/div1"
            xmlns:pages="http://www.language-explorer.org/XTE/pages"
            targetNamespace="http://www.language-explorer.org/XTE/div1pages"
            elementFormDefault="qualified">

<xsd:import namespace="http://www.language-explorer.org/XTE"
            schemaLocation="XTE.xsd"/>
<xsd:import namespace="http://www.language-explorer.org/XTE/div1"
            schemaLocation="div1.xsd"/>
<xsd:import namespace="http://www.language-explorer.org/XTE/pages"
            schemaLocation="pages.xsd"/>
```

Listing 2.24: div1pages.xsd (continued)

```
<xsd:annotation>
  <xsd:documentation xml:lang="en">
     A collection of external encodings which can be used with
     the XTE Schema version 0.1

     This collection combines the 'div1' and the 'pages' encoding.
  </xsd:documentation>
</xsd:annotation>

<xsd:complexType name="sentence.with.parts">
  <xsd:complexContent>
    <xsd:extension base="div1:s">
      <xsd:choice maxOccurs='unbounded'>
        <xsd:element name="latin" type="latin"/>
        <xsd:element name="french" type="french"/>
      </xsd:choice>
    </xsd:extension>
  </xsd:complexContent>
</xsd:complexType>

<xsd:complexType name="latin">
  <xsd:attributeGroup ref="xte:defaultAttributes"/>
</xsd:complexType>

<xsd:complexType name="french">
  <xsd:attributeGroup ref="xte:defaultAttributes"/>
</xsd:complexType>

</xsd:schema>
```

The interesting point about listing 2.24 is how it is possible for the user to refine the definition of the sentence element `s`, which was initially defined in listing 2.22. This is achieved with the help of the derivation mechanism provided by the XML Schema language. Because the complex type `sentence.with.parts` is derived from the sentence type `s`, it becomes possible to create sentence elements in a document instance which are in fact of type `sentence.with.parts` in places where sentence elements of type `s` are expected by the paragraph- and sentence-wise encoding previously shown in listing 2.22. The only requirement for this substitution to work is to denote the actual type of an `s` element by using a `type` attribute from the `http://www.w3.org/2001/XMLSchema-instance` namespace. While default sentence elements which contain no child elements could still be declared without `type` attribute, the declaration of a sentence element which contains a `latin` element could be achieved as shown in the following listing:

```
<s start="82" end="91" link="1" style="title2" xsi:type="sentence.with.parts">
  <latin start="85" end="88"/>
</s>
<s start="91" end="298" link="2" style="title3" />
```

Notice that the creator of the schema for the paragraph- and sentence-wise encoding did not had to take special care to make the sentence element `s` customizable by the user as this had to be done in the DTD case (compare with listing 2.15). Instead, the XML Schema language provides this extensibility feature. On the other hand, the XML Schema language also allows the creator of an encoding to use the `final` attribute on a type to specify which element types should not be further refined by derivation.

Finally, the customized XTE XML Schema created in listing 2.24 could be used to validate a document instance by including the attributes shown in the following listing into the root element of the document:

Listing 2.25: An example XML file which uses the XML Schema defined in listing 2.24

```
<?xml version="1.0" encoding="UTF-8"?>
<XTE xmlns="http://www.language-explorer.org/XTE"
     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
     xsi:schemaLocation="resources/div1pages.xsd">
 ...
</XTE>
```

The XTE XML Schema realized with derivation

Besides the possibility of realizing the XTE Schema extensibility with substitution groups, it is also possible to achieve the same results by using the XML Schema derivation mechanism. This mechanism has been used already in the last section to make elements defined in a partial encoding customizable by other users. In the case of the base XTE XML Schema, derivation will be applied to the `body` element. The type of the `body` element has to be defined as follows:

Listing 2.26: The definition of the `body` type for the XTE Schema realized with derivation

```
<xsd:complexType name="body">
  <xsd:attribute name="encodingName" use="required"/>
  <xsd:attribute name="type" use="required">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="default"/>
        <xsd:enumeration value="auxiliary"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:attribute>
  <xsd:attribute name="view" use="required"/>
</xsd:complexType>
```

The only change with respect to the old definition of the `body` type (see listing 2.20) is the fact that `body` now contains no other elements. By default there are just a few attributes defined for this element. However in document instances, the plain `body` element type will be not used. Elements which have a type derived from `body` will be used instead. The sentence- and page-wise encoding already presented in listing 2.23, would have to be defined as follows to work with the new schema:

Listing 2.27: Definition of the page-wise encoding for the XTE Schema realized with derivation

```
...
<!-- derive a new body type from the abstract 'body' type in XTE.xsd which
     uses the 'pages' encoding schema -->
```

Listing 2.27: Definition of the page-wise encoding for the XTE Schema realized with derivation (continued)

```
<xsd:complexType name="pagesBody">
  <xsd:complexContent>
    <xsd:extension base="xte:body">
      <xsd:sequence>
        <xsd:element name="pages" type="pages"/>
      </xsd:sequence>
    </xsd:extension>
  </xsd:complexContent>
</xsd:complexType>

<xsd:complexType name="pages">
...
</xsd:complexType>
...
```

Notice that a new type called pagesBody has been introduced, which is derived from body. Also, the div type no longer has to be derived from encoding. In fact the auxiliary element encoding, which was previously used, is not necessary any more.

Merging different encodings together with the base XTE Schema and customizing them can be done in exactly the same way as shown in listing 2.24 in the previous section. However, in the document instance that uses the new schema for validation purpose, the body elements will have to be supplemented with an XML Schema Instance type attribute that denotes the actual type of the body element. For a body element which contains elements of the page-wise encoding shown in listing 2.27, this looks as follows:

Listing 2.28: Example of a body element which is of type pagesBody

```
<body encodingName="Default" type="default" view="native" xsi:type="pagesBody">
  <div1 link="1">
    <p link="1">
      <s start="0" end="44" link="1" style="title1" />
  ...
</body>
```

Notice that the body element also contains another type attribute for the target namespace. This is not to be confused with the type attribute defined in the XML Schema Instance namespace which was introduced in the root XTE element (see listing 2.25) and which was bound to xsi: in this example.

Both of the extension mechanisms for the XTE Schema presented in the last two sections work equally well. However, because of compatibility reasons with the DTD version, which will be explained in more detail in the next section, the actual schema version of XTE uses substitution groups as extension mechanism.

2.4.3 Using the XTE DTD together with the XTE XML Schema

The last two sections showed in some detail how the XTE can be defined as a DTD as well as an XML Schema. However these two solutions do not necessarily have to be mutually exclusive. By taking some special care during the design of the two XTE implementations, it becomes possible to finally use both of them at the same time for the validation of an instance document.

This approach has several advantages. First of all, a larger number of applications will be able to validate the instance document because all applications that understand either a DTD or an XML Schema will be able to validate the document. Further on, the schema version of XTE can be used to define additional constraints that are not expressible in a DTD for the elements. In such a case, an application may choose to validate the instance document just against the weaker DTD, or if capable to do so, also validate against the more rigorous XML Schema.

The biggest challenge for using a DTD together with an XML Schema is the fact that DTDs do not understand namespaces (for a discussion see section 2.1.1). This means that it is not possible to declare attributes or elements to belong to a certain namespace in a DTD. Therefore, it seems as if it would be impossible to declare a target namespace in the XTE schema definitions because doing so would require all the elements in an instance document to be qualified with the same namespace prefix.

However, by applying the techniques already demonstrated in listing 2.9 it becomes possible to customize the namespace prefixes used in the DTD. While the XML Schema validator uses the real namespace to which name prefixes are bound to in order to validate an instance document, the DTD is customized to use the exact namespace prefix as defined in the XML Schema.

As shown in listing 2.25 and 2.28 there are two places where namespace qualified attributes are necessarily needed if a document instance should be validated against a schema. The first one is the root element where the location of the corresponding schema has to be specified with the `schemaLocation` attribute from the `http://www.w3.org/2001/XMLSchema-instance` namespace. The second one is every element which may be substituted by an element of a derived type and which has to explicitly state its actual type by using a `type` attribute from the same namespace. The following listing shows the changes that are necessary to make the XTE DTD from listing 2.9 XML Schema compatible:

Listing 2.29: Changes to the base XTE DTD from listing 2.9 to make it “Schema compatible”

```
<!ENTITY % xsi.ns.suffix             ":xsi">
<!ENTITY % xsi.ns.prefix             "xsi:">
<!ENTITY % namespace.xsi             "xmlns%xsi.ns.suffix;">
<!ENTITY % noNamespaceSchemaLocation "%xsi.ns.prefix;noNamespaceSchemaLocation">
<!ENTITY % schemaLocation            "%xsi.ns.prefix;schemaLocation">
<!ENTITY % typeAttribute             "%xsi.ns.prefix;type">

... more entity definitions ...

<!ELEMENT XTE (text)>
<!ATTLIST XTE
  %namespace.xsi; CDATA #FIXED "http://www.w3.org/2001/XMLSchema-instance"
  %schemaLocation; CDATA #IMPLIED
  %noNamespaceSchemaLocation; CDATA #IMPLIED
  %namespace.xte; CDATA #FIXED "http://www.language-explorer.org/XTE"
  %namespace.xlink; CDATA #FIXED "http://www.w3.org/1999/xlink"
  xmlns CDATA #IMPLIED
>

<!ELEMENT %body; %local.encodings;>
<!ATTLIST %body; encodingName        CDATA #REQUIRED
                 type                (default|auxiliary) #REQUIRED
                 view                CDATA #REQUIRED
```

Listing 2.29: Changes to the base XTE DTD from listing 2.9 to make it "Schema compatible" (continued)

```
                 %typeAttribute;     CDATA #IMPLIED
                 xmlns:typeNS        CDATA #IMPLIED
                 xmlns               CDATA #IMPLIED
>

... more element definitions ...

<!ENTITY % default.attributes "start     CDATA #IMPLIED
                               end       CDATA #IMPLIED
                               ... more attribute definitions ...
                               %typeAttribute;    CDATA #IMPLIED
                               xmlns:typeNS       CDATA #IMPLIED
                               xmlns              CDATA #IMPLIED"
>
```

First of all we define entities for the namespace prefix of the `http://www.w3.org/2001/XMLSchema-instance` namespace and entities for attributes from this namespace. For brevity we will use the default `xsi:` namespace prefix for this namespace in the following part of this section. The `XTE` root element is then extended by the `xmlns:xsi` attribute the content of which is preset to the fixed value `http://www.w3.org/2001/XMLSchema-instance` and the `xsi:schemaLocation` attribute which will hold the URL of the Schema against which the instance document should be validated. For the case where the user also wants to validate against an XML Schema that uses no target namespace, we additionally add the `xsi:noNamespaceSchemaLocation` attribute.

The second change extends the attribute list of the `body` element and the default attributes defined in `default.attributes` with the `xsi:type` attribute. This is done in order to support the user customization of encodings through derivation as demonstrated in listing 2.24. Because all new encoding elements should use the attributes defined in the parameter entity `default.attributes`, they all are customizable by default. If the derived element is defined in its own namespace, a possibility is needed to make this namespace available before it can be referenced in the `xsi:type` attribute. This is exactly the function of the `xmlns:typeNS` attribute. It can be used to bind the `typeNS:` prefix to an arbitrary namespace, which can then be referenced in the `xsi:type` attribute.

Notice that the additional `xsi:type` and `xmlns:typeNS` attributes on the `body` element are only necessary if the XTE Schema is defined by means of derivation. The following listing shows how they would be used in an instance document validated by the custom encoding `div1Body` which is defined in the namespace `http://www.language-explorer.org/XTE/div1`.

Listing 2.30: Usage of the `xsi:type` and `xmlns:typeNS` attributes.

```
...
<xte:body encodingName="Default" type="default" view="native"
          xmlns:typeNS="http://www.language-explorer.org/XTE/div1"
          xsi:type="typeNS:div1Body">
  <div1 xmlns="http://www.language-explorer.org/XTE/div1" link="1">
    <p link="1">
      <s start="0" end="44" link="1" style="title1" />
    </p>
    ...
```

2.4.4 Encoding facsimile texts with XTE

In this section a short description of an encoding is given which can be used to include facsimile editions of a document into LanguageExplorer and LanguageAnalyzer. The idea behind the encoding, which is shown in listing 2.31, is to define a `facsimile-book` element that holds an arbitrary number of facsimile pages. Notice how the `viewClass` attribute defined initially in the parameter entity `default.attributes` in the base XTE DTD is refined and set to the fixed value of the class name that should be used to render elements of that type.

Listing 2.31: A simple DTD for encoding facsimile documents in LanguageExplorer.

```
<!--
   An external encoding which can be used with the XTE DTD version 0.1

   This encoding divides the text into pages and lines as present in a certain
   edition of a printed version of the text.
-->

<!ELEMENT facsimile-book (facsimile-page+)>
<!ATTLIST facsimile-book viewClass CDATA #FIXED
                                   "com.languageExplorer.text.xml.VBoxView"
                         %default.attributes;
                         edition   CDATA #IMPLIED
>

<!ELEMENT facsimile-page ((facsimile-fragment | facsimile-fragments)+)>
<!ATTLIST facsimile-page viewClass CDATA #FIXED
                                   "com.languageExplorer.text.xml.XMLImageView"
                         %default.attributes;
                         url      CDATA #IMPLIED
                         location CDATA #IMPLIED
>

<!ENTITY % fragment.attr "x       CDATA #REQUIRED
                          y       CDATA #REQUIRED
                          width   CDATA #REQUIRED
                          height  CDATA #REQUIRED
                          type    (glyph|character|syllable|word|line|paragraph|page|other)
                                       #IMPLIED"
>

<!ELEMENT facsimile-fragments ((facsimile-fragment | facsimile-fragments)+)>
<!ATTLIST facsimile-fragments %default.attributes;
                              %fragment.attr;
>

<!ELEMENT facsimile-fragment EMPTY>
<!ATTLIST facsimile-fragment %default.attributes;
                             %fragment.attr;
>
```

Each facsimile page, which is represented by the `facsimile-page` element, has a link to the facsimile image which may be given as a URL in the `url` attribute or a local file system resource in the `location` attribute. Each facsimile page may be composed out of an arbitrary number of so called facsimile fragments that are represented by the `facsimile-fragment` element. Each of them describes a rectangular area of the facsimile image. Fragments, which belong together logically, can be grouped together in a `facsimile-fragments` element. Because `facsimile-fragments` elements can not only contain `facsimile-fragment` elements but also other `facsimile-fragments` elements, they can be used to recursively refine of the description of a facsimile document.

The `type` attribute of the fragment elements gives a description of the content represents by the fragment and may contain such values like `character`, `word` or `line`.

This simple encoding may be used for example to represent the results of processing a scanned text image with an OCR program. Notice that the `facsimile-fragment` element uses the `start` and `end` attributes defined in `default.attributes`, that is a text model is constructed even for a facsimile document. Although the content of this model is not relevant for the visual representation, it can be used for example to linearize the different fragments and provide an easier way of navigation and access. See figure 3.9 on page 55 for a picture of how a facsimile document encoded with this encoding may be represented in LanguageExplorer and LanguageAnalyzer.

Chapter 3

The software architecture of LanguageExplorer and LanguageAnalyzer

This chapter will give a high level overview of the different software packages which are part of the LanguageExplorer/LanguageAnalyzer framework. It contains design rationals and explains how the different modules of the system work together. Finally it outlines the different extension points, interfaces and plugin mechanisms which can be used to customize and extend the system. Some general support libraries and implementation techniques will be described in chapter 4.

3.1 The Java programming language

Before the start of a new software project, the selection of the appropriate programming language is one of the first decisions one has to take. And of course we were also faced with this problem when the project started some years ago. If political questions can be disregarded, there still remain a couple of objective requirements which have to be fulfilled by the languages in question. As our goal was to build an open system, one of the most important requirements was platform and system independency. We also wanted to use a modern, object oriented programming language which comes with a rich set of standard libraries. Finally, we looked for a language for which free compilers/interpreters and development environments from different sources were available and which has considerable support by a big user community in order to ensure continuity in the future.

Taking into account these constraints, we finally had the choice between C++ [Str] and Java [GoJoSt], which both seemed to fulfill the desired requirements. Although C++ has the reputation of generating faster code and offers more elaborate language concepts like multiple inheritance and genericity[1] compared to Java, we favored Java in the end because of two main reasons. The first one was the availability of many free, professional integrated development environments (IDEs) [SAFKKC, BGGSW, JBuil] for Java.

The second and in our eyes the most important advantage of Java, is the tremendous number of available standard and extension libraries for any imaginable application do-

[1] Starting with version 1.5, the Java programming language will also offer genericity as a language feature. Although different approaches which extend Java with generics existed already for a while [CarSt, OdWa, MyBaLi], we did not use them in the current work. Using generics may be however an option for the future development of the system, as they are becoming a standardized feature now.

main. And because Java is a language which is translated to byte code and executed by a virtual machine (JVM) [JVM], all these libraries[2] are available on every platform for which a Java virtual machine is available. This benefit combined with the better tool support outweighs the performance advantage of C++ in our opinion.

3.1.1 The Java APIs

Modern software development is not possible today without the usage of supported standard libraries. Especially in the area of graphical user interfaces (GUIs), the needs and expectations of the users can only be fulfilled by building upon the predefined widgets defined in such libraries. But file input and output (IO), processing of XML documents or the handling of different media types like for example graphics or sound are also hard to cope with if there exist no supporting libraries.

The advantage of Java is the fact that it constantly increased the number of standard libraries since its appearance in 1995. Among others, these are today libraries for GUIs, IO, networking, image processing, sound, input methods, UNICODE text processing, help systems, XML processing, cryptography, persistence, remote method invocation, containers and basic algorithms to name just a few. And, as already mentioned earlier, if these libraries are implemented in pure Java, they are system independent and run on every hardware and under every operating system which supports a JVM.

During the implementation of LanguageExplorer and LanguageAnalyzer we more or less used most of these libraries. The two most important ones, on which our system is directly built on, are the XML libraries commonly known under the name JAXP (Java API for XML Processing) [MacLa] and the GUI library commonly known under the name JFC (Java Foundation Class) and Swing [ELW]. The next sections will introduce these libraries in some more depth.

Swing and the Java Foundation classes

It was a big deal that at the time of its first appearance Java offered a system independent, easy to use, widget set for GUI programming. This Abstract Window Toolkit (AWT) [Zuk97] was implemented as a kind of unification layer for the different, platform specific widget sets. Every AWT component was in fact just a wrapper class for a concrete counterpart (called peer) provided by the host system. These peers were internally accessed with the help of the Java Native Interface (JNI) [Lia]. This kind of architecture however made it particularly hard to port the AWT to new operating systems or native widget sets and restricted the number and functionality of the widgets provided by the AWT to the lowest common denominator of all the supported native widget sets.

These problems led to the development of the Java Foundation Classes which are a set of GUI libraries composed from the old AWT, a new 2D library called Java2D, support libraries for accessibility and internationalization and Swing, a platform independent, rich widget set implemented completely in Java. The new libraries are based on modern design principles and commonly accepted design patterns. The most important ones in this context are the Model View Controller (see section 4.3.2 for a discussion of the implementation of the MVC pattern in Swing) and the Observer pattern.

Other features provided by Swing are the pluggable look and feel architecture which allows a customization of the look and feel, the input method framework which gives the developer the opportunity to develop system independent input methods for the input of arbitrary languages with the help of a normal keyboard and accessibility support which

[2] This is not strictly true, because Java programs may execute platform depended code through the Java Native Interface (JNI) [Lia]. However most of the available libraries are written in pure Java and rely solely on the services provided by the Java Runtime Environment (JRE).

allows developers to create applications with assistive technologies which support disabled people in using the applications.

For LanguageExplorer and LanguageAnalyzer the pluggable look and feel architecture has been used for example to create a new, multi-lingual user interface (see section 4.3) and the input method framework has been used to create input methods for Cyrillic and Hebrew letters (see section 29). Figure 3.1 finally gives an overview of the widgets of the Swing library. Most of them have been used in our applications and will be subsequently referenced in the description of LanguageExplorer and LanguageAnalyzer.

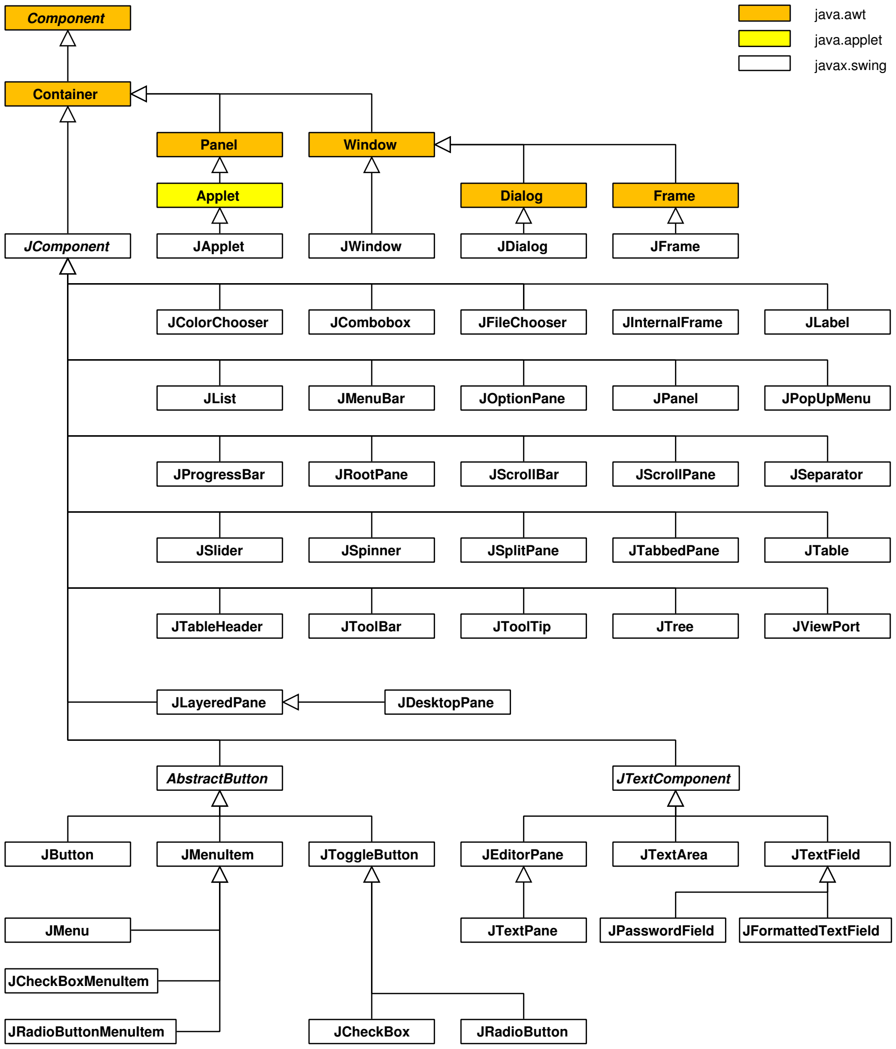


Figure 3.1: A class diagram of the Swing classes along with the few AWT classes they are built on. Notice that these AWT classes are simple containers or graphic panes, so there is only a minimal system dependency compared to the AWT widgets, where every single widget depends on the corresponding system widget.

The Java text package

Java provides an extensive collection of classes for working with text. One of the innovations of Java was the fact that the representation format of all kind of textual data of the language itself as well as the format of all the textual data types is fully based on the UNICODE [U30] standard. This solves a lot of problems of older programming languages like C or C++ which usually use an 8-bit character set for the builtin, textual data types and which therefore always have to use special libraries if they want to process textual data stored in the UNICODE format (e.g ICU [ICU]).

As already discussed in section 1.1.2, the UNICODE standard not only defines a character encoding for a wide range of modern and ancient languages, it also defines methods for handling collation, directionality, searching and other important language aspects for texts stored in that encoding.

Figure 3.3 gives an overview of the different text related classes in the standard Java libraries. As can be seen in the figure, they are split around several packages. Among others, the package `java.text` contains the class `Bidi` for determining the writing direction of a text, collator classes for doing locale-sensitive string comparisons and the class `BreakIterator` which can be used to find for example word and sentence boundaries in a text. Most of the tasks performed by these classes seem to be trivial. However, for other languages than English they can be quit complicated. There are for example languages like Hebrew which have different writing directions for text (right to left) and numbers or foreign words (left to right) and these writing directions can be arbitrary nested. Other languages like for example Thai need special, dictionary based word iterators because there exist no word separators in the text. Collation is also not straightforward, because every language has its own collation rules for accented and other special characters. And finally, as a consequence of the UNICODE standard, letters can have several representations like for example single character code entries, composition of several character code entries or just the part of a character code entry representing a ligature. Therefore, even finding single letters in a character stream may be a nontrivial task. Together with the character class `java.lang.Character` the classes of the `java.text` package serve as a base library for all other classes dealing with text in Java.

With `java.util.regex` a powerful, new regular expression package has been added in Java 1.4. It allows for Perl style regular expressions [Friedl] but also supports the full syntax of UNICODE regular expressions [UnReEx]. See section 5.4.6 for an explanation of the usage of regular expressions in LanguageExplorer.

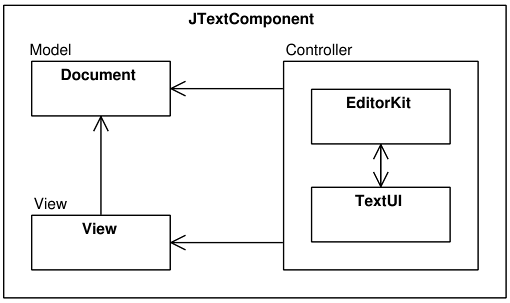


Figure 3.2: The high level view of a Swing text component.

Finally, the package `javax.swing.text` and its sub-packages contain all the classes which are responsible for the visual representation of textual data on the screen and the interaction of the user with this data. Many parts of LanguageAnalyzer and LanguageExplorer have been derived from these classes.

The high level text components like for example `JTextPane` for styled text which are all located in the `javax.swing` package and are all derived from `JTextComponent`, are in fact just container classes for the different model, view and controller related classes located in the

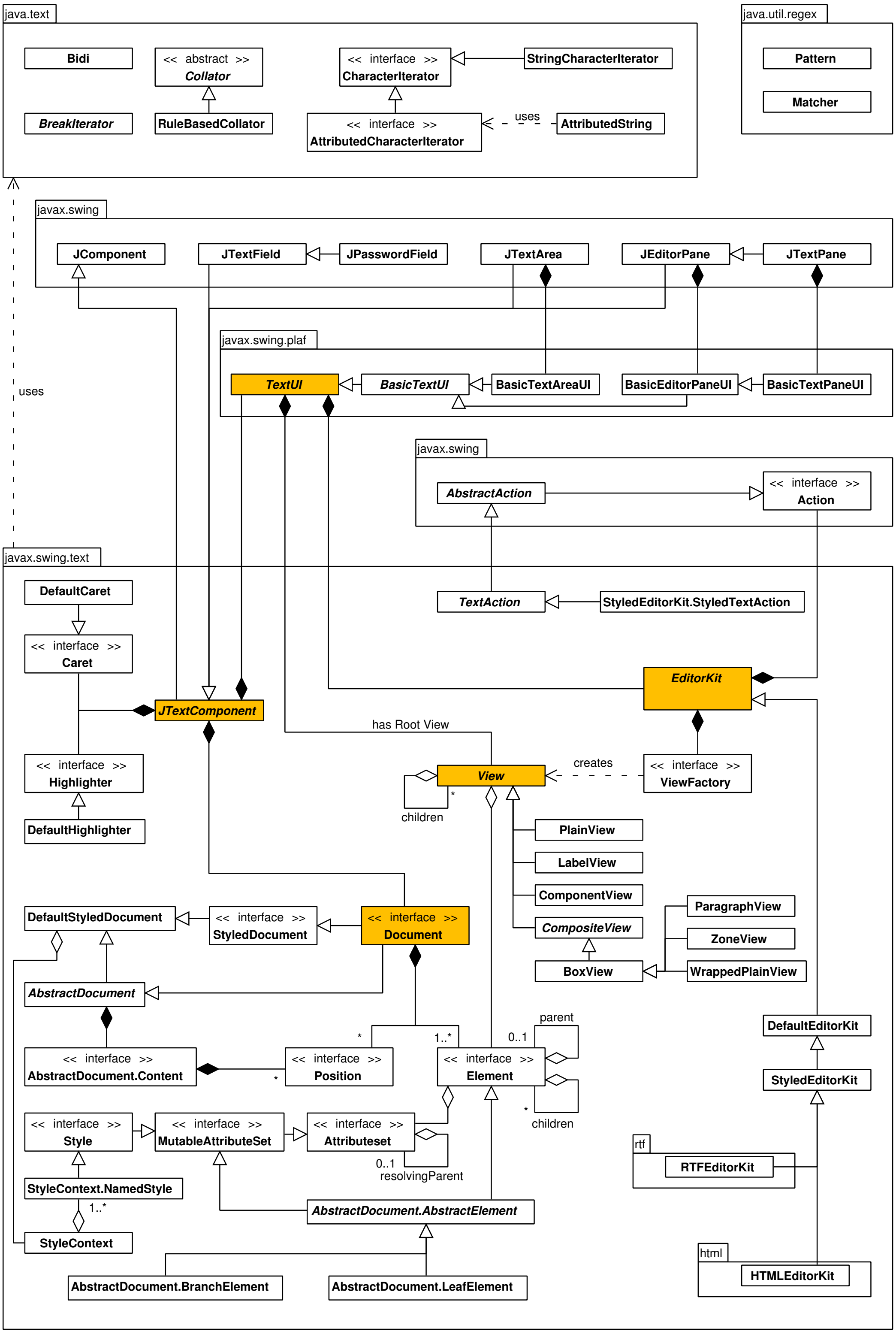


Figure 3.3: An overview of the text related classes and their dependencies in the standard Java APIs. The shaded classes correspond to the parts with the same names in figure 3.2.

javax.swing.text package. The model consists of one or more tree like structures of elements of type Element over a linear character data content. The controller part is a combination of the class TextUI which associates every element of the model with a corresponding view object and the class EditorKit which is responsible for building and changing the model and controlling the user interaction. Finally, the view part is a hierarchy of View objects created by the controller which render the different element structures of the model. In order to support styled text, every element of the model can have associated attributes which in turn may resolve through global styles.

JAXP - The Java API for XML processing

Since version 1.4, Java comes with a new standard library for XML processing. This library which is commonly known under its abbreviation JAXP, is in fact just an abstraction layer for some common, standard XML processing libraries. Different implementations of these libraries can be easily plugged into JAXP, without the need to rewrite any code which uses just the abstract functionality provided by JAXP and the underlying standard XML libraries. Currently, JAXP supports the two XML parser standards SAX and DOM and XSLT, the 'Extensible Stylesheet Language Transformations'.

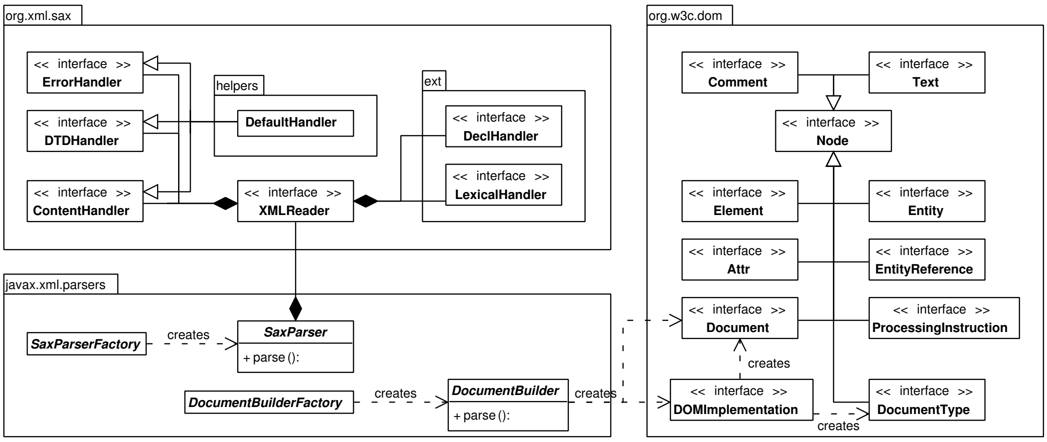


Figure 3.4: The parser part of the Java API for XML processing together with the SAX and DOM interfaces.

SAX [Broe] is the abbreviation for Simple API for XML. It was developed in a public review process on the xml-dev mailing list at http://xml.org[3] and was one of the first libraries available for XML parsing. Initially a Java only library, there now exist language bindings for many other languages like C, C++, Perl, Python and others. Meanwhile SAX is widely adopted and a de facto standard for XML parsing.

SAX is an event-driven, serial-access mechanism that does element-by-element processing of the XML file. It therefore does not need to read the whole file into memory before processing it which may be a considerable performance advantage for big XML files or files read from a network connection. It should be noticed, that SAX itself provides just interfaces for the most part and there exist many different parser implementations which adhere to these interfaces. SAX however offers unified methods for setting and querying features and properties of the underlying parser implementations like for example the validation property or the namespace awareness.

[3] Today the xml-dev mailing list is hosted by OASIS [OASIS]

Users who wish to use SAX have to implement the different event handler interfaces like for example `ContentHandler` or `DTDHandler` (see figure 3.4), create an `XMLReader` instance, that is an object which implements the SAX parser interface and calls the `pares()` method on this object with the event handler as argument. The parser will then call the user defined callback methods every time when the corresponding parts in the XML source are found. JAXP, on its part, defines a factory class which facilitates the creation and configuration of different SAX parsers.

DOM, the Document Object Model library, is the second parser interface offered by JAXP. The DOM API creates a complete in-memory, tree representation of an XML file or allows the user to build up such a model from scratch. Once the DOM is created, it can be navigated, altered and finally saved back as XML file. In contrast to SAX, the DOM API always works on a complete copy of an XML file. This may be convenient for many applications, however the increased start-up time and memory consumption should always be considered. Notice that also not mandatory, many DOM implementations internally use a SAX parser to create the in-memory tree representation of an XML file.

The Document Object Model is a platform- and language-neutral interface published by the W3C consortium as a technical recommendation [DOM]. Just like SAX specifies callback methods for every part of an XML file, DOM specifies interfaces for every XML entity. As can be seen in figure 3.4, these interfaces are all derived from `Node`. A DOM is a tree build up from various `Node` elements.

Again, the JAXP API acts like a wrapper and factory for the different DOM implementations which are available. It offers a unified interface for setting and querying various DOM properties to the programmer and frees her from the burden of bothering with the peculiarities of every single implementation. It should be noticed however, that there meanwhile exist three DOM levels and for example serialization of a DOM to disc is standardized in DOM level 3 only but not before. Therefore it is often necessary in practice to cast the DOM objects created by the standard factory classes to their real type in order to take advantage of non-standard conformant functionalities provided by different implementers.

3.2 The LanguageExplorer text classes

As this work is about "structuring, analyzing and presenting" text, the central part of the two applications LanguageAnalyzer and LanguageExplorer is of course the text component. Building on the foundations laid by the Swing text package, we created our own text component `XMLEditorPane` which is derived from `JEditorPane`. It uses an instance of the class `XMLDocument` which is derived from `DefaultStyledDocument` and custom elements as document model. Finally, an editor kit of type `XMLEditorKit` which extends `StyledEditorKit` is responsible for loading and saving documents for LanguageAnalyzer and LanguageExplorer. Several new view classes can be used together with the ones provided by Swing to render the elements of the document model hierarchy. An overview of the basic LanguageAnalyzer/LanguageExplorer text classes is given in figure 3.5.

As implied by the different class names, the created text classes are in fact classes which can handle arbitrary content stored in XML format. However, we did not wanted to implement a generic XML editor mainly for two reasons. First of all, there already exist quite a number of different high quality XML editors. And the second and more important reason is the fact that we did not pretend to handle every single XML document in a useful way. We think that XML is just a structured text format where the DTD (or the Schema) contains little to no semantics at all. They only define the structure of data, but not its meaning. It makes no sense to try to handle for example a MathML [MathML] file and a MusicXML [MusicXML] file with the same editor, although both of them are XML formats. It would be the same as if we would use the same text editor for programming and writing just because

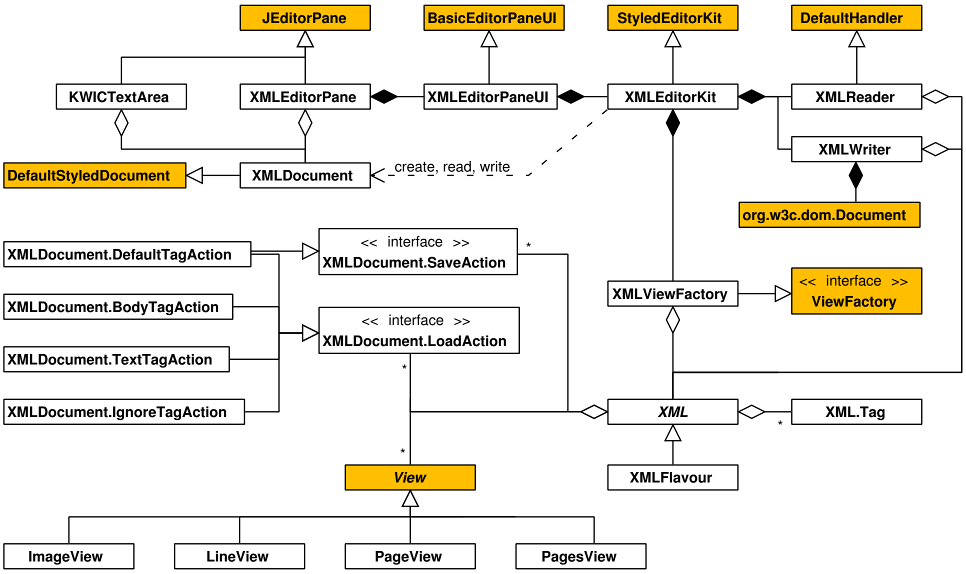


Figure 3.5: An overview of the basic LanguageAnalyzer/LanguageExplorer text classes and their relation with the standard Java APIs. The shaded classes represent the standard Java API classes with the same names from figure 3.3 and 3.4.

our programs and our articles are both stored as ASCII text. Although this would be possible, it is a lot more comfortable to use a special desktop publishing (DTP) system for writing articles and an integrated development environment (IDE) for programming purposes.

It is much the same thing with the XTE format defined in section 2.4. A generic XML editor could be used to have a look at such a file or even to make some small changes in it. But the semantics of the different linking attributes for example, would be unclear to such an editor. While this would just complicate the navigation in such a document in the common case, it could lead to a severe corruption of the internal semantics of the file because the XML document type definitions and schemas (see sections 2.1 and 2.1.2) can only describe and ensure the structure of the document, not the semantics.

Another aspect is the aesthetics of the presentation. While LanguageAnalyzer is more or less a tool for the structuring and linking of different documents where the aesthetics of the representation is not the most important thing compared to performance, LanguageExplorer is used as a viewer and reader for true works of art and as such should be able to appropriately display them. Therefore the application of techniques like text anti-aliasing as well as the usage of different, high quality fonts which support hinting and kerning should be possible to allow a reading experience comparable to that of a printed book.

3.2.1 The document class

The document model class `XMLDocument` is the representation of a part of an XTE (refer to section 2.4 for a description of XTE) encoded text in the memory for the purpose of displaying and editing it. As opposed to the standard `DefaultStyledDocument` document class, `XMLDocument` supports an arbitrary number of so called root elements, each of which corresponds to one of the XTE encodings defined in the XTE file. In fact, every `text` element nested inside a `group` element in the XTE file is represented by a single `XMLDocument` instance whereas each of the `body` elements of a `text` element in the XTE file is represented by a root element in the `XMLDocument` object. Figure 3.6 depicts this relation graphically.

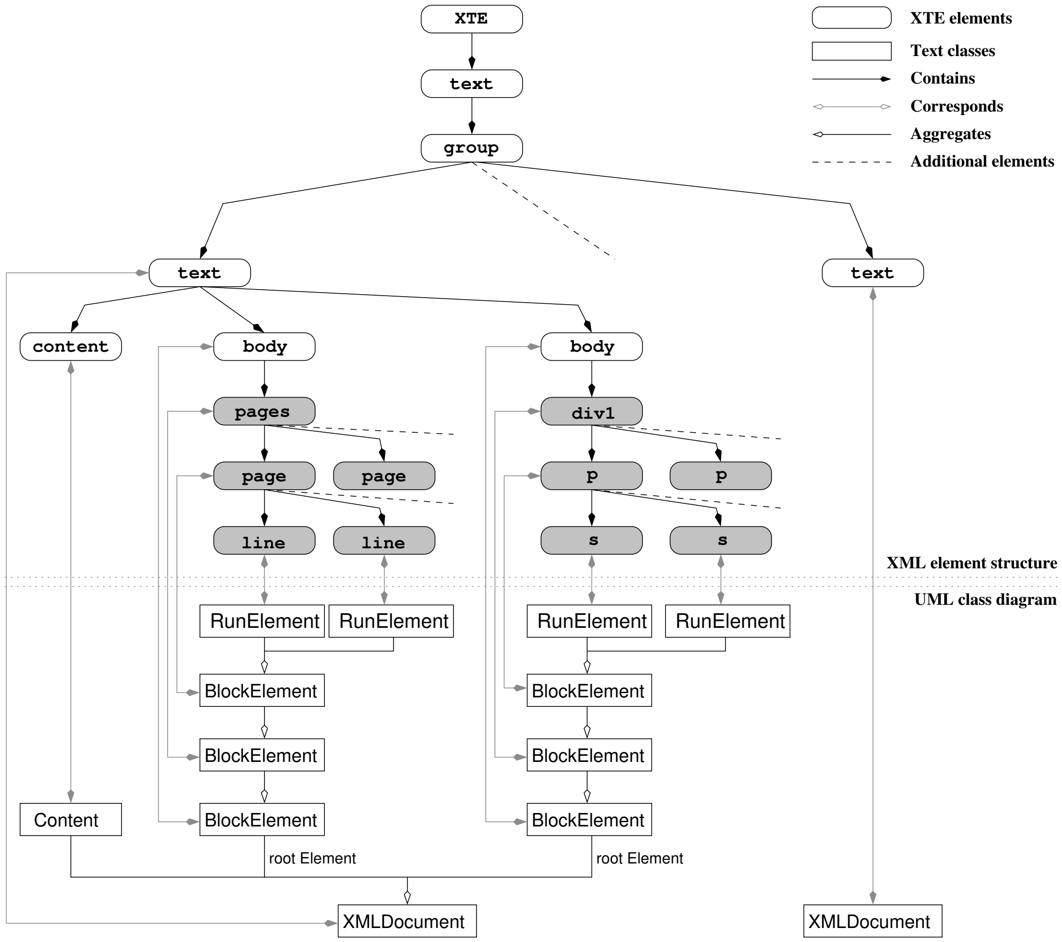


Figure 3.6: The in-memory representation of an XTE encoded text with the help of the various model related text classes of LanguageAnalyzer and LanguageExplorer. Refer to figure 2.2 for a more detailed picture of the XTE encoding.

As can be seen in figure 3.6, XTE elements will be usually mapped to `Element` instances in the `XMLDocument`. However, there is no strict one to one mapping, as the exact relation between an XTE element and an `Element` object is determined by the `LoadAction` object associated with the corresponding XTE element type (i.e. the XML tag). This association is resolved through an object of type `XML` (see figure 3.5). The exact procedure of how this resolving takes place will be explained in more depth in section 3.2.2. For now it is enough to assume a one to one relation between the XTE elements and the `Element` objects in an `XMLDocument` where the attributes of the XTE element are stored in the `AttributeSet` of the `Element` object. One exception to this rule, which is also visible in figure 3.6, should be mentioned here however: the content elements of an XTE text element are collapsed and their character data is stored as the content of the `XMLDocument`. This is done by a `TextTagAction` object, which is the `LoadAction` usually associated with an XTE content element. The text which is stored as content of the `XMLDocument` will be referenced by the elements created in the `XMLDocument` by translating the start and end attributes of the corresponding XTE elements to the new content representation.

Figure 3.7 shows the `XMLDocument` class in some more detail along with the inner classes it defines. The different classes derived from `LoadAction` as well as the `ImageReader` class have

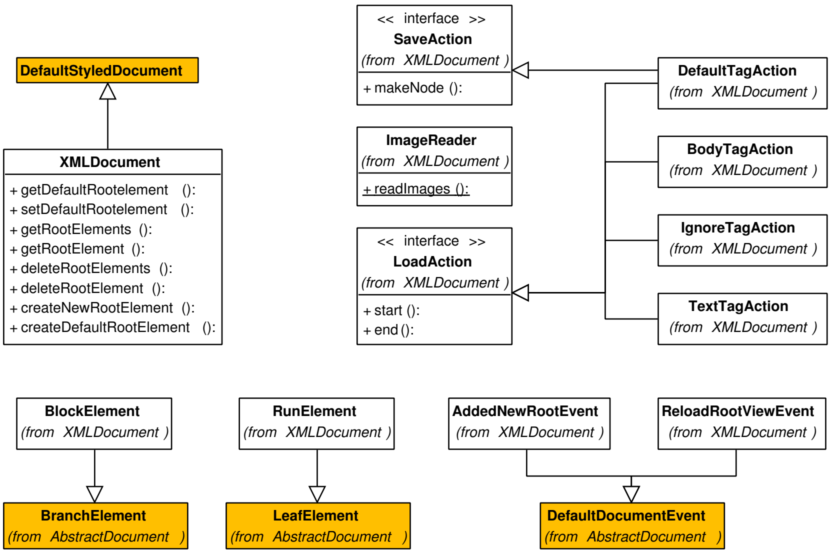


Figure 3.7: The UML diagram of the `XMLDocument` class. Again, shaded classes denote classes from the standard Java text packages (see figure 3.3).

to be defined as inner classes, because they are used to build up a new document model and therefore they need access to some document methods which have protected access.

Several methods which deal with the creation, maintenance and removal of the different root elements, each of which represents a single XTE encoding, have been added to the document class. There is always a default root element or encoding which is used by the `TextUI` class (the controller part of a text component) as the starting point for building up the view hierarchy. The two event classes `AddNewRootEvent` and `ReloadRootViewEvent` have been added to signal interested listeners that new root elements (i.e. encodings) have been added to the document or that the default root element has been changed. One of these listeners is for example the associated `TextUI` object, which rebuilds the view hierarchy such that it always corresponds to the structure represented by the default root element.

Notice that document models may be shared between different text components. The KWIC-Index window of LanguageExplorer (see figure 5.2 on page 119) for example is a text component of type `KwicTextArea` (see figure 3.5) which shares its document model with the corresponding text component for which the KWIC-Index has been created. The KWIC-Index is in fact just a custom encoding of the text content. As such it is represented in the model by an element hierarchy with a root element which is created on the fly after a corresponding user request.

3.2.2 The editor kit

Reading XTE files and transforming them into the internal representation on the one side and storing documents from the internal representation as XTE files on the other side is the main duty of the editor kit class `XMLEditorKit`. To achieve this functionality, it uses many of the XML related classes described in section 3.1.1. However, not only XTE files can be loaded. As a bootstrapping process, other formats can be loaded and translated to the XTE format as well.

If the user requests the loading of a new file, this request is routed to the corresponding `XMLEditorKit` method. The editor kit has to decide how the file should be loaded based on the file format. All the different input formats supported by LanguageAnalyzer like for example pure text, image or XTE files are transformed into a uniform internal representation. If the loaded file is not already XTE encoded, the editor kit creates a default document with a default element structure to allow basic display, navigation and editing of the content.

After the user has finished the editing process, the document is stored as an XTE formatted XML file. Currently LanguageAnalyzer supports pure text, various graphic formats like JPEG, PNG and GIF and XTE encoded XML files as input formats and XTE encoded XML files as output format, while LanguageExplorer handles XTE files only. It is easy however to add new, unsupported input and output formats to LanguageAnalyzer by using the plugin mechanism described in section 3.6. In fact, these plugins just have to build an appropriate document model for the desired input formats or serialize the internal document model to the desired output format.

Reading other XML formats is especially easy because the loading of XTE documents is already designed to be highly customizable. This is necessary because XTE is an open encoding which is intended just as a starting point for users who wish or need to define their own encodings (see 2.4). It is therefore essential to give these users a possibility to influence the way how their proprietary encodings will be loaded, transformed into the internal representation and finally displayed on the screen.

This mapping between XTE elements and `XMLDocument` elements is handled by the abstract class `XML` and its concrete descendant `XMLFlavour` which are shown in figure 3.8. The `XML` class maps document type definitions (DTDs) to `XMLFlavour` objects. For every DTD it instantiates an `XMLFlavour` object, associates it with the name of the DTD and stores in a static map from where it can be queried by the user.

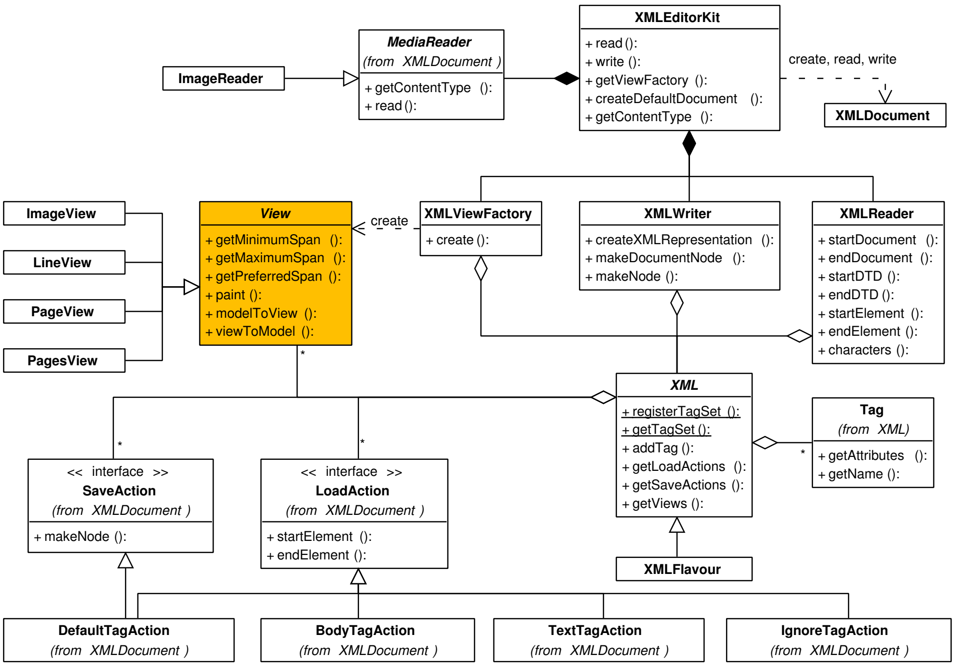


Figure 3.8: The class `XMLEditorKit` together with the various helper classes used for loading, storing and displaying an XTE file.

The `XMLFlavour` class maps the tags of the DTD to special action and view classes which are responsible for loading, saving and displaying the corresponding elements. For this purpose it uses simple, textual configuration files with the base name of the DTD which conform to the Java property file format. This file format contains key/value pairs separated by an '=' character. In our case the key represents the tag name while the value part contains the fully qualified class name of the corresponding action or view class. Once an XMLFlavour object has read its configuration files, it searches the specified classes on the class path, loads them dynamically into the running JVM and stores them in a local map from where they can be queried by using the corresponding tag name. The settings from the configuration file can be overridden by the special loadClass, saveClass and viewClass attributes which can be used on every element in the XTE file.

The final process of loading an XTE file into LanguageAnalyzer or LanguageExplorer is as follows: The editor kit creates an object of type XMLReader which is an instance of a SAX event handler. As soon as the document type of the file and the types of the different XTE encodings in the file are available during the parsing of the DTD, the corresponding XMLFlavour objects are created and associated with the encoding names. Finally, at the time when the first ordinary element is reported by the SAX parser, the XMLReader object can query the XML object with the tag name of the element for the proper load action and execute it with the current element as argument. This load action will subsequently initiate the creation of the appropriate model representation in the XMLDocument object.

Saving works exactly the other way round with the only difference that the DOM API is being used instead of the SAX API used in the loading case. Depending on the chosen output format, the editor kit queries the appropriate save action objects for every element. The duty of these save action objects is the creation of the necessary nodes in the DOM tree for the XMLDocument element they are responsible for. Once the whole document is translated into the DOM representation, the DOM can be written to an XML-file by using its built-in write method.

3.2.3 The view classes

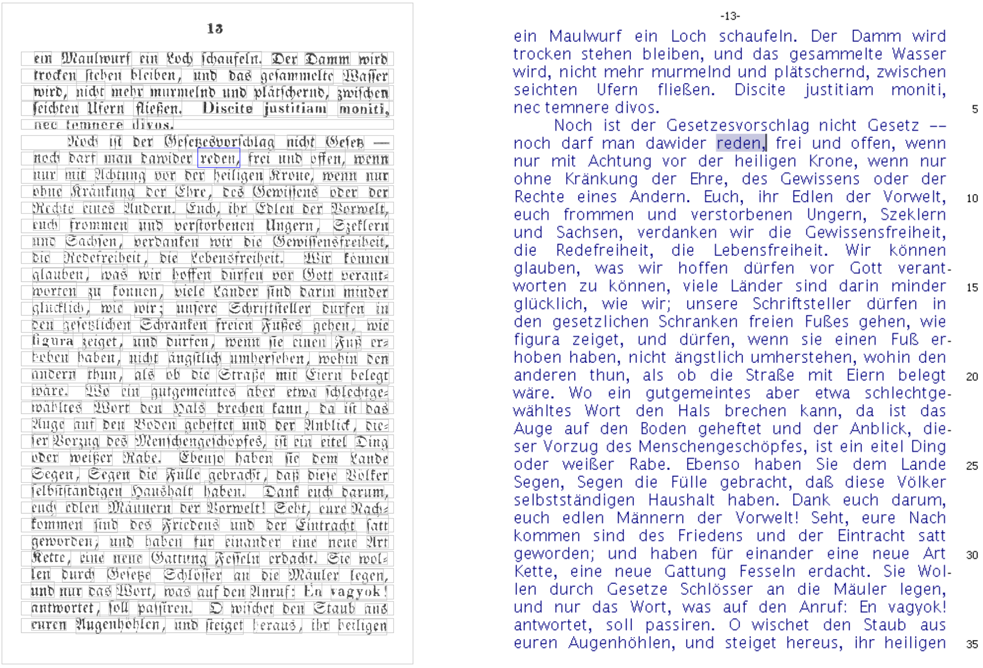
Another responsibility of the editor kit not discussed in the previous section is the creation and provision of a so-called view factory. The view factory is responsible for creating the view objects which render the different elements of the document model on the screen. For performance reasons, the view classes are lightweight objects not derived from any of the standard Swing components shown in figure 3.1. They just render a part of the model to the appropriate part of the text component.

Usually, every element is represented by a view object, however, there again is no strict one to one mapping between them. A view object which represents a branch element may for example decide not to act as a container for the view objects of its child elements but instead to render the child elements only directly. In fact, every view object can be thought of as kind of TEX box [Kn91a] and boxes representing child elements are nested inside the box of their parent element. Every box lays out and renders its child boxes depending on their layout attributes. In this way the whole document model is recursively represented on the screen.

Beside the participation in the layout and rendering process the second task of the view classes is to translate between the view coordinate space and model positions and vice versa. This is a crucial and not trivial task which is necessary to enable comfortable navigation and editing of the represented documents.

Although the Swing library already comes with quite a few view classes, we still had to develop new ones to cover our special needs. We developed for example the ImageView class which represents a bit-mapped version of text (facsimile) and allows the display of child elements as arbitrary, possibly nested regions which can easily be navigated with the usual cursor keys (see the left part of figure 3.9). Refer to section 2.4.4 for a description of how facsimile texts are encoded in XTE.

Another example of custom view classes are the LineView and PageView classes which can be used to display a line- and page-wise encoded text much the same way like in a printed



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ein Maulwurf ein Loch ſchaufeln. Der Damm wird trocken ſtehen bleiben, und das geſammelte Waſſer wird, nicht mehr murmelnd und plätſchernd, zwiſchen ſeichten Ufern fließen. Discite justitiam moniti, nec temnere divos.

Noch iſt der Geſetzesvorſchlag nicht Geſetz — noch darf man dawider reden, frei und offen, wenn nur mit Achtung vor der heiligen Krone, wenn nur ohne Kränkung der Ehre, des Gewiſſens oder der Rechte eines Andern. Euch, ihr Edlen der Vorwelt, euch frommen und verſtorbenen Ungern, Szeklern und Sachſen, verdanken wir die Gewiſſensfreiheit, die Redefreiheit, die Lebensfreiheit. Wir können glauben, was wir hoffen dürfen vor Gott verantworten zu können, viele Länder ſind darin minder glücklich, wie wir; unſere Schriftſteller dürfen in den geſetzlichen Schranken freien Fußes gehen, wie figura zeiget, und dürfen, wenn ſie einen Fuß erheben haben, nicht ängſtlich umherſehen, wohin den andern thun, als ob die Straße mit Eiern belegt wäre. Wo ein gutgemeintes aber etwa ſchlechtgewähltes Wort den Hals brechen kann, da iſt das Auge auf den Boden geheftet und der Anblick, dieſer Vorzug des Menſchengeſchöpfes, iſt ein eitel Ding oder weißer Rabe. Ebenſo haben ſie dem Lande Segen, Segen die Fülle gebracht, daß dieſe Völker ſelbſtſtändigen Haushalt haben. Dank euch darum, euch edlen Männern der Vorwelt! Seht, eure Nachkommen ſind des Friedens und der Eintracht ſatt geworden; und haben für einander eine neue Art Kette, eine neue Gattung Feſſeln erdacht. Sie wollen durch Geſetze Schlöſſer an die Mäuler legen, und nur das Wort, was auf den Anruf: En vagyok! antwortet, ſoll paſſiren. O wiſchet den Staub aus euren Augenhöhlen, und ſteiget heraus, ihr heiligen

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ein Maulwurf ein Loch schaufeln. Der Damm wird trocken stehen bleiben, und das gesammelte Wasser wird, nicht mehr murmelnd und plätschernd, zwischen seichten Ufern fließen. Discite justitiam moniti, nec temnere divos.

Noch ist der Gesetzesvorschlag nicht Gesetz -- noch darf man dawider reden, frei und offen, wenn nur mit Achtung vor der heiligen Krone, wenn nur ohne Kränkung der Ehre, des Gewissens oder der Rechte eines Andern. Euch, ihr Edlen der Vorwelt, euch frommen und verstorbenen Ungern, Szeklern und Sachsen, verdanken wir die Gewissensfreiheit, die Redefreiheit, die Lebensfreiheit. Wir können glauben, was wir hoffen dürfen vor Gott verantworten zu können, viele Länder sind darin minder glücklich, wie wir; unsere Schriftsteller dürfen in den gesetzlichen Schranken freien Fußes gehen, wie figura zeiget, und dürfen, wenn sie einen Fuß erhoben haben, nicht ängstlich umherstehen, wohin den anderen thun, als ob die Straße mit Eiern belegt wäre. Wo ein gutgemeintes aber etwa schlechtgewähltes Wort den Hals brechen kann, da ist das Auge auf den Boden geheftet und der Anblick, dieser Vorzug des Menschengeschöpfes, ist ein eitel Ding oder weißer Rabe. Ebenso haben Sie dem Lande Segen, Segen die Fülle gebracht, daß diese Völker selbstständigen Haushalt haben. Dank euch darum, euch edlen Männern der Vorwelt! Seht, eure Nach kommen sind des Friedens und der Eintracht satt geworden; und haben für einander eine neue Art Kette, eine neue Gattung Fesseln erdacht. Sie Wollen durch Gesetze Schlösser an die Mäuler legen, und nur das Wort, was auf den Anruf: En vagyok! antwortet, soll passiren. O wischet den Staub aus euren Augenhöhlen, und steiget hereus, ihr heiligen

Figure 3.9: The left picture shows how the encoding of a facsimile text (in this case words and lines) is rendered as gray blocks onto the image of the text by the `ImageView` class. The cursor is displayed as a blue rectangle at the current model position. The right side shows a picture produced by the `PageView` class view which internally uses the `LineView` objects. Notice the line and page numbers which do not belong to the text model but are added as a kind of decoration by the view classes.

edition. The lines and pages can be augmented with additional meta-information like for example page and line numbers which do not belong to the text model (see right side of figure 3.9).

The user may define other view classes at any time. Adding new classes to the system is straightforward because `XMLViewFactory`, the view factory used by the `XMLEditorKit`, also uses the `XML` class for resolving the appropriate view classes for the elements of the document model. This can be done by editing the corresponding configuration files or by inserting the names of the desired view classes as attributes directly into the XTE documents.

3.3 The LanguageExplorer file formats

LanguageExplorer and LanguageAnalyzer use two different sorts of file formats. The first, and most important one, is the leb file format which is used to store XTE documents along with related data files. The second one is the file format used by LanguageExplorer and LanguageAnalyzer to persistently store user preferences between different executions of the program. These two file formats will be discussed in the next sections.

3.3.1 The LanguageExplorer book format

As described in full detail in section 2.4, LanguageExplorer and LanguageAnalyzer documents are stored as XML files using the XTE encoding scheme. Although this scheme is quite flexible and extensible, there exist situations where even more functionality is needed. This is especially the case if third party content like for example data from dictionaries and

Name	**Description**
Main LanguageExplorer attributes.	
Name	The name of the XTE encoded XML file.
Book-ID	A string which contains no white space and which should be unique across all the different leb files. Used as key into the personal preferences file where user settings like for example the font family and size can be stored on a per book basis (see section 3.3.3).
Encryption attributes.	
Encrypted	Indicates whether the XTE XML file is encrypted (yes | no).
Encryption-Provider	If the XTE XML file is encrypted, this attribute may be used to specify the provider of the encryption engine used to encrypt this file. See section 3.3.2 for more information.
Encryption-Algorithm	If the XTE XML file is encrypted, this attribute may be used to specify the encryption algorithm used for encryption.
Bibliographic attributes.	
Title*n*	The title of the *n*th document in the XTE file.
Author*n*	The author of the *n*th document in the XTE file.
Language*n*	The ISO-639 [ISO639] two letter language code of the language of the *n*th document in the XTE file.
Extension attributes.	
Dictionary	Indicates whether the leb file contains dictionaries for the documents encoded in the XTE file (yes | no | partial).
Dictionary*n*	The name of the *n*th dictionary file. The name should begin with the hyphen separated ISO-639 two letter language codes of the languages provided by the dictionary.
Encyclopedia	Indicates whether the leb file contains encyclopedias for the documents encoded in the XTE file (yes | no | partial).
Encyclopedia*n*	The name of the *n*th encyclopedia file. The name should begin with the ISO-639 two letter language code of the encyclopedia language.

Table 3.1: Custom attributes defined for the leb file format. Inside the manifest file, keys and values are separated by a combination of a colon character and a space ′`: `′. Keys have to begin at the first column of a line. Values can span several lines. Continuation lines are signaled by a space character at the beginning of a line.

encyclopedias should be bundled with an XTE document, if facsimile pictures and sound files need to be stored along with the document or if the document content should be encrypted. For this purpose an additional container format has been defined which is based on Java archive (jar) files. The jar file format itself [CaWaHu] is based on the popular zip file format which uses a combination of the Lempel-Ziv algorithm [LeZi] and Huffman coding [Huff] to compress files. The innovation of the jar format is to define and add meta-information to the archive in a well-defined way. This information can be used for example to cryptographically sign the archive or to improve the processing of the file in certain, common cases like for example when loading classes from it.

All the meta-information available for a jar file is located inside the archive in a special subdirectory called `META-INF`. The most prominent file in this directory is the so-called manifest file `MANIFEST.MF` that can be used to specify arbitrary attributes as key/value pairs. There exist several standard attributes like for example `Manifest-Version` which gives the version of the manifest file format and `Main-Class` which can be used to specify the main class file if the archive stores Java class files. However, it is also possible to define custom attributes which consist of arbitrary key/value pairs. Together with the various classes offered by the standard Java API in the `java.util.jar` package which can be used to easily create and access jar files, the jar file format can be handled quite comfortable within own applications.

For the jar file format used here, the standard `.jar` file suffix has been replaced by the suffix `.leb` which stands for "LanguageExplorer book" in order to simplify the identification of the documents in the file system. Moreover, new, LanguageExplorer specific attributes have been defined which can be divided in different groups as shown in table 3.1.

The main attributes are used to identify the XTE document. The bibliographic attributes are used to get a quick overview of the contents of an XTE file without the need to parse the XTE file itself. They are used for example in the accessory component of the LanguageExplorer open file dialog (see figure 5.3 on page 121) but they can also be useful in the case where the content of the XTE file is encrypted. The extension attributes can be used to declare the names of certain extension files like for example dictionaries or encyclopedias which are packed together with the XTE file in the archive.

3.3.2 Encryption of LanguageExplorer books

Works of literary are usually protected by copyright for a certain amount of time. The details of how the copyright rules apply to different works in different countries should not be the subject of this work, however the tools presented here are aware of this problem and designed in a way which allow the encryption of the content in question. In this way, it becomes possible to license and distribute even copyright protected material.

But encryption could also be desirable to protect the mark-up if the content is already freely available. Considering for example an edition which combines a novel which is sentence-wise aligned with several different translations to other languages and possibly augmented with additional historical information and dictionaries, it may very well be worthwhile to protect such an editorial work independently of the underlying content.

Usually only the XTE file in a leb archive will be encrypted, but is also possible to encrypt the extension files like dictionaries or encyclopedias. For the encryption of the files the Triple-DES-EDE algorithm is used. Triple-DES-EDE is the usual DES [DES] algorithm applied three times in turn to encrypt, decrypt and again encrypt the data source in question with three different keys. DES is a symmetric block cipher cryptosystem which means that it uses the same key for encryption and decryption. Standard DES uses 64-bit keys and Triple-DES uses three 64-bit keys.

Our system currently varies only one of the three 64-bit Triple-DES keys on a per user and book basis. That is, for every combination of a user and book a new 64-bit key is generated and this key is used together with the two other, currently hard-wired 64-bit keys to encrypt the content of the book with the Triple-DES algorithm. In the future however, the remaining two 64-bit keys could be fetched for example from a license-server or from a license file to enable more sophisticated licensing policies.

To safe the user from remembering a randomized 64-bit key value for every encrypted book a so-called password based encryption algorithm (PBE) [PKCS5] is applied to encrypt the key with a user-supplied, secret password. PBE works by generating a message digest from the user supplied password with a one-way hash function and then uses the created hash value as a key for a symmetric block cipher to encrypt the requested content. Our system currently uses PBE with SHA1 [SHA] as hash function and triple DES as block cipher, however the applied algorithm can be configured with the Encryption-Algorithm attribute (see table 3.1) in the leb file.

In order to decrypt an encrypted LanguageExplorer book, the user has to supply the encrypted key and his secret password. The password will be used to decrypt the encrypted

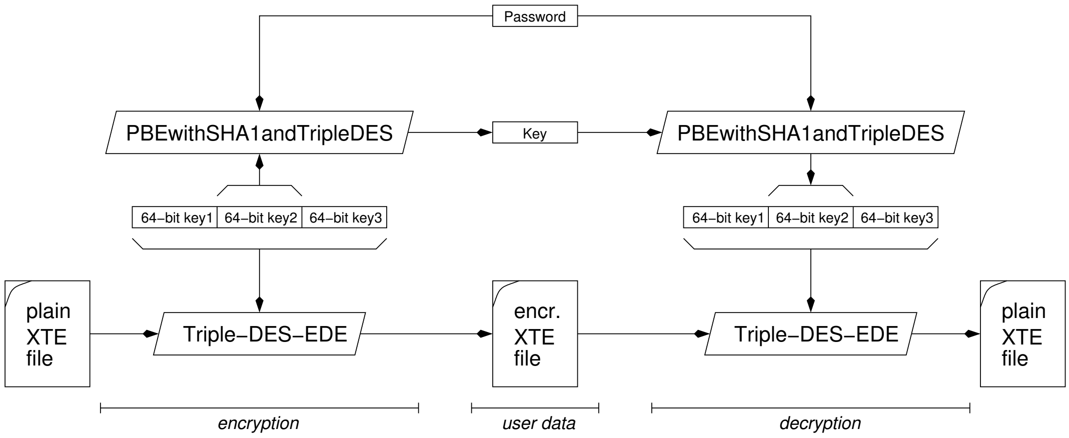


Figure 3.10: Encryption and decryption of leb books. The user gets only the data which is marked as *user data*. Notice that decryption happens fully inside the LanguageExplorer application, so the plain content will be only available within the application. Also, because the user has just a part of the triple DES key, he cannot gain access to the encrypted content by manually decrypting it.

key which is a part of the 192-bit Triple-DES key and finally the Triple-DES algorithm will be used to decrypt the encrypted XTE file. Notice that the encrypted key has to be entered only one time into the system. Afterwards it will be persistently stored and associated with the corresponding LanguageExplorer book in the users preferences file (see section 3.3.3). If the same, encrypted book will be loaded the next time, the encrypted key will be available from the users preference file and only the password will have to be supplied (see section 5.4.1). Notice that it is also possible to store the password in the users preference file, however this is not absolutely safe, because even though the password will be stored in an encrypted form, the password used to encrypt and decrypt the user passwords is currently hard-wired into the application.

Figure 3.10 shows how the encryption and decryption of LanguageExplorer books takes place. In a Web-Shop scenario, a user which orders a copyright protected book would be queried for a password. A new 64-bit key would be generated and used to encrypt the desired book using the Triple-DES algorithm as described above. Then the 64-bit key would be processed with a PBE algorithm which uses the user-supplied password as parameter resulting in an encrypted version of the key. The user would receive the encrypted book along with the encrypted key. If he likes to read the book, he would have to provide the encrypted key along with his secret password in order to decrypt the encrypted key first and then finally decrypt the whole book with the help of the now decrypted key.

For the implementation of the cryptographic features described so far we used the Java Cryptographic Architecture (JCA) and the Java Cryptographic Extension (JCE) [GaSo], both of them standard Java APIs which define an abstract interface for cryptographic algorithms and providers of cryptographic services. Libraries of different providers can be easily plugged into the architecture and their algorithms can be used in a consistent way.

3.3.3 LanguageExplorer configuration files

Complex applications with many configuration options need a possibility to persistently store these options across different program executions to free the user from the burden of adjusting them again every time he starts the application. For this purpose, LanguageExplorer supports personal configuration files which are stored in the home directory of every user. The format of this file which is named `.LanguageExplorer` for LanguageExplorer and `.LanguageAnalyzer` for LanguageAnalyzer is a simple text format where each line corresponds to a user preference and each user preference is composed of a name and a value separated by an equal sign '`=`'.

Currently many characteristics of the GUI like for example the window geometry are automatically stored in the preference file. But the preference file is also used to store certain attributes like the font family and font size on a per book basis. In the font selection dialog for example (see figure 5.11 on page 133), the user can select if he wants to save the settings in the preference file for the current book, if he wants to save them as the default settings which are applied to every book for which no custom settings are available or to keep them just local in the running application.

As mentioned before, the preference file is also used to store the keys of encrypted books after they have been decrypted for the first time. It is also possible to store the users passwords there, however, even though they are encrypted before they are written to the preference file, this is not very save, because the password used for encryption is hard-coded into the application.

The actual preferences implementation is sufficient for the current needs of LanguageExplorer and LanguageAnalyzer. However, a more powerful approach for the storage of preferences may be appropriate in the future. This could use for example the preferences package `java.util.prefs` which has been newly introduced in Java 1.4. It stores the preferences as XML files instead of plain text, it separates user from system properties and it organizes them in a tree like structure. This could be an advantage over the actual flat storage model especially for the different plugins and extensions that need to store own configuration data.

3.4 The design of LanguageAnalyzer

LanguageAnalyzer, the editor part of the system described in this work, is intended as an application which can be used to create and edit the various encodings of a text and to establish links between the elements of different encodings in the same or even in other documents.

The main considerations taken into account during the design process have been to make the above-mentioned tasks as comfortable as possible for the user to achieve, but also to keep the application as simple as possible. This resulted in the decision to allow at most two text documents to be worked on simultaneously. Therefore, the main window of LanguageAnalyzer is horizontally split into two main parts. Each of these two parts is vertically split into a text window which displays the actual content of a document and a window which shows the different encodings of the content. Notice that the text window must not necessarily contain an electronically encoded text. It may also be the facsimile picture of a text or the wave graph of a spoken text.

The different encodings are displayed as tree views where every encoding is represented by its own tree and every tree is located in its own tab. As indicated by the dashed lines in figure 3.11, the size of the two main windows as well as the size of a text window and the corresponding encoding window may be adjusted relatively to each other.

Different tools will have the opportunity to plug into the menu- and the toolbar. These tools will usually operate on the content and/or the encodings of one or of both documents and as a result will produce new encodings or change the existing ones. Depending on the available input plugins, different media types like text, graphics or sound files may be loaded. The document windows can be saved and loaded either together or separately, depending on the users requirements. A more detailed usage instruction of LanguageAnalyzer can be found in chapter 6.

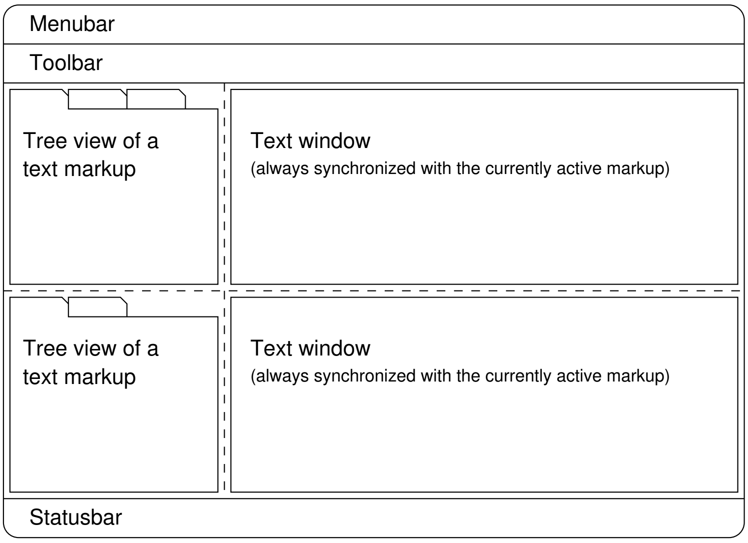

Menubar
Toolbar
Tree view of a text markup
Text window
(always synchronized with the currently active markup)
Tree view of a text markup
Text window
(always synchronized with the currently active markup)
Statusbar

Figure 3.11: A schematic view of the main application window of LanguageAnalyzer. Dashed lines indicate draggable frame borders in the final realization.

The text windows in figure 3.11 are implemented with the help of the text classes described in section 3.2. The tree views in the encoding windows in figure 3.11 are implemented with the help of a customized version of the standard `JTree` class and placed into a tab of type `JTabbedPane`. Menu-, tool- and status-bars are wrapped in a container of type `ScrollabelBar` (see section 4.4) to prevent them from cluttering the GUI if they grow because they are unexpectedly extended by many client plugins. The encoding window and the corresponding text window are coupled by listeners so each of the windows will be notified and updated if the encoding structure on the one side or the content on the other side will change.

Notice that it is very well possible to create editions with more than two parallel document versions by using tools and plugins which are supplied with LanguageAnalyzer. It was just a simple design decision to restrict the number of parallel text versions which are visible together in the GUI.

3.5 The design of LanguageExplorer

LanguageExplorer is the viewer and browser component of the system described in this work. Because by far more people will usually use LanguageExplorer to work with an edition created with LanguageAnalyzer than people have been involved in creating it, one of the main requirements during the design process has been to achieve a maximum of user friendliness.

Besides the menu- and toolbar, the whole area of the application window is occupied by the different text windows. Notice that LanguageExplorer supports an arbitrary number of parallel document versions which is only restricted by the physical extent of the screen. Initially, the available space is equally distributed between the different text windows. However, as indicated by the dashed lines in figure 3.12, the text windows can be arbitrary resized with respect to each other.

Because many of the available actions and tools need a target document on which they will operate (e.g. searching), each of the text windows is equipped with a local toolbar. The encoding chooser, which can be used to choose the default encoding which determines the

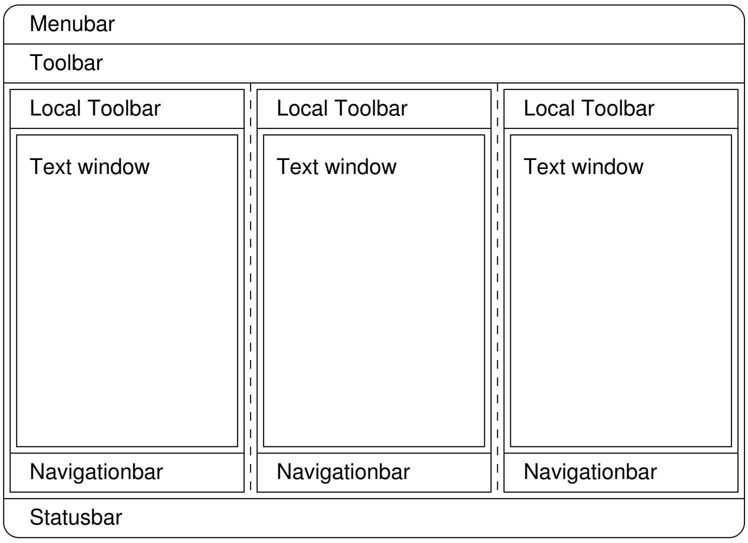


Figure 3.12: Layout of the main LanguageExplorer application window. The figure shows three text windows but an arbitrary number of parallel text windows are supported.

encoding on which the view of the document content is based on, is a prominent entry in this local toolbar. Other tools are free to plug into the local as well as into the main toolbar. The navigation bar which is located in the lower part of each text area, offers the possibility of a structural navigation in the document based on the current default encoding (i.e. the encoding which has been chosen with the encoding chooser).

But just displaying the aligned, parallel document versions is not the only job that LanguageExplorer has been designed for. Many other tools like for example dictionaries or index generators can be build in. The data generated or found by these tools can be presented in two additional, so-called extension areas, which can be opened in the upper and the lower part of the application window (see figure 3.13). The user can individually adjust

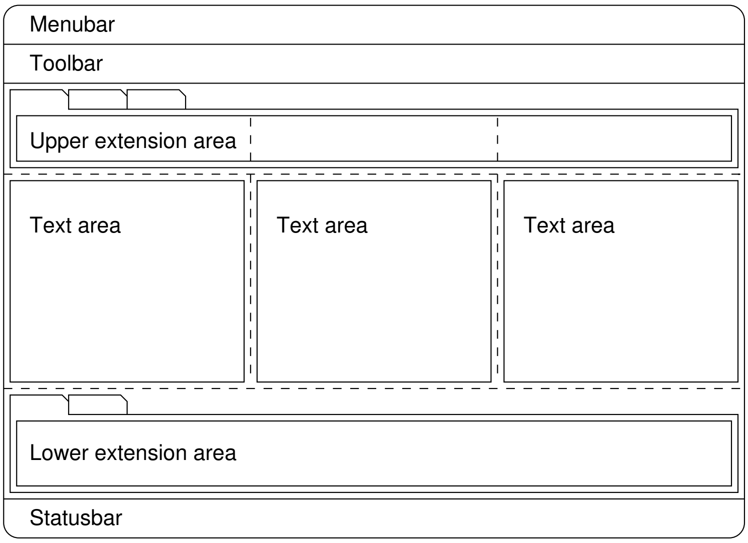


Figure 3.13: The LanguageExplorer application window with the upper and lower extension areas.

the size of both these windows and both of them can be closed with a single click if the information presented inside them is not necessary anymore.

Each of these extension windows can contain a number of different tabs which are created by the different plugins on user request and each of these tabs can be removed separately by the user. The upper extension area is intended for tools like dictionaries or encyclopedias, but also for displaying annotations or other out of band data. In general it is designed to display external, static data which is not strictly contained within the analyzed document.

In contrast, the lower extension area is intended for data which can be generated from the document content on the fly like for example a KWIC index (see section 5.4.3) or a word frequency list. Every newly requested KWIC index will open a new tab in the lower extension area. The user can choose which of the indices he wants to keep and which he wants to remove. Closing the whole extension area effectively only hides the available tabs. They are still accessible when the extension area will be opened again.

3.6 The plugin concept

Our framework offers three different extension points which differ in their complexity and satisfy different needs. This section will describe each of them in some more detail. The common ground among all these extensions is the fact that they have to be realized as Java classes which implement certain interfaces. To make them available to the applications they have to be accessible on the system classpath. This can be achieved for example by bundling related extension classes into a jar-file and copying this jar-file into the `extensions/` directory of the LanguageAnalyzer or LanguageExplorer installation directory. The applications will automatically load these jar-files on start-up and inspect the classes which are available there with the help of the Java Reflection API [CaWaHu] in order to make them available.

3.6.1 Handling new XTE elements

First of all there exists the possibility to extend the system to support new element types. This will be the most common extension requested by the user because potentially every new element introduced in a customized XTE encoding can require special handling. In order to support such a new element in LanguageAnalyzer and LanguageExplorer three different classes would have to be supplied.

If the element requires a customized loading procedure, a new load and probably also a new save class should be implemented. Doing this is simply a matter of implementing the two public interfaces `LoadAction` and `SaveAction` which are defined inside the `XMLDocument` class (see section 3.2.2). The implementation of the standard save and load classes which are implemented as inner classes of `XMLDocument` can serve as a boilerplate for new classes.

Some elements also may require special handling in the way how they want to be displayed on the screen. In such a case, customized view classes can be implemented for the corresponding elements. The only convention new view classes have to adhere to is that they have to be derived from the abstract class `javax.swing.View` or one of its numerous child classes. Again, the available view classes may serve as a starting point for new experiments.

Notice that the mapping of the new elements to the corresponding load, save and view classes can be established either in the textual configuration files described in section 3.2.2 or directly in the XTE files by using the `loadClass`, `saveClass` and `viewClass` attributes defined in the base XTE DTD (see listing 2.13 in section 2.4).

3.6.2 Support for new media types

Supporting new media types like for example sound files requires an additional effort compared to the handling of new elements which was described in the previous section. Of course new media types will almost surely require new element types, but that is not enough. Because they are not available in an XML format initially, they have to be converted in a kind of bootstrapping process into an XTE format. This is exactly the task performed by a media reader object. Media readers have to extend the abstract `MediaReader` class, an `XMLDocument` inner class (see figure 3.8 on page 53), which declares two methods:

```
public abstract String getContentType();
public abstract void read(XMLDocument doc, File[] files);
```

The `read` method will be called by the editor kit to load the files specified in the *files* argument into the document *doc*, if the media type of the files corresponds to the mime-type returned by the `getContentType()` method of the media reader class.

`ImageReader` is a default media reader supplied with LanguageAnalyzer which reads bitmap files and creates an XTE document from them. It can serve as an example for the support of other media types like for example sound files.

3.6.3 Adding new tools

Finally it is possible to extend LanguageAnalyzer and LanguageExplorer with new functionality by adding new tools to the applications. Tools operate on the content and the currently available encodings and possibly alter these encodings, create new encodings or simply present the results of their computations in one of the LanguageExplorer extension windows.

These tools, which are referred to as plugins in section 6.3.5 of the LanguageAnalyzer tutorial, are usually accessible from the toolbars and menus of the corresponding application. In order to make this possible, they implement the Swing `Action` interface. They get access to the different documents and extension windows through the `MainWindow` interface which is implemented by LanguageAnalyzer as well as by LanguageExplorer. A reference to the corresponding `MainWindow` object is passed to every plugin object when it gets installed in the application at program start-up.

Usually, the tools or plugins will show an options dialog when they get called. This dialog can be used for example to specify on which logical document they should operate on, how the created output should be named and of course for setting parameters needed for the internal operation of the plugin.

The implementation of the numerous plugins described in section 6.3.5 which are located in the `com.languageExplorer.text.actions` package can serve as a good starting point for new tools.

Chapter 4

Implementation techniques and libraries

During the planning and creation of the framework presented in this work, a lot of thoughts have been spent about how to properly describe and document the evolving system in a way to make it useful and usable for others. Besides the application of established methods of object-oriented design [Meyer] and the use of well-known software patterns [GHJV], the author felt the need for a more precise description of the lower level implementation details. This is particularly useful because one of the main features of the described system is adaptability and extensibility, both of which are impossible without a good documentation.

In order to solve this problem and to fill the gap which is still left by the high level Unified Modeling Language (UML) diagrams [BRJ1, BRJ2] and the automatically created API documentation, a new software documentation system has been developed which will be introduced in the first two sections of this chapter. The application of the described system can be seen for example in section 2.4.

The third and fourth section of this chapter describe some parts of the developed framework which are of general use and can be incorporated into arbitrary other applications as well. The resulting libraries are also documented with the new software documentation system.

4.1 Program documentation with Prog*DOC*

Though programming languages and programming styles evolve with remarkable speed today, there is no such evolution in the field of program documentation. And although there exist some popular approaches like Knuth's literate programming system WEB [Kn92], and nowadays JavaDoc [GoJoSt] or Doxygen [Hee], tools for managing software development **and** documentation are not as widespread as desirable.

This section analyses a wide range of literate programming tools available during the past two decades and introduces ProgDOC, a new software documentation system. It is simple, language independent, and it keeps documentation and the documented software consistent. It uses LaTeX for typesetting purposes, supports syntax highlighting for various languages, and produces output in Postscript, PDF or HTML format. ProgDOC has been used to document the software packages described in this chapter and the XTE encoding presented in section 2.4. A part of this section has been published in [Sim03].

4.1.1 Introduction

The philosophy of ProgDOC is to be as simple as possible and to pose as less requirements as possible to the programmer. Essentially, it works with any programming language and any development environment as long as the source code is accessible from files and the programming language offers a possibility for comments. It is non-intrusive in the sense that it leaves the source code untouched, with the only exception of introducing some comment lines at specific places.

The ProgDOC system consists of two parts. A so called *weaver* weaves the desired parts of the source code into the documentation, and a *highlighter* performs the syntax highlighting for that code. Source code and documentation are mutually independent (in particular they may be processed independently). They are linked together through special handles which are contained in the comment lines of the source code and may be referenced in the documentation.

ProgDOC is a good choice for writing articles, textbooks or technical white papers which contain source code examples and it proved especially useful for mixed language projects and for documenting already existing programs and libraries. Some examples of output produced by ProgDOC are available at [Sim].

4.1.2 Some words on Literate Programming

With an article published 1984 in the Computer Journal [Kn84] Donald Knuth coined the notion of "Literate Programming". Since those days for many people literate programming is irrevocable inter**weave**d with Knuth's WEB [Kn92] and TEX [Kn91] systems.

Knuth justifies the term "literate programming" in [Kn84] with his belief that "... the time is ripe for significantly better documentation of programs, and that we can best achieve this by considering programs to be works of literature." To support this programming style, he introduced the WEB system which is in fact both a language and a suite of utilities. In WEB, the program source code and the documentation are written together into one source file, delimited by special control sequences. The program source can be split into parts which can be presented in arbitrary order. The `tangle` program extracts these code parts from the WEB file and assembles them in the right order into a valid source file. Another program called `weave` combines the documentation parts of the WEB files with pretty printed versions of the code parts into a file which thereupon can be processed by TEX.

This system has many advantages. First of all, it fulfills the "one source" property. Because source code and documentation reside in one file, they are always consistent with each other. Second, the programmer is free to present the code he writes in arbitrary order, thus simplifying it for a human reader to understand the program. This can be done by rearranging code parts, but also by using macros inside the code parts, which can be defined later on in the WEB file. This way a top-down development approach is supported, in which the structure of a program as a whole is presented in the beginning and then subsequently refined, as well as a bottom up design, in which a program is assembled out of low level code fragments defined before. `tangle` will always expand these macros at the right place when constructing the source file out of the WEB file.

Another feature of the WEB system is the automatic construction of exhaustive indexes and cross references by `weave`. Every code part is accompanied by references which link it to all other parts which reference or use it. Also, an index of keywords with respect to code parts is created and the source code is pretty printed for the documentation part. The best way to convince yourself of WEB's capabilities is to have a look at Knuth's TEX implementation [Kn91a]. It was entirely written in WEB and is undoubtfully a masterpiece of publishing and literate programming.

WEB and its descendants

Besides its many advantages, the WEB system also has a couple of drawbacks. Many of them apply only to the original WEB implementation of Knuth and have been corrected or worked around in numerous WEB clones implemented thereafter. In this section we will present some of them[1] and discuss their enhancements.

One of the biggest disadvantages of WEB was the fact that it was closely tied to TEX as typesetting system and to Pascal as implementation language. So one of the first flavors of WEB was CWEB [KnLe] which extended WEB to C/C++ as implementation languages. It was implemented by Knuth himself together with Silvio Levy. CWEBx [Leeu] is an alternative CWEB implementation with some extensions by Marc van Leeuwen. They both suffer from the same problems like WEB, as they are closely coupled to TEX and the C programming language.

To overcome these language dependencies, noweb [Ram] (which evolved from spiderWEB) and nuweb [Brig] have been developed by Norman Ramsey and Preston Briggs, respectively. They are both language independent concerning the programming language, whereas they still use LATEX for typesetting. Nuweb is a rather minimalistic but fast WEB approach with only four control sequences. Both noweb and nuweb offer no pretty printing by default, but noweb is based on a system of tools called filters which are connected through pipes. The current version comes with pretty printing filters for C and Java (see the actual documentation).

Another descendant of an early version of CWEB is FWEB [Krom]. FWEB initially was an abbreviation for "Fortran WEB", but meanwhile FWEB supports not only Fortran, but C, C++, Ratfor and TEX as well. These languages can be intermixed in one project, while FWEB still supports pretty printing for the different languages. On the other hand, FWEB is a rather complex piece of software with a 140 page user's manual.

Ross Williams' funnelWEB [Wil] is not only independent of the programming language, but of the typesetting language as well. It defines own format macros, which can be bound to arbitrary typesetting commands (currently for HTML and LATEX).

General drawbacks of WEB based literate programming tools

Though many of the initial problems of the WEB system have been solved in some of the clones, their sheer number indicates that none of them is perfect.

One of the most controversial topics in the field of literate programming is pretty printing where *pretty printing* stands for syntax highlighting[2] **and** code layout and indentation. There are two questions here to consider: Is pretty printing desirable at all, and if yes, how should the pretty printed code look like? The answer is often a matter of personal taste, however there also exist some research results in this area like for example [BaeMa].

From a practical point of view it must be stated that doing pretty printing is possible for Pascal, although a look at the WEB sources will tell you that it is not an easy task. Doing it for C is even harder[3]. Taking into account the fact that `weave` usually processes only a small piece of code, which itself even does not have to be syntactically correct, it should be clear that pretty printing such code in a complex language like for example C++ will be impossible.

To overcome these problems, special tags have been introduced by the various systems to support the pretty printing routines. But this clutters the program code in the WEB file

[1] Only systems known to the authors will be mentioned here. A more complete overview may be found at the Comprehensive TEXArchive Network (CTAN) under http://www.ctan.org/tex-archive/web or at http://www.literateprogramming.org.

[2] *Syntax highlighting* denotes the process of graphically highlighting the tokens of a programming language.

[3] The biggest part of CWEB consists of the pretty printing module. Recognition of keywords, identifiers, comments, etc. is done by a hard coded shift/reduce bottom up parser.

and even increases the problem of the documentation looking completely different than the source. This can be annoying in a develop/run/debug cycle. As a consequence, the use of pretty printing is discouraged. The only feasible solution could be simple syntax highlighting instead of pretty printing, as it is done by many editors nowadays.

Even without pretty printing and additional tags inserted into the program source, the fact that the source code usually appears rearranged in the WEB file with respect to the generated source file makes it very hard to extend or debug such a program. A few lines of code laying closely together in the source file may be split up to completely different places in the WEB file.

Once this could be called a feature, because it gave the programmer new means of structuring his program code for languages like Pascal which offered no module system or object hierarchy. As analysed in [ChSa] it could be used to achieve a certain amount of code and documentation reuse. However the WEB macro system could also be misused by defining and using macros instead of defining and using functions in the underlying programming language.

Another problem common to WEB systems is their "one source" policy. While this may help to hold source code and documentation consistent, it breaks many other development tools like debuggers, revision control systems and make utilities. Moreover, it is nearly impossible for a programmer not familiar with a special WEB system to debug, maintain or extend code devolved with that WEB.

Even the possibility of giving away only the tangled output of a WEB is not attractive. First of all, it is usually unreadable for humans[4], and second this would break the "one source" philosophy. It seems that most of the literate programming projects realized until now have been one man projects. There is only one paper from Ramsey and Marceau [RamMar] which documents the use of literate programming tools in a team project. Additionally, some references can be found about the use of literate programming for educational purpose (see [Child] and [ShuCo]).

The general impression confirms Van Wyk's observation in [VanWyk] "... that one must write one's own system before one can write a literate program, and that makes [him] wonder how widespread literate programming is or will ever become." The question he leaves to the reader is whether programmers are in general too individual to use somebody else's tools or if only individual programmers develop and use (their own) literate programming systems. The answer seems to lie somewhere in between. Programmers are usually very individual and conservative concerning their programming environment. There must be superior tools available to make them switch to a new environment.

On the other hand, integrated development environments (IDEs) evolved strongly during the last years and they now offer sophisticated navigation, syntax highlighting and online help capabilities for free, thus making many of the features of a WEB system, like indexing, cross referencing and pretty printing become obsolete (see section 4.1.3). Finally the will to write documentation in a formatting language like TEX using a simple text editor is constantly decreasing in the presence of WYSIWYG word processors.

Other program documentation systems

With the widespread use of Java a new program documentation system called JavaDoc was introduced. JavaDoc [GoJoSt] comes with the Java development kit and is thus available for free to every Java programmer. The idea behind JavaDoc is quite different from that of WEB, though it is based on the "one source" paradigm as well. JavaDoc is a tool which extracts documentation from Java source files and produces formatted HTML output. Con-

[4] NuWEB is an exception here, since it forwards source code into the tangled output without changing its format.

sequently, JavaDoc is tied to Java as programming and HTML as typesetting language[5]. By default JavaDoc parses Java source files and generates a document which contains the signatures of all public and protected classes, interfaces, methods, and fields. This documentation can be further extended by specially formatted comments which may even contain HTML tags.

Because JavaDoc is available only for Java, Roland Wunderling and Malte Zöckler created DOC++ [WunZoe], a tool similar to JavaDoc but for C++ as programming language. Additionally to HTML, DOC++ can create LaTeX formatted documentation as well. Doxygen [Hee] by Dimitri van Heesch, which was initially inspired by DOC++, is currently the most ambitious tool of this type which can also produce output in RTF, PDF and Unix man-page format. Both DOC++ and Doxygen can create a variety of dependency-, call-, inclusion- and inheritance graphs, which may be included into the documentation. Notice that customized versions of tools like DOC++ and Doxygen may be used as preprocessors for the documentation extensions which will be proposed in section 4.2.

C# [CSharp], Microsoft's answer to Java, comes with its own documentation system as well. In principle it works in the same way as JavaDoc. The only difference is the resulting output format which is XML. This is a big advantage compared to JavaDoc, because the output is not tied to a special typesetting language. Instead the produced XML format is specified in the Appendix E of the C# language definition [CSharp]. Additional tools like NDoc [Diam] must be used to produce printable or displayable versions from the XML output of the C# documentation generator.

Synopsis [DaSe] by Stephen Davies and Stefan Seefeld is another similar tool. Written mainly in Python [Lutz] it supports an architecture of pluggable parsers and formatters for various source languages and output formats. Currently it supports Python, IDL and C++ as programming languages and among others HTML, DocBook and TexInfo as output formats. The interesting thing about Synopsis is the fact that it really parses the whole source code and builds an internal abstract syntax tree (AST) of the code. With the help of this AST exhaustive cross references can be build like for example linking every variable to the place where it was declared or to the place where its type is defined. Moreover, Synopsis can produce highlighted listings of the source files which are linked to the generated API documentation.

The new documentation tools presented so far are mainly useful for creating hierarchical, browesable HTML documentations of class libraries and APIs. They are intended for interface descriptions rather than the description of algorithms or implementation details. Although some of them support LaTeX, RTF or PDF output, they are not particularly well suited for generating printed documentation.

Another approach which must be mentioned in this chapter is Martin Knasmüller's "Reverse Literate Programming" system [Knasm]. In fact it is an editor which supports folding and so called *active text elements* [MoeKo]. Active text elements may contain arbitrary documentation, but also figures, links or popup buttons. All the *active text* is ignored by the compiler, so no tangle step is needed before compilation. Reverse Literate programming has been implemented for the Oberon system [WirGu].

The GRASP [Hend] system relies on source code diagramming and source code folding techniques in order to present a more comprehensible picture of the source code, however without special support for program documentation or literate programming. In GRASP, code folding may be done according to the programming language control structure boundaries as well as for arbitrary, user-selected code parts.

[5] Starting with Java 1.2, JavaDoc may be extended with so called "Doclets", which allow JavaDoc to produce output in different formats. Currently there are Doclets available for the MIF, RTF and LaTeX format (see [Docl]).

4.1.3 Software documentation in the age of IDEs

Nowadays, most software development is done with the help of sophisticated IDEs (Integrated Development Environments) like Microsoft Visual Studio [VisSt], IBM Visual Age [VisAge], Borland JBuilder [JBuil], NetBeans [BGGSW] or Source Navigator [SouNav] to name just a few of them. These development environments organize the programming tasks in so called projects, which contain all the source files, resources and libraries necessary to build such a project.

One of the main features of these IDEs is their ability to parse all the files which belong to a project and build a database out of that information. Because the files of the project can be usually modified only through the builtin editor, the IDEs can always keep track of changes in the source files and update the project database on the fly.

With the help of the project database, the IDEs can offer a lot of services to the user like fast, qualified searching or dependency-, call-, and inheritance graphs. They allow fast browsing of methods and classes and direct access from variables, method calls or class instantiations to their definitions, respectively. Notice that all these features are available online during the work on a project, in contrast to the tools like JavaDoc or Doxygen mentioned in the previous section which provide this information only off-line.

The new IDEs now deliver under such fancy names like “Code Completion” or “Code Insight” features like syntax directed programming [KhUr] or template based programming which have been proposed already in the late seventies by [TeRe, MoSch]. In the past, these systems couldn’t succeed because of two main reasons: they where to restrictive in the burden they put on the programmer and the display technology and computing power have not been good enough[6]. However, the enhancements in the area of user interfaces and the computational power available today allow even more: context sensitive prompting of the user with the names of available methods or with the formal arguments of a method, syntax highlighting and fast recompilation of affected source code parts.

All this reduces the benefits of a printed, highly linked and indexed documentation of a whole project. What is needed instead, additionally to the interface description provided by the IDE, is a description of the algorithms and of certain complex code parts. One step into this direction was Sametinger’s DOgMA [Samet, SamPom] tool which is an IDE that also allows writing documentation. DOgMA, like modern IDEs today, maintains an internal database of the whole parsed project. It allows the programmer to reference arbitrary parts of the source code in the documentation while DOgMA automatically creates and keeps the relevant links between the source code parts and the documentation up to date. These links allow a hypertext like navigation between source code and documentation.

While it seems that modern IDEs adopted a lot of DOgMA’s browsing capabilities, they didn’t adopted its literate programming features. However, systems like NetBeans [BGGSW], SourceNavigator [SouNav] or VisualAge [Sor]) offer an API for accessing the internal program database. This at least would allow one to create extensions of these systems in order to support program documentation in a more comfortable way.

The most ambitious project in this context in the last few years was certainly the “Intentional Programming” project lead by Charles Simonyi [Simo96, Simo99] at Microsoft. It revitalized the idea of structured programming and propagated the idea of programs being just instantiations of intentions. The intentions could be written with a fully fledged WYSIWYG editor which allowed arbitrary content to be associated with the source code. Of course, this makes it easy to combine and maintain software together with the appropriate documentation. Some screen-shots of this impressive system can be found in chapter 11 of [CzEi], which is dedicated solely to Intentional Programming. Unfortunately, this system was never made publicaly available.

[6] A good survey about the editor technology available at the beginning of the eighties can be found in [MeyDa].

4.1.4 Software documentation and XML

With the widespread use of XML [XML] in the last few years it is not surprising that various XML formats have been proposed to break out of the "ASCII Straitjacket" [Abr] in which programming languages are caught until now. While earlier approaches to widen the character set out of which programs are composed like [Abr] failed mainly because of the lack of standards in this area, the standardization of UNICODE [U30] and XML may change the situation now.

There exist two concurring approaches. While for example JavaML [Bad] tries to define an abstract syntax tree representation of the Java language in XML (which, by the way, is not dissimilar from the internal representation proposed by the early syntax directed editors) the CSF [San] approach tries to define an abstract XML format usable by most of the current programming languages. Both have advantages as well as disadvantages. While the first one suffers from it's dependency on a certain programming language, the second one will always fail to represent every exotic feature of every given programming language.

A third, minimalistic approach could ignore the syntax of the programming language and just store program lines and comments into as few as two different XML elements. Such an encoding has been proposed by E. Armstrong [Arm].

However, independent of the encoding's actual representation, once that such an encoding would be available, literate programming and program documentation systems could greatly benefit from it. They could reference distinct parts of a source file in a standard way or they could insert special attributes or even elements into the XML document which could be otherwise ignored by other tools like compilers or build systems. Standard tools could be used to process, edit and display the source files, and internal as well as external links could be added to the source code.

Peter Pierrou presented in [Pier] an XML literate programming system. In fact it consists of an XML editor which allows one to store source code, documentation and links between them into an XML file. A tangle script is used to extract the source code out of the XML file. The system is very similar to the reverse literate programming tool proposed by Knasmüller, with the only difference that it is independent of the source language and stores its data in XML format. An earlier, but very similar effort described in [Ger] used SGML as markup language for storing documentation and source code.

Anthony Coates introduced xmLP [CoRe], a literate programming system which uses some simple XML elements as markup. The idea is to use these elements together with other markup elements, for example those defined in XHTML [XHTML], MathML [MathML] or DocBook [DocB]. XSLT [XSLT] stylesheets are then used in order to produce the woven documentation and the tangled output files. A similar system has also been presented by Norman Walsh [Walsh], the Author of DocBook. He introduces a few elements for source fragments which are located in their own namespace. Thus every XML vocabulary which allows the inclusion of new elements from a different namespace may be used to write the literate program. Finally XSLT stylesheets are used to weave and to tangle the literate program.

Oleg Kiselyov suggested the representation of XML as an s-expression in Scheme called SXML [Kisel]. SXML can be used to write literate XML programs. Different Scheme programs (also called stylesheets in this case) are available to convert from SXML to LaTeX, HTML or pure XML files.

Recently the Boost Initiative [Boost], an effort to provide free, peer-reviewed and portable C++ source libraries has started a new project called BoostDoc [Greg]. The goal of the project is to document all the Boost libraries in a consistent way and to keep the documentation synchronised with the constantly developing libraries. BoostDoc uses various tools like Doxygen [Hee] or Synopsis [DaSe] to create an API documentation in XML format out of the library source files. This API documentation is later merged with the BoostBook documentation written by the programmer, where BoostBook is an extension of the DocBook [WaMu] format specially tailored for C++ library documentation.

Some of the approaches presented in this section are quite new, but the wide acceptance of XML also in the area of the source code representation of programming languages could give new impulses to the literate programming community. A good starting point for more information on literate programming and XML is the Web site of the OASIS consortium, which hosts a page specifically dedicated to this topic [OASLit].

4.1.5 Overview of the ProgDOC system

With this historical background in mind, ProgDOC takes a completely different approach. It releases the "one source" policy, which was so crucial for all WEB systems, thus giving the programmer maximum freedom to arrange his source files in any desirable way. On the other hand, the consistency between source code and documentation is preserved by special handles, which are present in the source files as ordinary comments[7] and which can be referenced in the documentation. `pdweave`, ProgDOC's weave utility incorporates the desired code parts into the documentation.

But let's first of all start with an example. Suppose we have a C++ header file called `ClassDefs.h` which contains some class declarations. Subsequent you can see a verbatim copy of the file :

```
class Example1 {
private :
  int x;
public :
  explicit Example1(int i) : x(i) {}
};

class Example2 {
private :
  double y;
public :
  explicit Example2(double d) : y(d) {}
  explicit Example2(int i) : y(i) {}
  explicit Example2(long i) : y(l) {}
  explicit Example2(char c) : y((unsigned int)c) {}
};
```

It is common practice until now, especially among programmers not familiar with any literate programming tools, that system documentations contain such verbatim parts of the source code they want to explain. The problem with this approach is the code duplication which results from copying the code from the source files and pasting it into the text processing system. From now on every change in the source files has to be repeated in the documentation. This is reasonable of course, but the practice tells us that the discipline among programmers to keep their documentation and their source code up to date is not very high.

At this point, the ProgDOC system enters the scene. It allows us to write `ClassDefs.h` as follows :

```
// BEGIN Example1
class Example1 {
private :
```

[7] As far as I know, any computer language offers comments, so this seems to be no real limitation.

```
  int x;                           // Integer variable
public :
  explicit Example1(int i) : x(i) {} // The constructor
};
// END Example1

// BEGIN Example2
class Example2 {
// ...
private :
  double y;
// ...
public :
  explicit Example1(double d) : y(d) {}
  explicit Example2(int i) : y(i) {}
  explicit Example2(long i) : y(l) {}
  explicit Example2(char c) : y((unsigned int)c) {}
};
// END Example2
```

The only changes introduced so far are the comments at the beginning and at the end of each class declaration. These comments, which of course are non-effective for the source code, enable us to use the new `\sourceinput`[*options*]{*filename*}{*tagname*} command in the LaTeX documentation. This will results in the inclusion and syntax highlighting of the source code lines which are enclosed by the "`// BEGIN` *tagname*" and "`// END` *tagname*" lines respectively. Consequently the following LaTeX code:

```
''.. next we present the declaration of the class {\mytt Example1}:

\sourceinput[fontname=blg, fontsize=8, listing, linenr,
             label=Example1]{ClassDefs.h}{Example1}

as you can see, there is no magic at all using the {\mytt \symbol{92}sourceinput}
command ..''
```

will result in the following output:

".. next we present the declaration of the class `Example1`:

Listing 4.1: ClassDefs.h [Line 2 to 7]

```
class Example1 {
private :
  int x;                           // Integer variable
public :
  explicit Example1(int i) : x(i) {} // The constructor
};
```

as you can see, there is no magic at all using the `\sourceinput` command .."

First of all, we observe that the source code appears nicely highlighted, while its indentation is preserved. Second, the source code is preceded by a caption line similar to the one known from figures and tables. In addition to a running number, the caption also contains the file name and the line numbers of the included code. Furthermore this code sequence can be referenced everywhere in the text through a usual `\ref` command (like for example here: see Listing 4.1). Notice however that the boxes shown here are used for demonstrational purpose only and are not produced by the ProgDOC system.

After we got an impression of how ProgDOC's output looks like, it's time to explain the way how it is produced. First of all the style file 'progdoc.sty' has to be included into the latex source file. Among some definitions and default settings (see section 4.1.12) 'progdoc.sty' contains an empty definition of \sourceinput. If LaTeX will process any file with this command, it will only print out the following warning:

WARNING !!! Run pdweave on this file before processing it with LaTeX. Then you will see the sourcecode example labeled Example1 from the file ClassDefs.h instead of this message.

The reason for this behavior is shown in Figure 4.1: ProgDOC isn't implemented in pure LaTeX. Instead, the weaver component pdweave is an AWK [AKW] script while the syntax highlighter pdhighlight is a program generated with flex [Flex]. It was originally based on a version of Norbert Kiesel's c++2latex filter. It not only marks up the source code parts for LaTeX, but also inserts special HTML markup into the LaTeX code it produces such that an HTML-version of the documentation may be created with the help of Nikos Drakos' and Ross Moore's latex2html [DrMo] utility. However, pdweave is not restricted on pdhighlight as highlighter. It may use arbitrary highlighters which conform to the interface expected by the weaver. And indeed, ProgDOC provides a second highlighter, called pdlsthighlight, which is in fact just a wrapper for the LaTeX listings package [Heinz].

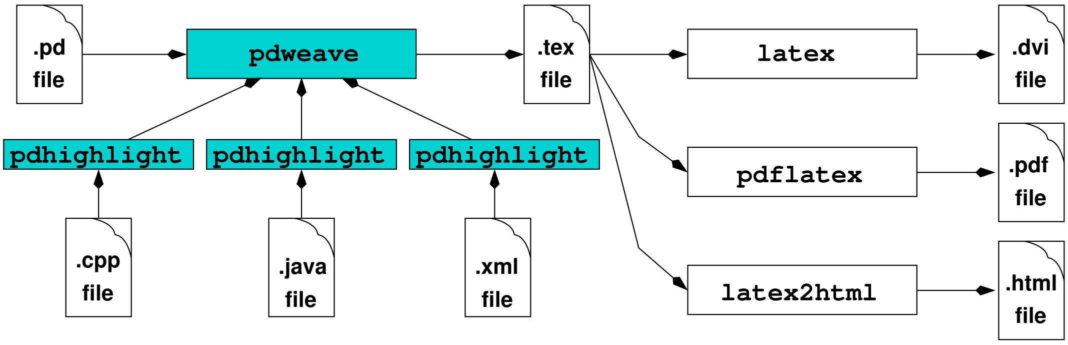


Figure 4.1: Overview of the ProgDOC system.

The main idea behind ProgDOC is to write the documentation into so called '.pd' files which contain pure LaTeX code and, as an extension to ordinary LaTeX, some additional commands like the above mentioned \sourceinput. These '.pd' files are processed by pdweave which extracts the desired parts out of the source files, highlights them and finally merges them with the ordinary parts of the documentation. The file generated this way is an usual LaTeX source file which in turn can be passed to the LaTeX text processor.

Usually, all this steps are simplified by the use of a special Makefile which also keeps track of dependencies between source files and the documentation itself (see section 4.1.13 for an example).

In the next sections a brief description of the different commands available in '.pd' files will be given. The format of the handles required in the source files will be explained and finally an example Makefile which automates the generation of the program documentation will be presented.

4.1.6 The `\sourceinput` command

Now that we have an idea of the general mechanism of the ProgDOC system, let's have a closer look on the `\sourceinput` command. Its syntax is similar to that of other LaTeX commands though, as we know by now, it will be normally processed by `pdweave` and not by LaTeX. The general form of the command is:

“sourceinput[*options*]{*filename*}{*tagname*}

Like in LaTeX, arguments in {}-brackets are required whereas the ones in []-brackets are optional.

`\sourceinput` Arguments	
filename	Absolute or relative pathname of the source file. This may be internally preceded by a base path if the command `\sourceinputbase`{*filename*} (see section 4.1.10) has been used.
tagname	This is an arbitrary string which uniquely identifies a part of source code in the file specified by *filename*. A special *tagname* “`ALL`” is available, which includes a whole file. (See section 4.1.11 for a detailed description of the comment format in the source files).
`\sourceinput` Options	
label=name	An ordinary LaTeX label name which will be declared inside of the produced source listing and which can be used subsequently as parameter for the `\ref` command.
fontname=name	The name of the base font used for highlighting the source listing. It is desirable here to specify a mono spaced font of which italic, bold and bold italic versions exist, since they are used to emphasize keywords, comments, string constants and so on[8]. (The default is the initial setting for `\ttdefault`, usually `cmtt`)
fontenc=encoding	The encoding of the font chosen with the *fontname* option above. (The default is OT1.)
fontsize=pt	The fontsize in point used for highlighting the listings. Since mono spaced fonts are usually some wider compared to proportional counterparts, a somewhat smaller size is recommended here. (The default is 8pt.)
linesep=length	The line separation used for the source listings. (The default is 2.5ex.)
type=language	This option controls the type of language assumed for the source file. The *language* argument will be handed over to the actual highlighter (see the option *highlighter*). Currently the default highlighter `pdhighlight` supports the values *c*, *cpp*, *java*, *xml*, *scm*, *el* or *text*. If not set, the default language is *cpp*. If type is set to *text* no syntax highlighting will be done at all. Notice that this option also affects the way in which comments are recognized in the source files (see also the option *comment* and chapter 4.1.11 about the source file format 4.1.11 on page 79).
tab=value	The value of *tab* indicates the number of space characters used to replace a tab character ('`\t`'). The dafault is 8.

[8] For more information on choosing the right base font see the ProgDOC manual [Sim]

`\sourceinput` Options	
comment='string'	If you use one of the supported languages listed in the table on page 79, the tag names will be recognized automatically. If you however include parts of a file in an unsupported language, it may be necessary to set the string which denotes the beginning a comment in that language with this option.
listing`[=noUnderline]`	If the *listing* option is present, a heading will be printed above the listing, which contains at least the running number of the listing and the name of the file it was extracted from. By default, this heading will be underlined. You can change this behavior by using the optional `noUnderline` argument
linenr	If the *linenr* option is set, the heading additionally will contain the line numbers of the code fragment in its source file. The special *tagname* “`ALL`” always turns line numbers off.
center	With this option set, the listing will appear centered, without it will be left justified.
underline	If this option is set, `pdhighlight` will underline keywords instead of setting them in bold face. This is useful for fonts for which there exists no bold version (e.g. `cmtt`).
caption='captiontext'	If this option is set, then the caption produced by the *listing* option will contain *captiontext* instead of the file name and possibly the line numbers. Notice that *captiontext* must be enclosed between apostrophe signs “ ’ ”.
wrap=column	With this option, you can instruct `pdweave` to wrap the lines of the source code you include at the specified *column*. `pdweave` uses a heuristics in order to find a “good” break position, so the column argument supplied with *column* is just a maximum value which will be not exceeded. Lines broken by `pdweave`, will be marked by an arrow (“↩”) at the breaking point. This option is especially useful in two-column mode. For en example see Listing 4.4.
highlighter=program	This option controls which program is used to highlight the source code. The default highlighter is `pdhighlight`. Currently the only additional highlighter is `pdlsthighlight`. Refer to section 4.1.8 for further information.
useLongtable DEPRECATED	This is a compatibility option which forces the default highlighter `pdhighlight` to arrange the source listings in a longtable environment. Because of layout problems which resulted from the interaction of longtables with other float objects, the use of the longtable environment has been abandoned. This option is only for people who want to typeset a document in exactly the same way it was done with older versions of ProgDOC.

Apart from whitespace, the `\sourceinput` command must be the first to appear in a line and it must end in a line of its own. However the command itself can be split over up to five different lines. (This number can be adjusted by setting the variable `DELTA` in the script `pdweave.awk`.). It may also be necessary to quote some option arguments between apostrophe signs “ ’ ”, if they contain white space or special characters like angle or curly brackets.

Some of this options like *fontname* or *fontsize* can be redefined globally in the ’`.pd`’ file. See section 4.1.12 on page 81 for more information.

4.1.7 Using ProgDOC in two-column mode

Starting with version 1.3, ProgDOC can be used in the LaTeX two-column or multicolumn mode. However some restrictions apply in these modes which will be discussed here. We will switch now to two-column mode by using the multicols environment with the command `\begin{multicols}{2}`:

First of all, there is no two-column support when using the deprecated *useLongtable* option, because the longtable environment doesn't work in the two-column mode.

Otherwise, the two-column mode set with the `twocolumn` option of the `documentclass` command or inside the document with the `\twocolumn` command is supported as well as the two- or multicolumn mode of the `multicols` environment (see [Mitt]), however with some minor differences.

Listing 4.2: A short Python example

```
#
# QuickSort and Greatest Common Divisor
# Author: Michael Neumann
#

<see Listing 4.3 on page 77>

<see Listing 4.4 on page 77>

print "Hello␣World"
print quicksort([5,99,2,45,12,234,29,0])
```

Because of incompatibilities between the `multicols` environment and the `afterpage` package, the caption "**Listing** x: ... (continued)" on subsequent columns or pages is not supported for listings inside the `multicols` environment (as can be seen in Listing 4.2 to 4.4 which are printed inside a `multicols` environment). If in `twocolumn` mode, columns are treated like pages for the caption mechanism of ProgDOC (see section C in the ProgDOC manual [Sim] for an example printed in `twocolumn` mode). Therefore the "**Listing** x: ... (continued)" captions are repeated on the top of each new column the listings spans on, just as if it was a new page.

4.1.8 Using the alternative highlighter `pdlsthighlight`

In addition to the default highlighter `pdhighlight` ProgDOC comes now with an additional highlighter called `pdlsthighlight` which is in fact a wrapper for the `listings` environment of Carsten Heinz (see [Heinz]).

Listing 4.3: test.py [Line 8 to 12] (Referenced in Listing 4.2 on page 77)

```
def ggd(a, b):
  if a < b: a,b = b,a
  while a%b != 0:
    a,b = b,a%b
  return b
```

To use this highlighter the `listings.sty` package has to be installed and manually loaded into the document with `\usepackage{listings}`. The Listings 4.2 to 4.4 are typeset using `pdlsthighlight` with the following options: `[linenr, listing, wrap=40, fontname=blg, highlighter='pdlsthighlight', type=Python]`.

`pdlsthighlight` also works in both, single and two-column mode, however it doesn't support the "**Listing** x: ... (continued)" captions at all. The benefits of the new highlighter are the many supported language for which the `listings` package performs syntax highlighting. One of the main drawbacks is the fact that you can not produce an HTML version of the document because LaTeX2HTML doesn't support the package.

Notice furthermore that you have to set the *type* option of the `\sourceinput` command to a value recognized by the `listings` environment if you use `pdlsthighlight` as highlighter (e.g. *type*=C++ instead of *type=cpp*). Refer to [Heinz] for a complete list of supported languages.

Listing 4.4: test.py [Line 16 to 21] (Referenced in Listing 4.2 on page 77)

```
def quicksort(arr):
  if len(arr) <= 1: return arr
```

```
m = arr[0]
return quicksort(filter(lambda i,j=m: ↩
                     i<j, arr)) + \
       filter(lambda i,j=m: i==j, ↩
                           arr) + \
       quicksort(filter(lambda i,j=m: ↩
                     i>j, arr))
```

In this context it may also be necessary to use the *comment* option to specify the comment characters of a language not known to `pdweave`.

4.1.9 The `\sourcebegin` and `\sourceend` commands

Beneath the `\sourceinput` command there exists another pair of commands, which can be used to highlight source code written directly into the '`.pd`' file. Of course they are pseudo LaTeX commands as well and will be processed by the `pdweave` utility rather than by LaTeX. Their syntax is as follows:

“**sourcebegin**[*options*]{ *header*}
source code
“**sourceend**

The `\sourcebegin` command has the same options like the `\sourceinput` command, but no *filename* and *tagname* options, since the source code begins in the line that follows the command. For compatibility reasons with older ProgDOC versions there is an optional *header* argument. It will be printed instead of the filename in the header of the listing if the option *listing* is set. The recommendation for new users however is to use the *caption* option instead. Notice that in contrast to the usual LaTeX conventions, this is an optional argument. The source code will be terminated by a line which solely contains the `\sourceend` command.

This commands are useful if some code must be presented in the documentation which is not intended to appear in the real source code. Consider for example the following code:

```
.. we don't use void pointers and ellipsis for our function {\mytt func}

\sourcebegin[fontname=blg, fontsize=8, listing, center]{Just an example ..}
void func(void *p, ...) {
  cout << "A function with an arbitrary number of arguments\n";
  ..
}
\sourceend

since they are bad programming style and can lead to unpredictable errors ..
```

which will result in the following output:

“.. we don’t use void pointers and ellipsis for our function `func`

Listing 4.5: Just an example ..

```
void func(void *p, ...) {
  cout << "A function with an arbitrary number of arguments\n";
  ..
}
```

since they are bad programming style and can lead to unpredictable errors ..”

The same restrictions that apply for the `\sourceinput` command hold good for `\sourcebegin` and `\sourceend` as well. Additionally, if present, the opening brace of the optional *header* argument must start in the same line like the closing bracket of the *options* argument.

4.1.10 The `\sourceinputbase` command

If you want to present to the reader a certain view of the source code, relative and absolute path names may be not enough for the `\sourceinput` command. In this case you can use the command:

“**sourceinputbase**{*pathname*}

It defines a global path prefix for all `\sourceinput` commands which follow in the same file. You can reset this path prefix by calling `\sourceinputbase{}` with a zero length argument. Like the `\sourceinput` command, the `\sourceinputbase` command must be in its own line and may be preceded only by whitespace. This command has file scope.

Notice that automatic references between nested code sequences (see section 4.1.11) will work only if the code sequences have been included with the same path prefix. This is because of the algorithm which automatically generates the labels for nested code sequences. It uses the pathname of the file from which a code sequence has been included as a part of the generated label name.

4.1.11 The source file format

As shown in the first section, arbitrary parts of a source file can be made available to ProgDOC by enclosing them with comment lines of the form ’// `BEGIN` *tagname*’ and ’// `END` *tagname*’ respectively where in this and the following examples we will use the C++ comment syntax. However ProgDOC also supports a number of other languages.

When speaking about supported languages, one has to distinguish between highlighting support for a language which comes from `pdhighlight` and the support to extract code snippets out of files of a given language, which is provided by `pdweave`. The following table lists the supported languages with respect to both these tools. In general, any file may be used as input source, even if not listed here, by specifying “text” as *type* argument and the corresponding comment character(s) as *comment* argument to the `\sourceinput` command (see table on page 75).

type	Language	Comment character(s)	`pdweave`	`pdhighlight`
c	C	// , /*	√	√
cpp	C++	// , /*	√	√
java	Java	// , /*	√	√
xml	XML	<! – –	√	√
scm	Scheme	; , ;; , ;;; , ;;;;	√	√
el	ELisp	; , ;; , ;;; , ;;;;	√	√
vb	VisualBasic	’	√	–
py	Python	#	√	–
text	Text	# , // , -	√	–

Hiding code parts

An arbitrary even number of ’// `... [text]`’ comments may appear inside a ’`BEGIN/END`’ code block. All the code between two of these comment lines will be skipped in the output and replaced by a single “dotted line” (...) or a line of the form “... *text* ...” if the optional `text` argument was present in the first comment line. `text` may be an arbitrary LaTeX string (not containing double quotes) enclosed between double quotes. This feature is useful for example, if you want to show the source code of a class, but don’t want to bother the reader with all the private class stuff.

Recall the header file from section 4.1.5, which will be reprinted here for convenience, by using the following command: "\sourceinput[fontname=blg, fontsize=8, listing]{ClassDefs.h}{ALL} ". Notice the use of the special tag name "ALL", which includes a source file as a whole.

Listing 4.6: ClassDefs.h

```
// BEGIN Example1
class Example1 {
private :
  int x;                           // Integer variable
public :
  explicit Example1(int i) : x(i) {} // The constructor
};
// END Example1

// BEGIN Example2
class Example2 {
// ... some private stuff
private :
  double y;
// ...
public :
  // BEGIN Constructors
  explicit Example2(double d) : y(d) {}
  explicit Example2(int i) : y(i) {}
  explicit Example2(long l) : y(l) {}
  explicit Example2(char c) : y((unsigned int)c) {}
  // END Constructors
  void doSomething(); // do something
};
// END Example2
```

In the way described until now we can include the class definition of the class "Example2" by issuing the command: "\sourceinput[fontname=ul9, fontenc=T1, fontsize=7, listing, linenr, label=Example2]{ClassDefs.h}{Example2}".

Listing 4.7: ClassDefs.h [Line 11 to 24]

```
class Example2 {
...
public :
  <see Listing 4.8 on page 81>
  void doSomething(); // do something
};
```

As you can see however, the private part of the class definition is replaced by the mentioned "dotted line" which stands for as much as "there is some hidden code at this position in the file, but this code is not important in the actual context".

Displaying nested code sequences

Another possibility of hiding code at a specific level, is to nest several "BEGIN/END" blocks where nested BEGIN lines may also have an optional text argument as described in the previous section. If a "BEGIN/END" block appears inside another block, then it will be replaced by a single line of the form "*¡[text] see Listing xxx on page yyy¿*". *xxx* denotes the listing number in which the code of the nested block actually appears and *yyy* the page number on which that listing begins. Of course this is only possible, if the mentioned nested block will be or already has been included by a \sourceinput command.

In turn, if a nested block will be included through a \sourceinput command, his heading line will additionally contain the listing and page number of his enclosing block. You can see this behavior in the following example where we show the constructors of the class Example2 by issuing the following command: "\sourceinput[fontname= ul9, fontenc=T1, fontsize=7, listing, linenr, label=Constructors]{ClassDefs.h} {Constructors}".

Listing 4.8: ClassDefs.h [Line 18 to 21] (Referenced in Listing 4.7 on page 80)

```
explicit Example2(double d) : y(d) {}
explicit Example2(int i) : y(i) {}
explicit Example2(long l) : y(l) {}
explicit Example2(char c) : y((unsigned int)c) {}
```

This hiding of nested code parts can be thought of as a kind of code folding as it is available in many programmer editors today [Knasm, Hend].

So lets finally state more precisely the difference between hiding code through '// ...' comment lines and the nesting of code blocks. While '// ...' comments always match the following '// ...' line, a nested 'BEGIN *tagname*' always matches its correspondent 'END *tagname*' and can potentially contain many '// ...' lines or even other nested chunks. Another difference is the fact that nested chunks can be presented later on in the documentation and will be linked together by references in that case , while parts masked out by '// ...' lines will simply be ignored. Nevertheless, '// ...' lines can be useful for example if a part of a source file contains many lines of comments which aren't intended to be shown in the ProgDOC documentation. If you want to use nested "BEGIN/END" chunks together with the \sourceinputbase command, be sure to read the comments on this topic in section 4.1.10.

One last word on the format of the comments processed by the ProgDOC system. They must be in a line on their own. The comment token, BEGIN/END and the tagname must be separated by and only by whitespace. The comment token must not necessarily begin in the first column of the line as long as it is preceded only by whitespace. The tagname should consist only of characters which are valid in a LaTeX \label statement.

4.1.12 LaTeX customization of ProgDOC

Some of the options available for the '\sourcebegin' and the '\sourceinput' command (see section 4.1.6 on page 75) can be set globally by redefining LaTeX commands. Additional commands can be used to adjust the appearance of the generated output even further. Following a list of the available commands:

\pdFontSize	The font size used for printing source listings. The default is 8pt. This command is the global counterpart of the *fontsize* option of '\sourcebegin' and '\sourceinput'.
\pdLineSep	The line separation used for printing source listings. The default is 2.5ex. This command is the global counterpart of the *linesep* option of '\sourcebegin' and '\sourceinput'.

`\pdBaseFont`	The font family which is used to print source listings. The default is '`\ttdefault`'.This command is the global counterpart of the *fontname* option of '`\sourcebegin`' and '`\sourceinput`'.
`\pdFontEnc`	The encoding of the font family chosen with `\pdBaseFont` or with the *fontname* option of the '`\sourcebegin`' or '`\sourceinput`' commands. The default is OT1. This command is the global counterpart of the *fontenc* option of '`\sourcebegin`' and '`\sourceinput`'.
`\pdCommentFont`	The font shape used for highlighting comments in the source listing. The default setting is '`\itshape`'.
`\pdKeywordFont`	The font shape used to highlight the key words of a programming language. The default is '`\bfseries`'.
`\pdPreprFont`	The font shape used to highlight preprocessor commands in C or C++. The default is '`\bfseries\itshape`'.
`\pdStringFont`	The font used to highlight string constants in source listings. The default setting is '`\slshape`'.
`\ProgDoc`	Command to print the ProgDOC logo.
`\pdULdepth`	This is a length command which controls the depth of the line under a listing caption. ProgDOC uses the `ulem.sty` package for underlining which does a pretty good job in guessing a reasonable value for this purpose. However it may sometimes be necessary to manually fine tune it, depending on the used font. The length may be set with the `\setlength` command. Resetting `\pdULdepth` to 0pt reactivates the initial `ulem.sty` algorithm. (This tutorial for example uses `\setlength{\pdULdepth}{2.5pt}`.)
`\pdPre`[9] DEPRECATED	This and the following three length commands correspond to the longtable commands `\LTpre`, `\LTpost`, `\LTleft` and `\LTright` respectively. For more information see the documentation of the longtable package [Car]. `\pdPre` sets the amount of space before a listing. The default is `\bigskipamount`.
`\pdPost`[9] DEPRECATED	`\pdPost` sets the amount of space after a listing. The default is `0cm`.
`\pdRight`[9] DEPRECATED	The margin at the right side of the listing. The default is `\fill`.
`\pdLeft`[9] DEPRECATED	`\pdLeft` sets the amount of space at the left side of a listing. Usually the listing is left justified or centered (see also section 4.1.6, The `\sourceinput` command). But because listings are typeset inside a longtable environment, they aren't indented for example inside list environments. In that case it can be useful to set `\pdLeft` to `\leftmargin`. If the listing will be insight a nested list environment, you can use `\renewcommand{\pdLeft}{x\leftmargin}` where `x` is the nesting level. The default is `0cm`.

All these commands can be redefined. If you want to typeset string constants in italic, you could insert the following line in the preamble of your '`.pd`' file: '`\renewcommand{\pdStringFont}{\slshape}`'. The words used to built up the header of each listing also can be set by the user according to his preferences (though this is intended mainly to permit a certain kind of localization). They are defined in '`progdoc.sty`' as follows:

[9] Because ProgDOC internally used the longtable environment in older versions to render the program listing, some of the longtable options have been made available to ProgDOC users. As new versions of ProgDOC don't use longtable anymore, this options have no effect. (See the *useLongtable* option of the `\sourceinput` command on page 4.1 for a compatibility option to enable the old style mode which uses the longtable environment).

`\ListingName`	The name used to name listings. The default is "Listing".
`\LineName`	The name of a line. The default setting is "Line".
`\toName`	The word for "to" in "Line xxx to yyy". Defaults to "to".
`\ReferenceName`	The sentence "Referenced in".
`\PageName`	The words "on page".
`\ListingContinue`	A word to indicate that the current listing is a continuation from a previous page. Defaults to "continued".
`\NextPage`[9] DEPRECATED	This should be a small symbol to indicate that a listing is not finished, but will be continued on the next page. The default setting is '`\ding{229}`' which is the '➥' symbol.

You could customize these entries for the german language by inserting the following lines into the preamble of your '`.pd`' file:

```
\def\LineName{Zeile}
\def\toName{bis}
\def\ReferenceName{Referenziert in}
\def\PageName{auf Seite}
\def\ListingContinue{Fortsetzung}
```

4.1.13 An example `Makefile`

In this chapter a makefile will be presented which simplifies the task of calling all the scripts in the right order and keeps track of dependencies between source and documentation files. For the sake of simplicity, the makefile used to build this documentation will be shown:

Listing 4.9: Makefile

```
dvi   : tutorial.dvi
ps    : tutorial.ps
pdf   : tutorial.pdf
html  : tutorial/tutorial.html
out   : example
clean :
        rm -rf *.dvi *.ps *.pdf *.log *.aux *.idx *~ part1.tex tutorial.tex \
               *pk *.out _pdweave.tmp _pd_html.html tutorial

tutorial.dvi : tutorial.tex part1.tex

tutorial.pdf : tutorial.tex part1.tex progdoc.pdf

progdoc.pdf : progdoc.eps
        epstopdf progdoc.eps

part1.tex    :  ClassDefs.h test.xml test.py version.el

example : example.cpp ClassDefs.h
        g++ -o example example.cpp

tutorial/tutorial.html: tutorial.dvi
        latex2html -html_version 4.0 -show_section_numbers -image_type gif \
```

Listing 4.9: Makefile (continued)

```
                -up_title "ProgDoc Home Page" -up_url "../progdoc.htm"  \
                -no_footnode -local_icons -numbered_footnotes tutorial.tex

# We generate ps from pdf now in order to depend only on pdfLaTeX!
# %.ps  : %.dvi
#        dvips -D 600 -o $@ $<

%.ps  : %.pdf
        acroread -toPostScript -binary $<

%.dvi : %.tex
        latex $< && latex $<

%.pdf : %.tex
        rm -f $*.aux && pdflatex $< && pdflatex $<

%.tex : %.pd
        pdweave $<
```

Of course this file can be included with the \sourceinput command as well. Because syntax highlighting for makefiles is not supported yet, the file was included by using the *type* option set to *text*. But even in this case, there are still benefits in using the \sourceinput command. First of all, the documentation will always contain the actual makefile. Second, this makefile can be referenced throughout the documentation like every other source file (see Listing 4.9). And last but not least, ProgDOC may be extended in the future to highlight various other file formats, so you may improve your documentation by simply rebuilding it with a new version of ProgDOC.

Now lets have a closer look on the makefile. The first five lines define shortcuts for the different targets, namely the dvi, ps, pdf and html versions of the documentation and the example executable. clean, the last target removes all files created during a build process. Notice that '_pdweave.tmp' and '_pd_html.html are temporary files created by pdweave.

In the next lines, the dependencies are defined. The dvi output depends on the tex files of the documentation which in turn depend on the source code of the files they document. Therefore the documentation will be rebuild not only if the documentation source files will change, but also if the source code files change.

The next two rules tell make utility how to build the example executable and the html version of the documentation. The latter will be created by LaTeX2HTMLin its own subdirectory.

The last four parts of the makefile contain generic actions which tell the make utility how to generate '.ps' files out of '.dvi' files, '.dvi' files out of '.tex', '.pdf' files out of '.tex' files and finally '.tex' files out of .pd-files. As you can see, for the last step the pdweave utility will be used.

Using this example as skeleton, it should be straightforward how to write makefiles for your own projects.

4.2 Program documentation with XDoc

Traditionally program documentation has never been treated as a first class citizen of computer programs and as such has not received wide support by language designers. Comment lines which are ignored by the compiler have been the broadest common denominator in virtually all programming languages. In this section a universal documentation extension will be proposed which may be applied non-intrusively to any arbitrary programming language. It may be used for automatic interface documentation generation as well as for linking external documentation with parts of the actual source code. The benefits of this new documentation scheme are: synchronized code and documentation, different levels of compiler support for program documentation and wider tool support due to the independence from the actual programming language and a standardized output format. A prototype implementation of the new approach is presented for the Java programming language and the DocBook system.

4.2.1 Introduction

From the very beginning programming languages knew the concept of comments. Because comment lines were completely ignored by the compiler they could contain arbitrary content. So it became good programming practice to use comments in order to document the most important and the most intricate parts of a program in prose. However, documenting a program in such a way has a number of serious drawbacks. First of all, the intended reader needs full access to the source code. Sometimes a subject may be most easily explained by a picture or a formula which is extremely hard to do by using merely ASCII characters. Finally, excessive documentation with comment lines can make the program code itself hard to read and edit.

These problems lead to the development of the concept of *Literate Programming* by D. Knuth [Kn84] where the source code and the documentation are written into a single file using TeX [Kn91]. This way the full power of the TeX typesetting system can be used for the documentation. However, before compiling the program the source code has to be extracted from the documentation first (see also section 4.1.2).

In recent days, Java [GoJoSt] introduced a new documentation system called JavaDoc. It is based on API documentation which is automatically generated by the compiler and which can be augmented by the programmer with the help of special comments which are inserted into the source code. However only high level, interface documentation can be achieved this way.

All these three mentioned approaches do not handle program documentation in its entirety. Therefore a new, universal and language independent documentation scheme which can be applied non-intrusively to any programming language will be proposed here.

The language extension is non-intrusive because it is completely transparent to any compiler which is unaware of the extension. Therefore, as a first step before compiler support will be available, the extension may also be handled by an external preprocessor.

The documentation scheme is language independent because it may be used with any programming language which offers simple comments. It is universal because it offers a uniform interface and output format no matter with which programming language it is actually used. Finally it is new in the sense that it combines well known and approved techniques in a new and innovative way.

4.2.2 The new XDoc approach

The usefulness and necessity of a good software documentation is generally accepted by every programmer. However there is no such unity when it comes to the question what is a good documentation and there is even less agreement upon how to produce such a documentation. Nevertheless, the following features seem to be crucial for every documentation system:

1. Documentation and source code should always be consistent and synchronized.

2. The system should be easy to use in order to be accepted by the programmer. (I.e. programming should not be constrained and documenting should be as easy as just writing with a usual word processor.)

3. Different levels of documentation like interface or implementation documentation for different audience should be possible.

4. The documentation should be legible, appealing and equally well suited for various output formats like printed manuals, books or online browsing.

5. Interoperability, team and tool support are crucial today because projects tend to use more than one programming language, support more then one platform and are being worked on by many people simultaneously.

The previous sections about the ProgDOC program documentation system already alnalyzed and categorized the majority of the program documentation systems available today with respect to these criteria (see pages 66 to 72). The next sections will introduce the new XDoc system which is based on two simple properties fulfilled by virtually every programming language.

- Every programming language is based on a formal grammar and every compiler or interpreter internally builds a parse tree of a program when parsing it. Therefore it would be easy for each such tool to dump the parse tree in a XML format standardized on a per language basis.

- Every programming language offers line comments. Defining some of these comments to have a special semantic would enable the compiler to produce additional markup in the XML version of the parsed file. This comment format should also be standardized on a per language basis.

Once the two requirements postulated above are fulfilled it becomes easy to produce interface as well as implementation documentation from the resulting XML source code representation by using standard tools like XInclude [XInc] or XSLT [XSLT] processors.

Taking into account the XML elements introduced by the programmer with the special comments presupposed before, it is possible to address arbitrary code parts and include them into the documentation. Given the standardized XML format, it becomes trivial to include source code into the documentation based on syntactic information (e.g. including a class or method definition by name). And finally an API documentation could be generated automatically by extracting the interface part together with possible documentation comments (eg. JavaDoc, C# or Doxygen style comments) from the XML representation.

The key point is in fact the per language standardization of the proposed special comment scheme and the XML representation of the source code because it will permit the development of documentation tools with respect to a standardized interface. How such a tool may look like will be demonstrated in section 4.2.3 while the following two subsections will discuss the special comment format and the representation of the sourc code in XML.

The comment format

For the semantics of the special line comments we propose the following simple extension to usual line comments:

line-comment-token '<'|'>'|'<>' *element-name* {*attribute=value*}*

where *line-comment-token* is the token which introduces a line comment in the specific programming language (e.g. '//' in C++/Java or '#' in AWK) and *element-name* denotes the name of the resulting XML element. If the character following the comment token is '<', the result will be an opening tag for the corresponding element, if the character is '>' the compiler will generate a closing tag for the corresponding element, and finally a '<>' after the comment token will introduce an empty element. All the additional text after *element-name* will be copied verbatim into the resulting element tag and should contain valid XML attributes in order to produce a well-formed XML document.

Notice that introducing opening and closing tags for an element has to be done in such a way that they do not intersect with the opening and closing tags produced by the compiler for certain programming language constructs. So for example placing a comment which will produce an opening tag just before a while loop and the comment for the closing tag inside that loop will in general produce a XML document which is not well formed because the introduced tags will overlap with the opening and closing tags of the while loop. Such errors however can be detected easily by the compiler.

The advantage of the fact that comments for opening and closing tags have to align with the structure of the program is that they can be used also as anchors for user defined code folding [Hend, Knasm]. For example jEdit [Pest], a cross platform, programmer's text editor written by Slava Pestov uses '//{{{ *text*' and '//}}}' line comments to specify the beginning and the end of a text fold. Unifying these notations would enable code folding for source code marked up with documentation comments as well as inclusion of arbitrary predefined code folds into the documentation. Notice that although the opening and closing comments may not overlap they may be nested.

The XML representation

Because most programming languages are defined by a grammar anyway, the simplest approach would be to define a XML DTD or a XML Schema [XMLSch0] based on that grammar. There also exist already a number of XML mappings for various programming languages like for example JavaML [Bad] for Java or the generic approaches of Armstrong [Arm] and Sandø [San]. Like for the syntax of the documentation comment, the crucial point here is that is is highly desirable for the XML representation to be standardized together with the corresponding programming language in order to enable compatibility of code and interoperability of tools.

It has to be stressed however that we do not necessarily need a full compiler in order to create the XML representation. Tools like DOC++ [WunZoe] or Doxygen [Hee] which only partially parse the source file may be fully adequate. The advantage of using a full fledged compiler for this purpose would be the additional information which could be gathered like overload resolution or exact type information for every identifier in the source code. This information could be used for example for cross linking in the generated documentation.

Also, it is not strictly necessary to store the XML representation in files corresponding to the underlying source files. It can be useful storing this information in a database which may save time in the face of recompilation or it may simplify querying the information for big projects.

Advantages and drawbacks of the new approach

The proposed documentation system fulfills the first three properties postulated in section 4.2.2. The code and the documentation can be kept synchronized although they are mutually independent. Only the syntax of the new documentation comment has to be learned by the programmer. And finally, as stated before, the generated XML representation can be used to produce interface as well as implementation documentation.

Legibility, appealing look and eligibility for different output formats which was the fourth property from section 4.2.2, are mainly dependent on the typesetting system actually used. However, XML based documentation system are widely used and the prototype presented in section 4.2.3 which is based on DocBook [WaMu] demonstrates the strength of this approach. Finally, interoperability and team and tool support is granted through the wide acceptance and support of XML and XML related technologies as industry standards.

One last benefit of the proposed documentation style is its applicability to multilingual documentation because once the relevant code parts have been identified and marked they can be included in the same way into arbitrary documents. With the Literate Programming approach described in section 4.1.2 several versions of the same documentation in different languages are not possible without duplication of the source code which is embedded inside the documentation. Also, even if possible, embedding all the documentation into the source code as for example with the JavaDoc style would become confusing already with the second language because the source code would contain more comments than actual program code. These arguments of course apply not only to multilingual documentation, but also for the case where different kinds of documentation (e.g. user documentation, developer documentation) have to be created for the same code.

There are two major drawbacks of the new documentation system. First of all, standardizing a computer language is a complicated and intricate task. Therefore adding the proposed extensions to the definition of already existing languages will be not easy. However there may be a good chance for the user community of each programming language to establish a De-facto standard for these extensions.

For some programming languages like C/C++ which use a preprocessor it may be difficult to reconstruct the source representation from the abstract syntax tree available to the compiler because the preprocessor step can potentially replace and change the source code. In particular the C/C++ preprocessor simply strips all the comments from the source code before feeding it to the compiler. Therefore tools like GCC-XML [King], an extension of the GNU C++ compiler [GCC] by Brad King which generates an XML description of a C++ program from GCC's internal representation, does not handle comments at all. However other tools like Synopsis [DaSe] or techniques similar to the ones described in [BaNo] may be used to overcome this problem.

4.2.3 A prototype implementation

This section will present a prototype implementation of the ideas presented in the last section. The prototype works for the Java programming language and uses DocBook for writing the documentation along with the DocBook XSL-FO stylesheets and a FO [XSL] processor to produce PDF documentation. Two pages of a resulting document are shown in Figure 4.2.3 and 4.2.3, respectively. Notice that the two pages were in A4 format initially and have been shrinked by a factor of 0.6 in order to fit the layout of this journal.

For the prototype the Java compiler which is available as a part of the Java Specification Request 14 [JSR14] dedicated to adding Generics to the Java programming language has been used and extended. As XSLT processor version 6.5.2 of Michael Kay's Saxon [Kay] has been choosen. Furthermore, version 4.1.2 of the DocBook DTD and version 1.60.1 of the DocBook XSL-FO stylesheets [Walsh2] have been used and extended. As a last step the

```
/**
 * A quick sort demonstration algorithm
 *
 * @author James Gosling
 * @author Kevin A. Smith
 * @version 1.3, 29 Feb 1996
 */
public class QSortAlgorithm {

  /** A generic version of C.A.R Hoare's Quick Sort algorithm.
   * It handles sorted arrays, and arrays with duplicate keys.
   *
   * If you think of a one dimensional array as going from
   * the lowest index on the left to the highest index on the right
   * then the parameters to this function are lowest index or
   * left and highest index or right.  The first time you call
   * this function it will be with the parameters 0, a.length - 1.
   *
   * @param a       an integer array
   * @param lo0     left boundary of array partition
   * @param hi0     right boundary of array partition
   * @return        returns nothing, just for demonstration purpose
   */
  //< Include ID="QSMethod" label='The whole "QuickSort" method.'
  public static void QuickSort(int a[], int lo0, int hi0) {
    int lo = lo0;
    int hi = hi0;
    int mid;

    if ( hi0 > lo0) {
      // Arbitrarily establishing partition element as the midpoint of
      // the array.
      //
      mid = a[ ( lo0 + hi0 ) / 2 ];

      //< Include ID="whileLoop" label="Loop through the array until indices cross"
      while( lo <= hi ) {
        // find the first element that is greater than or equal to
        // the partition element starting from the left Index.
        //
        while( ( lo < hi0 ) && ( a[lo] < mid ) ) {
          ++lo;
        }

        // find an element that is smaller than or equal to
        // the partition element starting from the right Index.
        //
        while( ( hi > lo0 ) && ( a[hi] > mid ) ) --hi;

```

Figure 4.2: The first part of the example program `QSortAlgorithm.java`.

resulting XML document was run through the RenderX Formatting Object engine [XEP] to produce the final PDF version. The next three subsections will describe the extensions in more detail and explain how the mentioned systems work together to produce the final documentation.

In order to demonstrate the possibilities of the system a slightly modified version of a Quicksort class written by James Gosling and Kevin Smith which is presented verbatim in the Figures 4.2 and 4.3 will be used. Along with the implementation of the prototype it is available for download from `http://www.progdoc.org/xprogdoc`.

Extending the Java compiler

The decision to use the JSR 14 prototype compiler was made because of two main reasons. First of all it offers the chance to immediately support the Generic Java constructs which will be added to the Java programming language in version 1.5 of the Java Development Kit. The second reason was the fact that the compiler is implemented in a clear and well structured

```
50         // if the indexes have not crossed, swap
51         if( lo <= hi ) {
52           swap(a, lo, hi);
53           ++lo;
54           --hi;
55         }
56       }
57       //> Include
58 
59       //If the right index has not reached the left side of array
60       //  must now sort the left partition.
61       //
62       if( lo0 < hi ) QuickSort( a, lo0, hi );
63 
64       // If the left index has not reached the right side of array
65       // must now sort the right partition.
66       //
67       if( lo < hi0 ) QuickSort( a, lo, hi0 );
68 
69     }
70   }
71   //> Include
72 
73   public static void sort(int a[]) {
74     QuickSort(a, 0, a.length - 1);
75   }
76 
77   private static void swap(int a[], int i, int j) {
78     int T;
79     T = a[i];
80     a[i] = a[j];
81     a[j] = T;
82   }
83 
84   private static void print(int a[]) {
85     for(int i = 0; i < a.length; i++) {
86       if (i > 0) System.out.print(", ");
87       System.out.print(a[i]);
88     }
89     System.out.println();
90   }
91 
92   public static void main(String argv[]) {
93     int test[] = new int[] { 9, 5, 2, 6, 2, 7, 5, 1, 0, 4};
94     print(test);
95     sort(test);
96     print(test);
97   }
98 }
```

Figure 4.3: The second part of the example program `QSortAlgorithm.java`.

way and contains a nice, easy to understand recursive descend parser. The compiler source code is available for free download at [JSR14].

The compiler was extended to support the new command line option '`-x`', which instructs the compiler to dump the Java files given on the command line in XML format. An example of how this output looks like is presented in Figure 4.4. Notice the `Include` element at line 101 in Figure 4.4 which was introduced by the special comment at line 36 in `QSortAlgorithm.java`. The `label` attribute of this element is used in Listing 1 in Figure 4.2.3 in order to denote the content omitted from the listing. Also notice the fact that empty lines of the Java source file are represented by special XML comments like the one at line 100 in Figure 4.4. Though not strictly necessary, this information is preserved in order to simplify the production of the formatted Java output in a later step.

The mapping of the Java language to XML elements is straightforward. General language constructs are mapped to corresponding XML elements. Sometimes additional attributes are used to further describe the construct (e.g. the `operator` attribute for the `binary-`

```
100 <!-- empty-line -->
101 <Include ID="whileLoop" label="Loop through the array until indices cross" line="38" colum="7">
102   <while-loop  line="39" colum="7">
103     <condition  line="39" colum="7">
104       <binary-expression operator="&lt;=" line="39" colum="17">
105         <var name="lo"  line="39" colum="14"/>
106         <var name="hi"  line="39" colum="20"/>
107       </binary-expression>
108     </condition>
109     <body single="false"  line="39" colum="7">
110       <comment value=" find the first element that is greater than or equal to " line="40" colum="9"/>
111       <comment value=" the partition element starting from the left Index." line="41" colum="9"/>
112       <comment value="" line="42" colum="9"/>
113       <while-loop  line="43" colum="9">
114         <condition  line="43" colum="9">
```

Figure 4.4: Some lines of the compiler generated file `QSortAlgorithm.xml`. These lines correspond to the Java source from line 35 to the first opening brace at line 41 in Figure 4.2.

`expression` element (see Figure 4.4 line 104) or the `visibility` attribute for `method`, `var-def` and `class` elements). Additionally, every element has a `line` and a `column` attribute which denotes the exact position of the corresponding construct in the Java source file.

The first step in order to achieve these results was the introduction of two new tokens into the scanner part of the Java compiler. One token for line comments and one for empty lines. Notice that the scanner originally skipped all comments except the special JavaDoc comments. They where just stored in a symbol table along with the class definition or variable declaration they belong to and not reported directly to the parser.

The parser was changed to accept the new tokens. Therefore the production rule for *BlockStatement* [GoJoSt, §14.2] was changed to accept line comments and empty lines alternatively to usual language statements. The productions for *ClassBodyDeclaration* [GoJoSt, §8.1] and *InterfaceMemberDeclaration* [GoJoSt, §9.1] were changed to additionally accept line comments and empty lines.

The parser builds an abstract syntax tree of the source code which is processed and augmented in turn by various transformers which perform task like resolving names, doing flow analysis, optimization and code generation. All these transformers where changed to simply ignore the subtrees representing line comments and empty lines. Finally, a new transformer was written which dumps the abstract syntax tree in XML format. This transformer will be prepented to the chain of transformers right after parsing has been finished if the compiler is given the new '`-x`' command line option.

Extending DocBook

The DocBook DTD was extended by two new elements as shown in Figure 4.5. The first one, `SourceBase`, has the single, required attribute `xml:base`. It can be used to specify a base path under which source files considered for inclusion will be searched. `Listing`, the second element, can be used to include parts of a source file into the documentation. It has several attributes which will be described briefly now. The `href` attribute which is required denotes the file from which the code will be included. It will be interpreted relatively to the path which was set by the last `SourceBase` element if there was one at all. The `type` attribute which is also a required one is used to specify the kind of listing to produce. Setting the value of this attribute to `include` will tell the stylesheet by which the DocBook document will be processed to include all the code contained in the `Include` element with an ID attribute which is equal to the `anchor` attribute of the actual `Listing` element. Remember that such elements can be introduced by the programmer with the special documentation comments described in section 4.2.2 (e.g. line 24 and 36 in Figure 4.2). The first listing of the

```
<!--
  ProgDocBook DTD version 0.1

  This DTD module is identified by the PUBLIC and SYSTEM identifiers:

  PUBLIC "-//OASIS//DTD DocBook XML V4.1.2 Extension ProgDoc V0.1//EN">
  SYSTEM "http://www.progdoc.org/xdoc/dtd/ProgDocBook.dtd"
-->

<!--========== Add 'Listing' and 'SourceBase' elements to the DTD ==========-->

<!ENTITY % local.formal.class "| Listing | SourceBase">


<!--========== Define the new 'Listing' and 'SourceBase' elements ==========-->

<!ELEMENT SourceBase EMPTY>
<!ATTLIST SourceBase xml:base CDATA #REQUIRED>

<!ELEMENT Listing EMPTY>
<!ATTLIST Listing recursive-include (true|false) "false"
                  java-doc (true|false) "false"
                  type (include|select|api) "include"
                  href CDATA #REQUIRED
                  anchor ID #REQUIRED
                  kind CDATA #IMPLIED
                  name CDATA #IMPLIED
>

<!--=== Allow SourceBase and Listing inside chapter or section elements  ===-->

<!ENTITY % local.divcomponent.mix "| SourceBase | Listing">

<!--========================== Import DocBook DTD ==========================-->

<!ENTITY % DocBookDTD PUBLIC
           "-//OASIS//DTD DocBook XML V4.1.2//EN"
           "http://www.oasis-open.org/docbook/xml/4.0/docbookx.dtd">

%DocBookDTD;
```

Figure 4.5: The extension of the DocBook DTD.

example document shown in Figure 4.2.3 was included by the following command:

```
<Listing href="QSortAlgorithm.java" type="include" anchor="QSMethod"
         recursive-include="false" java-doc="false"/>
```

Because the `recursive-include` attribute is set to `false` the nested `Include` element which spans the lines 36 to 57 in Figure 4.2 and 4.3 is not included into the documentation. Instead it is replaced by a link to the listing which contains these lines if the author decides to also include them, as it has been done in Listing 2 of Figure 4.2.3. Otherwise, a notice that the lines are not shown in the actual documentation will be printed.

Notice the use of the `label` attribute which can be declared in the documentation comment of the programming language (line 36 in Figure 4.2). It is used internally by the stylesheet during the transformation as a short description of nested code parts and does not have to be specified in the extended DocBook DTD.

`java-doc`, the last attribute in the example given above, instructs the stylesheet not to show JavaDoc comments which appear in the included source code. As a second example consider the following line which has been used to include Listing 4 into the document shown in Figure 4.2.3:

```
<Listing href="QSortAlgorithm.java" type="select" kind="class"
         name="QSortAlgorithm" anchor="classQSortAlgorithm"
```

```
<xsl:template match="/">
  <!-- First of all we do the inclusion stage -->
  <xsl:variable name="doc1">
    <xsl:copy>
      <xsl:apply-templates select="@*|node()|comment()" mode="IncludeMode"/>
    </xsl:copy>
  </xsl:variable>
  <!-- In a second step we pretty-print and link the included source code -->
  <xsl:variable name="doc2">
    <xsl:copy>
      <xsl:apply-templates select="$doc1" mode="PrettyPrint"/>
    </xsl:copy>
  </xsl:variable>
  <!-- Finally we hand over control to the original rule from 'docbook.xsl' -->
  <!-- which will be applied now to the new root element.                  -->
  <xsl:apply-templates select="$doc2" mode="originalRootRule"/>
</xsl:template>
```

Figure 4.6: The main transformation rule of the XSL-FO stylesheet in `ProgDocBookFO.xsl`.

```
         recursive-include="false" java-doc="true"/>
```

It sets the `type` attribute to `select` thus including not a range of code specified by the programmer, but a syntactic entity of the programming language which is specified by the additional attributes `kind` and `name`. Consequently, this example includes the source code of the whole `QSortAlgorithm` class. Notice that this time the JavaDoc comments which belong to the class are shown because the `JavaDoc` attribute is set to `true`. The `recursive-include` attribute is still set to `false` which prevents the inclusion of the `Quicksort` method because it is embedded into special documentation comments by the programmer. Instead it is replaced by a line with a link to the actual listing and the short description given with the `label` attribute in the source code (line 24 in Figure 4.2).

The last example shown below demonstrates how API documentation in JavaDoc format can be included into the documentation by setting the `type` attribute to `api`:

```
<Listing href="QSortAlgorithm.java" type="api" kind="method"
         name="QuickSort" anchor="QuickSortAPI"/>
```

The result of this example can be seen in Listing 5 in Figure 4.2.3. It contains the JavaDoc API documentation (lines 10 to 23 in Figure 4.2) for the `QuickSort` method in a nicely formatted way. Notice furthermore that the `anchor` attribute can additionally be used as a target for cross referencing, no matter of the value of the `type` attribute. In the PDF version of the example document, references like for example "see Listing 2" are true hyperlinks which can be navigated.

Extending the DocBook XSL-FO stylesheets

While the extension of the DocBook DTD required only a few lines of code, extending the DocBook XSL-FO stylesheets which produces formatting objects output from an input file which conforms to the newly defined DTD, proved much harder.

All the functionality of the new DocBook elements and attributes described in the previous section is effectively implemented in the extended stylesheet. It uses an XSLT 1.1 feature which treats result tree fragments as real node sets and different modes to implement a three step policy during the XSL transformation. As shown in Figure 4.6, the first step is used to include source code parts identified by corresponding `Listing` elements. In this step all the original DocBook elements are just copied recursively to a temporary tree and the `document()` function is used to replace the `Listing` elements with the actual source code from the source files in XML format.

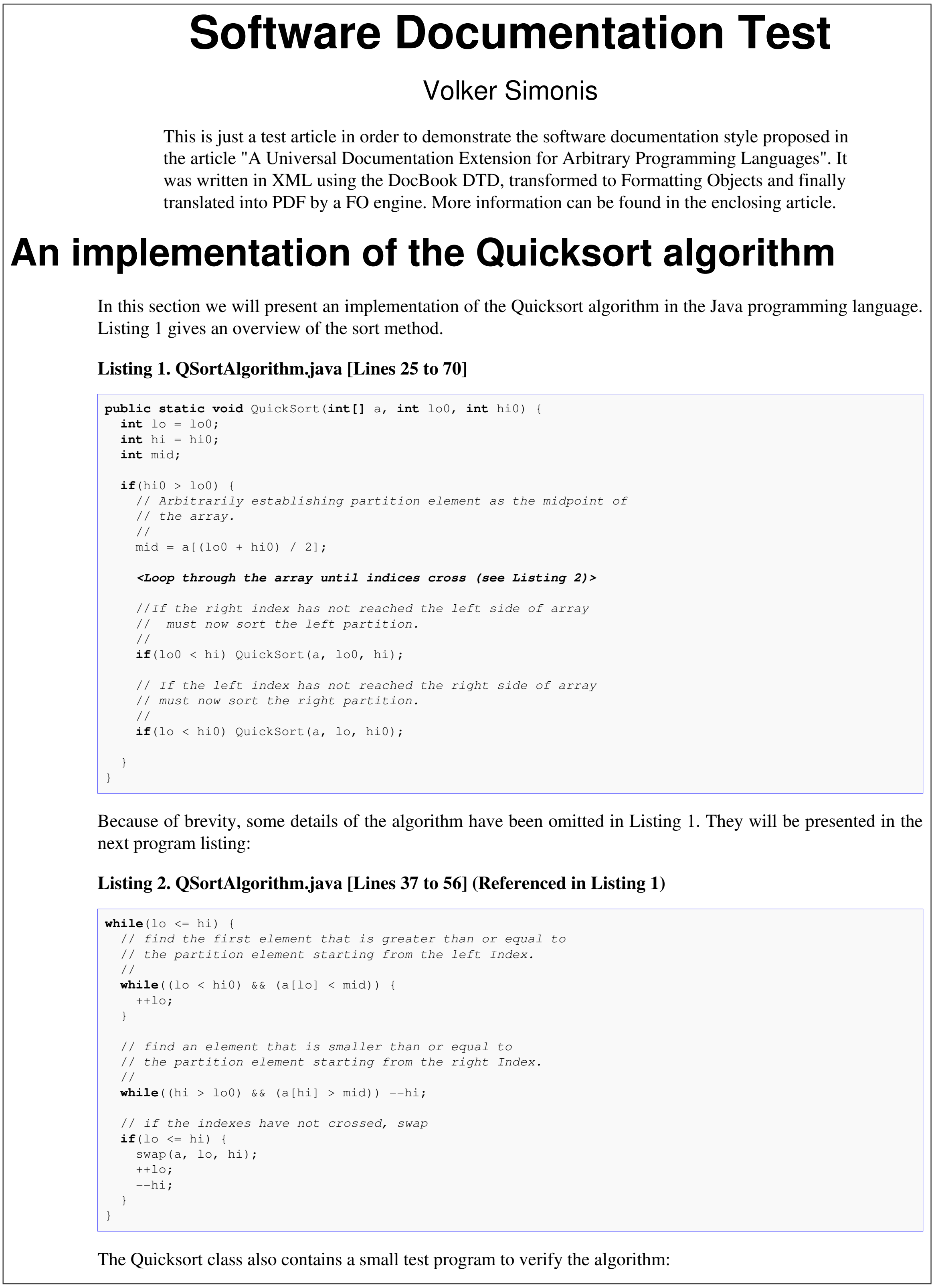
The second step uses the newly constructed tree and transforms the XML version of the Java source code into valid DocBook elements. Like in the first step the original DocBook elements are just copied to the new tree. The second step is also used to establish the automatic links between nested code parts. It is the most elaborate step with more than 500 lines of code because a transformation rule for every single element which can appear in the XML version of the source file is needed.

In the third and last step, the root rule of the original XSL-FO stylesheet is called with the second intermediate tree as argument. At this stage the tree contains only valid DocBook elements an can be transformed into a formatting object file.

Finally the XSL-FO stylesheet also contains some local customizations and some rules for a new DocBook element called `listing`. This element is effectively handled in the same way as the DocBook `example` element. It was only necessary to introduce it because listings have their own label, referencing style and numbering. Because the `listing` elements are created only in the second temporary tree during the transformation, they do not have to be declared in the extended DocBook DTD.

4.2.4 Conclusion

The new documentation style complies to the five demands postulated in section 4.2.2. It combines and uses well known and established techniques for documentation purpose in a new and effective way and proposes the standardization of the comment style together with the format of the XML representation as a an integral part of every programming language. Therewith, documenting becomes vendor and implementation independent in the same way as programming became vendor and implementation independent by the standardization of programming languages.



Software Documentation Test

Volker Simonis

This is just a test article in order to demonstrate the software documentation style proposed in the article "A Universal Documentation Extension for Arbitrary Programming Languages". It was written in XML using the DocBook DTD, transformed to Formatting Objects and finally translated into PDF by a FO engine. More information can be found in the enclosing article.

An implementation of the Quicksort algorithm

In this section we will present an implementation of the Quicksort algorithm in the Java programming language. Listing 1 gives an overview of the sort method.

Listing 1. QSortAlgorithm.java [Lines 25 to 70]

```
public static void QuickSort(int[] a, int lo0, int hi0) {
  int lo = lo0;
  int hi = hi0;
  int mid;

  if(hi0 > lo0) {
    // Arbitrarily establishing partition element as the midpoint of
    // the array.
    //
    mid = a[(lo0 + hi0) / 2];

    <Loop through the array until indices cross (see Listing 2)>

    //If the right index has not reached the left side of array
    //  must now sort the left partition.
    //
    if(lo0 < hi) QuickSort(a, lo0, hi);

    // If the left index has not reached the right side of array
    // must now sort the right partition.
    //
    if(lo < hi0) QuickSort(a, lo, hi0);

  }
}
```

Because of brevity, some details of the algorithm have been omitted in Listing 1. They will be presented in the next program listing:

Listing 2. QSortAlgorithm.java [Lines 37 to 56] (Referenced in Listing 1)

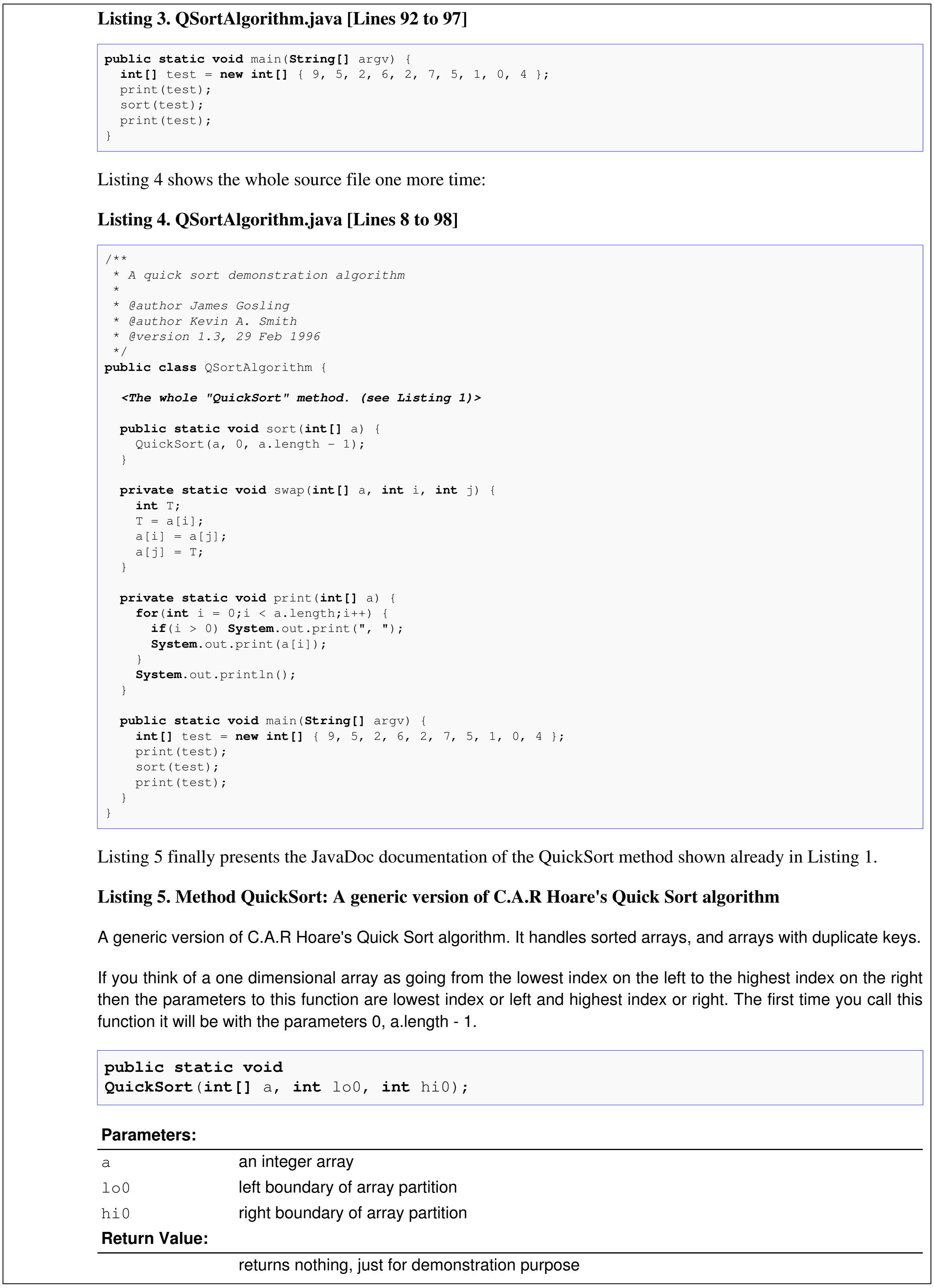
```
while(lo <= hi) {
  // find the first element that is greater than or equal to
  // the partition element starting from the left Index.
  //
  while((lo < hi0) && (a[lo] < mid)) {
    ++lo;
  }

  // find an element that is smaller than or equal to
  // the partition element starting from the right Index.
  //
  while((hi > lo0) && (a[hi] > mid)) --hi;

  // if the indexes have not crossed, swap
  if(lo <= hi) {
    swap(a, lo, hi);
    ++lo;
    --hi;
  }
}
```

The Quicksort class also contains a small test program to verify the algorithm:

Figure 4.7: The first page of the example document.



Listing 3. QSortAlgorithm.java [Lines 92 to 97]

```
public static void main(String[] argv) {
  int[] test = new int[] { 9, 5, 2, 6, 2, 7, 5, 1, 0, 4 };
  print(test);
  sort(test);
  print(test);
}
```

Listing 4 shows the whole source file one more time:

Listing 4. QSortAlgorithm.java [Lines 8 to 98]

```
/**
 * A quick sort demonstration algorithm
 *
 * @author James Gosling
 * @author Kevin A. Smith
 * @version 1.3, 29 Feb 1996
 */
public class QSortAlgorithm {

  <The whole "QuickSort" method. (see Listing 1)>

  public static void sort(int[] a) {
    QuickSort(a, 0, a.length - 1);
  }

  private static void swap(int[] a, int i, int j) {
    int T;
    T = a[i];
    a[i] = a[j];
    a[j] = T;
  }

  private static void print(int[] a) {
    for(int i = 0;i < a.length;i++) {
      if(i > 0) System.out.print(", ");
      System.out.print(a[i]);
    }
    System.out.println();
  }

  public static void main(String[] argv) {
    int[] test = new int[] { 9, 5, 2, 6, 2, 7, 5, 1, 0, 4 };
    print(test);
    sort(test);
    print(test);
  }
}
```

Listing 5 finally presents the JavaDoc documentation of the QuickSort method shown already in Listing 1.

Listing 5. Method QuickSort: A generic version of C.A.R Hoare's Quick Sort algorithm

A generic version of C.A.R Hoare's Quick Sort algorithm. It handles sorted arrays, and arrays with duplicate keys.

If you think of a one dimensional array as going from the lowest index on the left to the highest index on the right then the parameters to this function are lowest index or left and highest index or right. The first time you call this function it will be with the parameters 0, a.length - 1.

```
public static void
QuickSort(int[] a, int lo0, int hi0);
```

Parameters:	
a	an integer array
lo0	left boundary of array partition
hi0	right boundary of array partition
Return Value:	
	returns nothing, just for demonstration purpose

Figure 4.8: The second page of the example document.

4.3 A Locale-Sensitive User Interface

For the two applications LanguageExplorer (see chapter 5) and LanguageAnalyzer (see chapter 6) developed for this thesis a special graphical user interface has been developed which allows the user to switch the language of the user interface at run time without the need to restart the application.

Although LanguageExplorer and LanguageAnalyzer have been implemented in Java and its GUI library Swing which provides software developers with a highly customizable framework for creating truly "international" applications, the Swing library is not locale-sensitive[10] to locale switches at run time.

Taking into account Swings elaborate Model-View-Controller architecture, this section describes how to create GUI applications which are sensitive to locale changes at runtime, thus increasing their usability and user friendliness considerably. The content of this section has been published in [Sim02].

4.3.1 Introduction

Sometimes GUI applications are created with internationalization[11] in mind, but are not immediately fully localized[12] for all target languages. In such a case a user native to an unsupported language would choose the language he is most familiar with from the set of supported languages. But the ability to easily switch the language at run time could still be desirable for him if he knows more than one of the supported languages similarly well.

Other applications like dictionaries or translation programs are inherently multi-lingual and are used by polyglot users. Such applications would greatly benefit if the user interface language would be customizable at runtime.

Unfortunately, this is not a builtin feature of the Java Swing GUI library. However this article will sketch how it is easily possible to customize Swing such that it supports locale switching at runtime. Therefore a new Look and Feel called the `MLMetalLookandFeel` will be created, where `ML` is an abbreviation for "multi lingual". This new Look and Feel will extend the standard Metal Look and Feel with the ability of being locale-sensitive at runtime.

As an example we will take the `Notepad` application which is present in every JDK distribution in the `demo/jfc/Notepad/` directory. It is localized for French, Swedish and Chinese, as can be seen from the different resource files located in the `resources/` subdirectory. Depending on the locale of the host the JVM is running on, the application will get all the text resources visible in the GUI from the corresponding resource file. The loading of the resource file is achieved by the following code:

Listing 4.10: Notepad.java [Line 59 to 65]

```
try {
    resources = ResourceBundle.getBundle("resources.Notepad",
                                         Locale.getDefault());
} catch (MissingResourceException mre) {
    System.err.println("resources/Notepad.properties not found");
    System.exit(1);
}
```

[10] *locale-sensitive*: A class or method that modifies its behavior based on the locale's specific requirements. (All definitions taken from [DeiCza].)

[11] *internationalization*: The concept of developing software in a generic manner so it can later be localized for different markets without having to modify or recompile source code.

[12] *localization*: The process of adapting an internationalized piece of software for a specific locale.

The ResourceBundle class will try to load the file resources/Notepad_XX_YY.properties where XX is the two letter ISO-639 [ISO639] language code of the current default locale and YY the two letter ISO-3166 [ISO3166] country code, respectively. For more detailed information about locales have a look at the JavaDoc documentation of java.util.Locale. The exact resolution mechanism for locales if there is no exact match for the requested one is described at java.util.ResourceBundle. In any case, the file resources/Notepad.properties is the last fall back if no better match is found.

You can try out all the available resources by setting the default locale at program startup with the two properties user.language and user.country[13]. To run the Notepad application with a Swedish user interface you would therefore type:

```
java -Duser.language=sv Notepad
```

However, a user interface internationalized in this way is only customizable once, at program startup. After the resources for the default locale are loaded, there is no way to switch the locale until the next start of the program. We will call this type of internationalization *static* internationalization. Throughout this paper we will change Notepad.java to make it *dynamically* internationalized, i.e. locale-sensitive at run time. We will call this new application IntNotepad.

4.3.2 The Java Swing architecture

A GUI application is composed out of many UI components like labels, buttons, menus, tool tips and so on. Each of these components has to display some text in order to be useful. Usually, this text is set in the constructor of the component for simple components like labels or buttons. Additionally, and for more complex components like file choosers, the text can be set or queried with set and get methods.

Internationalized applications like the Notepad application do not hard code these text strings into the program file, but read it from resource files. So instead of:

```
JFrame frame = new JFrame();
frame.setTitle("Notepad");
```

they use the following code:

```
JFrame frame = new JFrame();
frame.setTitle(resources.getString("Title"));
```

where resources denotes the resource bundle opened in Listing 4.10.

Basically, we could just reset all these strings at run time every time the user chooses a different locale. But for an application which uses tens to hundreds of different components it would not be practicable to manually do this. Even worse, some components like JFileChooser do not even offer accessory methods for all the strings they display. So we have to come up with another solution which requires a closer look at the architecture of the Swing GUI library.

The design of the Swing library is based on a simplified Model-View-Controller [GHJV] pattern, called Model-Delegate [ZuStan]. Compared to the classical MVC pattern, the Model-Delegate pattern combines the View and the Controller into a single object called the Delegate (see figure 4.9). In Swing, these delegates, which are also called the user interface (UI) of a component, are Look and Feel specific. They are derived from the abstract class ComponentUI. By convention have the name of the component they are the delegate for with

[13] Be aware that setting the default locale on the command line with help of the mentioned properties does not work with all JDK versions on all platforms. Refer to the bugs 4152725, 4179660 and 4127375 in the Java Bug Database [JDB].

the J in the component class name replaced by the name of the specific Look and Feel and UI appended to the class name. So for example the UI delegate for JLable in the Metal Look and Feel has the name MetalLabelUI.

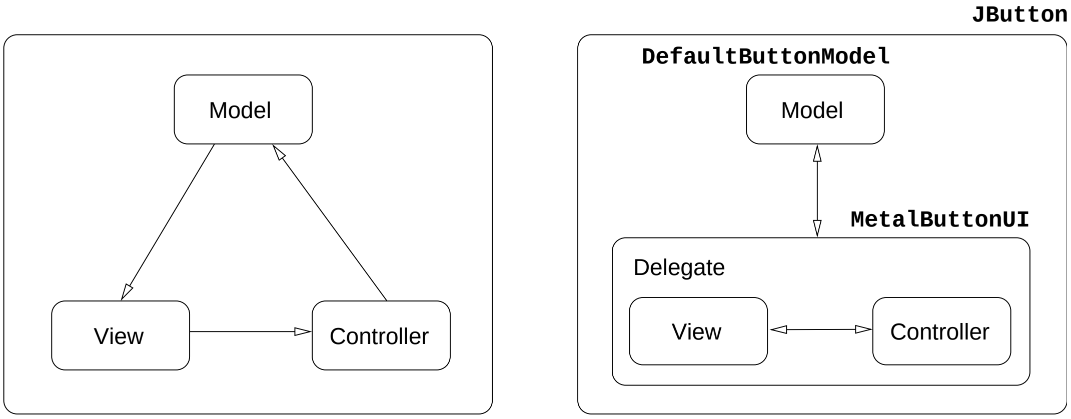


Figure 4.9: The left side shows the common Model-View-Controller pattern, whereas the right side shows the Model-Delegate pattern used in Swing along with the class realizations for JButton.

One of the tasks the UI delegate is responsible for is to paint the component it is tied to. In contrast to the AWT library, in Swing it is not the paint() method of every component which does the work of painting itself. Instead, the component's paint() method just calls the paint() method of its delegate along with a reference to itself.

4.3.3 The solution - idea and implementation

After knowing the internals of the Swing architecture, we are ready to make the Swing components aware of locale switches at runtime. To achieve such a behavior, we will introduce one more level of indirection. Instead of just setting a text field of a component to the real string which should be displayed, we set the field to contain a key string instead. Then we override the UI delegate in such a way that instead of just painting the string obtained from its associated component, it will look up the real value of the string to paint depending on the actual locale.

Let us substantiate this in a small example. Listing 4.11 shows how a JLabel is usually created and initialized, followed by a code snippet taken from the BasicLabelUI.paint() method which is responsible for rendering the label's text:

Listing 4.11: Creating a usual JLabel and a part of the BasicLabelUI.paint() method.

```
// Create a label.
JLabel label = new JLabel();
label.setText("Hello");

// Taken from javax.swing.plaf.basic.BasicLabelUI.java
public void paint(Graphics g, JComponent c)  {
  JLabel label = (JLabel)c;
  String text = label.getText();

  // Now do the real painting with text.
  ...
}
```

We will now create a new UI delegate for `JLable` called `MLBasicLabelUI` which overrides the `paint()` method such that it not simply queries the text from the `JLable` and renders it. Instead it interprets the string received from its associated `JLable` as a key into a resource file which is of course parameterized by the current Locale. Only if it doesn't find an entry in the resource file for the corresponding key, it will take the key text as the string to render. Thus, the changes in the UI are fully transparent to the component itself.

Getting the localized resource strings

Because this procedure of querying the localized text of a component from a given resource file will be common for all UI delegates which we will create for our Multi Lingual Look and Feel, we put the code into a special static method called `getResourceString()`:

Listing 4.12: ml/MLUtils.java [Line 35 to 44]

```
public static String getResourceString(String key) {
  if (key == null || key.equals("")) return key;
  else {
    String mainClass = System.getProperty("MainClassName");
    if (mainClass != null) {
      return getResourceString(key, "resources/" + mainClass);
    }
    return getResourceString(key, "resources/ML");
  }
}
```

This method builds up the name of the resource file which is searched for the localized strings. Therefore it first queries the system properties for an entry called `MainClassName`. If it succeeds, the resource file will be a file with the same name in the `resources/` subdirectory. If not, it will assume `ML` as the default resource file name. This file name along with the original `key` argument are passed to the second, two parameter version of `getResourceString()`, shown in Listing 4.13.

Listing 4.13: ml/MLUtils.java [Line 50 to 76]

```
private static Hashtable resourceBundles = new Hashtable();

public static String getResourceString(String key, String baseName) {
  if (key == null || key.equals("")) return key;
  Locale locale = Locale.getDefault();
  ResourceBundle resource =
    (ResourceBundle)resourceBundles.get(baseName + "_" + locale.toString());
  if (resource == null) {
    try {
      resource = ResourceBundle.getBundle(baseName, locale);
      if (resource != null) {
        resourceBundles.put(baseName + "_" + locale.toString(), resource);
      }
    }
    catch (Exception e) {
      System.out.println(e);
    }
  }
```

Listing 4.13: ml/MLUtils.java [Line 50 to 76] (continued)

```
  if (resource != null) {
    try {
      String value = resource.getString(key);
      if (value != null) return value;
    }
    catch (java.util.MissingResourceException mre) {}
  }
  return key;
}
```

This method finally does the job of translating the key text into the appropriate localized value. If it can not find the corresponding value for a certain key it just returns the key itself, consequently not altering the behavior of a component which isn't aware of the multi lingual UI it is rendered with.

Notice that for performance reasons, `getResourceString()` stores resource files in a static map after using them for the first time. Thus, any further access will use this cached version, without the need to reload the file once again.

Overloading the `paint()` method of the UI delegates

After having understood the way how localized strings can be queried with the functions introduced in Listing 4.12 and 4.13, the overloaded version of the `paint()` method in `MLBasicLabelUI` (Listing 4.14) should be no surprise. Additionally, the label is now initialized to `"MyApplication.HelloString"` which is a key into the possibly localized resource file `resources/MainClassName_XX_YY.properties`.

Listing 4.14: A locale-sensitive `JLabel` and the `paint()` method of `MLBasicLabelUI`.

```
// Create a locale-sensitive label which has a MLBasicLabelUI delegate.
JLabel label = new JLabel();
label.setText("MyApplication.HelloString");

// Taken from MLBasicLabelUI.java which inherits from BasicLabelUI.
public void paint(Graphics g, JComponent c)  {
  JLabel label = (JLabel)c;
  String text = MLUtils.getResourceString(label.getText());

  // Now do the real painting with text.
  ...
}
```

Notice that a string which will not be found in the resource file will be displayed "as is" in the label. So our example would work perfectly fine even with the usual component UI, it only would not respond to locale changes at run time.

If we want to make the GUI of a whole application locale-sensitive at runtime, we have to create new UI classes for each Swing component we use in our GUI. This sounds like a lot of work to do, but in fact we just have to redefine the methods which query text data from the component they are associated with.

One problem which we may encounter is the fact that in Swing actual Look and Feels like the Metal Look and Feel or the Windows Look and Feel use their own UI classes which are not directly derived from `ComponentUI` (see figure 4.10). Instead all the different UI classes for a single component inherit from a class called BasicXXXUI where XXX stands for an arbitrary component name. This is done to factor out all the functionality which is common to all the different Look and Feels into one base class.

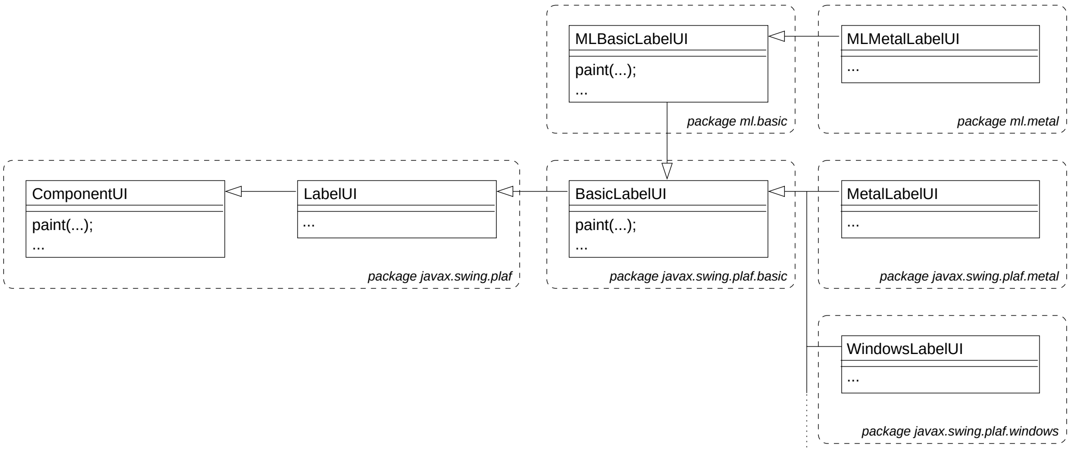


Figure 4.10: The class hierarchy of the component UI classes of Swing for JLabel. In this diagram, Label may be substituted by any other Swing component like Button, Tooltip and so on. The two classes in the upper part of the diagram from the package ml are the locale-sensitive UI classes developed in this paper.

This makes our job more difficult, because usually we would like to override the UI's of a distinct Look and Feel, but often the task of querying and painting the actual text is done only or at least in part in the BasicXXXUI base classes. Therefore we need to specialize two classes. First we have to specialize the BasicXXXUI class for our component and redefine the methods which query the text fields of our component. We will call this class MLBasicXXXUI. Then we have to copy and rename the actual component UI belonging to our desired Look and feel from MetalXXXUI to MLMetalXXXUI and change the base class from which it inherits from BasicXXXUI to MLBasicXXXUI which is the name of our overloaded version of BasicXXXUI. Again, Metal is just an example here. It could be just as well Windows, Motif or any other Look and Feel. Additionally, if necessary, we have to redefine the methods in MLMetalXXXUI which display text attributes from our associated component.

After having implemented all the needed UI delegates, we have to tell our application in some way to use the new delegates instead of the old, default ones. This can be done in two ways. The first one, which is perhaps more simple, is to just register our delegates with the component names at program startup as shown in Listing 4.15.

Listing 4.15: Associating Swing components with their UI delegates.

```
UIManager.put("ToolTipUI",     "ml.mllf.mlmetal.MLMetalToolTipUI");
UIManager.put("LabelUI",       "ml.mllf.mlmetal.MLMetalLabelUI");
UIManager.put("MenuUI",        "ml.mllf.mlbasic.MLBasicMenuUI");
UIManager.put("MenuItemUI",    "ml.mllf.mlbasic.MLBasicMenuItemUI");
UIManager.put("ButtonUI",      "ml.mllf.mlmetal.MLMetalButtonUI");
UIManager.put("RadioButtonUI", "ml.mllf.mlmetal.MLMetalRadioButtonUI");
UIManager.put("CheckBoxUI",    "ml.mllf.mlmetal.MLMetalCheckBoxUI");
UIManager.put("FileChooserUI", "ml.mllf.mlmetal.MLMetalFileChooserUI");
UIManager.put("ToolBarUI",     "ml.mllf.mlmetal.MLMetalToolBarUI");
```

The second, perhaps more elegant way is to define a new Look and Feel for which the new

UI delegates which have been created by us are the default ones. This approach is shown in Listing 4.16.

Listing 4.16: ml/mllf/mlmetal/MLMetalLookAndFeel.java [Line 22 to 44]

```
public class MLMetalLookAndFeel extends MetalLookAndFeel {

  public String getDescription() {
    return super.getDescription() + " (ML Version)";
  }

  protected void initClassDefaults(UIDefaults table) {
    super.initClassDefaults(table); // Install the metal delegates.

    Object[] classes = {
      "MenuUI",         "ml.mllf.mlbasic.MLBasicMenuUI",
      "MenuItemUI",     "ml.mllf.mlbasic.MLBasicMenuItemUI",
      "ToolTipUI",      "ml.mllf.mlmetal.MLMetalToolTipUI",
      "LabelUI",        "ml.mllf.mlmetal.MLMetalLabelUI",
      "ButtonUI",       "ml.mllf.mlmetal.MLMetalButtonUI",
      "RadioButtonUI", "ml.mllf.mlmetal.MLMetalRadioButtonUI",
      "CheckBoxUI",     "ml.mllf.mlmetal.MLMetalCheckBoxUI",
      "FileChooserUI", "ml.mllf.mlmetal.MLMetalFileChooserUI",
      "ToolBarUI",      "ml.mllf.mlmetal.MLMetalToolBarUI",
    };
    table.putDefaults(classes);
  }
}
```

Finally, after each locale switch we just have to trigger a repaint of the dynamically internationalized components. This can be achieved by a little helper function as presented in Listing 4.17 which takes a root window as argument and simply invalidates all the necessary child components.

Listing 4.17: ml/MLUtils.java [Line 106 to 112]

```
public static void repaintMLJComponents(Container root) {
  Vector validate = recursiveFindMLJComponents(root);
  for (Enumeration e = validate.elements(); e.hasMoreElements();) {
    JComponent jcomp = (JComponent)e.nextElement();
    jcomp.revalidate();
  }
}
```

It uses another method named `recursiveFindMLJComponents` which recursively finds all the child components of a given container. In the form presented in Listing 4.18, the method returns all components which are instances of `JComponent`, but a more sophisticated version could be implemented which returns only dynamically internationalized components.

Listing 4.18: ml/MLUtils.java [Line 154 to 173]

```
private static Vector recursiveFindMLJComponents(Container root) {
  // java.awt.Container.getComponents() doesn't return null!
```

Listing 4.18: ml/MLUtils.java [Line 154 to 173] (continued)

```
  Component[] tmp = root.getComponents();
  Vector v = new Vector();
  for (int i = 0; i < tmp.length; i++) {
    if (tmp[i] instanceof JComponent) {
      JComponent jcomp = (JComponent)tmp[i];
      if (jcomp.getComponentCount() == 0) {
        v.add(jcomp);
      }
      else {
        v.addAll(recursiveFindMLJComponents(jcomp));
      }
    }
    else if (tmp[i] instanceof Container) {
      v.addAll(recursiveFindMLJComponents((Container)tmp[i]));
    }
  }
  return v;
}
```

Notice that the version of `repaintMLJComponents` shown in Listing 4.17 only works for applications with a single root window. If an application consists of more than one root window or if it uses non-modal dialogs, they also have to be repainted. This can be done by defining a static method `registerForRepaint` (Listing 4.19) for registering the additional windows and dialogs and by extending `repaintMLJComponents` in a way to take into account these registered components.

Listing 4.19: ml/MLUtils.java [Line 142 to 146]

```
private static Vector repaintWindows = new Vector();

public static void registerForRepaint(Container dialog) {
  repaintWindows.add(dialog);
}
```

The new version of `repaintMLJComponents()` is shown in Listing 4.20:

Listing 4.20: ml/MLUtils.java [Line 116 to 138]

```
public static void repaintMLJComponents(Container root) {
  Vector validate = recursiveFindMLJComponents(root);
  Iterator it = repaintWindows.iterator();
  while (it.hasNext()) {
    Container cont = (Container)it.next();
    validate.addAll(recursiveFindMLJComponents(cont));
    // Also add the Dialog or top level window itself.
    validate.add(cont);
  }
  for (Enumeration e = validate.elements(); e.hasMoreElements(); ) {
    Object obj = e.nextElement();
    if (obj instanceof JComponent) {
      JComponent jcomp = (JComponent)obj;
```

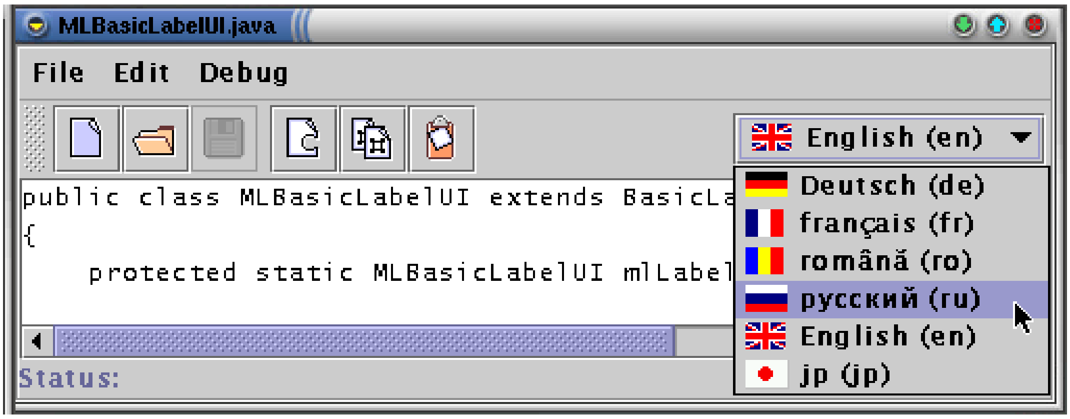
Listing 4.20: ml/MLUtils.java [Line 116 to 138] (continued)

```
      jcomp.revalidate();
    }
    else if (obj instanceof Window) {
      // This part is for the Dialogs and top level windows added with the
      // 'registerForRepaint()' method.
      Window cont = (Window)obj;
      cont.pack();
    }
  }
}
```

The Locale Chooser

After we discussed in detail the techniques necessary to make Swing components aware of locale switches at runtime there remains as last step the presentation of a widget which displays all the available locales to the user and allows him to choose from this list a new default locale.

Figure 4.11 and 4.12 show the new IntNotepad application with the builtin locale chooser. Additionally, the original Notepad was extended by a permanent status bar to demonstrate locale switches for labels. The first figure shows the application with the English default locale while the user is just switching it to Russian.

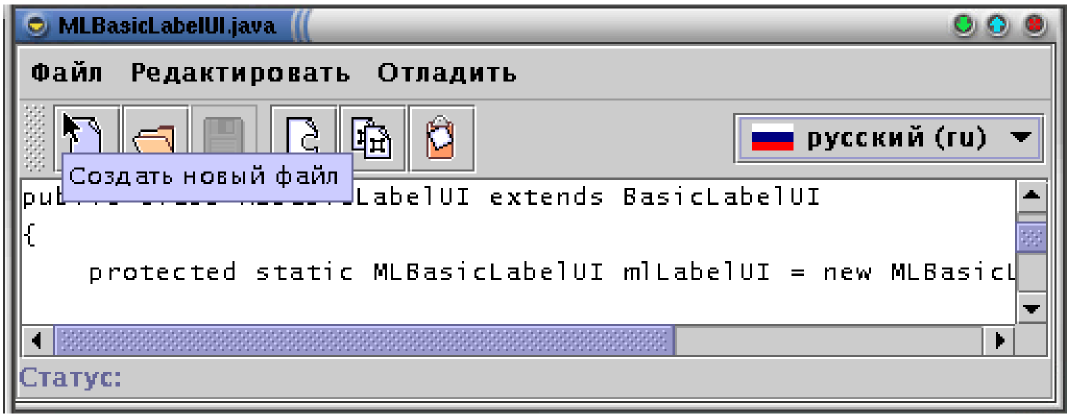


```
public class MLBasicLabelUI extends BasicLa
{
    protected static MLBasicLabelUI mlLabel
```

Figure 4.11: A screen shot of the IntNotepad application. The user just selects Russian as the default locale with the new locale chooser, which is located on the right side of the tool bar.

Figure 4.12 shows the application after the switch to Russian. Menus, labels, buttons and even tool tips are now displayed with Cyrillic letters in Russian language. Notice that the size of the menus has been resized automatically in order to hold the longer Russian menu names.

The class LocaleChooser is a small extension of a JComboBox with a custom renderer which displays each available Locale with a flag and the name of the corresponding language. The language name is displayed in its own language if available and in English otherwise. Please notice that there is no one to one mapping between languages and country flags, as many languages are spoken in more than one country and there are countries in which more then one language is spoken. Therefore one must be careful when choosing a flag as representation for a language to not hurt the feelings of people who speak that language in



```
pu                 LabelUI extends BasicLabelUI
{
    protected static MLBasicLabelUI mlLabelUI = new MLBasicL
```

Figure 4.12: This screen shot shows the `IntNotepad` application after the default locale has been switched to Russian. Labels, menus and even tool tips appear in Russian now.

a different country. After all, the flags should be just visual hints to simplify the selection of a particular language.

The `LocaleChooser` constructor expects as parameters a `String` which denotes the resource directory of the application and a `Container` which will be the root component passed to the `repaintMLJComponentes()` method presented in Listing 4.17 when it comes to a repaint of the application caused by a locale switch.

For every language or language/country combination the resource directory passed to the `LocaleChooser` constructor should contain a subdirectory named by the two letter language code or the two letter language code plus an underscore plus the two letter country code, respectively. Each of this subdirectories should contain a file `flag.gif` which will be the image icon displayed by the `LocaleChooser` for the corresponding language.

Thus, adding more locales to the list of locales displayed by `LocaleChooser` is merely a fact of adding the corresponding directories and files to the resource directory and does not require a recompilation of `LocaleChooser`. Remember however that for a locale switch to show any effects a resource file with the localized component strings has to be available as well.

Putting it all together

Finally, after the discussion of all the details involved in making Swing components aware of locale switches at runtime, we will summarize the important steps and show how they fit into the big picture of a real application.

First of all the new component UI delegates have to be created for all the components which should be dynamically internationalizable. These UI delegates should be packed together into a new Look and Feel which is derived from an already existing Look and Feel. This way we don't have to create UI delegates for the full set of Swing components at the very beginning, but we have the possibility to stepwise extend our new Look and Feel for new components. Creating the UI delegates has been extensively described in section 4.3.3.

Once our new Look and Feel is available, we can start to modify our application to make it locale-sensitive at run time. The first step is to set the system property `MainClassName` to the name of our application. This information will be needed by the `getResourceString()` method (see Listing 4.12) presented in section 4.3.3. Then we have to set our new Look and Feel as the standard Look and Feel for our application. These two steps can be achieved by the following two lines of code:

```
System.setProperty("MainClassName", "IntNotepad");
UIManager.setLookAndFeel(new MLMetalLookAndFeel());
```

As a third step, we have to install an instance of the `LocaleChooser` presented in section 4.3.3 somewhere in our application. Usually this will be the tool bar, but it can also be installed in a menu or in a special options window along with other configuration options. The `LocaleChooser` has to be instantiated with a reference to the main application window, in order for the repaint method shown in Listing 4.17 to work properly.

That's all. From now on, whenever we create a new Swing component, we have the choice of setting its string attributes to either a concrete string or just to a key value. If the string attribute is available in the applications resource file as a key, its value will be displayed instead, according to the current default locale. Otherwise, the string attribute itself will be displayed.

4.3.4 Conclusion

This paper presented a technique to make Swing components locale-sensitive at run time. It works by simply creating a new Look and Feel, without changing any code in the components themselves. As example the `IntNotepad` application was derived from the `Notepad` example application available in every JDK distribution. `IntNotepad` is aware of local changes and rebuilds the whole user interface every time such a change occurs at run time. Together with all the other source code presented in this paper it is available for download at [Sim02].

Notice that by using the techniques presented here, it would be possible to lift the entire Swing library and make it locale-sensitive for run time locale switches without any compatibility problems with older library versions.

Finally I want to thank Roland Weiss and Dieter Bühler for their assistance and for reviewing this paper.

4.4 Scrolling on demand - A scrollable toolbar component

Modern GUI programs offer the possibility to easily access status informations and functionalities by means of various menus, toolbars and information panels. However, as a program becomes more complex, or in the case where users have the possibility to configure and extend these components, they often tend to get overfilled. This leads to scrambled or even truncated components.

This section introduces a new container component called `ScrollableBar`, which can be used as a wrapper for any Swing component. As long as there is enough place to layout the contained component, `ScrollableBar` is completely transparent. As soon as the available space gets too small however, `ScrollableBar` will fade in two small arrow buttons on the left and the right side (or on the top and the bottom side if in vertical mode), which can be used to scroll the underlying component, thus avoiding the above mentioned problems.

`ScrollableBar` is a lightweight container derived from `JComponent` which uses the standard Swing classes `JViewport` and `JButton` to achieve its functionality. It fills a gap in the set of the standard Swing components and offers the possibility to create more robust and intuitive user interfaces. The content of this section has been published in [Sim04].

4.4.1 Introduction

Every professional applications comes with a fancy graphical user interface today and with Swing, the standard widget set of Java, it is quite easy to create such applications. However, the design and implementation of a robust and user friendly GUI is not a trivial task. One common problem is the fact that the programmer has no knowledge about the clients desktop size. This may vary today from the standard notebook and flat panel resolution of 1024x768 to 1900x1200 for high end displays. Even worse, Java applications can run on many other devices like for example mobile phones, which have an even more restricted resolution.

Another challenge arises from the extensibility of applications. While having the possibility to extend an application with various plugins may be a nice feature for the user, the fact that these plugins will populate the menus and toolbars in an unpredictable way imposes new problems on the programmer.

One possibility to solve these problems is to limit the size of the GUI components to a certain minimal size. However, this may impose unnecessary restrictions on the user. (Think for example of somebody who by default works with such an application, which needs at least a resolution of 1024x768 but who occasionally gives demo talks with a beamer which only supports an 800x600 resolution.) Furthermore, if an application with a graphical user interface pretends to be resizable by displaying a resizable frame, than the user expects he will be able to resize it based on his needs, not the programmer ones.

The second possibility is to do nothing and wait what happens. This is the way how most of the GUI applications are written today. Just compare the right picture from figure 4.13 with figure 4.15 and see how parts of the status- and toolbars are cut of if the window is shrinked beyond its optimal size. In the best case, the user could just reenlarge the application if this happens. In the worst case, if she is working on a device with a restricted resolution, it may be impossible to access the desired functionality. In any case such an application looks highly unprofessional!

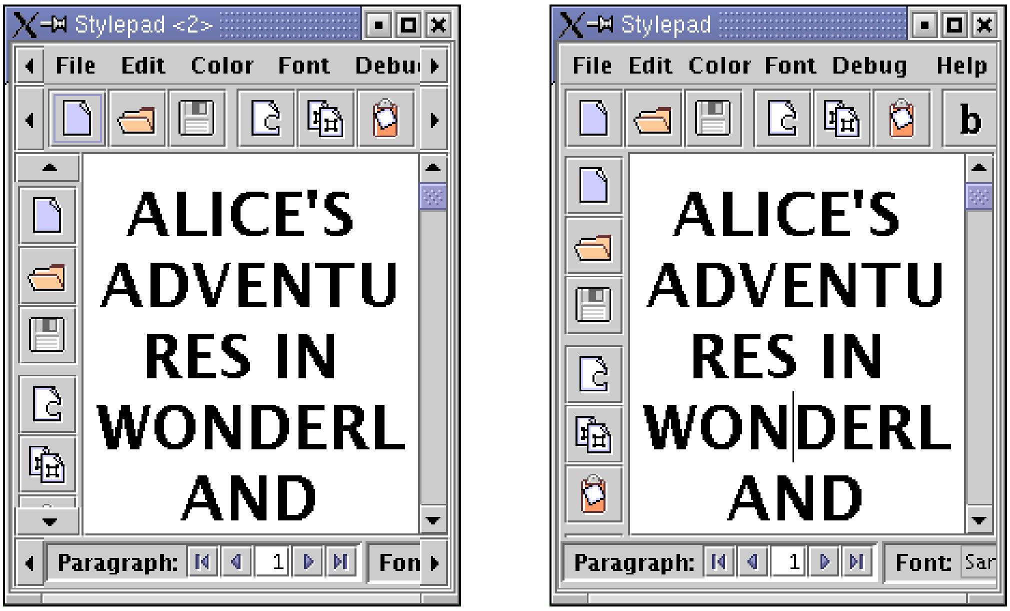

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Figure 4.13: The left picture shows the Stylepad application from figure 4.15 with scrollable menu, tool and status bars while the right picture shows the same application with truncated tool and status bars.

4.4.2 Scrollable menus and toolbars!

The solution for all the above mentioned problems would be scrollable menus and toolbars. However Swing, as many other widget sets, does not offer such kind of components. Using the standard `JScrollPane` component as a container for menus and toolbars is not an option here, because `JScrollPane` is too heavy weight. Its scrollbars are simply too big. But there is another Swing component which can serve us as a template: since version 1.4, the `JTabbedPane` class offers the possibility to scroll its panes instead of wrapping them on several lines if they do not fit on a single line. As can be seen in figure 4.14, arrow buttons for moving the tabs have been added at the upper right part (for more information see [Zuk]).

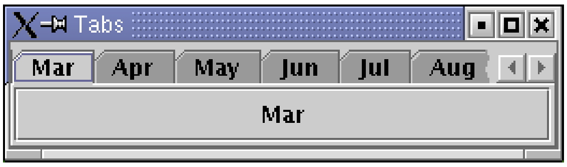
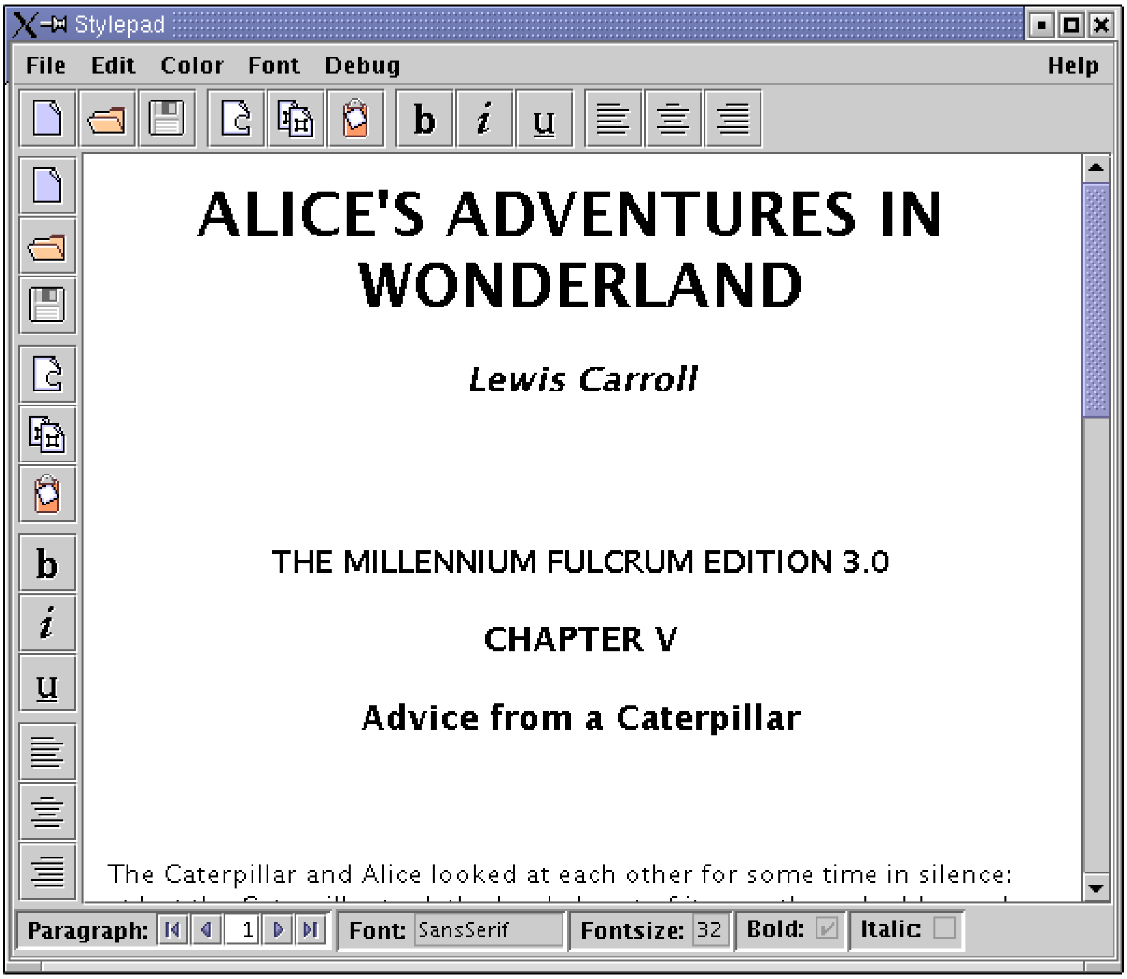


Figure 4.14: Example of a `JTabbedPane` with the tab layout policy set to `SCROLL_TAB_LAYOUT`.

We now want to achieve the same behavior for menus, toolbars and other status bars and information panels. To get a visual impression of how the modified components will look like compare the two pictures in figure 4.13. They both show a screen-shot of the Stylepad demo application shipping with every JDK which has been extended by a vertical toolbar and a useful status bar (see figure 4.15). While the menu, status bar and the toolbars are truncated and partially inaccessible in right picture, they can be scrolled and are fully functional in the left picture by using the arrow buttons which have been faded in.



ALICE'S ADVENTURES IN WONDERLAND

Lewis Carroll

THE MILLENNIUM FULCRUM EDITION 3.0

CHAPTER V

Advice from a Caterpillar

The Caterpillar and Alice looked at each other for some time in silence:

Paragraph: 1 Font: SansSerif Fontsize: 32 Bold: ☑ Italic: □

Figure 4.15: The Stylepad application at preferred size.

4.4.3 The implementation

We will now describe how to implement a class called `ScrollableBar`, which can serve as a container for a `java.awt.Container` object or any other object derived from it. Most of the time, `ScrollableBar` objects are completely transparent. Only if the place required by the wrapped component for layout becomes too small, the `ScrollableBar` object will fade in two arrow buttons at the left and right side of the component (or on the top and the bottom side if in vertical mode) which can be used to scroll the wrapped component. As soon as there will be again enough place for the layout of the enclosed component, these arrow buttons will disappear immediately.

The Swing architecture

For a better understanding of the `ScrollableBar` implementation, it is helpful to revisit the architecture of Swing which has been explained already in section 4.3.2. The Swing library is a modern widget set based on the Model-View-Controller (MVC) pattern [GHJV]. But while the classical MVC pattern consists of three independent parts, namely the model, the view and the controller, Swing uses a simplified version of this pattern where the view and the controller part are combined in a so called Delegate [ZuStan, ELW] (see figure 4.9).

One of the main responsibilities of the UI delegate is to paint the component it is tied to. In contrast to the AWT library, in Swing it is not the `paint()` method of every component which does the work of painting itself. Instead, the component's `paint()` method just calls the `paint()` method of its delegate with a reference to itself.

The `ScrollableBar` class

Figure 4.16 shows the class diagram of the `ScrollableBar` class. As already mentioned, it is derived from `JComponent`. It also implements the `SwingConstants` interface in order to easily access the constants `HORIZONTAL` and `VERTICAL` which are defined there.

`ScrollableBar` has 4 properties. The two boolean properties `horizontal` and `small` store the orientation of the component and the size of the arrows on the scroll buttons. The integer property `inc` stores the amount of pixels by which the enclosed component will be scrolled if one of the arrow buttons is being pressed. Smaller values lead to a smoother but slower scrolling. Finally, the wrapped component is stored in the `comp` property. While `horizontal` is a read-only property which can only be set in the constructor, the other three properties are read/write bound properties in the sense described in the Java Beans specification [JaBean].

The following listing shows the two-argument constructor of the `ScrollableBar` class:

Listing 4.21: ScrollableBar.java [Line 30 to 41]

```java
public ScrollableBar(Component comp, int orientation) {
  this.comp = comp;
  if (orientation == HORIZONTAL) {
    horizontal = true;
  }
  else {
    horizontal = false;
  }
  small = true; // Arrow size on scroll button.
  inc = 4;      // Scroll width in pixels.
  updateUI();
}
```

Notice the call to `updateUI()` in the last line of the constructor. As can be seen in listing 4.22, `updateUI()` calls the static method `getUI()` from the class `UIManager` to query the right UI delegate and associates it with the current `ScrollableBar` object.

Listing 4.22: ScrollableBar.java [Line 45 to 52]

```java
public String getUIClassID() {
  return "ScrollableBarUI";
}

public void updateUI() {
  setUI(UIManager.getUI(this));
  invalidate();
}
```

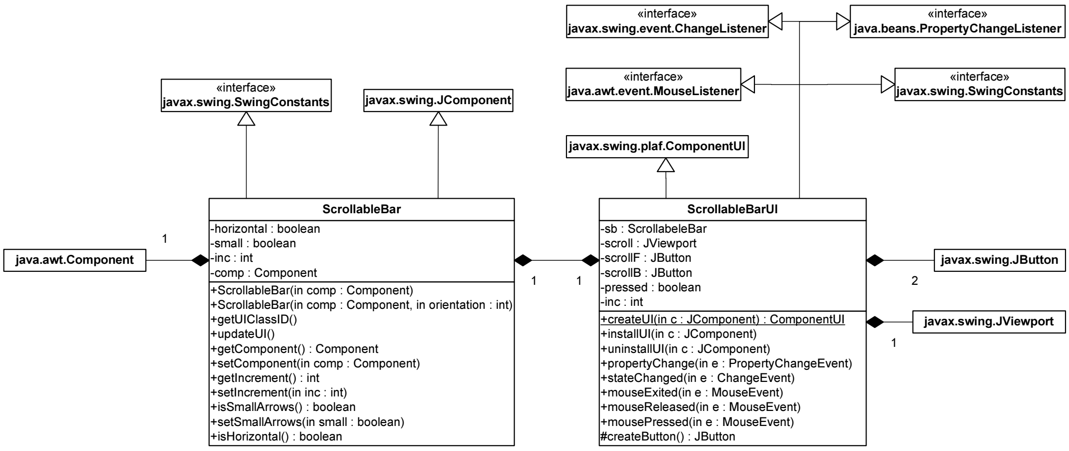

«interface»
javax.swing.event.ChangeListener
«interface»
java.beans.PropertyChangeListener
«interface»
java.awt.event.MouseListener
«interface»
javax.swing.SwingConstants
«interface»
javax.swing.SwingConstants
javax.swing.JComponent
javax.swing.plaf.ComponentUI
ScrollableBar
-horizontal : boolean
-small : boolean
-inc : int
-comp : Component
+ScrollableBar(in comp : Component)
+ScrollableBar(in comp : Component, in orientation : int)
+getUIClassID()
+updateUI()
+getComponent() : Component
+setComponent(in comp : Component)
+getIncrement() : int
+setIncrement(in inc : int)
+isSmallArrows() : boolean
+setSmallArrows(in small : boolean)
+isHorizontal() : boolean
ScrollableBarUI
-sb : ScrollabeleBar
-scroll : JViewport
-scrollF : JButton
-scrollB : JButton
-pressed : boolean
-inc : int
+createUI(in c : JComponent) : ComponentUI
+installUI(in c : JComponent)
+uninstallUI(in c : JComponent)
+propertyChange(in e : PropertyChangeEvent)
+stateChanged(in e : ChangeEvent)
+mouseExited(in e : MouseEvent)
+mouseReleased(in e : MouseEvent)
+mousePressed(in e : MouseEvent)
#createButton() : JButton
java.awt.Component
1
1
1
javax.swing.JButton
2
javax.swing.JViewport
1

Figure 4.16: The UML class diagram of `ScrollableBar` and `ScrollableBarUI`.

`UIManager.getUI()` calls `getUIClassID()` (see listing 4.22) to get the key which is used to query the actual UI delegate from a Look and Feel dependent internal table. Usually, the association of the standard Swing components to the appropriate UI classes is done by the different Look and Feels while they are initialized. However, as we are writing a new component, we have to establish this link manually, as shown in the following listing:

Listing 4.23: ScrollableBar.java [Line 19 to 22]

```
static {
  UIManager.put("ScrollableBarUI",
                "com.languageExplorer.widgets.ScrollableBarUI");
}
```

Notice that linking a component to its UI delegate in this way results in one and the same UI class being used independently of the actual Look and Feel.

Besides the getter and setter methods for the corresponding properties, there is no more functionality in the `ScrollableBar` class. All the painting and user interaction is handled by the UI delegate `ScrollableBarUI`.

The `ScrollableBarUI` class

One of the most important methods of the UI classes is `installUI()` which is called every time when a component is being associated with its UI delegate. This gives the UI delegate a chance to properly initialize itself and the component it is responsible for.

Listing 4.24: ScrollableBarUI.java [Line 51 to 106]

```
public void installUI(JComponent c) {

  sb = (ScrollableBar)c;

  inc = sb.getIncrement();
  boolean small = sb.isSmallArrows();

  // Create the Buttons
```

Listing 4.24: ScrollableBarUI.java [Line 51 to 106] (continued)

```
  int sbSize = ((Integer)(UIManager.get( "ScrollBar.width" ))).intValue();
  scrollB = createButton(sb.isHorizontal()?WEST:NORTH, sbSize, small);
  scrollB.setVisible(false);
  scrollB.addMouseListener(this);

  scrollF = createButton(sb.isHorizontal()?EAST:SOUTH, sbSize, small);
  scrollF.setVisible(false);
  scrollF.addMouseListener(this);

  int axis = sb.isHorizontal()?BoxLayout.X_AXIS:BoxLayout.Y_AXIS;
  sb.setLayout(new BoxLayout(sb, axis));

  scroll = new JViewport() {
    ... see source code ...
   };

  Component box = sb.getComponent();
  scroll.setView(box);

  sb.add(scrollB);
  sb.add(scroll);
  sb.add(scrollF);

  // Install the change listeners
  scroll.addChangeListener(this);
  sb.addPropertyChangeListener(this);
}
```

In our case, the UI delegate queries and stores the components properties along with a reference to the component itself as private instance variables. Further on, it creates two arrow buttons and an object of type `JViewport` which is used to wrap the scrollable component. Based on the orientation of the associated `ScrollableBar` object, the newly created elements are then being added to it by using a vertical or horizontal box layout. Notice that the scroll buttons are initially set to be invisible. Finally, the UI object registers itself as property change listener on the associated component, as a change listener on the viewport and as a mouse listener on the arrow buttons.

The UI delegate gets informed about every size change of the `ScrollableBar` object and the wrapped component, by a receiving a `ChangeEvent` from the viewport object. Depending on the new sizes, it can change the visibility state of the arrow buttons and relayout the component. Property changes in the `ScrollableBar` object are signaled to the UI delegate by a `PropertyChangeEvent`. Based on these events, it can update the internally cached values of these properties.

Finally, the events resulting from the user interactions on the scroll buttons are handled by the different mouse listener methods. The UI delegate keeps a private boolean instance variable `pressed` which is set to true if a button was pressed and which is reset to false as soon as the button is released or the mouse pointer leaves the button. As can be seen in listing 4.25, pressing one of the buttons also starts a new thread which scrolls the underlying component by `inc` pixels in the corresponding direction and than sleeps for a short amount of time. These two actions are subsequently repeated in the thread as long as the value of the instance variable `pressed` is true, while the amount of sleeping time is reduced in every iteration step. This results in a continuously accelerating scrolling speed, as longer the user keeps on pressing the arrow button.

Listing 4.25: ScrollableBarUI.java [Line 174 to 238]

```
public void mousePressed(MouseEvent e) {
  pressed = true;
  final Object o = e.getSource();
  Thread scroller = new Thread(new Runnable() {
    public void run() {
      int accl = 500;
      while (pressed) {
        Point p = scroll.getViewPosition();
        ... Compute new view position ...
        scroll.setViewPosition(p);
        try {
          Thread.sleep(accl);
          if (accl <= 10) accl = 10;
          else accl /= 2;
        } catch (InterruptedException ie) {}
      }
    }
  });
  scroller.start();
}
```

It should be noticed that we need no special paint method for the `ScrollableBarUI` class, because painting occurs naturally from the standard Swing button and viewport components which we used.

After we have discussed the main parts of the implementation, it should be evident why the advantages of dividing the functionality of the `ScrollableBar` class into two classes outweigh the coding overhead. First of all we cleanly separated the properties of the component from the way how it is displayed and how it interacts with the user. Secondly, it is very easy now to define a new UI delegate which renders the component in a different way or to just derive a new UI delegate from the existing one which slightly adopts appearance or user interaction properties to a specific look and feel.

4.4.4 Using the `ScrollableBar` class

Using the `ScrollableBar` class is very easy and straight forward. In fact we can wrap every arbitrary Swing component inside a `ScrollableBar` object by passing it as argument to the constructor when creating the object. For the example application shown on the left side of figure 4.13 it was only necessary to change a single line:

```
JToolBar toolbar = new JToolBar();
...
panel.add("North", toolbar);
```

from the original Stylepad application into:

```
JToolBar toolbar = new JToolBar();
...
panel.add("North", new ScrollableBar(toolbar));
```

in order to make the horizontal toolbar scrollable if the space becomes too small to render it as a whole.

In general, the `ScrollableBar` class is more recommended for wide and not very high components in horizontal mode and narrow and high components in vertical mode. If used for other components the scroll buttons would get too big and take up too much space to be really useful.

Menu bars in `JFrame` objects

As shown in the last section it is very easy to use the `ScrollableBar` class in your own applications. Even upgrading existing applications is not very hard. The only problem which may arise is in the case where a `ScrollableBar` should be used as a wrapper for a menu bar which will be added directly to a `JFrame` object. (Notice that in our example application, the menu bar has been added to a `JPanel` object before the whole panel has been added to the `JFrame` object.)

The problem arises because `JFrame` provides a specialized `setJMenuBar()` method for adding menu bars and this method expects an argument of Type `JMenuBar`. At a first glance, we could just use one of the generic `add()` methods defined in `JFrame`'s ancestor classes instead. However, if we take a closer look, we will see that the problem is a little bit more complex.

First of all, in the case of `JFrame`, children are not being added to the component directly, but to the so called "root pane", which is a special child component of every `JFrame`. However, we also can not add the menu bar directly to the root pane, because the root pane itself also has a special method called `setJMenuBar()` which expects a `JMenuBar` object as argument. Using this method for adding menu bars is essential, because only if it is used the `RootLayout` layout manager used by the `JRootPane` class will honor the presence of the menu bar. `RootLayout`, which is a protected inner class of `JRootPane`, uses the protected `JRootPane` property `menuBar` which has been set by `JRootPane.setJMenuBar()` for layout calculations.

To cut a long story short, we have to create a new `SMJFrame` class (which stands for Scrollable Menu JFrame) which overrides the `createRootPane()` method to return a new, customized root pane class. For this purpose we just derive an anonymous class from `JRootPane` which overrides the two methods `setJMenuBar()` and `createRootLayout()`.

`setJMenuBar()`, the first one of this two methods wraps the menu bar into our `ScrollableBar` class, before storing it as a protected instance variable and adding it to the layered pane which is a part of the root pane.

The second method `createRootLayout()` returns an anonymous class which inherits from the `JRootPane` protected inner class `RootLayout`. It overrides the layout methods in that class in such a way, that they use the `ScrollableBar` instance variable for layout calculations instead of using the bare menu bar, as it was done by the original version of the methods.

These modifications finally give the desired result. A call to `setJMenuBar()` on a `SMJFrame` object will be forwarded to the customized root pane. There, the menu bar will be wrapped into a `ScrollabelBar` object before it will be actually added to the frame. Because the customized root pane uses a customized layout manager, it will handle the scrollable menu bar in the same way in which a `JFrame` object handles an ordinary menu bar. With respect to all other concerns, `SMJFrame` behaves exactly like its ancestor `JFrame`.

Limitations

The only limitation for the use of the `ScrollableBar` class so far is that it can not handle floating tool bars. This is because `JToolBar` objects have to be laid out into a container whose layout manager is of type `BorderLayout` if they want to be floatable. Additionally, no other children can be added to any of the other four ”sides”. This is obviously not the case, if the toolbar is wrapped inside a ScrollableBar object.

Fixing this problem would require extensive changes in BasicToolBarUI, the UI delegate of JToolBar. Unfortunately, because not all the methods which need to be customized are declared public or protected, in fact a complete rewrite of the delegate would be necessary.

4.4.5 Conclusion

This section presented a quite small and simple, yet very powerful container class which fills a gap in the set of standard Swing components. Using it involves no overhead, neither at development time nor at run time but yields a lot of benefits. The most important ones are: better usability and user friendliness and more robust and intuitive GUI applications.

Chapter 5

LanguageExplorer

5.1 Introduction

LanguageExplorer is a new program for reading texts in electronic form. However, in contrast to other, similar book readers, LanguageExplorer is specialized in displaying several versions of a text in parallel. This may be for example an original text along with its translation or several different translations of a certain text. Therefore LanguageExplorer may be characterized as an electronic synopsis[1] which offers comfortable navigation capabilities. Additionally, given a certain text position in one text, it allows to access the corresponding locations in the parallel versions of the text.

Furthermore LanguageExplorer serves as platform for the integration of arbitrary tools for text reception and analysis. Currently these are dictionaries, powerful search and indexing capabilities and tools for statistical text analysis. New features like bookmarks, user annotations and text apparatuses are currently implemented.

Another highlight of LanguageExplorer is its ability to cope with texts in virtually any language. Besides the common Western and Eastern European languages he supports languages like Greek and Russian, but also languages written from right to left like Hebrew and languages written with ideographic scripts like Chinese and Japanese. In fact even facsimile reproductions and sound can be handeled by LanguageExplorer, thus allowing uniform access to texts available in any arbitrary form.

LanguageExplorer stores its texts in a modern XML-based file format (see section 2.4 on page 22). Optionally he supports strong encryption of the content he displays, thus effectively preventing illegal duplication of protected materials.

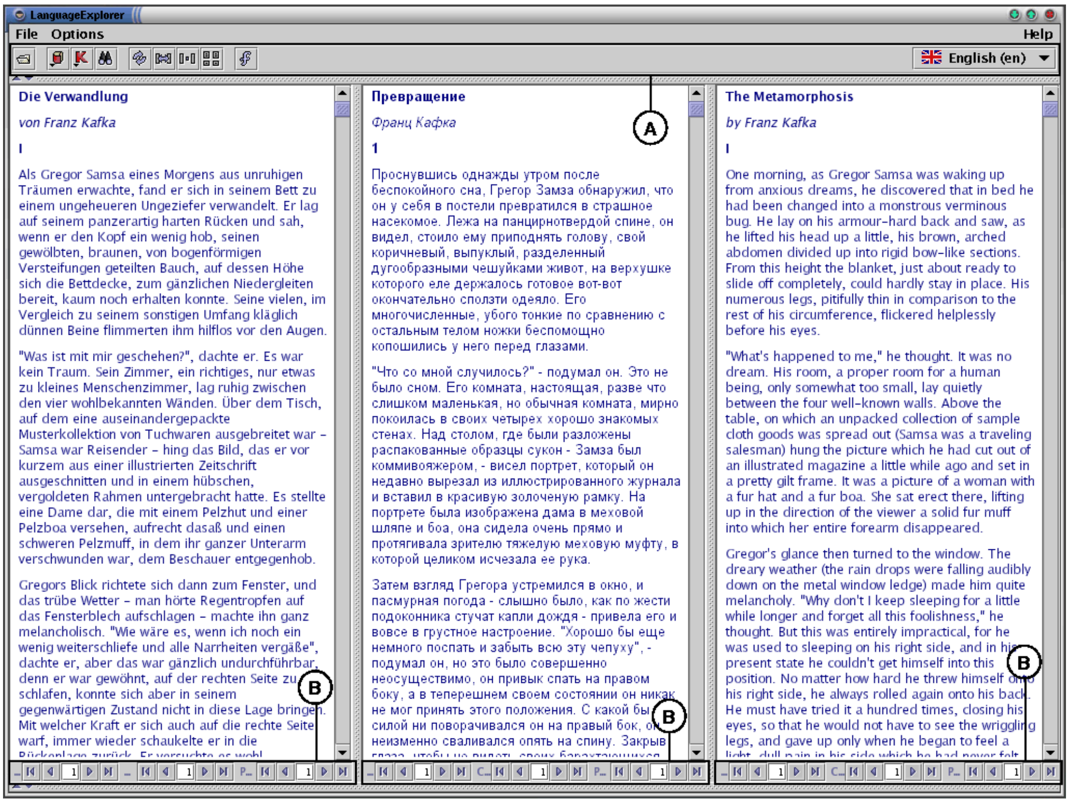
LanguageExplorer has been designed and implemented using cutting edge software technology. It offers a high degree of functionality and user-friendliness. System independence was one of the main goals during development, so today LanguageExplorer is available for the Linux, Windows and Mac OS X operating systems.

Together with LanguageExplorer, which is intended for reading and analysing texts, a second system called LanguageAnalyzer has been developed. LanguageAnalyzer allows the user to create sophisticated, linked editions suitable as input for LanguageExplorer out of simple text based sources. More information about LanguageAnalyzer is available in chapter 6. While LanguageExplorer may be seen as the viewer part of the project LanguageAnalyzer is in fact the editor part which allows the composition of editions for LanguageExplorer.

[1] synopsis: from Greek, "literally, comprehensive view, to be going to see together". A comparative juxtaposition of similar text version. Traditionally used for the juxtaposition of the four gospels.

5.2 Overview

In this section the basic functionality of LanguageExplorer will be demonstrated based on some screen-shots. Figure 5.1 shows LanguageExplorer after loading a book. The main part of the program are the text areas which display the different versions of the text: in this example, the original German version of the novel "Die Verwandlung" by Franz Kafka together with an English and a Russian translation.



Die Verwandlung

von Franz Kafka

I

Als Gregor Samsa eines Morgens aus unruhigen Träumen erwachte, fand er sich in seinem Bett zu einem ungeheueren Ungeziefer verwandelt. Er lag auf seinem panzerartig harten Rücken und sah, wenn er den Kopf ein wenig hob, seinen gewölbten, braunen, von bogenförmigen Versteifungen geteilten Bauch, auf dessen Höhe sich die Bettdecke, zum gänzlichen Niedergleiten bereit, kaum noch erhalten konnte. Seine vielen, im Vergleich zu seinem sonstigen Umfang kläglich dünnen Beine flimmerten ihm hilflos vor den Augen.

"Was ist mit mir geschehen?", dachte er. Es war kein Traum. Sein Zimmer, ein richtiges, nur etwas zu kleines Menschenzimmer, lag ruhig zwischen den vier wohlbekannten Wänden. Über dem Tisch, auf dem eine auseinandergepackte Musterkollektion von Tuchwaren ausgebreitet war – Samsa war Reisender – hing das Bild, das er vor kurzem aus einer illustrierten Zeitschrift ausgeschnitten und in einem hübschen, vergoldeten Rahmen untergebracht hatte. Es stellte eine Dame dar, die mit einem Pelzhut und einer Pelzboa versehen, aufrecht dasaß und einen schweren Pelzmuff, in dem ihr ganzer Unterarm verschwunden war, dem Beschauer entgegenhob.

Gregors Blick richtete sich dann zum Fenster, und das trübe Wetter – man hörte Regentropfen auf das Fensterblech aufschlagen – machte ihn ganz melancholisch. "Wie wäre es, wenn ich noch ein wenig weiterschliefe und alle Narrheiten vergäße", dachte er, aber das war gänzlich undurchführbar, denn er war gewöhnt, auf der rechten Seite zu schlafen, konnte sich aber in seinem gegenwärtigen Zustand nicht in diese Lage bringen. Mit welcher Kraft er sich auch auf die rechte Seite warf, immer wieder schaukelte er in die

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"Что со мной случилось?" - подумал он. Это не было сном. Его комната, настоящая, разве что слишком маленькая, но обычная комната, мирно покоилась в своих четырех хорошо знакомых стенах. Над столом, где были разложены распакованные образцы сукон - Замза был коммивояжером, - висел портрет, который он недавно вырезал из иллюстрированного журнала и вставил в красивую золоченую рамку. На портрете была изображена дама в меховой шляпе и боа, она сидела очень прямо и протягивала зрителю тяжелую меховую муфту, в которой целиком исчезала ее рука.

Затем взгляд Грегора устремился в окно, и пасмурная погода - слышно было, как по жести подоконника стучат капли дождя - привела его и вовсе в грустное настроение. "Хорошо бы еще немного поспать и забыть всю эту чепуху", - подумал он, но это было совершенно неосуществимо, он привык спать на правом боку, а в теперешнем своем состоянии он никак не мог принять этого положения. С какой бы силой ни поворачивался он на правый бок, он неизменно сваливался опять на спину. Закрыв

The Metamorphosis

by Franz Kafka

I

One morning, as Gregor Samsa was waking up from anxious dreams, he discovered that in bed he had been changed into a monstrous verminous bug. He lay on his armour-hard back and saw, as he lifted his head up a little, his brown, arched abdomen divided up into rigid bow-like sections. From this height the blanket, just about ready to slide off completely, could hardly stay in place. His numerous legs, pitifully thin in comparison to the rest of his circumference, flickered helplessly before his eyes.

"What's happened to me," he thought. It was no dream. His room, a proper room for a human being, only somewhat too small, lay quietly between the four well-known walls. Above the table, on which an unpacked collection of sample cloth goods was spread out (Samsa was a traveling salesman) hung the picture which he had cut out of an illustrated magazine a little while ago and set in a pretty gilt frame. It was a picture of a woman with a fur hat and a fur boa. She sat erect there, lifting up in the direction of the viewer a solid fur muff into which her entire forearm disappeared.

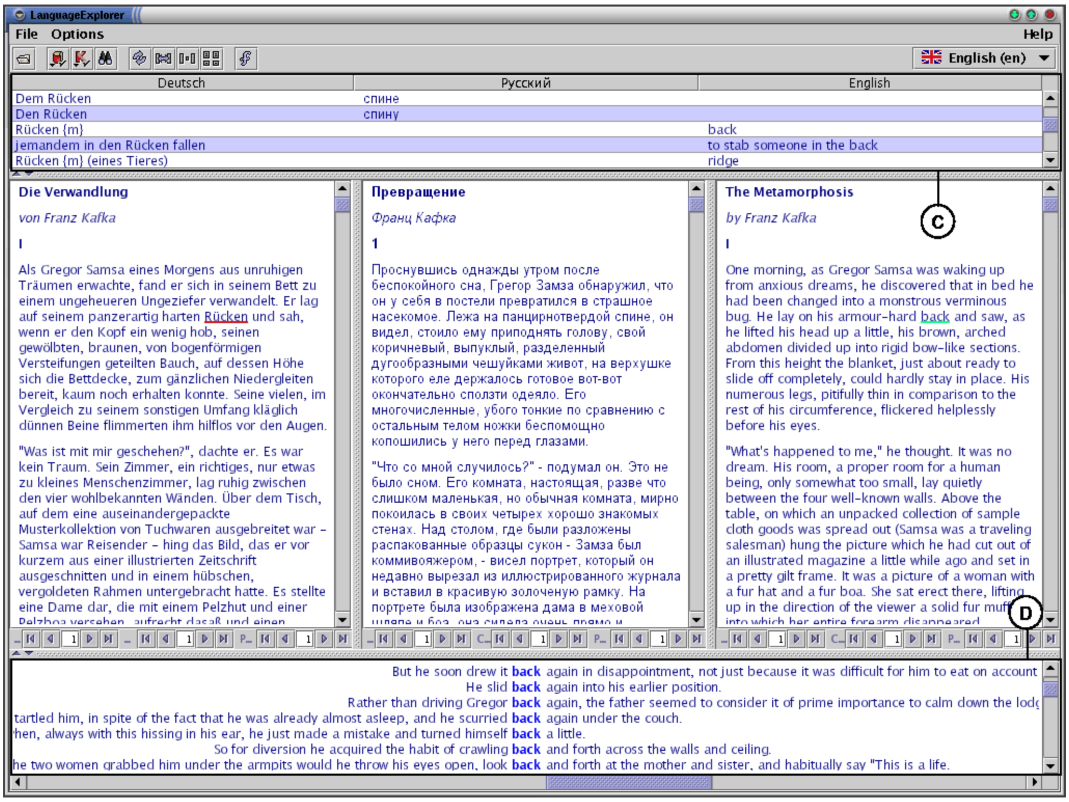
Gregor's glance then turned to the window. The dreary weather (the rain drops were falling audibly down on the metal window ledge) made him quite melancholy. "Why don't I keep sleeping for a little while longer and forget all this foolishness," he thought. But this was entirely impractical, for he was used to sleeping on his right side, and in his present state he couldn't get himself into this position. No matter how hard he threw himself onto his right side, he always rolled again onto his back. He must have tried it a hundred times, closing his eyes, so that he would not have to see the wriggling legs, and gave up only when he began to feel a

Figure 5.1: LanguageExplorer after loading a book. By clicking the left mouse button on a sentence in the left text area this sentence as well as the corresponding sentences in the other text areas are highlighted.

But LanguageExplorer consists of more than the menu and the text areas. In the region marked with A in figure 5.1, LanguageExplorer has a tool bar. It can be used to execute most of the commands offered by LanguageExplorer in a fast and comfortable way. Additionally, every text area has its own navigation bar (marked with B in figure 5.1) with the aid of which the books may be navigated section- and chapter-wise. While navigating, all the other text areas may be synchronized reciprocally with the actual one. More information about navigation can be found in section 5.4.2 on page 122.

Figure 5.2 shows LanguageExplorer with opened dictionary (region C) and KWIC-Index[2] window (region D). The size of both of these windows may be adjusted by the user according to his preferences and they may be opened or closed individually. If a dictionary query is triggered or if a KWIC-Index is generated by the user, the corresponding window will open automatically to the size previously adjusted by the user.

[2] KWIC-Index is an abbreviation for "KeyWord In Context"-Index. It denotes an index which not only contains every occurrence of the key word, but also a certain amount of the text before and after the key word. KWIC-Index generation is described in-depth in chapter 5.4.3 on page 126.



Deutsch	Русский	English
Dem Rücken	спине	
Den Rücken	спину	
Rücken {m}		back
jemandem in den Rücken fallen		to stab someone in the back
Rücken {m} (eines Tieres)		ridge

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```
                                                    But he soon drew it back again in disappointment, not just because it was difficult for him to eat on account
                                                              He slid back again into his earlier position.
                                             Rather than driving Gregor back again, the father seemed to consider it of prime importance to calm down the lodg
tartled him, in spite of the fact that he was already almost asleep, and he scurried back again under the couch.
hen, always with this hissing in his ear, he just made a mistake and turned himself back a little.
                                  So for diversion he acquired the habit of crawling back and forth across the walls and ceiling.
he two women grabbed him under the armpits would he throw his eyes open, look back and forth at the mother and sister, and habitually say "This is a life.
```

Figure 5.2: LanguageExplorer with opened dictionary and KWIC-Index window. The KWIC-Index visible in the region marked with D in the figure was produced by simultaneously pressing the `Shift` key and the left mouse button on the word "back". The dictionary (visible in the part C of the window) was opened by simultaneously pressing the `Ctrl` key along with the left mouse button on the same word.

After the basic functionality of LanguageExplorer has been demonstrated in this section, the next sections will present and explain every single feature in more detail.

5.3 Installation

This chapter covers the installation of LanguageExplorer. Because there are graphical installers available for all the platforms supported by LanguageExplorer the installation is usually a matter of a few minutes. Therefor the next sections will mainly focus on the peculiarities of the different platforms.

5.3.1 Installation under Windows

Insert the LanguageExplorer CD-ROM into the CD-ROM drive and Choose `Run...` from the `Start`-Menu. Type the command `D:\windows\setup.exe` into the appearing text field. Notice that it may be necessary to replace `D:\` with the real name of your CD-ROM drive. Thereafter follow the instructions given by the installation program. By default LanguageExplorer will be installed into the folder `C:\Program Files\LanguageExplorer` however the target folder may be changed by the user. Please be aware that under Windows NT, Windows 2000 or

Windows XP Professional you may need Administrator privileges in order to install LanguageExplorer into the default `C:\Program Files` folder.

After successful installation there will be a new LanguageExplorer menu entry in the `Programs` sub menu of the `Start`-Menu. Under this new menu the entry `LanguageExplorer` can be used to start LanguageExplorer and the entry `Uninstall` to remove LanguageExplorer from the system.

5.3.2 Installation under Linux

Insert the LanguageExplorer CD-ROM into the CD-ROM drive and mount it. The following instructions assume that your CD-ROM drive is available under `/mnt/cdrom`. Start the program `/mnt/cdrom/linux/setup.bin` and follow the instructions given by the installation program. Depending on which target directory you choose for installation you may be required to have `root`-privileges.

After the installation completed successfully LanguageExplorer can be started with the command `/opt/LanguageExplorer/LanguageExplorer` where `/opt/LanguageExplorer` may have to be replaced with the actual installation path chosen during installation. With the `Uninstall` program, which is located in the same directory, LanguageExplorer can be removed from the system.

Changing the hotkey for the input method activation

As described in chapter 29 on page 137 LanguageExplorer supports input methods for the input of characters not available on the keyboard. Such an input method may be selected from the input method menu which can be activated by pressing a certain hotkey combination. By default this is the `F4` key. However, this hotkey may be changed by setting the environment variables `INPUTMETHOD_SELECTKEY` and `INPUTMETHOD_SELECTKEY_MODIFIERS`. By appending the line `export INPUTMETHOD_SELECTKEY=VK_F8` to the end of the `.bashrc` configuration file, the hotkey can be changed to `F8`. The file `.bashrc` is located in the users home directory. The environment variable `INPUTMETHOD_SELECTKEY` can be set to the values `VK_F1` to `VK_F12` and `VK_A` to `VK_Z` corresponding to the keys available on the keyboard.

Additionally, the second environment variable `INPUTMETHOD_SELECTKEY_MODIFIERS` may be set to the value of a modifier key, which has to be pressed together with the key defined before, in order to activate the input method selection menu. The actual values for the three modifier keys can be `SHIFT_MASK`, `CTRL_MASK` or `ALT_MASK`. Setting this variable can also be omitted, in which case pressing the hotkey defined before will be enough to activate the input method selection menu.

5.3.3 Installation under Mac OS X

Insert the LanguageExplorerCD-ROM into the CD-ROM drive. In the folder `macosx` of CD-ROM click on the archive `setup.sit`. This will expand the installer program and create the application `setup` in the folder you chose. By executing `setup` the actual installation process will be started.

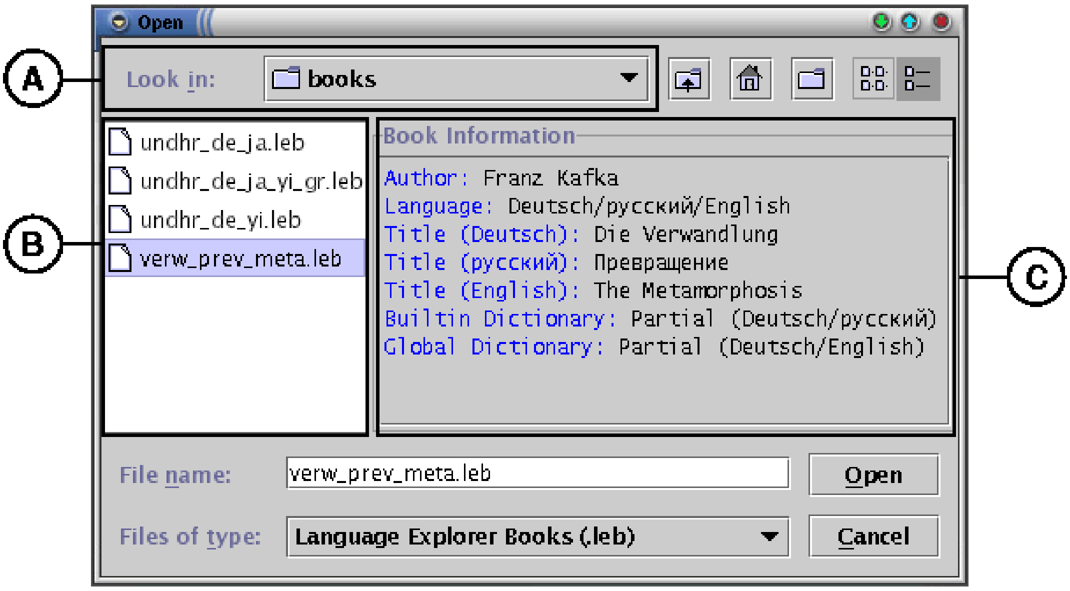
By default LanguageExplorer will be installed into the application folder which may require administrator privileges. However an arbitrary installation folder can be selected during the installation process. After completing the installation, LanguageExplorer can be started by clicking the LanguageExplorer icon on the desktop.

5.4 Handling

This chapter will give a brief description of every single function available in LanguageExplorer. Functions are grouped together into section based on their subject, where every sections starts with the description of the most important functions for a given area. Subsections contain the description of special auxiliary functions.

5.4.1 Loading books

After starting LanguageExplorer, the first thing to do, before any meaningful work will be possible, is opening a book. This can be achieved by choosing `Open Book` from the `File` menu or by clicking the `Open Book` button (see left margin) on the tool bar.



undhr_de_ja.leb
undhr_de_ja_yi_gr.leb
undhr_de_yi.leb
verw_prev_meta.leb

Book Information

Author: Franz Kafka
Language: Deutsch/русский/English
Title (Deutsch): Die Verwandlung
Title (русский): Превращение
Title (English): The Metamorphosis
Builtin Dictionary: Partial (Deutsch/русский)
Global Dictionary: Partial (Deutsch/English)

File name: verw_prev_meta.leb

Files of type: Language Explorer Books (.leb)

Figure 5.3: The open book dialog. After the file `verw_prev_meta.leb` has been chosen in the region marked with B, the accessory component visible in region C displays the bibliographic data of the selected book.

Like every menu entry available in LanguageExplorer, the `Open Book` menu entry may be reached by using a keyboard shortcut. For the `Open Book` menu entry this so called accelerator is the combination of pressing the `Control` key together with the `O` key on the keyboard. It will bring up the open book dialog shown in figure 5.3.

The open book dialog is a default file dialog extended by a custom accessory component tailored specially for LanguageExplorer (see region C in figure 5.3). While region A of the dialog shows the actual folder, region B displays all the available files in that folder. If a file is chosen which is in LanguageExplorer book format, the accessory component displays the bibliographic data of the corresponding book. It consists of the author's name, the languages of the different book versions, and the titles of each version in the corresponding language.

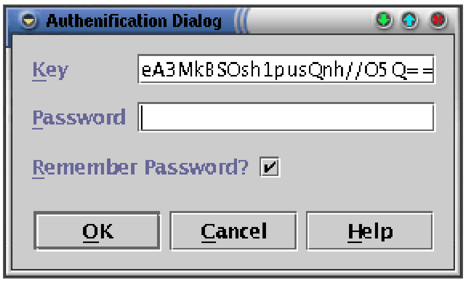
One additional information displayed in the accessory is the availability of dictionaries for the selected book. LanguageExplorer supports two kinds of dictionaries: global ones and builtin dictionaries. While global dictionaries are available to all books, builtin dictionaries are packed together with the books into the LanguageExplorer book files. They can be used only by the corresponding book and they usually contain only the words occurring in that book. If both dictionaries are present for a certain book, LanguageExplorer uses a two step algorithm when looking up a word in the dictionary where the builtin dictionary will always be favored against to the global one. More information on the dictionary function may be found in section 5.4.4 on page 128.

Finally, a book file may be opened by double clicking on the corresponding book file or by pressing the Open button for an already selected book file.

If the text areas contain some strange character glyph or don't display any characters at all after the loading of a new book, this indicates that the actual font is not capable of displaying that text. It may be necessary to select a new font by using the LanguageExplorer font selection dialog which is described in section 5.4.8 on page 132.

Encrypted books

As already mentioned in chapter 5.1, LanguageExplorer also supports encrypted books. They have the same file suffix like usual, unencrypted book (namely `.leb`) and they are displayed in the same fashion like usual books in the open file dialog. However when opened for the first time, a so called authentication dialog as shown in figure 5.4 is presented to the user.



Authenification Dialog

Key eA3MkBSOsh1pusQnh//O5Q==

Password

Remember Password? ☑

Figure 5.4: The authentication dialog with a key entered by the user.

It prompts the user for a key and a password for the selected book. This key/password combination is usually user and book dependent and was created by the publisher of the book for every user who bought that book. If you didn't receive your personal key and password combination for an encrypted book when buying it, please contact your dealer or the publisher of the book.

If the "Remember Password" check box is selected when entering the password, LanguageExplorer will store an encrypted version of the password in the personal preference file of the actual user in order to avoid the password dialog the next time the same book will be loaded again. Because the key for every encrypted book is stored by LanguageExplorer automatically, it has to be entered only when loading an encrypted book for the very first time.

5.4.2 Navigation

After loading a book as described in the previous chapter, LanguageExplorer looks as shown in figure 5.1 on page 118. By dragging the drag bar which is located between the different text areas, the size available to each of them can be customized. This makes sense if one text area contains a more condensed version of a text than the other ones for example. By adjusting their width, the text areas can be usually customized in such a way to hold approximately the same amount of information per window.

Pressing the left mouse button on an arbitrary sentence in one of the text areas will highlight that sentence and all the corresponding sentences in the other text areas as well. It must be noticed that in the other text areas more then one sentence may correspond to the sentence selected first. Under certain circumstances it may also be possible that there is no corresponding sentence in a particular text version in one of the other text windows. Pressing the right mouse button in one of the text areas will remove the highlighting in each of them again.

The cursor keys (see left margin) as well as the `PageUp` and `PageDown` keys can be used to navigate the text inside the text areas. While the cursor keys scroll the text line by line the `PageUp` and `PageDown` keys (see left margin) may be used to scroll the text page wise, where a page always corresponds to the currently visible text in the corresponding text area. Page wise scrolling is done in such a way that there will be always at least one line of overlap between the page which was displayed last and the new one.

The actions just described can be initiated with the mouse as well. For it, the mouse has to be pressed on the scrollbar (see left margin) located on the right side of every text area. In doing so, clicking the small arrows of the scroll bar corresponds to the line by line scrolling done with the cursor keys while just clicking inside the scrollbar area is equivalent to the page wise scrolling done with the `PageUp` and `PageDown` keys. By dragging the scrollbar with the mouse to a fixed position, it is possible to directly navigate to the text position which corresponds to the relative location of the scroll bar. Independently of the navigation method used, the scrollbar position always signals the relative position of the displayed page in relation to the whole text.

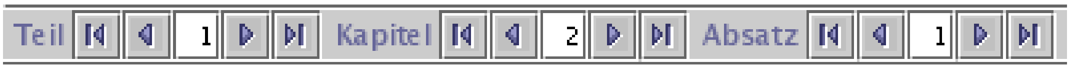


Figure 5.5: A picture of the navigation bar. The text area belonging to this navigation bar just displays the first section in the second chapter in the first part of its book.

As a last possibility the navigation bar (see figure 5.5) located at the bottom of every text area (see region B in figure 5.1) may be used for a structural navigation of the text. By clicking the corresponding arrow buttons with the mouse, the text may be navigated section, chapter or part wise back and forward. It is also possible to jump to a certain of these structures by entering its number into the appropriate text field.

Additionally it is possible to jump to the very first and the very last element of the before mentioned structures (e.g. the first or the last section of a chapter) with the help of the `Begin` and the `End` buttons (see left margin). Similarly to the scrollbars, the navigation bars are always synchronized with their corresponding text area. They always show the element which is displayed in the upper left corner of the text area, no matter which means of navigation is used.

Synchronizing the text areas

One of the main features of LanguageExplorer is its ability to show different versions of a text in parallel where always the corresponding part of each version is visible. Usually the synchronization is done automatically. Even if navigating in one of the text areas as described in the previous section, the other text areas are always updated to show the corresponding parts.

However sometimes this synchronization may be not necessary or even hindering. For example when searching in one of the text areas (see section 5.4.5 on page 128) it may be helpful to temporarily disable the synchronization. And indeed this is possible in LanguageExplorer. Every text area may be individually synchronized or unsynchronized with the other ones.

Synchronization for two text areas By clicking the left synchronization button on the tool bar (region A in figure 5.1 on page 118) the left text window will be unsynchronized from the right one. This means that the right window will not follow any navigation in the left window. Notice that the synchronization buttons are so called toggle buttons. Clicking the left button once again will reconnect the left text area to the right one such that all movements done in the first one will be followed by the second one respectively. The state of the button is indicated by the small check mark in the lower right side of the button. If the check mark is present, the corresponding window is connected to its sibling window. If the check mark is absent as shown in the right icon on the left margin, then the navigation in the corresponding text area is independent of the second one.

The hot key `Ctrl-L` or the menu entry `Options`→`SyncLeft` may be used instead of the synchronization button located on the tool bar to configure the synchronization behavior of the left text area.

The right window may be synchronized with the left one in the same manner like the left window with the right one. The user may choose between the right synchronization button from the tool bar (see left margin), the menu entry `Options`→`SyncRight` and the hot key `Ctrl-R`.

Synchronization for several text areas The synchronization buttons on the tool bar automatically switch their appearance in the way shown on the left margin if a book with more then two version of a text is loaded. Because now it is not possible anymore to represent the synchronization status of every single window by its own button, a different approach was taken. The left synchronization button has the duty to synchronize a single window with all the other windows, while the right button may decouple a window from the other ones.

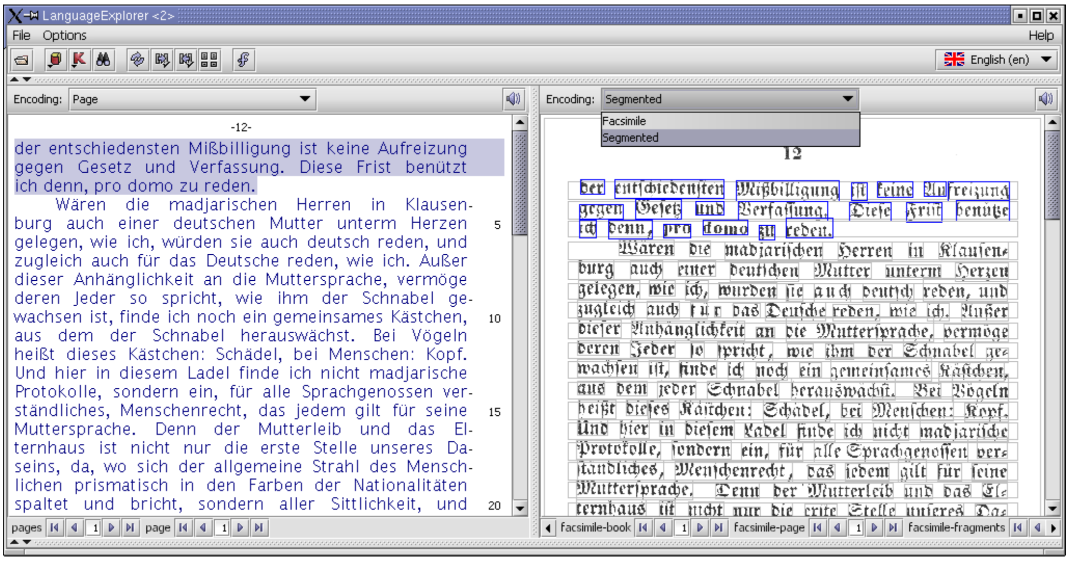
Clicking on the left synchronization button changes the cursor to the shape shown on the left margin. After the cursor has changed, it is possible to synchronize an arbitrary text area with all th other ones by simply clicking with the mouse into that text area. After clicking, the mouse cursor changes back to its default shape. If the mouse will be clicked outside of a text area, it will also resume to its default shape and no action will be taken at all. Notice that after a book has been loaded all the text areas are synchronized by default.

Clicking on the left synchronization button changes the cursor to the shape shown on the left margin. Subsequent clicking with this mouse cursor into a text area decouples the movements in that window from all the other windows. As with the left synchronization button, clicking into any other part of the application than a text area leads to no action at all. After the first click, the mouse cursor changes back to its initial shape.

For books with several text versions the same hot keys and menu entries for text synchronization are available like for two version books. The menu entry `Options`→`Synchronize Window` and the hot key `Ctrl-L` have the same effect like pressing the left synchronization button whereas the functionality of the right synchronization button is also covered by the menu entry `Options`→`Unsynchronize Window` and the hot key `Ctrl-R`.

Interchanging the text areas

Right after a book has been loaded into LanguageExplorer the different versions of the book are displayed from left to right in the text areas in the same order in which they are stored in the book file. This is also the order in which the dictionaries appear in the dictionary view (region C in figure 5.2 on page 119) of LanguageExplorer. The order of the different text versions may be changed however by the user while the order of the dictionaries will be automatically updated to always reflect the text area order.



-12-

der entschiedensten Mißbilligung ist keine Aufreizung gegen Gesetz und Verfassung. Diese Frist benützt ich denn, pro domo zu reden.

Wären die madjarischen Herren in Klausenburg auch einer deutschen Mutter unterm Herzen gelegen, wie ich, würden sie auch deutsch reden, und zugleich auch für das Deutsche reden, wie ich. Außer dieser Anhänglichkeit an die Muttersprache, vermöge deren Jeder so spricht, wie ihm der Schnabel gewachsen ist, finde ich noch ein gemeinsames Kästchen, aus dem der Schnabel herauswächst. Bei Vögeln heißt dieses Kästchen: Schädel, bei Menschen: Kopf. Und hier in diesem Ladel finde ich nicht madjarische Protokolle, sondern ein, für alle Sprachgenossen verständliches, Menschenrecht, das jedem gilt für seine Muttersprache. Denn der Mutterleib und das Elternhaus ist nicht nur die erste Stelle unseres Daseins, da, wo sich der allgemeine Strahl des Menschlichen prismatisch in den Farben der Nationalitäten spaltet und bricht, sondern aller Sittlichkeit, und

Figure 5.6: A picture of LanguageExplorer displaying a document marked up with multiple encodings. The encoding chooser from the toolbar in the upper part of the text areas can be used the select the active encoding.

Interchanging with two text areas If a book consists only of two version, interchanging theirs text areas can be done simply by clicking the swap button on the tool bar (see left margin). Alternatively the menu entry `Options`→`Swap Windows` or the hot key `Ctrl-S` may be used.

Interchanging with several text areas If a book contains more than two different version of a text, pressing the swap button on the tool bar does not automatically interchanges two text areas but instead changes the mouse cursor to the shape shown on the left margin. Now interchanging two arbitrary text areas is simply a matter of subsequently clicking with the mouse into the two windows. Notice that after successfully clicking into the first window the mouse cursor will slightly change again into the form shown on the left margin.

Clicking with this changed mouse cursor on any other region than a text area will abort the interchanging operation and reset the mouse cursor to its original form. The menu entry `Options`→`Swap Windows` as well as the hot key `Ctrl-S` may be also used to start the interchanging operation for several text areas.

Aligning the text areas

Usually text layout is done in every text area, independently of the other text areas. However LanguageExplorer offers the possibility to align the text in all text areas section wise. This will give all corresponding sections in all text areas the same vertical extent. It may be useful for example to get a quick overview of parallel text versions. Especially for synopses where there are no analogous parts for some structures of a given text in the parallel versions, it may help to identify the gaps faster.

The default setting after starting LanguageExplorer is normal, not aligned text layout. By pressing the align text button on the tool bar, this may be changed by the user at any time. The align text button is a toggle button. Its state is displayed by a small check mark in its lower right corner. If this check mark is present, the sections of the different text versions are aligned, otherwise they are laid out normally.

The align text action may also be reached from the menu entry `Options→Align View` and by pressing the hotkey combination `Ctrl-A`.

Choosing the text encoding

Starting with version 2.0, LanguageExplorer can handle documents which are marked up by different encodings. If a document comes with different encodings, the corresponding text area will have an additional toolbar with an encoding chooser element as shown in figure 5.6. The user has the possibility to select an active encoding by using this encoding chooser. The layout and the part of the content visible in the text window may change depending on the currently active encoding. Notice that the navigation bar at the bottom of every text window which can be used to easily navigate within the document always adopts to and shows the structures of the active encoding.

5.4.3 The KWIC-Index

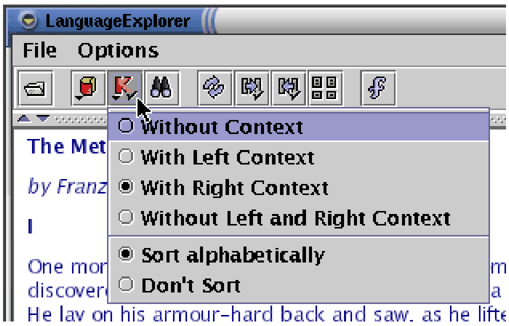
One of the most helpful features provided by LanguageExplorer is its ability to create arbitrary KWIC-Indices on the fly. As explained in chapter 5.1, KWIC-Index is an abbreviation for "KeyWord In Context"-Index. It denotes an index which not only contains every occurrence of the given key word, but also a certain amount of text before and after that key word. Usually the index is sorted alphabetically based on the suffix of the key word. The advantage of such an index is the ability to see at once the different context in which the key word appears in the text.

With LanguageExplorer the KWIC-Index for a word can be created by holding down the `Shift` key and pressing the left mouse button on the desired word in the text. Thereafter the KWIC-Index window as shown in part D of figure 5.2 on page 119 will open and display the generated index. For systems which already define the mentioned key combination, an alternative way for generating KWIC-Indices is available. Simultaneously pressing the `Alt` and the `K` key on the keyboard will augment the mouse cursor with a small `K` in its lower right corner (see left margin). Clicking a word with this mouse cursor will now generate a KWIC-Index of the corresponding word as well. After the KWIC-Index has been generated or after the mouse cursor leaves the original text window, the cursor will be restored to its default shape.

The generation of a KWIC-Index automatically opens the KWIC-Index window. However this window may be closed and reopened at any time by using the KWIC-Index button on the tool bar. The content of the KWIC-Index window will be conserved until a new index for another word will be created. Similarly to the Synchronization buttons described in chapter 5.4.2 on page 123 the KWIC-Index button has a small check mark on its lower right corner which indicates whether the KWIC-Index window is opened or closed. Opening and closing this window may also be performed with the hot key `Ctrl-K` or by executing the `Options→KWIC` menu entry.

Another characteristic of the KWIC-Index button compared with the other buttons of the tool bar described until now is the small arrow on the lower left side of the button. It indicates that a context menu is reachable from this button by pressing (not clicking) it for a while. As shown in figure 5.7 the context menu pops down right under the button and allows further customization of the KWIC-Index creation process.

In the upper part of the context menu the user may choose how the KWIC-Index will be created out of the key word selected by the user. The default is to use just the plain word as keyword. It is however possible to create a KWIC index not only for the simple word which has been selected, but for all the words which begin, end or contain the selected word. This can be achieved by selecting the options "With Right Context", "With Left Context", and "With Left and Right Context" respectively. For example a KWIC-Index for the word "**in**"



○ Without Context
○ With Left Context
● With Right Context
○ Without Left and Right Context

● Sort alphabetically
○ Don't Sort

The Met
by Franz
I
One mor … m
discover … a
He lav on his armour-hard back and saw, as he lifte

Figure 5.7: Opening the KWIC-Index context menu.

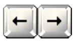
with the option “Without Context” would contain just the word “**in**”. Together with the option “With Right Context” it could also contain the word “**in**side”, with the option “With Left Context” it could additionally contain the word “with**in**” and finally if the option “With Left and Right Context” had been chosen, all the words which contain “**in**”, like for example “runn**in**g” or “w**in**dow” would appear in the index.

In the lower part of the context menu it is possible to choose how the entries of the index will be sorted. Alphabetic sorting means that the entries of the index will be sorted alphabetically with respect to the trailing context of the key word. It must be taken into account that key word suffixes which can occur with the option “With Right Context” are counted as trailing context when sorting. So for example a sorted KWIC-Index with right context for the word “**in**” would contain the sentence “**in**adequate clothing...” sorted before the sentence “**in** both cases...”.

In LanguageExplorer KWIC-Indices can also be created from the Find-Dialog. It offers more sophisticated possibilities like for example ignoring the case of a words or creating KWIC-Indices for arbitrary patterns described by regular expressions. More information on this can be found in section 5.4.5 on page 128 the Find-Dialog is described.

Once the KWIC-Index has been generated, it contains a single line for every occurrence of the key word. In this line, the keyword will be highlighted and centered so all the key words will be displayed one beneath the other. Notice that highlighting will be done only for the original key word and not for possible suffixes or prefixes of the keyword which may be present because of the various context options.

Navigation in the KWIC-Index window is the same like in the usual text windows (see section 5.4.2 on page122) with the only difference that clicking with the left mouse button on a sentence in the KWIC-Index window will highlight that sentence in the text window out of which the KWIC-Index has been created. Additionally, the corresponding sentences in all the other windows will be highlighted as well and all the sentences will be made visible in theirs windows. All this happens independently of the synchronization settings for the different windows.



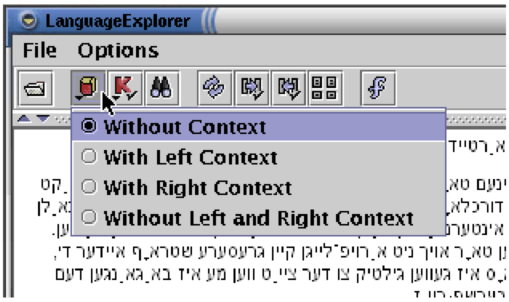
In addition to the usual means of navigation, the KWIC-Index window supports the left and right cursor keys to move the whole content of the window to the left or to the right. The size of the KWIC-Index window is customizable in the same way like the size of the different text areas: by dragging the corresponding drag bar (see left margin) with the mouse to the desired position. Clicking the small arrows on the left side of the drag bar is another possibility of opening and closing the whole window.

5.4.4 The dictionary

As already mentioned in the introduction, one feature of LanguageExplorer is its ability to integrate and use different dictionaries. It is possible to use general dictionaries which will be available to all the books in the corresponding languages or special dictionaries which are integrated into the books and usually contain only the vocabulary used in them. If dictionaries exist for a book at all, and if they are global or builtin may be determined at load time by using the accessory component of the File-Dialog (see figure 5.3 on page 121).

If at least one dictionary is present, it is possible to query it for a certain word by simply clicking with the left mouse button on that word while simultaneously pressing the `Ctrl` key. As with the KWIC-Index generation there is a second way to query the dictionary. Pressing the `Alt-D` key combination will change the cursor by adding a small `D` to its lower right corner as shown in the picture on the left margin. Now querying the dictionary is a simple matter of clicking the desired word with this mouse cursor.

If at least one entry will be found in the dictionary for the selected word, the dictionary window in the upper part of LanguageExplorer will open automatically and display the matching results. By using the dictionary button from the tool bar it is possible to open and close the dictionary window as desired. The buttons functionality, which conforms to that of the the KWIC button described in the last section, may also be reached from the menu entry `Options`→`Dictionary` or by using the keyboard shortcut `Ctrl-D`.



● Without Context
○ With Left Context
○ With Right Context
○ Without Left and Right Context

Figure 5.8: Opening the dictionary context menu.

The size of the dictionary window may be adjusted in the same way like the size of the KWIC-Index window: by moving around the corresponding drag bar. The arrows on the left side of the drag bar can be used as an alternative for opening and closing the window. The only difference during navigation in the dictionary window compared to the other LanguageExplorer windows is the fact that clicking with the mouse has no effect in this window.

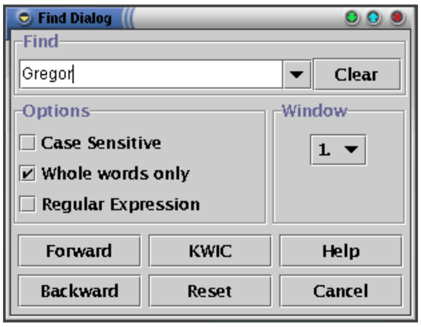
Pressing the dictionary button for a while will open a context menu which allows some customization of the dictionary look up process. As can be seen from figure 5.8 it not only resembles the KWIC-Index context menu, it also has the same options concerning the context of the word to query. The only difference compared with the KWIC-Index generation is the fact that dictionary look up is always case insensitive.

5.4.5 Searching

The find dialog (see figure 5.9) is currently the most complex dialog supported by LanguageExplorer. It can be used to search the text of the loaded book for arbitrary strings or regular expressions[3]. Instead of scanning for individual occurrences of the search item it is

[3] Regular expressions are search patterns which may contain control characters with a special meaning during searching. More information about regular expressions can be found in section 5.4.6 on page 130.

also possible to generate a KWIC-Index (see section 5.4.3 on page 126) which contains all the appearances of that item.


Find Dialog

Find: Gregor

Options:
☐ Case Sensitive
☑ Whole words only
☐ Regular Expression

Window: 1

Figure 5.9: The Find-Dialog.

The Find part of the find dialog contains a text field for entering the desired word or expression to search for and two buttons. The arrow button may be used to open a pull down menu with the history of the last few search terms while the clear button can be used to clear the text field. A search item will be entered into the history list of the pull down menu only after it was searched at least one time.

▼ Clear

In the Options part of the dialog it is possible to choose how to search for the search item. The "Case Sensitive" check box selects whether the search will be case sensitive, the "Whole words only" check box selects whether the search will only find the search item as a single word and finally the "Regular Expression" check box selects whether the search item should be interpreted as a regular expression.

Finally the window which will be searched for the search term entered by the user may be specified in the Window part of the dialog by simply selecting it from the corresponding pull down menu.

After all the search options have been specified, the search process may be started with the buttons located in the lower part of the dialog. It is possible to search forward in the corresponding text area as well as backward. The search process always starts in the upper left corner of the visible part of the text area for the forward search and in the lower right corner of the visible part of the text window for the backward search. Thereafter searching continues relative to the last occurrence of the search item.

Forward Backward

However several peculiarities have to be taken into account. The find dialog is a so called "non-modal dialog" with the consequence that it is possible to navigate in any of the LanguageExplorer windows while the dialog is displayed, create a KWIC-Index or even look up a word in the dictionary. If no sentence has been marked in the corresponding search window before the search is resumed, the search will continue as described above. If however a sentence had been selected in between, forward searching will continue at the beginning and backward searching at the end of the last selected sentence respectively.

The Reset button can be used to reposition the visible part of the actual text area to the position valid before the find dialog was called or before the target window in the find dialog was changed for the last time. The Cancel button quits the find dialog, however without repositioning the current view position.

Reset Cancel

Finally, the KWIC button can be used to create a KWIC-Index of the search item. Because the search item can be interpreted as a regular expression, the KWIC-Indices generated this way can be much more complex than the ones created in section 5.4.3. If the KWIC-Index is generated for a regular expression, the whole text string that matches the expression will be taken as key word. And because of the properties of regular expression, these key words may well be different text strings for the same regular expression. Sorting is done based

KWIC

on the suffix which follows the text string that was matched by the regular expression and based on the settings made in the KWIC-Index context menu (see section 5.4.3 on page 127). Notice that it is possible to generate a KWIC-Index which is case insensitive with respect to the key word by simply unselecting the “Case Sensitive” check box.

5.4.6 Regular expressions

Regular expressions are search patterns which can contain special control characters. These special characters are called meta characters. They must be quoted with a preceding \ character to treat them as usual characters. There are a lot of different idioms for regular expression which usually differ in the kind of the meta characters and the extensions they add to the classical regular expressions. LanguageExplorer uses a syntax similar to the one known from Perl regular expressions [PeReEx] with some extensions for Unicode processing [UnReEx]. Following, inside the quotes, all the meta characters available in the LanguageExplorer flavor of regular expressions: “`()[]{}\^$.|?*+`”.

The following table lists the most important meta characters and explains their semantics. Finally, the section will be ended by some examples. More informations about regular expressions can be found for example in J. Friedels book “Regular Expressions” [Friedl].

Pattern	**Matches the following text:**
Single letters and characters	
`x`	the character “`x`”. “`x`” may be any character except a meta character.
`\x`	the special character “`x`” where “`x`” has to be a meta character (e.g. “`\.`” for the dot sign “`.`”).
`\u`*hhhh*	the Unicode letter with the hexadecimal value *hhhh* (e.g. “`\u0416`” for the Russian letter “Ж”).
Character classes	
`[abc]`	one of the characters “`a`”, “`b`” or “`c`”. A simple character classes.
`[^abc]`	any character except “`a`”, “`b`” or “`c`”. A negated character classes.
`[a-z]`	all the characters between “`a`” and “`z`”. A simple character range.
`[a-m[v-z]]`	all the characters between “`a`” and “`m`” or between “`v`” and “`z`”. The union of two character classes.
`[a-o&&[l-z]]`	all the characters between “`l`” and “`o`”. The intersection of two character classes.
`[a-z&&[^l-o]]`	all the characters between “`a`” and “`k`” and between “`p`” and “`z`”. The subtraction of two character classes.
Predefined character classes	
`.`	any single character.
`\p{In`*Block*`}`	a character in the Unicode block “*Block*”. “*Block*” can be for example “Greek”, “Cyrillic” or “Arabic”[4].
`\P{In`*Block*`}`	any character except the ones defined to be in the Unicode block with the name “*Block*”.
`\p{Is`*Cat*`}`	any character with the Unicode category “*Cat*”. For example `\p{Is`*Lu*`}` for uppercase letters[5].
`\P{Is`*Class*`}`	any characters except the ones with the Unicode category “*Cat*”.
Logical operators and quantifiers	
`XY`	the regular expression `X` followed by the regular expression `Y`. The simple concatenation.

...to be continued on the next page ➥

[4] Block may be any Unicode block name with the white space characters removed from the name. Table A.1 in appendix A lists all the valid Unicode block names

[5] The Unicode character categories are listed in table A.2 in appendix A.

Pattern	Matches the following text:
`X|Y`	the regular expression `X` or the regular expression `Y`. The simple alternation. The regular expression `he|she` for example matches "he" as well as "she".
`(X)`	the regular expression `X`. The parenthesis are used to delimit a capturing group (see next operator). They also override normal operator precedence. While the expression `r(unn)|(ead)er` for example will match all the words containing either "runn" oder "eader" the pattern `r(unn|ead)er` will only match the words "runner" and "reader".
\n	the text corresponding to the *n*-th capturing group. Every text that matches the part of a regular expression enclosed by parenthesis is called a capturing group. Capturing groups are stored during pattern matching from left to right and numbered from 1 to 9. The expression `\1` for example matches exactly the same text that was previously matched by the first capturing group.
`X?`	the regular expression `X` once or not at all. The expression `s(ing)?` for example would match "s" and "sing" but not "singing".
`X*`	the regular expression `X` zero or more times. The expression `s(ing)*` for example would match "s", "sing" and "singing".
`X+`	the regular expression `X` one or more times. The expression `s(ing)+` for example would match "sing" and "singing" but not "s".
X{*n*}	the regular expression `X` exactly *n* times. The expression `s(ing){2}` for example would match only "singing" but not "s" or "sing".
X{*n*,}	the regular expression `X` at least *n* times. The expression `s(ing){1}` for example would match "sing" and "singing" but not "s".
X{*n*,*m*}	the regular expression `X` at least *n* times but not more than *m* times.

Even if regular expressions seem to be quite complicated to understand at first glance, it may be nevertheless useful to learn how to use them. As a motivation, the following paragraphs contain some interesting examples.

The regular expression`[\p{InCyrillic}&&[\p{IsLl}]]` matches all the Cyrillic lower case characters. It is the intersection of the set of the Cyrillic characters with the set of the lower case characters.

The regular expression[6] `(␣\p{IsL}+)(␣\p{IsL}+){2,3}\1␣` matches every repetition of an arbitrary word which is separated by at least two but no more than three other words (e.g "..*to* pay attention *to*.." or "...*he* felt as if *he*..."). In the example the first parenthesized part `(␣\p{IsL}+)` matches a space character followed by at least one letter. This corresponds to a word. Notice that because of the fact that the expression is parenthesized, it will be stored as the first capturing group. The second part of the original regular expression `(␣\p{IsL}+){2,3}` therefore matches at least two but not more than three single words. Finally the last part `\1␣` matches the first capturing group, that is the first word which has been matched, followed by a last space character.

5.4.7 Audio output

Starting with version 2.0, LanguageExplorer supports the audio output of the document content. Two different forms of audio output is supported. Some LanguageExplorer books may be bundled and linked with audio files which contain a spoken version of the whole book. If this is not the case, there is still a chance that the language of the book is supported by the speech synthesizer built into LanguageExplorer. While the quality of this synthesizer

[6] In this example the ␣-character will be used instead of the usual space character in order to increase the readability.

is not comparable with that of a professional speaker, it nevertheless gives the reader an idea how a sentence will sound in the corresponding language.

If either of the two conditions just described are true, the speaker button in the local toolbar of every text window (see figure 5.6) will be active. Pressing this active speaker button will read the currently selected text.

5.4.8 Configuration

This chapter will discuss the various configuration properties offered by LanguageExplorer which don't apply to special functions but to the program and its user interface as a whole. For convenience, most of these configuration options will be stored persistently between subsequent execution of the program, so they will have to be adjusted only once.

Look and Feel

LanguageExplorer offers the possibility of changing the Look and Feel of an application at run time. Different Look and Feels are provided and every Look and Feel may be used with different color themes. The Look and Feel, as well as the current color scheme can be changed by invoking the `Look and Feel` sub menu of the `Options` menu as shown in figure 5.10.

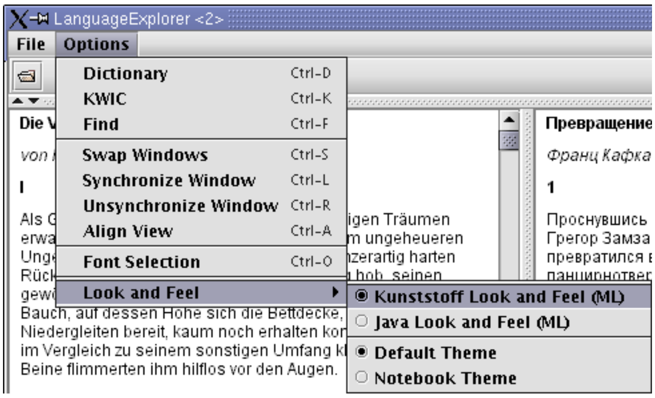


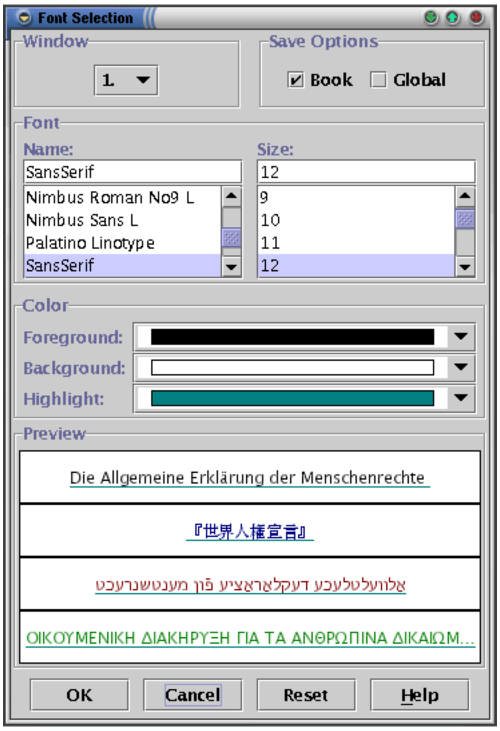
Figure 5.10: Setting the Look and Feel and the color scheme.

The user is adviced to try the available Look and Feels and color themes and choose the combination which is most convenient for him. As other settings, the Look and Feel settings are preserved in the personal preferences files between different LanguageExplorer sessions.

Font selection

The font dialog shown in figure 5.11 offers the possibility to select the fonts used to display the LanguageExplorer books on the screen. Font selection is usually made based on several criteria first of which is the personal taste of the user. However usability should be taken into account as well, and fonts which are readable well on the screen should be preferred.

The most important aspect when speaking about font selection is the question which character glyph are supported by the given font and if a font is capable of displaying all the characters available in a book. This is not a trivial task taking into account that LanguageExplorer books may contain arbitrary UNICODE[7] characters [UNI]. The UNICODE standard defines about 60.000 characters today. Starting with the well known Latin characters defined in ASCII, it also defines, among others, the letters for the Arabia, Hebrew, Cyrillic, Indic, Thai or Ethiopian scripts but also Chinese, Korean and Japanese ideographs. Unfortunately, there exist few fonts which contain all the characters defined in UNICODE. Therefore LanguageExplorer offers the possibility to select different fonts for every single text window. That way it will be possible to read different versions of a book in parallel even if there is no single font available which contains all the needed characters. Different fonts which contain only the characters needed for a single version will suffice.



Window: 1

Save Options: ☑ Book ☐ Global

Name: SansSerif

Nimbus Roman No9 L
Nimbus Sans L
Palatino Linotype
SansSerif

Size: 12

9
10
11
12

Foreground: ■

Background: □

Highlight: ■

Die Allgemeine Erklärung der Menschenrechte

『世界人権宣言』

אַלוועלטלעכע דעקלאַראַציע פֿון מענטשנרעכט

OIKOYMENIKH ΔΙΑΚΗΡΥΞΗ ΓΙΑ ΤΑ ΑΝΘΡΩΠΙΝΑ ΔΙΚΑΙΩΜ...

Figure 5.11: The font selection dialog.

In the Window part, in the upper left corner of the font selection dialog the window for which the font selection will be done can be selected. It is possible to select a single window here or to select all the windows in order to set the same font for all windows simultaneously.

Basically it is preferable to use the same font for all windows because this leads to more balanced presentation. However in the above mentioned case where a font doesn't cover all the required characters, different fonts have to be used. The Preview part of the font dialog displays the title of every text version of the current book, each in its own text field. These text lines may be used to check if the desired font supports the characters needed by the corresponding text version.

It is also possible to choose the window for which the font should be changed by simply clicking into the text field with the corresponding title. Clicking into the Preview area outside of any of the text fields will select all the windows for font change.

[7] UNICODE is a consortium which developed a character encoding system for most of the languages used in the world today. This coding system has been approved as an international standard under the number ISO/IEC-10646.

Finally, a new font can be selected in the Font part of the font selection dialog. Clicking on one of the displayed font names will select the font and update the Preview panel in order to reflect the font change. Depending on whether a single window or all the windows have been selected for update, only one or all the text fields will change. The same holds true if a new font size will be selected in the Font panel.

There are small editable text fields above the font name and font size selection lists. They can be used to manually enter the desired font name or font size. For the font name, it is sufficient to enter the first unique letters a name in order to select it. While the new input for the font name has to be present already in the name list in order to be acceptable, it is possible to enter size values not offered in the size list. Such new values will be inserted into the list.

The Color part of the font dialog offers pull down menus for the selection of the foreground, background, and underline color respectively. Any changes made in this panel will be reflected immediately in the Preview panel as well.

Reset

The Reset button can be used to undo the changes made so far in the font dialog box. Pressing it will only reset the settings changed in the font dialog since the dialog was opened. If a single window has been selected in the Window part of the dialog, only changes for that particular window will be undone, otherwise, all the font attributes for all the windows will be reseted to their initial values.

It is possible to make the actual changes persistent between different LanguageExplorer executions by selecting one of the options in the “Save Options” part of the font dialog. If neither of the two check boxes is selected, the changes will be effective only for the current LanguageExplorer session. They will be lost when LanguageExplorer will be started the next time. With the Book option, the actual settings will be saved for the current book. If at any later time the book will be reloaded, the current font settings will be immediately applied to the corresponding text windows. Using the Global option when leaving the dialog will save the current settings as the default LanguageExplorer settings which will be loaded every time at program start up and for books for which there exist no font settings until now.

OK

The save options just mentioned apply only if the dialog is left by pressing the OK button. This will store the font settings in the desired way and update the text windows to reflect the changes as well. All the windows will be updated simultaneously in the way displayed by the preview panel of the font dialog, no difference which window was selected in the dialog when the OK button was pressed.

Cancel

Leaving the font dialog with the Cancel button discards all the changes done so far and leaves the text areas of LanguageExplorer unchanged.

The user interface language

One of the nice features of LanguageExplorer is its ability to switch the language of the user interface elements at run time, without the need to restart the whole program.

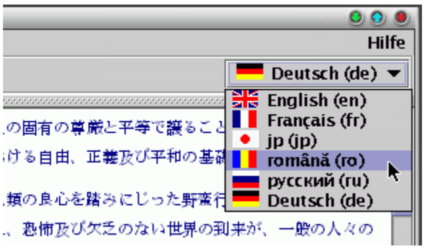


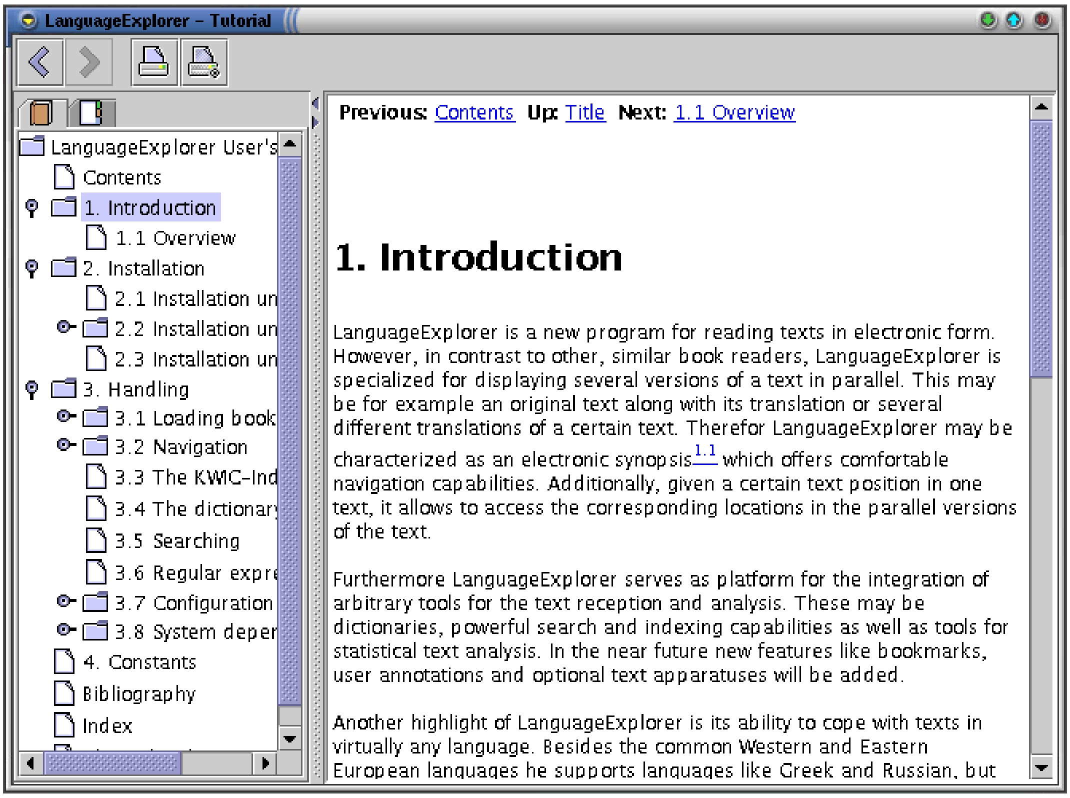
Figure 5.12: The LanguageExplorer locale chooser.

Switching the user interface language at run time can be easily done with the locale chooser shown in figure 5.12. The locale chooser is a pull down menu which can be opened by clicking the small arrow on its right side. In the closed state it displays the current language while it offers a list of available languages in the open state. LanguageExplorer is fully localized[8] for German, English, Russian and French. If switching to a language not fully supported by LanguageExplorer until now, all the string resources not localized will be displayed by using their English default values.

The online help system

LanguageExplorer comes with a fully fledged and comfortable online help system with searchable index (see figure 5.13). The whole user's manual is available in electronic form during program execution. It can be accessed at any time through the menu bar (`Help`→`Tutorial`) or by pressing the `F1` key. Additionally, most of the LanguageExplorer dialogs have an auxiliary `Help` button which was not mentioned until now. Pressing such a `Help` button will automatically open the help system and jump to the corresponding place in the manual where the description of the dialog is located.

F1



1. Introduction

LanguageExplorer is a new program for reading texts in electronic form. However, in contrast to other, similar book readers, LanguageExplorer is specialized for displaying several versions of a text in parallel. This may be for example an original text along with its translation or several different translations of a certain text. Therefor LanguageExplorer may be characterized as an electronic synopsis[1.1] which offers comfortable navigation capabilities. Additionally, given a certain text position in one text, it allows to access the corresponding locations in the parallel versions of the text.

Furthermore LanguageExplorer serves as platform for the integration of arbitrary tools for the text reception and analysis. These may be dictionaries, powerful search and indexing capabilities as well as tools for statistical text analysis. In the near future new features like bookmarks, user annotations and optional text apparatuses will be added.

Another highlight of LanguageExplorer is its ability to cope with texts in virtually any language. Besides the common Western and Eastern European languages he supports languages like Greek and Russian, but

Figure 5.13: The online help system of LanguageExplorer.

[8] Localization is the process of adapting a program to conform to the language, formatting rules, and cultural nuances of a specific region of the world.

5.4.9 System dependencies

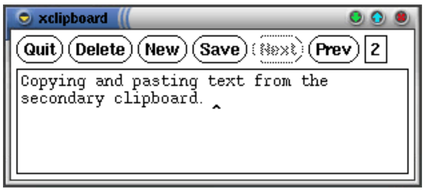
LanguageExplorer has been developed from the very beginning to be platform independent. Due to the significant differences of the target platforms supported by LanguageExplorer it is unavoidable however, that minor differences in the handling may occur. This chapter is devoted to explaining and working around these system dependencies.

Copying and pasting text

While copying and pasting text between other applications and LanguageExplorer works as expected under Windows and Mac OS X, there are some peculiarities to be considered under Linux. While the before mentioned systems have just one clipboard, the Linux's X Windows system[9] has two of them: a primary clipboard and a secondary clipboard. Selecting text with the left mouse button under the X Windows system automatically copies this selected text into the primary clipboard. Thereafter it can be pasted by pressing the middle mouse button. The problem with this kind of clipboard is that every text selection automatically replaces the old content of the clipboard with the new selection.

That's why X Windows additionally supports the secondary clipboard. Like under the Windows, text is not implicitly inserted into the clipboard by simply selecting text. Instead this has to be done explicitly. However how this is achieved varies between applications. Nowadays most X Windows applications support the `Ctrl-C` and `Ctrl-V` hot keys respectively for copying and pasting text.

LanguageExplorer supports only the secondary clipboard together with the `Ctrl-C` and `Ctrl-V` hot keys under the X Windows system. Therefore it is not enough to simply select text in another application with the left mouse button in order to paste it into LanguageExplorer. Instead the desired text has to be moved into the secondary clipboard. If this is not supported by the source application, the standard X Windows tool `xclipboard` (see figure 5.14) may be used to help.



Copying and pasting text from the secondary clipboard.

Figure 5.14: The X Windows helper application `xclipboard`.

Using `xclipboard` is quite simple. Executing `xclipboard` on the command line opens the window shown in figure 5.14. Text may now be selected in an arbitrary application with the left mouse button and pasted into the `xclipboard` window with the middle button. Pasting the text into the `xclipboard` program automatically enters this text into the secondary clipboard. Now it can be pasted into LanguageExplorer by simply pressing the `Ctrl-V` hot key.

Pasting text from LanguageExplorer into a Linux application which does not support the secondary clipboard also works well with the `xclipboard` application. Copying text into the clipboard in LanguageExplorer by using the `Ctrl-C` hot key, automatically inserts that text into the xclipboard window. Thereafter it can be selected with the left mouse button, thus implicitly inserting it into the primary clipboard, and subsequently pasted into arbitrary other applications by pressing the middle mouse button.

[9] X Windows is the graphical windowing system of Linux and virtually any Unix based operating system. For more information see `http://www.x.org`.

`xclipboard` is also useful because it supports a history of the last few entries of the clipboard. More information about `xclipboard` can be obtained at the command line by typing the command `man xclipboard`.

Input methods

Especially when working with texts in different languages the problem arises that not all letters can be typed with the keyboard attached to the computer because it usually offers only keys for one language. Therefore several different systems have been developed in the last years which allow not only the input of letters not present on the keyboard, but also the input of ideographs for languages like Chinese or Japanese. These systems are commonly called input methods. Input methods range from simple systems which implement a new keyboard mapping for the input of Cyrillic or Greek characters on a Latin keyboard to highly complex programs which allow the comfortable and fast construction of thousands of different ideographs with a usual computer keyboard.

LanguageExplorer not only supports the generic input methods offered by the native operating system, but also custom input methods specific to LanguageExplorer. Because the invocation of these input methods is system dependent, they will be discussed in the following subsections. Basically, every input method belongs to a top level window and all the widgets inside that window. However different top level windows may well have different input methods associated with them. So it would be possible for example for the open book dialog to use the default system input method while the search dialog uses a Cyrillic input method.

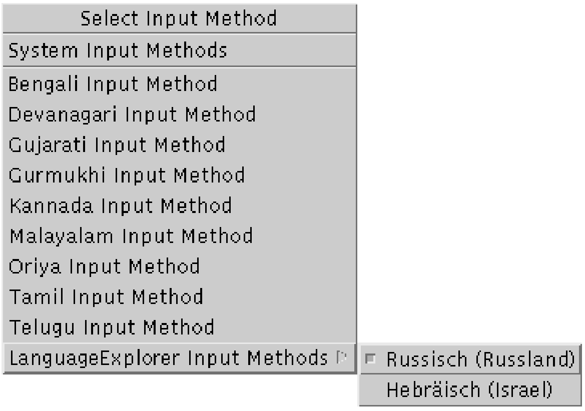


Figure 5.15: The input method selection menu under Linux.

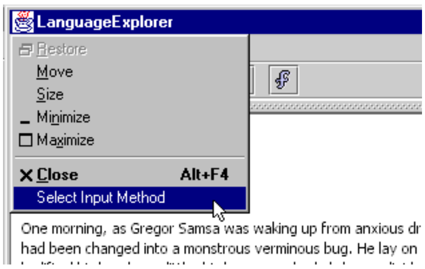
Input method invocation under Linux To activate a different input method for a top level window under the Linux operating system it is necessary to first click into that window in order to give the window the input focus. Thereafter the `F4`[10] function key can be used to bring the input method selection menu on the screen (see figure 5.15).

While the first line denotes the default system input method, the last line of the menu which reads "LanguageExplorer Input methods" opens a sub menu with the input methods specific to LanguageExplorer.

Input method invocation under Windows The Windows operating system offers a stan-

[10] `F4` is just the predefined default key for calling the input method selection menu. This key may be configured as described in section 5.3.2 on page 120.

dard way to open a input method for an application. If the application supports input methods, its context menu (as shown in figure 5.16), offers an additional menu entry for the input method selection menu.



One morning, as Gregor Samsa was waking up from anxious dr
had been changed into a monstrous verminous bug. He lay on

Figure 5.16: The default context menu of LanguageExplorer under windows gives access to the input method selection menu.

Finally the input method selection menu looks exactly the same like the one shown for the Linux operating system shown in figure 5.15.

Input methods under Mac OS X Under Mac OS X LanguageExplorer currently only supports the system input methods provided by the operating system. Thy are invoked through the keyboard menu of the application. Notice that the keyboard menu will be visible only if there is more than one input method available. It is possible to install additional system input methods by choosing the "Keyboard Menu" tab from the "International" section of the "System Preferences" window.

Using the LanguageExplorer input methods After a certain LanguageExplorer input method has been selected for a top level window, a small helper window as shown in figure 5.17 will be displayed in the lower right side of the screen while the top level window has the keyboard focus. This helper window displays the language of the associated input method in its title bar and a picture of the new keyboard bindings. The bindings may change if certain modifier keys (e.g. the `Shift` key) is pressed on the keyboard, but they will always display the characters currently available.

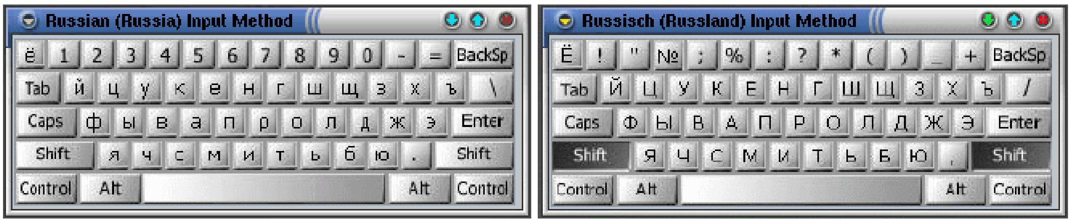

Russian (Russia) Input Method
ё 1 2 3 4 5 6 7 8 9 0 - = BackSp
Tab й ц у к е н г ш щ з х ъ \
Caps ф ы в а п р о л д ж э Enter
Shift я ч с м и т ь б ю . Shift
Control Alt Alt Control
Russisch (Russland) Input Method
Ё ! " № ; % : ? * ( ) _ + BackSp
Tab Й Ц У К Е Н Г Ш Щ З Х Ъ /
Caps Ф Ы В А П Р О Л Д Ж Э Enter
Shift Я Ч С М И Т Ь Б Ю , Shift
Control Alt Alt Control

Figure 5.17: The help windows displayed by the LanguageExplorer input method for Russian. On the left side the new default keyboard configuration, on the right side the keyboard layout valid when holding down the `Shift` key.

As long as an input method is valid for a window, any keyboard action will result in the input of the corresponding characters shown in the helper window instead of the characters visible on the real keyboard. Switching back to the original keyboard layout is just a matter of selecting the system input method for the corresponding top level window.

In LanguageExplorer input methods are especially useful in the find dialog if searching a text version written in a language that contains letters which are not directly accessible from the keyboard.

Chapter 6

LanguageAnalyzer

6.1 Introduction

LanguageAnalyzer is the integrated development environment (IDE) for the LanguageExplorer text reader presented in the previous chapter. It is a comfortable tool for editing text documents with the focus being laid on analysis, segmentation and mark-up of already existing texts. Like LanguageExplorer, LanguageAnalyzer can handle texts in any language supported by the Unicode [U30] standard. Furthermore facsimile reproductions and sound files can be processed and tagged in a uniform way. Finally, the single documents can be linked together and saved in the XTE XML format which has been described in section 2.4 and which is the native input format for LanguageExplorer.

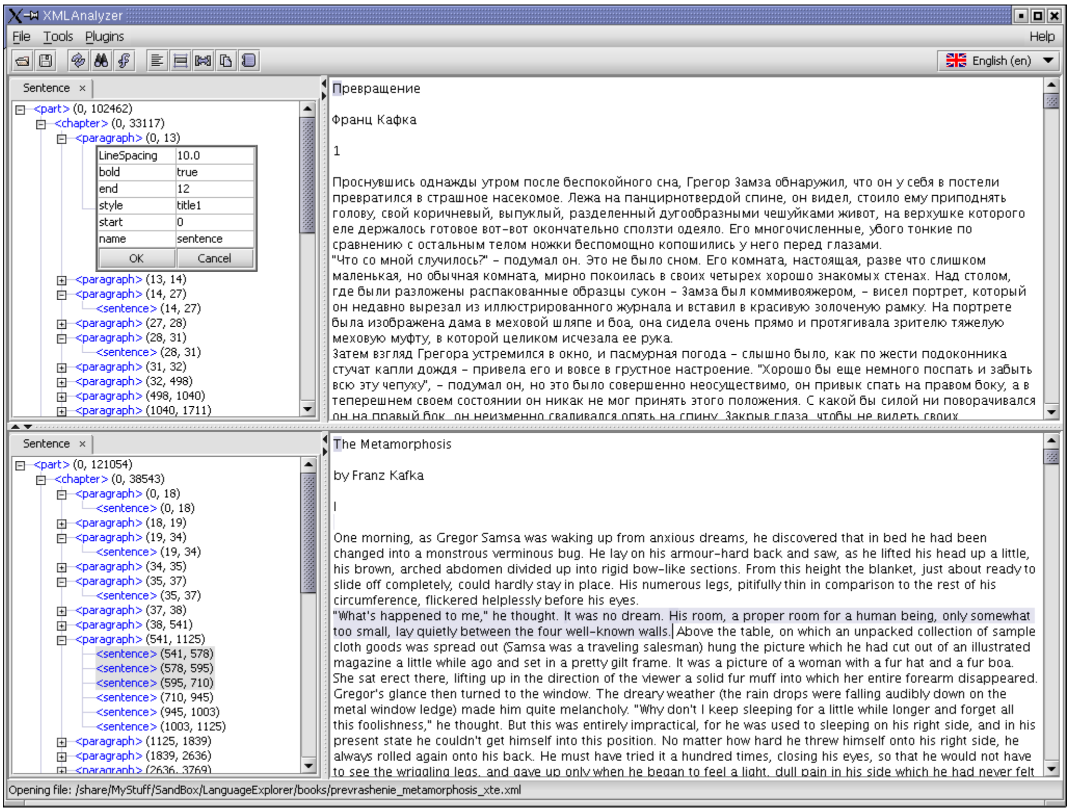
LanguageAnalyzer and LanguageExplorer have been developed in parallel and a big part of the architectural characteristics and classes described in chapter 3, mainly the text related classes, are shared by both projects. Many general features extensively described in the previous chapter like the input method framework, the help system or the configurable look and feel are also available and supported in LanguageAnalyzer and will not be described in full detail once again. Like LanguageExplorer, LanguageAnalyzer is currently available for the Linux, Windows and the Mac OS X operating systems.

6.2 Overview

In this section the basic functionality of LanguageAnalyzer will be outlined based on a screen-shot of the application. Figure 6.1 shows LanguageAnalyzer after loading the Russian and the English version of Franz Kafka's novel "The Metamorphosis". Below the menu and tool bar the two equally sized main windows which contain the two text versions are horizontally arranged one above the other. Each of these two main windows is further subdivided vertically into a tree view which represents the different mark-up structures of the text on the left side and a text area which contains the text content on the right side.

Notice that the text area is fully synchronized with the associated tree view. Clicking on a tree node underlines the content in the text area which is described by the selected element (as can be seen in the lower window in figure 6.1) and clicking into the text area selects the corresponding element node in the associated tree view.

Each node in the element tree has several attributes. Some of them like for example the linking information and the start and end positions of the text content described by each element are displayed by default. All the attributes can be viewed and edited by clicking with the right mouse button onto the corresponding node (as shown in the left, upper window in Figure 6.1).



<part> (0, 102462)
<chapter> (0, 33117)
<paragraph> (0, 13)

LineSpacing	10.0
bold	true
end	12
style	title1
start	0
name	sentence

<paragraph> (13, 14)
<paragraph> (14, 27)
<sentence> (14, 27)
<paragraph> (27, 28)
<paragraph> (28, 31)
<sentence> (28, 31)
<paragraph> (31, 32)
<paragraph> (32, 498)
<paragraph> (498, 1040)
<paragraph> (1040, 1711)

Превращение

Франц Кафка

1

Проснувшись однажды утром после беспокойного сна, Грегор Замза обнаружил, что он у себя в постели превратился в страшное насекомое. Лежа на панцирнотвердой спине, он видел, стоило ему приподнять голову, свой коричневый, выпуклый, разделенный дугообразными чешуйками живот, на верхушке которого еле держалось готовое вот-вот окончательно сползти одеяло. Его многочисленные, убого тонкие по сравнению с остальным телом ножки беспомощно копошились у него перед глазами.
"Что со мной случилось?" - подумал он. Это не было сном. Его комната, настоящая, разве что слишком маленькая, но обычная комната, мирно покоилась в своих четырех хорошо знакомых стенах. Над столом, где были разложены распакованные образцы сукон - Замза был коммивояжером, - висел портрет, который он недавно вырезал из иллюстрированного журнала и вставил в красивую золоченую рамку. На портрете была изображена дама в меховой шляпе и боа, она сидела очень прямо и протягивала зрителю тяжелую меховую муфту, в которой целиком исчезала ее рука.
Затем взгляд Грегора устремился в окно, и пасмурная погода - слышно было, как по жести подоконника стучат капли дождя - привела его и вовсе в грустное настроение. "Хорошо бы еще немного поспать и забыть всю эту чепуху", - подумал он, но это было совершенно неосуществимо, он привык спать на правом боку, а в теперешнем своем состоянии он никак не мог принять этого положения. С какой бы силой ни поворачивался он на правый бок, он неизменно сваливался опять на спину. Закрыв глаза, чтобы не видеть своих

<part> (0, 121054)
<chapter> (0, 38543)
<paragraph> (0, 18)
<sentence> (0, 18)
<paragraph> (18, 19)
<paragraph> (19, 34)
<sentence> (19, 34)
<paragraph> (34, 35)
<paragraph> (35, 37)
<sentence> (35, 37)
<paragraph> (37, 38)
<paragraph> (38, 541)
<paragraph> (541, 1125)
<sentence> (541, 578)
<sentence> (578, 595)
<sentence> (595, 710)
<sentence> (710, 945)
<sentence> (945, 1003)
<sentence> (1003, 1125)
<paragraph> (1125, 1839)
<paragraph> (1839, 2636)
<paragraph> (2636, 3769)

The Metamorphosis

by Franz Kafka

I

One morning, as Gregor Samsa was waking up from anxious dreams, he discovered that in bed he had been changed into a monstrous verminous bug. He lay on his armour-hard back and saw, as he lifted his head up a little, his brown, arched abdomen divided up into rigid bow-like sections. From this height the blanket, just about ready to slide off completely, could hardly stay in place. His numerous legs, pitifully thin in comparison to the rest of his circumference, flickered helplessly before his eyes.
"What's happened to me," he thought. It was no dream. His room, a proper room for a human being, only somewhat too small, lay quietly between the four well-known walls. Above the table, on which an unpacked collection of sample cloth goods was spread out (Samsa was a traveling salesman) hung the picture which he had cut out of an illustrated magazine a little while ago and set in a pretty gilt frame. It was a picture of a woman with a fur hat and a fur boa. She sat erect there, lifting up in the direction of the viewer a solid fur muff into which her entire forearm disappeared. Gregor's glance then turned to the window. The dreary weather (the rain drops were falling audibly down on the metal window ledge) made him quite melancholy. "Why don't I keep sleeping for a little while longer and forget all this foolishness," he thought. But this was entirely impractical, for he was used to sleeping on his right side, and in his present state he couldn't get himself into this position. No matter how hard he threw himself onto his right side, he always rolled again onto his back. He must have tried it a hundred times, closing his eyes, so that he would not have to see the wriggling legs, and gave up only when he began to feel a light, dull pain in his side which he had never felt

Opening file: /share/MyStuff/SandBox/LanguageExplorer/books/prevrashenie_metamorphosis_xte.xml

Figure 6.1: LanguageAnalyzer after loading two versions of a text. The upper and the lower part of the application contain a vertically split window which contains the text content on the right side and tree controls representing the mark-up structures of the text on the left side.

Each of the two main windows may be loaded and saved independently of the other window. However, the usual procedure is to load a single, plain text version into each of the two windows respectively, edit, segment and link them together and finally save them as one file in the XTE XML format (see section 2.4 on page 22).

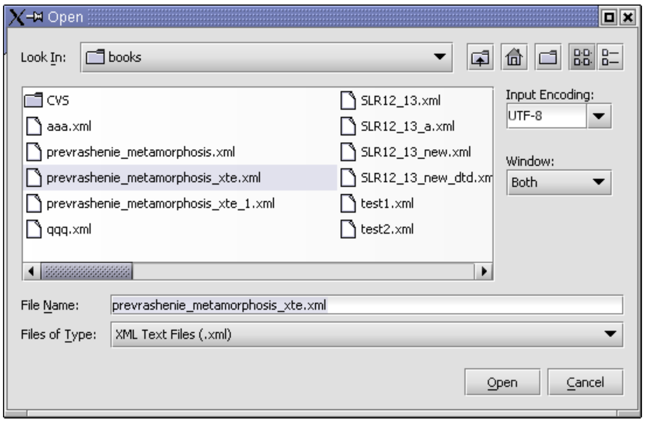
6.3 Handling

This chapter will give a brief description of the functions available in LanguageAnalyzer. Notice that general, user interface related functions like for example the resizing of the internal windows are described in section 5.4.

6.3.1 Loading content

Currently, the source files may be in an untagged character format (e.g. ASCII, UTF8,..), in the LanguageExplorer XTE format or in a bitmap format like JPG, GIF or PNG. However, as already noticed in section 3.6, loading documents in other formats like for example sound files or texts encoded in other XML formats is just a question of writing the corresponding load and save actions.

The open file dialog of LanguageAnalyzer shown in figure 6.2 is a standard open file dialog with a customized accessory component on the right side. In this accessory component it is possible to choose the character encoding of the file which should be loaded and to choose the window(s) in which the file(s) should be loaded into.



Look In: books

CVS
aaa.xml
prevrashenie_metamorphosis.xml
prevrashenie_metamorphosis_xte.xml
prevrashenie_metamorphosis_xte_1.xml
qqq.xml
SLR12_13.xml
SLR12_13_a.xml
SLR12_13_new.xml
SLR12_13_new_dtd.xm
test1.xml
test2.xml

Input Encoding: UTF-8

Window: Both

File Name: prevrashenie_metamorphosis_xte.xml

Files of Type: XML Text Files (.xml)

Figure 6.2: The customized open file dialog of LanguageAnalyzer.

Choosing the correct character encoding is especially important for text files because it is not possible to determine this encoding from the files automatically. LanguageAnalyzer supports a huge number of encodings beginning with the standard UTF-8, UTF-16 and ISO-8859 encodings, including the various Windows, Macintosh and IBM code-pages, up to the more exotic encodings for Japanese, Korean or Thai to name just a few of them.

For XML files, LanguageAnalyzer tries to determine the character encoding from the `encoding` attribute of the XML declaration if this is present. In case of success and if the encoding specified in the XML file differs from the encoding chosen by the user, the file is reopened with the proper encoding.

Text and graphic files can only be loaded into one single text window at a time, while XTE files, which can contain two or more documents can be loaded such that each of the documents will be loaded into one of the two text windows. However, it is also possible to load just one document out of an XTE file with more than one document. This way it is possible for example to combine single documents from different XTE files into new XTE files.

Notice that it is also possible to select more than one file in the open file dialog. This is especially useful if a set of bitmap files which contain the facsimile pages of a text edition should be assembled into a new XTE document or if the text content of a document is split over several files.

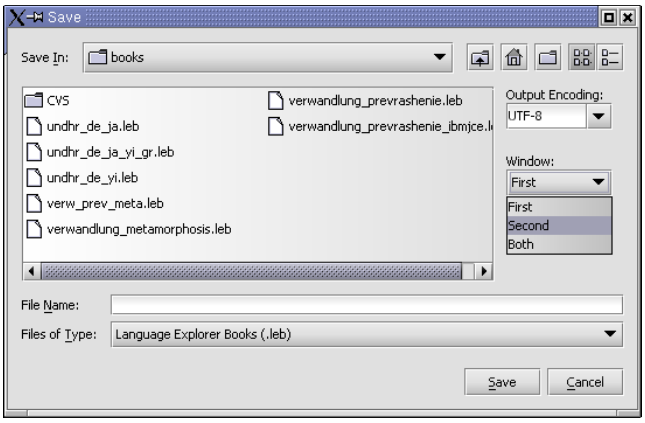
6.3.2 Saving XTE files

The dialog for saving the current documents which is shown in figure 6.3 supports similar options like the open file dialog described above.

It is possible to choose the character encoding of the output file and the user has the possibility to choose whether to store the content of a single text window or to store both documents from within the two text windows into a single XTE file. Currently, only the XTE format is supported as output format, but new formats may be added in the future.

6.3.3 Working with multiple documents and encodings

As described in section 2.4, one of the features of the XTE encoding is its ability to support an arbitrary number of independent encodings. In LanguageAnalyzer, each of these encod-



Output Encoding: UTF-8

Window: First

Files of Type: Language Explorer Books (.leb)

Figure 6.3: The customized save file dialog of LanguageAnalyzer.

ings is represented by its own tab in the encoding window on the left side of every main window (see figure 6.4).

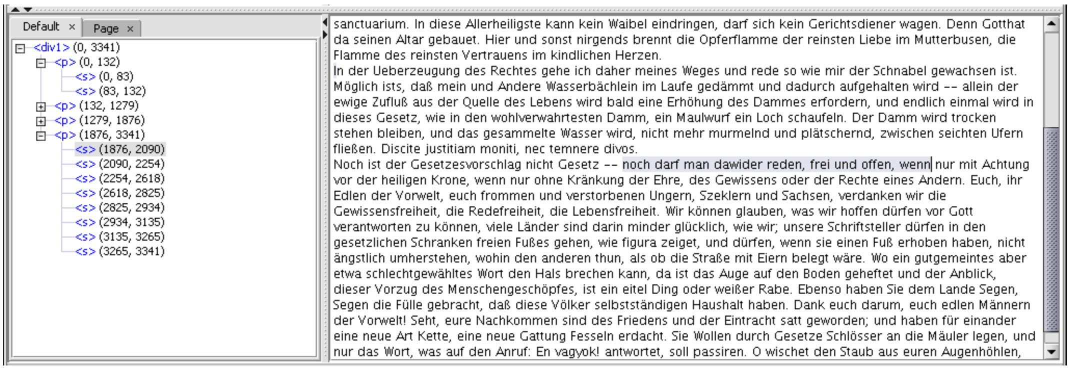
Every tab contains a label with the name of the encoding and a tree view which represents the encoding. All the different encodings of a document refer to the same content, however every encoding may encode just a part of the complete character content or may encode the same content in a different way[1]. Clicking on a tab will select the corresponding encoding as the active encoding. The text displayed in the text area on the right side of the encoding window is always a view of the currently active encoding.

Because every element may be visually represented by its own view class, the same text may be displayed quite differently depending on the currently active encoding even if the different encodings encode the same part of the content. The consequences of this feature can be seen by comparing figure 6.4 with figure 6.5 which both display the same content, however with a different active encoding.

While figure 6.4 is displaying the text based on the default sentence- and paragraph-wise encoding selected in that figure, figure 6.5 is showing the same text based on a line- and page-wise encoding which corresponds to the layout of the original edition of the text.

Notice however once again that these are two different views of the same underlying

[1] One nice example of an unusual encoding is the KWIC Index produced by LanguageExplorer (see figure 5.2). It presents the same content like the associated text component, however in a completely different order. If the key word appears more than one time in a sentence, this sentence may even appear multiple times in the encoding.

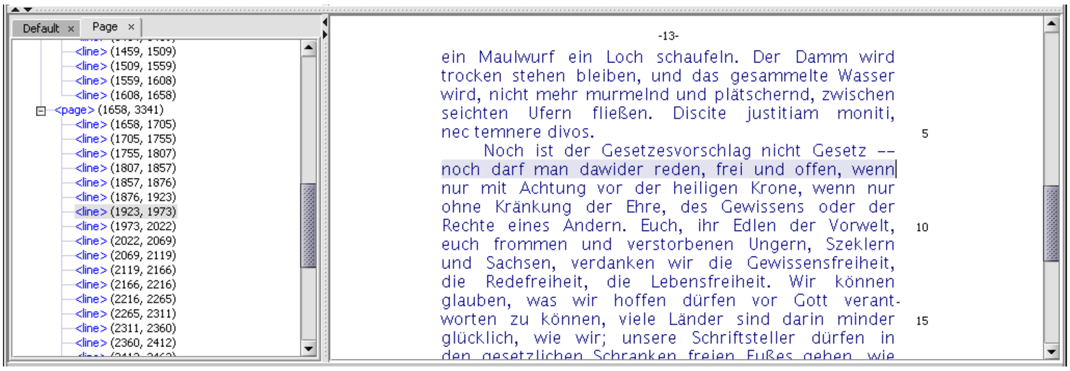


sanctuarium. In diese Allerheiligste kann kein Waibel eindringen, darf sich kein Gerichtsdiener wagen. Denn Gotthat da seinen Altar gebauet. Hier und sonst nirgends brennt die Opferflamme der reinsten Liebe im Mutterbusen, die Flamme des reinsten Vertrauens im kindlichen Herzen.

In der Ueberzeugung des Rechtes gehe ich daher meines Weges und rede so wie mir der Schnabel gewachsen ist. Möglich ists, daß mein und Andere Wasserbächlein im Laufe gedämmt und dadurch aufgehalten wird -- allein der ewige Zufluß aus der Quelle des Lebens wird bald eine Erhöhung des Dammes erfordern, und endlich einmal wird in dieses Gesetz, wie in den wohlverwahrtesten Damm, ein Maulwurf ein Loch schaufeln. Der Damm wird trocken stehen bleiben, und das gesammelte Wasser wird, nicht mehr murmelnd und plätschernd, zwischen seichten Ufern fließen. Discite justitiam moniti, nec temnere divos.

Noch ist der Gesetzesvorschlag nicht Gesetz -- noch darf man dawider reden, frei und offen, wenn nur mit Achtung vor der heiligen Krone, wenn nur ohne Kränkung der Ehre, des Gewissens oder der Rechte eines Andern. Euch, ihr Edlen der Vorwelt, euch frommen und verstorbenen Ungern, Szeklern und Sachsen, verdanken wir die Gewissensfreiheit, die Redefreiheit, die Lebensfreiheit. Wir können glauben, was wir hoffen dürfen vor Gott verantworten zu können, viele Länder sind darin minder glücklich, wie wir; unsere Schriftsteller dürfen in den gesetzlichen Schranken freien Fußes gehen, wie figura zeiget, und dürfen, wenn sie einen Fuß erhoben haben, nicht ängstlich umherstehen, wohin den anderen thun, als ob die Straße mit Eiern belegt wäre. Wo ein gutgemeintes aber etwa schlechtgewähltes Wort den Hals brechen kann, da ist das Auge auf den Boden geheftet und der Anblick, dieser Vorzug des Menschengeschöpfes, ist ein eitel Ding oder weißer Rabe. Ebenso haben Sie dem Lande Segen, Segen die Fülle gebracht, daß diese Völker selbstständigen Haushalt haben. Dank euch darum, euch edlen Männern der Vorwelt! Seht, eure Nachkommen sind des Friedens und der Eintracht satt geworden; und haben für einander eine neue Art Kette, eine neue Gattung Fesseln erdacht. Sie Wollen durch Gesetze Schlösser an die Mäuler legen, und nur das Wort, was auf den Anruf: En vagyok! antwortet, soll passiren. O wischet den Staub aus euren Augenhöhlen,

Figure 6.4: One of the LanguageAnalyzer main windows with the encoding window on the left side.



```
<line> (1459, 1509)
<line> (1509, 1559)
<line> (1559, 1608)
<line> (1608, 1658)
<page> (1658, 3341)
  <line> (1658, 1705)
  <line> (1705, 1755)
  <line> (1755, 1807)
  <line> (1807, 1857)
  <line> (1857, 1876)
  <line> (1876, 1923)
  <line> (1923, 1973)
  <line> (1973, 2022)
  <line> (2022, 2069)
  <line> (2069, 2119)
  <line> (2119, 2166)
  <line> (2166, 2216)
  <line> (2216, 2265)
  <line> (2265, 2311)
  <line> (2311, 2360)
  <line> (2360, 2412)
```

-13-

ein Maulwurf ein Loch schaufeln. Der Damm wird trocken stehen bleiben, und das gesammelte Wasser wird, nicht mehr murmelnd und plätschernd, zwischen seichten Ufern fließen. Discite justitiam moniti, nec temnere divos.

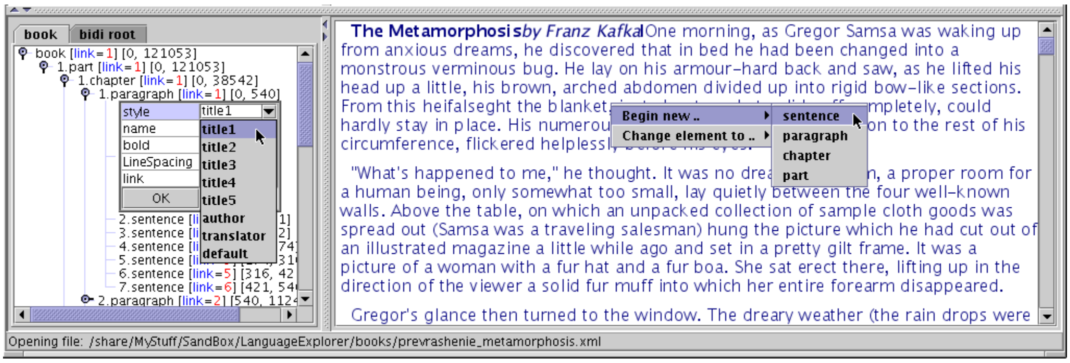
Noch ist der Gesetzesvorschlag nicht Gesetz -- noch darf man dawider reden, frei und offen, wenn nur mit Achtung vor der heiligen Krone, wenn nur ohne Kränkung der Ehre, des Gewissens oder der Rechte eines Andern. Euch, ihr Edlen der Vorwelt, euch frommen und verstorbenen Ungern, Szeklern und Sachsen, verdanken wir die Gewissensfreiheit, die Redefreiheit, die Lebensfreiheit. Wir können glauben, was wir hoffen dürfen vor Gott verantworten zu können, viele Länder sind darin minder glücklich, wie wir; unsere Schriftsteller dürfen in den gesetzlichen Schranken freien Fußes gehen wie

Figure 6.5: The same main window like the one shown in figure 6.4 with a different active encoding.

text content. This can be seen for example by selecting a line of text in one view (as done in figure 6.5) and then switching to another encoding as done in figure 6.4. Still the same part of text will be selected, although the selection does not correspond to an element in the new encoding anymore. Nevertheless, the corresponding element (or elements if necessary) which contains the selected text in the new encoding is highlighted in the encoding window. The same argumentation applies if the content would have been edited in one view: the changes would have been automatically propagated to all other the views. Notice that this may remove some elements of an encoding if the text contained in that elements would have been deleted completely.

Many of the plugins and tools which will be described in the next sections operate on the text content as well as on one or more of the currently available encodings. Some of them even create new encodings. If a document is saved as an XTE file as described in section 6.3.2, all the encodings will be saved in the file. However, the user has the possibility to remove any of the available encodings from a document before saving it by clicking on the small cross which is located on the right side of every tab.

Clicking the right mouse button on an element in the encoding window opens a dialog which may be used to edit the attributes of the corresponding element. Depending on the DTD, only certain values may be possible for some attributes as shown on the left side of figure 6.6. If the right mouse button is pressed on the text area, a context menu will appear which allows the insertion of new elements at the current cursor position based on the actual DTD. These tools are intended for the fine-tuning of encodings. It should be



```
book [link=1] [0, 121053]
  1.part [link=1] [0, 121053]
    1.chapter [link=1] [0, 38542]
      1.paragraph [link=1] [0, 540]
        2.sentence [li
        3.sentence [li
        4.sentence [li
        5.sentence [li
        6.sentence [link=5] [316, 42
        7.sentence [link=6] [421, 54
      2.paragraph [link=2] [540, 112
```

style	title1
name	
bold	
LineSpacing	
link	

title1
title2
title3
title4
title5
author
translator
default

The Metamorphosis*by Franz Kafka*One morning, as Gregor Samsa was waking up from anxious dreams, he discovered that in bed he had been changed into a monstrous verminous bug. He lay on his armour-hard back and saw, as he lifted his head up a little, his brown, arched abdomen divided up into rigid bow-like sections. From this heifalseght the blanket, mpletely, could hardly stay in place. His numerou on to the rest of his circumference, flickered helplessl

"What's happened to me," he thought. It was no drea n, a proper room for a human being, only somewhat too small, lay quietly between the four well-known walls. Above the table, on which an unpacked collection of sample cloth goods was spread out (Samsa was a traveling salesman) hung the picture which he had cut out of an illustrated magazine a little while ago and set in a pretty gilt frame. It was a picture of a woman with a fur hat and a fur boa. She sat erect there, lifting up in the direction of the viewer a solid fur muff into which her entire forearm disappeared.

Gregor's glance then turned to the window. The dreary weather (the rain drops were

Opening file: /share/MyStuff/SandBox/LanguageExplorer/books/prevrashenie_metamorphosis.xml

Figure 6.6: A main window with an open context menu on the text area and an open attribute window for an element of the encoding window.

mentioned however that LanguageAnalyzer is not a general, fully-fledged XML editor. The intention is to generate new encodings and linking structures automatically by plugins but still give the user the possibility to fine-tune the results if necessary.

6.3.4 Tools

Right after an XTE file has been loaded, the different documents which have been present in the file are displayed in the two main windows corresponding to their position in the file. This order can be changed by pressing the swap button (see left margin) on the tool bar. Notice that the tools and plugins which need a window argument always operate with the logical window positions currently visible in the application.

Searching and font selection work in the same way as described in the corresponding sections (5.4.5 and 5.4.8) of the LanguageExplorer manual. The only difference is the fact that the creation of a KWIC index from the find dialog will not open a new extension window but instead create a new encoding for the corresponding document. If this encoding will be selected as the active encoding, the KWIC index will be displayed in the text area.

6.3.5 Plugins

LanguageAnalyzer already comes with several default plugins which can be used to segment and link two documents, create word lists or copy existing encodings. These standard plugins will be presented and explained in some more detail in this section.

Segmenting text

The “Segment text” plugin which is accessible from the tool bar or from the Plugins menu is a simple, text segmentation tool which uses common heuristics to divide a plain text into different components. It can work in two modes. By default it takes a text and segments it into words, sentences and paragraphs. The plugin is based on the `BreakIterator` class from the `java.text` package which defines locale-dependent character-, word-, line- and sentence-iterators.

The plugin is configurable for example with respect to the handling of newlines and how they are mapped to paragraph, section, or chapter breaks. These settings are of course dependent on the format of the input files. Usually, one line-break character is ignored during the detection of sentence boundaries, two line-breaks are interpreted as paragraph boundaries, three line breaks as section boundaries and so on.

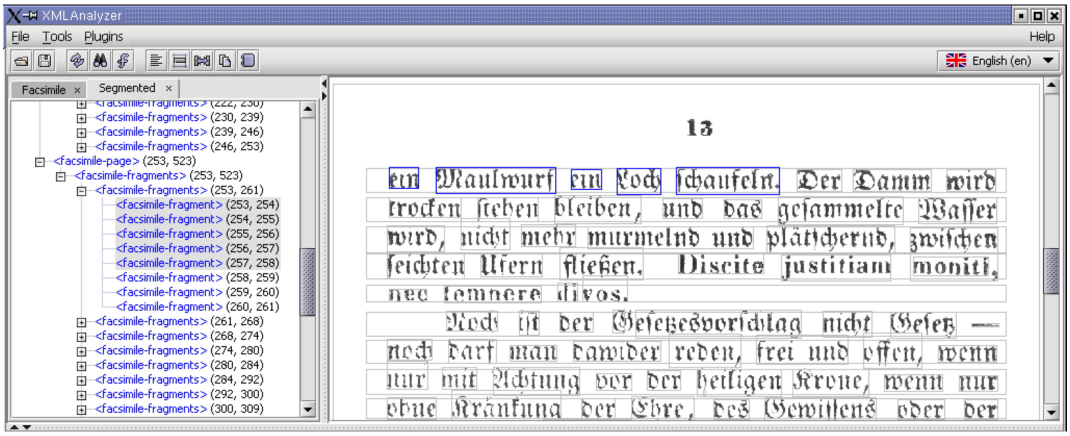
The “Segment text” plugin may also be used to detect line and page breaks. This is especially useful if the text sources have been created by an OCR (optical character recognition) program, because in such a case the source contains the pagination information of the initial edition. One important point to consider here is the correct handling of hyphen characters at the end of lines. These pagination and hyphenation information may be used later on by the view classes to improve the visual appearance of the text.

Every invocation of the “Segment text” plugin operates solely on the text content of the document and generates a new encoding structure which will be represented by a new tab in the encodings window of the document.

Segmenting facsimile documents

The second plugin which is available from the tool bar is the “Segment facsimile” plugin. It can be used to divide a facsimile picture of a page into character-, word- and line-boxes. Currently the “Segment facsimile” plugin is based on GOCR [GOCR], an open source OCR program which emits positional information of the recognized character boxes.

At the time of writing, the "Segment facsimile" plugin is basically being used to automatically get geometrical information about word positions in old, facsimile pages written with a Gothic type. Because there still exist no practical OCR solutions for the recognition of such texts, we simply ignore the recognized characters. This procedure may be also viable for the segmentation of other facsimile editions like for example old, hand-written manuscripts which cannot be recognized by OCR programs at all. Although the real text information still has to be extracted by transcription in this case, it is nevertheless helpful to automatically get the positional information.



```
<facsimile-fragments> (222, 230)
<facsimile-fragments> (230, 239)
<facsimile-fragments> (239, 246)
<facsimile-fragments> (246, 253)
<facsimile-page> (253, 523)
  <facsimile-fragments> (253, 523)
    <facsimile-fragments> (253, 261)
      <facsimile-fragment> (253, 254)
      <facsimile-fragment> (254, 255)
      <facsimile-fragment> (255, 256)
      <facsimile-fragment> (256, 257)
      <facsimile-fragment> (257, 258)
      <facsimile-fragment> (258, 259)
      <facsimile-fragment> (259, 260)
      <facsimile-fragment> (260, 261)
    <facsimile-fragments> (261, 268)
    <facsimile-fragments> (268, 274)
    <facsimile-fragments> (274, 280)
    <facsimile-fragments> (280, 284)
    <facsimile-fragments> (284, 292)
    <facsimile-fragments> (292, 300)
    <facsimile-fragments> (300, 309)
```

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ein Maulwurf ein Loch ſchaufeln. Der Damm wird
trocken ſtehen bleiben, und das geſammelte Waſſer
wird, nicht mehr murmelnd und plätſchernd, zwiſchen
ſeichten Ufern fließen. Discite justitiam moniti,
nec temnere divos.
Noch iſt der Geſetzesvorſchlag nicht Geſetz —
noch darf man dawider reden, frei und offen, wenn
nur mit Achtung vor der heiligen Krone, wenn nur
ohne Kränkung der Ehre, des Gewiſſens oder der

Figure 6.7: Segmentation of a facsimile document into words and lines. The character boxes have not been created in this case for clarity reasons.

Notice that is possible to manually resize and move the generated boxes (see figure 6.7) by using the mouse. It is also possible to remove boxes or add new boxes this way. Once a facsimile document is completely segmented, the elements that represent the positional boxes can be subsequently linked with the corresponding elements in the textual version of the document on a word and sentence level. This feature may be an interesting option especially for historical and critical editions.

As with the "Segment text" plugin, the invocation of the "Segment facsimile" plugin creates a new encoding structure which is represented by a new tab in the encodings window of the document.

Linking two documents together

One of the most powerful and potentially most complex plugins is the "Link documents" plugin. It takes two encodings and links the elements of these encodings together. Currently, the linking is performed based on the structural properties of the involved encodings. In the simplest case this means that elements with the same name are linked together. But this approach can also be parameterized such that for example a `facsimile-fragment` element with a type attribute set to `line` from a facsimile document will be linked with a `line` element of a page- and line-wise encoded text document.

Because of restrictions in the text synchronization mechanism in LanguageExplorer, the linking information is currently stored in the `link` attribute of every element. However this somewhat restricts the ability to link one encoding with more than one other encoding, although this is still possible by mangling the different links into one attribute. But this approach unnecessarily complicates the parsing of the link attributes. In the future, linking should be done based on the link base mechanism provided by the XLink specification as described in section 2.1.3 and 2.4.1 and the linking information should be stored independently from the encoding elements.

Another challenge for the future development of the system would be the implementation of more advanced aligning techniques which also take into account semantic information about the content referenced by the two involved encodings such as dictionary lookup or the aligning methods described in [HoJo].

Duplicating encodings

Sometimes it may be useful to make a copy of an existing encoding. This may be achieved with the "Duplicate encoding" plugin. Duplicating an encoding makes sense for example before an encoding is edited or adjusted manually to keep a copy of the original encoding. Duplicating encodings may also be appropriate with respect to the linking problems described above if one encoding should be linked to just one single other encoding.

Creating word lists

The last plugin presented in this section does not operate on encodings. Instead, it creates a word list of the underlying text content of a document. The word list can be stored in a file in a simple, customizable text format. Besides the character encoding of the file, the user has the possibility to choose if the word list should be sorted alphabetically or based on the word occurrence frequency. Finally, the words may be preceded by their frequency count.

In the absence of linguistic and morphological libraries, these word lists can be used together with other tools like for example automatic text translation programs to create dictionaries for LanguageExplorer which cover all the words in a text.

6.4 Command line tools

Some useful tools for the creation of LanguageExplorer books have not been built into LanguageAnalyzer until now but exist only as command line tools. This section will describe these tools which hopefully will be integrated into LanguageAnalyzer soon.

6.4.1 Merging XTE files

As already noticed in the design section 3.4, LanguageAnalyzer can only handle two documents at a time. However LanguageExplorer can handle books with an arbitrary number of parallel documents. How is it possible to create such kind of books?

This task is currently accomplished by the command line tool `MergeBooks` which can operate in two different modes. In the first mode, given two XTE files each with two properly interlinked documents from which one of the documents is available in both files, say the documents *A* and *B* in the first XTE file and the documents *A* and *C* in the second XTE file, `MergeBooks` can be used to create a new XTE file which contains the two properly interlinked documents *B* and *C*. The following line shows the formal calling syntax of the program:

`MergeBooks` [*-v*] *-s Book1.xte Book2.xte NewBook.xte*

The optional *-v* argument can be used to get a more verbose output while the three file arguments denote the two, two-document XTE input files and the name of the output file respectively.

Given for example a properly linked XTE file with the German and English version of a novel and a second, properly linked XTE file with the German and Russian version of the same novel, it is possible to automatically create a linked XTE file which contains the English and Russian version of that novel.

Notice that the automatically generated linking information in the created file is always correct if the linking in the two base files has been correct. It may be possible however, that the linking in the created file is not as exact as it might be. This case may occur if one element in the common document (i.e. document A in the context of the previous example) is mapped to several different elements in the corresponding sibling documents. The solution for the problem is to load the created XTE file into LanguageAnalyzer and refine the linking manually.

In the second operation mode, the command line syntax of which is given below, `MergeBooks` can be used to create an XTE file which contains n documents out of $(n^2 - n)/2$ XTE files with two documents respectively. The creation of a 4-document XTE file for example requires $(4^2 - 4)/2 = 6$ two-document files to be given on the command line where for every two documents A and B there must exist exactly one properly interlinked two-document file which contains these two documents. `MergeBooks` [*-v*] *-m Book1.xte .. Bookn.xte NewBook.xte*

In the second operation mode, `MergeBooks` does not create any links at all. It just collects the n documents and their linking information from the different input files and assembles them in the output file. Afterwards, every element in every document will contain the information about how it is linked to each of the other $n - 1$ documents.

6.4.2 Encrypting XTE files

As already described in section 3.3.2, LanguageExplorer supports the encryption of its content. There are several command line tools available which can be used to create keys, passwords and to finally encrypt the files. For a better understanding of this section it may be helpful to refer to figure 3.10 on page 58 which graphically summarizes the LanguageExplorer encryption schema.

The first program which is named `GenerateDESKey` can be used to generate a DES key. The first, mandatory argument specifies the file in which the key should be stored into.

`GenerateDESKey` *Key-File* [Algorithm = *DES* [Provider = *SUN*]]

The optional second and third argument may be used to specify the algorithm name which is used to create the key and the provider name of the employed cryptographic engine.

The second utility which is called `GeneratePBEDESKey` can be used to encrypt the key file which has been created in the first step with the help of a user-supplied password.

`GeneratePBEDESKey` *Key-File Enc-File Password* [Algorithm = *PBEandDES* [Provider = *SUN*]]

The first argument specifies the name of a file which contains a previously generated key. The second argument specifies the name of the file which should be used for the encrypted key and the last mandatory argument gives the password which should be used for the encryption. By using the two optional arguments it is also possible to change the employed algorithm or cryptographic engine.

Finally, the `EncryptFile` command can be used to encrypt an XTE file with a given key. The first argument specifies the source XTE file while the second argument denotes the name of the encrypted file which will be created. The third argument specifies the name of file which contains a key previously generated with `GenerateDESKey`

`EncryptFile` *Input-File Output-File Key-File* [Algorithm = *DESede* [Provider = *SUN*]]

Again, the optional arguments can be used to specify an alternative encryption algorithm or cryptographic engine provider. Notice that these values have to be recorded in the Manifest of the final leb file as described in section 3.3.1 if they are changed.

Chapter 7

Summary and outlook

This work has presented an extensible framework for the processing and presentation of multi-modal, parallel text corpora. XTE, a simple but powerful XML standoff annotation scheme has been developed and realized as a DTD and as an XML Schema. XTE is especially suited for the encoding of multiple, overlapping hierarchies in multi-modal documents and for the cross linking of the elements of these encodings across several documents. As such, it is especially well suited for the creation of electronic synopses.

Together with XTE, sophisticated editor and browser applications have been developed which allow the comfortable creation and presentation of XTE encoded documents. However, LanguageExplorer, the browser component and LanguageAnalyzer, the editor component are not monolithic, completed applications. Because they are both build around a flexible software framework they can be easily customized and extended. In the same way in which XTE can be extended by new encodings, the two applications are extendable by new components that can handle new encoding elements in an optimal way. Additionally, it is also possible to plug in arbitrary other tools into the system which operate on the textual content as well as on the different encodings.

This combination of a classical textual synopsis with the supplementary options of dictionaries, encyclopedias, multi-media extensions and powerful tools opens a wide area of applicability ranging from text analysis and language learning to the creation of critical editions and electronic publishing.

As a prove of concept, several multilingual editions of fiction (e.g. "The Metamorphosis", by F. Kafka in German, English and Russian) non-fiction (e.g. "The universal declaration of human rights" in English, Japanese, Yiddish and Greek) and historical texts ("Der Sprachkampf in Siebenbürgen", by St. L. Roth as facsimile and transcription) have been prepared and combined with dictionaries and other tools. LanguageExplorer, which is available as a ready to run application for Windows, Linux and MacOS X, has qualified for the finals of the famous "Multimedia Transfer" contest 2004 in Karlsruhe/Germany [MM04] and finally placed in the top ten there.

7.1 Outlook

Although the system presented in this work is quite mature, there always remains place for improvements. One of the main areas of extension is of course the creation of new tools and plugins. Currently we are developing for example a tool that displays the semantic neighborhood of a given word in a text corpus, that is the words which most often occur in a fixed distance around the given word [Her]. The results will be displayed as a graph-like structure in the lower extension area as shown in figure 7.1. The graph is navigable, such

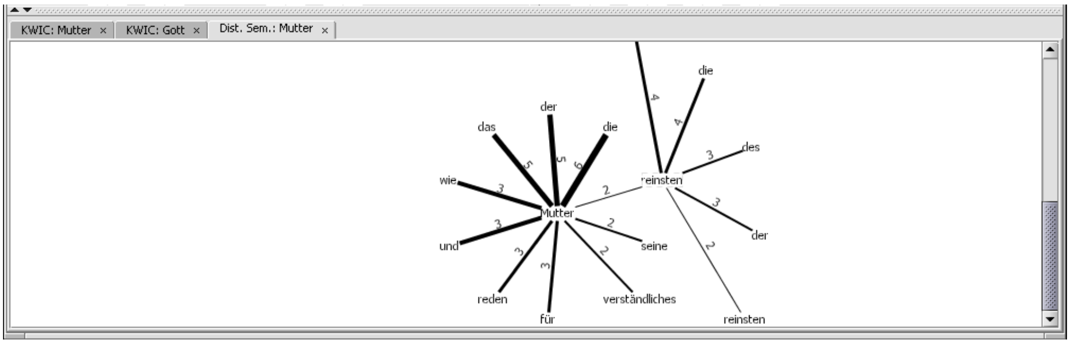

Figure 7.1: A prototype of a plug-in that displays the semantic neighborhood of a word. The left part of the graph has been created by clicking on the word "Mutter" in a text window of LanguageExplorer. The right part has been created by clicking on the word "reinsten" in the graph. It displays the neighborhood of "reinsten" in the same text document.

that clicking on a word in the graph will recursively reveal its semantic context.

For the improvement of such a kind of tools, but also for more accurate dictionary and encyclopedia look ups, it would be highly desirable to incorporate linguistic and morphologic libraries like for example the WMTrans libraries from Canoo [Canoo] into the system. They could also help to improve the automatic alignment process of parallel texts, which is currently based on structural and statistical information only.

Besides the many tools and plugins that may be desirable, it could be also interesting to create bigger corpora of aligned, multilingual texts. In order to avoid copyright problems it would be possible for example to use works of fictions whose authors are dead already more than 70 years, because these texts are usually copyright free in most countries. There already exist numerous such works in electronic from, for example from the project Gutenberg [Gutb]. With our tools they could be easily aligned, augmented with supplementary information and published electronically.

Another project that could be rewarding is the reimplementation of the whole system on top of an existing application platform like for example NetBeans [BGGSW] or Eclipse [SAFKKC]. These platforms offer a lot of common functionality like user interface management, configuration management, wizard frameworks, abstract storage management which unifies the data access to local and remote files, version control systems and unified database access. Because such a big refactoring and reimplementation would require quite a lot of resources it seems to be feasible only within the scope of a new, big project.

7.2 Related work

Because the system presented in this thesis potentially covers such a wide range of application areas, it is hard to compare it with other projects. In this section we will discuss other systems that can be used to achieve results that are at least in part comparable with the ones provided by our system.

7.2.1 Synopses and e-books

Synopses are already in use for a very long time. The oldest known synopsis is the famous Rosetta stone shown in figure 1.1 on page 2. There exist printed synopses of the gospels, which are as old as the first printed books. Today, synopses which show parallel versions of the gospels in Hebrew, Greek, Latin and other translations of contemporary languages are a common tool for every theologian (see [Aland] and [PeWiKr] for two examples of modern, printed synopses).

But synopses are not only used in theology, also jurists use synopses to highlight the changes between different versions of laws. In the European Community for example, all the laws and regulations have to bee translated in up to 20 different languages and the United Nations have to make their resolutions available in even more languages. These are all potential application areas that could be successfully covered by synopses.

Globalization and the opportunity of a higher education have also led to a growing interest in language learning which in turn resulted in a growing market for bilingual editions, that is books which show both, the original and the translated version of a text in parallel. A query for "bilingual editions" at the online book store Amazon for example returned more than 10.000 hits.

Despite this apparent interest in synopses and multilingual editions, there seem to be no general tool support for the creation and publication of such works. One system known to the author that directly supports the creation of synopses is TUSTEP, the "Tübinger System of Text-processing Programs". One of the highlights of this system, beneath the production of high-quality postscript output, is the fact that it supports a lot of ancient languages, which is essential for many historical and text-critical editions and not widely supported by other systems. However, TUSTEP is more or less an authoring tool comparable with LanguageAnalyzer, it has no browser and viewer component, which can be used by an end user to work with the created editions.

Another ambitious system for the creation of critical editions, which also supports synopses is CTE, the Classical Text Editor [CTE]. CTE is a windows only application. It supports the Unicode standard and can produce HTML, postscript and TEI output. One of the specialties of CTE is its ability to handle an arbitrary number of apparatus. CTE is a specialized word-processor however which does not support the integration of tools and is not extendable by the user.

Today more and more e-books (electronic books), that is digital versions of printed books, especially digital versions of ancient books, appear on the market and on the web. A prominent example for this process is for example the digital version of the " Arden Shakespeare" edition [Arden] which not only contains the complete works of Shakespeare in a searchable text database combined with a lot of additional materials but also links the text to the facsimile pictures of the first Quarto and Folio editions which have been published around 1600. Another example is a complete version of the fourth edition of the German encyclopedia "Meyers Konversationslexikon" which was published in Leipzig in the years 1888 and 1889. The more than 16000 pages of the 16 volumes have been scanned and processed by an optical character recognition (OCR) software. The extracted text, which is linked to the corresponding facsimile pages can be searched and browsed on-line [Meyers].

The problem with these editions is that they either use proprietary software and data formats as in the first of the two examples above, or they use simple web interfaces based on HTML as in the second case, which unnecessarily reduces their helpfulness. The system presented in this thesis tries to fill this gap.

Another interesting system from this category is the NOVeLLA e-book reader described in [HSJDNB]. It is implemented in Java, supports the Open Ebook document structure [OeB] and has support for an aural user interface, text to speech output and audio-annotations. This system, as well as the well-known e-book readers from Adobe and Microsoft is a pure software solutions, which run on every computer and do not need specialized hardware. Although reading a book on the computer is not very comfortable today, we believe that the advances in computer technology, especially in the area of miniaturization, display resolution and battery power will finally boost the e-book market.

7.2.2 Natural language processing systems

In the last decade one of the fastest growing fields in the area of information technology is the sector of natural language processing (NLP). NLP is a subfield of artificial intelligence and linguistics and studies areas such as speech recognition, machine translation, question answering and information retrieval and extraction. Many commercial and free tools have been developed to support the work and research in this area and some of them are comparable with LanguageAnalyzer, the editor component of our application framework.

One of the most prominent and most mature tools from this category is certainly GATE, the General Architecture for Text Engineering [GATE] from the NLP group of the University of Sheffield. It is a multi platform framework for natural language engineering (NLE) written completely in Java with many built-in NLE components and tools for tagging, information extraction and retrieval, summarization and ontology editing to name just a few of them. It supports arbitrary, multilingual text resources and processes and exports data in many standard XML formats.

Another tool, which has architectural similarities with our system is the MATE workbench [KIMMGK], an annotation tool for XML encoded speech corpora. Also written entirely in Java, it is primarily designed to annotate and align parallel speech and text corpora. It can handle arbitrary XML annotation schemes (even non-hierarchical ones by using the concept of standoff annotation described in [ThMcK]) through configurable editors and display formats and offers an extensible architecture for third-party annotation tools. As noted in [MueStr], especially the concept of the customizable display objects for the different annotation elements, which is realized by a stylesheet mechanism may cause serious performance problems. MMAX [MueStr], another tool for the annotation of multi-modal corpora which uses an annotation scheme similar to the one used in MATE, is a system which pretends to address this problems.

Translation corpora

In this section we will present some tools, which can be used to create and process translation corpora, that is multilingual, parallel text corpora. Such corpora can be used for a wide variety of different applications ranging from the research of linguistic phenomena and the extraction of data for machine translation and lexicography to the application in foreign language learning and translator training.

In [HoJo] a so-called "Translation Corpus Aligner", that is a program which automatically aligns a text that is available in two different languages is described. Despite the well-known statistical and structural approaches [Che93, Chu93, Mel97, SiPl96], the paper describes how anchor words, i.e. words that are reasonably frequent in the two languages in question and have straightforward equivalents in both languages, can be used to improve the alignment.

While the before mentioned translation corpus aligner only produces an XML output of the two aligned texts, Ebeling [Ebel] describes an interactive browser for parallel texts which is called TCE (for Translation Corpus Explorer). It takes an already aligned text corpus in a TEI format and stores it in an internal database, which can be used subsequently to search and browse the texts. Olsson and Borin describe a web-based system for exploring translation equivalents on word and sentence level in a multilingual, parallel corpora in [OlBo]. They developed a query and visualisation tool for corresponding entries in a corpus with two aligned text versions that has a HTML- and a Java-Applet-based front end.

More information and references on parallel, multilingual text corpora research and processing can be found in [JoOk, Ver].

7.2.3 Related standards

Our system and its goals are also related to some existing standards and ongoing projects. There is for example the ambitious HyTime standard [HyTime] which pretends to be able to "link everything with everything", i.e. to interconnect any kind of media and specify its intended placement in space and time. In [DeRoDu] the authors state that among others HyTime could be used for:

> "Managing documents that are studied and discussed in fine detail, such as Biblical, Classical, legal or medical texts. Such documents may exist in many editions or translations, as well as variant manuscript or print versions, which can be viewed in parallel, compared, and searched as needed".

This is exactly what we want to achieve with our system. The problem with the HyTime standard is that it is overall complex and even to a greater extent than this is the case with SGML, there are no tools or applications available which support the standard. This is however crucial for a standard like HyTime, which is a so called "enabling standard", that is an abstract standard which defines how to address, link, align, and synchronize hyper-media documents, but no concrete encoding schemes or element structures for such documents. Nevertheless it is interesting and highly instructive to see how the problems are solved in HyTime. After all, HyTime strongly influenced the XLink standard which tries to extend the linking functionality of XML and which is partially used in XTE (see 2.4.1).

One application of HyTime is the so-called Topic Maps [TopMa] as specified in the ISO standard 13250. Topic Maps are an effort to establish a standard way for the specification of semantic relations between information fragments, where these smallest parts of information are called topics in this context. Topic Maps are built on SGML and HyTime. They use SGML as a data exchange format and HyTime as a means of creating links and associations between the different elements of the standard. XTM, which stands for XML Topic Maps [XTM] is an attempt to port the Topic Maps standard to XML.

A similar standard defined by the W3C consortium is the Resource Description Framework (RDF) [RDF]. RDF defines an XML vocabulary for the representation of information about resources on the World Wide Web. Every resource may be described by several statements where each statement is a triple consisting of a subject (the resource), a predicate and an object. As described in [WiMue], Topic Maps are a more general approach for building semantic networks, however RDF is the key technology behind the Semantic Web propagated by Tim Berners-Lee and the W3C consortium (see [BeHeLa]) and as such will probably receive a great deal of attention in the next years.

Topic Maps and RDF both can be used to build so called ontologies, that is hierarchical data structures which containing all the relevant entities and their relationships and rules within a domain. The W3C consortium also specified its own ontology language called OWL Web Ontology Language [OWL] that is based on RDF. Well-known ontologies are provided for example by the Cyc [Cyc] and the WordNet [WordNet] projects.

Although the relation of LanguageExplorer and LanguageAnalyzer to the standards mentioned in this section may be not obvious at a first glance, some interesting parallels can be found: on the one hand, our tools could be used to export the processed data in one of the above mentioned formats, on the other hand, data in the above mentioned formats and tools based on such data could be used to considerably extend the functionality of our system.

Appendix A

Constants

Predefined character blocks in Unicode 3.0	
BasicLatin	Latin-1Supplement
LatinExtended-A	LatinExtended-B
IPAExtensions	SpacingModifierLetters
CombiningDiacriticalMarks	Greek
Cyrillic	Armenian
Hebrew	Arabic
Syriac	Thaana
Devanagari	Bengali
Gurmukhi	Gujarati
Oriya	Tamil
Telugu	Kannada
Malayalam	Sinhala
Thai	Lao
Tibetan	Myanmar
Georgian	HangulJamo
Ethiopic	Cherokee
UnifiedCanadianAboriginalSyllabics	Ogham
Runic	Khmer
Mongolian	LatinExtendedAdditional
GreekExtended	GeneralPunctuation
SuperscriptsandSubscripts	CurrencySymbols
CombiningMarksforSymbols	LetterlikeSymbols
NumberForms	Arrows
MathematicalOperators	MiscellaneousTechnical
ControlPictures	OpticalCharacterRecognition
EnclosedAlphanumerics	BoxDrawing
BlockElements	GeometricShapes
MiscellaneousSymbols	Dingbats
BraillePatterns	CJKRadicalsSupplement
KangxiRadicals	IdeographicDescriptionCharacters
CJKSymbolsandPunctuation	Hiragana
Katakana	Bopomofo
HangulCompatibilityJamo	Kanbun
BopomofoExtended	EnclosedCJKLettersandMonths
CJKCompatibility	CJKUnifiedIdeographsExtensionA
CJKUnifiedIdeographs	YiSyllables
YiRadicals	HangulSyllables
HighSurrogates	HighPrivateUseSurrogates

..to be continued on the next page ➥

Predefined character blocks in Unicode 3.0	
LowSurrogates	PrivateUse
CJKCompatibilityIdeographs	AlphabeticPresentationForms
ArabicPresentationForms-A	CombiningHalfMarks
CJKCompatibilityForms	SmallFormVariants
ArabicPresentationForms-B	Specials
HalfwidthandFullwidthForms	Specials

Table A.1: LanguageExplorer supports the character block names defined in Unicode 3.0 when constructing certain regular expressions (see section 5.4.6 on page 130). Notice that these names omit the space characters which are used in the Unicode standard as word separators (e.g. "BasicLatin" is defined as "Basic Latin").

The character categories defined Unicode 3.0	
Category	**Explanation**
	Characters
`L`	Letter.
`Lu`	Uppercase letter.
`Ll`	Lowercase letter.
`Lt`	Title case letter.
`Lm`	Modifier letter.
`Lo`	Any other letter.
	Numbers
`N`	Number.
`Nd`	Decimal digit.
`Nl`	Letter number.
`No`	Any other number.
	Symbols
`S`	A symbol.
`Sm`	A mathematical symbol.
`Sc`	A currency symbol.
`Sk`	A modifier symbol.
`So`	Any other symbol.
	Punctuation marks
`P`	A punctuation mark.
`Pc`	A connector.
`Pd`	A dash.
`Ps`	An opening punctuation mark.
`Pe`	A closing punctuation mark.
`Pi`	An initial quote.
`Pf`	A final quote.
`Po`	Any other punctuation mark.
	Separators
`Z`	A separator.
`Zs`	A space separator.
`Zl`	A line separator.
`Zp`	A paragraph separator.
	Combining marks
`M`	A combining mark.
`Mn`	A nonspacing mark.
`Mc`	A spacing combining mark.
`Me`	An enclosing mark.
	Other characters
`C`	Any other characters.

..to be continued on the next page ➥

Category	Explanation
Cc	Control character.
Cf	Format character.
Cs	Surrogate character.
Co	Private use character.
Cn	Not assigned character.

Table A.2: The character categories defined Unicode 3.0. In Unicode every character is assigned a general one letter category value. Each category may be subdivided into several, non-overlapping sub-categories which can be identified by a second letter in the category name. For more information consult the Unicode standard [UNI].

Bibliography

[Abr] P. W. Abrahams. *Typographical Extensions for Programming Languages: Breaking out of the ASCII Straitjacket.* ACM SIGPLAN Notices, Vol. 28, No. 2, Feb. 1993

[AKW] A.W. Aho, B.W. Kernighan and P. J.Weinberger. *The AWK Programming Language.* Addison-Wesley, 1988

[Aland] Kurt Aland (ed.) *Synopsis Quattuor Evangeliorum* Württembergische Bibelanstalt Stuttgart, 1964

[Arden] William Shakespeare; Bate Jonathan (ed.) *Arden Shakespeare CD-ROM* Texts and sources for Shakespeare studies, Thomas Nelson and Sons Ltd., 1997

[Arm] E. Armstrong. *Encoding Source in XML - A strategig Analysis.* http://www.treelight.com/software/encodingSource.html

[Bad] G. J. Badros. *JavaML: A Markup Language for Java Source Code.* 9th Int. WWW-Conference, Amsterdam, May 2000

[BaNo] G. J. Badros and D. Notkin. *A Framework for Preprocessor-Aware C Source Code Analyses.* Software - Practice & Experience, Vol. 30, No. 8, July 2000

[Ba95] Winfried Bader, *Lehrbuch TUSTEP* Max Niemeyer Verlag, Tübingen, 1995

[BaeMa] Ronald M. Baecker, Aaron Marcus. *Human Factors and Typography for More Readable Programs.* Addison-Wesley, 1990

[BE60] R.W.Bemer, *Survey of coded character representation* Commun. ACM 3, No. 12, 639-641, 1960 Dec

[BE63] R.W.Bemer, *The American standard code for information interchange*, Datamation 9, No. 8, 32-36, 1963 Aug, and ibid 9, No. 9, 39-44, 1963 Sep

[BeHeLa] Tim Berners-Lee, James Hendler and Ora Lassila, *The Semantic Web* Scientific American, May 2001

[BGGSW] T. Boudreau, J. Glick, S. Greene, V. Spurlin, J. Woehr. *NetBeans: The Definitive Guide.* O Reilly & Associates, 2002, http://www.netbeans.org/download/books/definitive-guide/

[Boost] *The Boost Library.* http://www.boost.org

[BRJ1] Grady Booch, James Rumbaugh, Ivar Jacobson, *The Unified Modeling Language User Guide* Addison-Wesley, 1999

[BRJ2] Grady Booch, James Rumbaugh, Ivar Jacobson, *The Unified Modeling Language Reference Manual* Addison-Wesley, 1998

[Brig] Preston Briggs. *nuWeb*, http://ctan.tug.org/tex-archive/web/nuweb

[Bryan] Martin Bryan *SGML - An authors guide to the standard generalized markup language*, Addison-Wesley, 1988

[Broe] David Brownell *SAX2*, O'Reilly, 2002

[BSW] R.W.Bemer, H.J.Smith, Jr., F.A.Williams, *Design of an improved transmission/data processing code*, Commun. ACM 4, No. 5, 212-217, 225, 1961 May

[Canoo] Canoo Technology AG, Basel, Switzerland *WMTrans - Multilingual Morphology Software*, available at: http://www.canoo.com/wmtrans

[Car] David Carlisle *The longtable package*, available at: ftp://ftp.dante.de/tex-archive/help/Catalogue/entries/longtable.html

[CarSt] Robert Cartwright and Guy Steele, *Compatible Genericity with Run-time Types for the Java(tm) Programming Language*, Proc. of the 13th ACM Conf. on Object Oriented Programming, Systems and Applications, Vancouver, B.C., October 1998. http://www.cs.rice.edu/~javaplt/papers/oopsla1998.pdf

[CaWaHu] Mary Campione, Kathy Walrath, Alison Huml, et. al. *The Java Tutorial Continued: The Rest of the JDK.* Addison-Wesley, 1998

[Che93] S.F. Chen. *Aligning sentences in bilingual corpora using lexical information.* Proc. of the 31st Annual Meeting of the Association for Computational Linguistics, Columbus, Ohio, 1993 available at: http://acl.ldc.upenn.edu/P/P93/P93-1002.pdf

[Chu93] K. Church. *Char_align: A Program for Aligning Parallel Texts at the Character Level.* Proc. 31st Ann. Conf. of the Association for Computational Linguistics (ACL), Columbus, Ohio, 1993 available at: http://acl.ldc.upenn.edu/P/P93/P93-1001.pdf

[Child] Bart Childs *Literate Programming, A Practitioner's View* TUGboat, Volume 13, No. 2, 1992, http://www.literateprogramming.com/farticles.html

[ChSa] B. Childs and J. Sametinger. *Analysis of Literate Programs from the Viewpoint of Reuse.* Software - Concepts and Tools, Vol. 18, No. 2, 1997, http://www.literateprogramming.com/farticles.html

[CoRe] A. B. Coates and Z. Rendon *xmLP - a Literate Programming Tool for XML & Text.* Extreme Markup Languages, Montreal, Quebec, Canada, August 2002, http://xmlp.sourceforge.net/2002/extreme/

[CSharp] ECMA 334, ISO/IEC 23270 *C# Language Specification.* http://www.ecma-international.org/publications/standards/ecma-334.htm

[CSS] H. Lie, B. Bos. *Cascading Style Sheets.* W3C Recommendation, Dec. 1996, available at: http://www.w3.org/Style/CSS

[CTE] Stefan Hagel. *CTE: The Classical Text Editor* available at: http://www.oeaw.ac.at/kvk/cte/

[Cyc] Cycorp, Inc. *OpenCyc: The Project* available at: http://opencyc.org/

[CzEi] K. Czarnecki and U. W. Eisenecker. *Generative Programming.* Addison-Wesley, 2000

[DaSe] Stephen Davies and Stefan Seefeld. *Synopsis.* http://synopsis.sourceforge.net

[DeiCza] Andrew Deitsch and David Czarnecki *Java internationalization*, O'Reilly & Associates, 2001

[DeRoDu] Steven DeRose and David G. Durand *Making Hypermedia Work - A users's guide to HyTime* Kluwer Academic Publisher, 1994

[DES] National Institute of Standards and Technology (NIST). *Data Encryption Standard.* FIPS Publication 46-2, December 1993

[Diam] Jason Diamond. *NDoc.* http://ndoc.sourceforge.net/

[DuOD01] Patrick Durusau, Matthew B. O'Donnell *Implementing Concurrent Markup in XML* Extreme Markup Languages 2001, Montreal, Canada, Aug 2001 online at: http://www.sbl-site2.org/Extreme2001/Concur.html

[DuOD02] Patrick Durusau, Matthew B. O'Donnell *Just-In-Time-Trees (JITTs): Next Step in the Evolution of Markup?* Extreme Markup Languages 2002, Montreal, Canada, Aug 2002 online at: http://www.sbl-site2.org/Extreme2002/JITTs.html

[DocB] Norman Walsh (Editor), *The DocBook Document Type* online at: http://www.oasis-open.org/committe/docbook

[Docl] Sun Microsystems, Inc. *The Doclets API.* http://java.sun.com/j2se/javadoc/

[DOM] A. Le Hors, P. Le Hégaret, L. Wood et. al. (ed.) *Document Object Model - Level 1,2 and 3* W3C Recommendation, 1998, 2000 and 2004 available at: http://www.w3.org/DOM/DOMTR

[DrMo] by Nikos Drakos and Ross Moore. *Latex2HTML.* http://saftsack.fs.uni-bayreuth.de/~latex2ht/ or: http://ctan.tug.org/ctan/tex-archive/support/latex2html

[DSSSL] ISO/IEC 10179:1996, *DSSSL - Document Style Semantics and Specification Language.* online at: http://www.oasis-open.org/cover/dsssl.html

[dtd2xsA] Syntext, Inc Syntext dtd2xs, Ver. 1.4 available at: http://www.syntext.com

[dtd2xsB] Joerg Rieger and Ralf Schweiger dtd2xs, Ver. 1.6 available at: http://www.lumrix.de/dtd2xs/

[DuCo] Diane I. Hillmann *Using Dublin Core* Dublin Core Metadata Initiative, Apr. 2002 online at: http://dublincore.org/documents/

[Ebel] Jarle Ebeling, *The Translation Corpus Explorer: A browser for parallel texts.* In Johansson, S. and Oksefjell, S. (eds.), Corpora and Cross-linguistic Research: Theory, Method, and Case Studies. Amsterdam: Rodopi, 1998

[ELW] R. Eckstein, M. Loy and D. Wood "*Java Swing*", O'Reilly, 1998

[ECMA] European Computer Manufacturer's Association, online at: http://www.ecma.ch

[EP87] Sandra L. Emerson and Karen Paulsell, *TROFF Typsetting for for UNIX Systems*, Prentice-Hall, 1987

[Flex] Free Software Foundation *The Fast Lexical Analyzer.* http://www.gnu.org/software/flex/

[Friedl] Jeffrey E. F. Friedl *Mastering Regular Expressions*, O'Reilly and Associates, 1997

[GaSo] Jess Garms and Daniel Sommerfield, *Java Security* Wrox Press Ltd., 2001

[GATE] The Sheffield NLP group, *GATE - General Architecture for Text Engineering* The University of Sheffield, Computer Science Departement, available from: http://gate.ac.uk

[GCC] Free Software Foundation *The GNU Compiler Collection.* http://gcc.gnu.org

[GHJV] E. Gamma, R.Helm, R. Johnson and J. Vlissides *Design Patterns: Elements of Reusable Object-Oriented Software*, Reading, MA, Addison-Wesley, 1995

[Ger] D.M. German, D.D. Cowan and A. Ryman. *SGML-Lite – An SGML-based Programming Environment for Literate Programming.* ISACC, Oct. 1996, http://www.oasis-open.org/cover/germanisacc96-ps.gz

[Go81] C. F. Goldfarb, *A generalized approach to document markup* Proceedings of the ACM SIGPLAN SIGOA symposium on Text manipulation, SIGPLAN Notices, June 1981

[Go90] C. F. Goldfarb, *The SGML Handbook* Oxford University Press, 1990

[GoJoSt] J. Gosling, B. Joy and G. Steele *"Java Language Specification"* Addison-Wesley, 1996

[GJ] Johannes Gutenberg, *Die 42-zeilige lateinische Bibel* Niedersächsische Staats- und Universitätsbibliothek Göttingen, available at: http://www.gutenbergdigital.de

[GOCR] Joerg Schulenburg, *GOCR* available from: http://jocr.sourceforge.net/

[Greg] Douglas Gregor. *The BoostBook Documentation Format*, http://www.boost.org/doc/html/boostbook.html

[Gutb] Project Gutenberg, Literary Archive Foundation, Oxford, MS, USA. online at: http://www.promo.net/pg/

[Hee] Dimitri van Heesch. *Doxygen.* http://www.doxygen.org

[Heinz] Carsten Heinz *"The Listings package"*, ftp://ftp.dante.de/tex-archive/help/Catalogue/entries/listings.html

[Hend] T. D. Hendrix, J. H. Cross II, L. A. Barowski and K. S. Mathias. *Visual Support for Incremental Abstraction and Refinement in Ada95.* SIGAda Ada Letters, Vol. 18, No. 6, 1998

[Her] Hans Jörg Heringer, *Das höchste der Gefühle - Empirische Studien zur distributiven Semantik* Stauffenberg Verlag, Tübingen, 1999

[HoJo] K. Hofland and S. Johansson, *The Translation Corpus Aligner: A program for automatic alignment of parallel texts.* In Johansson, S. and Oksefjell, S. (eds.), Corpora and Cross-linguistic Research: Theory, Method, and Case Studies. Amsterdam: Rodopi, 1998

[HSJDNB] J.S. Hodas, N. Sundaresan, J. Jackson, B.L. Duncan, W.I Nissen and J. Battista. *NOVeLLA: A Multi-Modal Electronic-Book Reader With Visual and Auditory Interfaces* International Journal of Speech Technology Vol. 4, Issue: 3/4, July - October 2001, pp. 269-284 online at: http://citeseer.ist.psu.edu/416147.html

[HTML] Dave Raggett, Arnaud Le Hors, Ian Jacobs (Editors), *The HyperText Markup Language.* W3C Recommendation, Dec. 1999, available at: http://www.w3.org/MarkUp

[Huff] D. A. Huffman, *A Method for the Construction of Minimum Redundancy Codes* Proc. of the Inst. of Radio Engineers, 1952, Volume 40, Number 9

[HyTime] Charles F. Goldfarb, Steven R. Newcomb, W. Eliot Kimber, Peter J. Newcomb (eds.) *Hypermedia/Time-based Structuring Language (HyTime) - 2nd edition* ISO/IEC 10744:1997, available at: http://www.y12.doe.gov/sgml/wg8/document/1920.htm

[ICU] IBM Corporation. *ICU - International Components for Unicode* available at: http://oss.software.ibm.com/icu

[ISO] International Standards Organisation, online at: http://www.iso.ch

[ISO639] ISO *The ISO-639 two letter language codes*, available at: http://www.unicode.org/unicode/onlinedata/languages.html

[ISO3166] ISO *The ISO-3166 two letter country codes*, available at: http://www.unicode.org/unicode/onlinedata/countries.html

[Jade] James Clark, *Jade – James' DSSSL Engine* available at: http://www.jclark.com or: http://openjade.sourceforge.net

[JaBean] Graham Hamilton (Ed.) *JavaBeans* Sun Microsystems, Version 1.01-A, August 1997 available at: http://java.sun.com/beans

[JBuil] Borland Software Corporation. *Borland JBuilder.* http://www.borland.com/jbuilder

[JDB] Sun Microsystems, Inc. *The Java Bug Database*, available at: http://developer.java.sun.com/developer/bugParade

[JILT] Sun Microsystems, Inc. *Java Internationalization and Localization Toolkit 2.0*, available at: http://java.sun.com/products/jilkit

[JoOk] S. Johansson and S. Oksefjell (eds.), *Corpora and Cross-linguistic Research: Theory, Method, and Case Studies.* Amsterdam: Rodopi, 1998

[JSR14] Java Community Process - Java Specification Request 14. *Adding Generics to the Java Programming Language.* http://jcp.org/aboutJava/communityprocess/review/jsr014/index.html http://developer.java.sun.com/developer/earlyAccess/adding_generics

[Kay] Michael Kay. *XSLT Programmer's Reference* Wrox Press Ltd., Birmingham, UK, 2002 http://saxon.sourceforge.net

[Ke78] Brian Kernighan, *A TROFF Tutorial* Bell Laboratories Murray Hill, New Jersey, 1978, available at: http://citeseer.nj.nec.com/78143.html

[KhUr] A. A. Khwaja and J. E. Urban. *Syntax-Directed Editing Environments: Issues and Features.* ACM SIGAPP Symposium on Applied Computing, Indianapolis, Indiana, 1993

[KIMMGK] D. McKelvie, A. Isard, A. Mengel, M.B. Møller, M. Grosse, M. Klein. *The MATE Workbench - an annotation tool for XML coded speech corpora* Speech Communication 33 (1-2) (2001) pp 97-112. available at: http://www.iccs.informatics.ed.ac.uk/~dmck/Papers/speechcomm00.ps

[King] Brad King. *GCC-XML, the XML output extension to GCC!* http://www.gccxml.org/HTML/Index.html

[Kisel] O. Kiselyov. *SXML Specification.* ACM SIGPLAN Notices, Volume 37, Issue 6, June 2002 http://pobox.com/~oleg/ftp/Scheme/xml.html

[Knasm] M. Knasmüller. *Reverse Literate Programming.* Proc. of the 5th Software Quality Conference, Dundee, July 1996

[Kn84] Donald E. Knuth *Literate Programming* The Computer Journal, Vol. 27, No. 2, 1984

[Kn91] Donald E. Knuth, *The TeXbook* Addison-Wesley, Reading, Mass., 11. ed., 1991

[Kn91a] Donald E. Knuth *TeX: The Program* Addison-Wesley, Reading, Mass., 4. ed., 1991

[Kn92] Donald E. Knuth *Literate Programming* CSLI Lecture Notes, no. 27, 1992 or Cambridge University Press

[KnLe] Donald. E. Knuth and Silvio Levy *The CWEB System of Structured Documentation* Addison-Wesley, Reading, Mass., 1993

[Krep] Uwe Kreppel. *WebWeb.* http://www.progdoc.de/webweb/webweb.html

[Krom] John Krommes. *fWeb.* http://w3.pppl.gov/~krommes/fweb.html

[Leeu] Marc van Leeuwen. *CWebx.* http://wwwmathlabo.univ-poitiers.fr/~maavl/CWEBx/

[La86] Leslie Lamport, *LaTeX: A Document Preparation System* Addison-Wesley, Reading, Mass., 1986

[LDP] The Linux Documentation Project, online at: http://www.tldp.org

[LeZi] A. Lempel and J. Ziv *A Universal Algorithm for Sequential Data Compression* IEEE Transactions on Information Theory, Vol. 23, No. 3

[JVM] Tim Lindholm, Frank Yellin, *The Java Virtual Machine Specification.* Addison Wesley, 1999

[MacLa] Brett MacLaughlin, *Java & XML* O Reilly & Associates, 2nd. ed., 2001

[Lia] Sheng Liang *The Java Native Interface* Addison Wesley, 1999

[Lutz] Mark Lutz. *Programming Python.* O Reilly & Associates, 2nd. ed., 2001

[MathML] D. Carlisle, P. Ion, R. Miner and N. Poppelier (Editors), *Mathematical Markup Language (MathML).* W3C Recommendation, Oct. 2004, available at: http://www.w3.org/TR/MathML2

[Mel97] I. Dan Melamed, *A Portable Algorithm for Mapping Bitext Correspondence.* Proc. 35st Ann. Conf. of the Association for Computational Linguistics (ACL), Somerset, New Jersey, 1997 available at: http://acl.ldc.upenn.edu/P/P97/P97-1039.pdf

[MeyDa] N. Meyrowitz and A. van Dam. *Interactive Editing Systems: Part I and II.* Computing Surveys, Vol. 14, No. 3, Sept. 1982

[Meyer] Bertrand Meyer *Object-oriented software construction.* Prentice Hall, 2nd. ed., 1997

[Meyers] *Meyers Konversationslexikon* Bibliographisches Institut, 4th. ed., Leipzig, 1888-1889, available at: http://susi.e-technik.uni-ulm.de:8080/meyers/servlet/index

[MIF] Adobe Systems Incorporated *FrameMaker 7.0 - MIF Reference Online Manual* available at: http://partners.adobe.com/asn/framemaker/onlinemanuals.jsp

[Mitt] Frank Mittelbach *"An environment for multicolumn output"*, available at: ftp://ftp.dante.de/tex-archive/help/Catalogue/entries/multicol.html

[MM04] Universität Karlsruhe, Rechenzentrum, *Multimedia Transfer 2004* online at: http://www.mmt.uni-karlsruhe.de/transfer2004

[MoeKo] H. Mössenböck and K. Koskimies. *Active Text for Structuring and Understanding Source Code.* Software - Practice and Experience, Vol. 27, No. 7, July 1996

[MoSch] J. Morris and M. Schwartz. *The Design of a Language- Directed Editor for Block-Structured Languages.* SIGLAN/SIGOA Symp. on text manipulation, Portland, 1981

[MueStr] Christoph Müller and Michael Strube. *MMAX: A tool for the annotation of multi-modal corpora.* Proc. of the 2nd IJCAI Workshop on Knowledge and Reasoning in Practical Dialogue Systems, Seattle, Wash., USA, August 5, pp.45-50. available at: http://www.eml-research.de/english/homes/strube/downloads/ijcai01-ws.ps.gz

[MusicXML] Michael Good, *MusicXML: An Internet-Friendly Format for Sheet Music.* XML Conference & Exposition 2001, Orlando, Florida available at: http://www.idealliance.org/papers/xml2001/papers/html/03-04-05.html

[MW] *Merriam-Webster's Collegiate Dictionary* Merriam-Webster, 10. ed. 1998, available at: http://www.m-w.com

[MyBaLi] Andrew C. Myers, Joseph A. Bank, Barbara Liskov, *Parameterized Types for Java* POPL 1997, Paris, France, http://www.cs.cornell.edu/andru/slides/popl97.ps.gz

[OASIS] The Organization for the Advance of Structured Information Standards (OASIS) online at: http://www.oasis-open.org

[OASLit] The Oasis Consortium. *SGML/XML and Literate Programming.* http://www.oasis-open.org/cover/xmlLitProg.html

[OeB] The Open eBook Forum *Open eBook Publication Structure*, avaialble at: http://www.openebook.org/oebps/index.htm

[OdWa] M. Odersky and P. Wadler *Pizza into Java: Translating Theory into Practice* Proc. of the 24th ACM Symposium on Principles of Programming Languages 1997, Paris, France http://homepages.inf.ed.ac.uk/wadler/papers/pizza/pizza.ps

[OeBF] The Open eBook Forum, online at: http://www.openebook.org

[OlBo] Leif-Jöran, Olsson and Lars Borin. *A web-based tool for exploring translation equivalents on word and sentence level in multilingual parallel corpora.* Erikoiskielet ja kännösteoria - Fackspråk och översättningsteori - LSP and Theory of Translation. 20th VAKKI Symposium. 2000, Vasa 11.-13.2.2000. Publications of the Research Group for LSP and Theory of Translation at the University of Vaasa, No. 27, 2000. available at: http://svenska.gu.se/~svelb/pblctns/VAKKI00.pdf

[Os76] J. F. Ossanna, *NROFF/TROFF User s Manual* Bell Laboratories Computing Science Technical Report 54, 1976

[OWL] D. MCGuinness and F. van Harmelen(eds.) *OWL Web Ontology Language* W3C Recommendation, 10 February 2004 available at: http://www.w3.org/TR/owl-features/

[Park] Richard Parkinson, *Cracking Codes - The Rosetta Stone and Decipherment* British Museum Press, London, 1999

[PDF] Adobe Systems Incorporated *PDF Reference, Version 1.4, 3rd Ed.* Addison-Wesley, 2001 available at: http://partners.adobe.com/asn/developer/technotes/acrobatpdf.html

[PeReEx] Perl 5 *Perl Regular Expressions'*, available at: http://www.perldoc.com/perl5.6/pod/perlre.html

[Pest] Slava Pestov, *jEdit - Open Source programmer's text editor.* http://www.jedit.org

[PeWiKr] R. Pesch, U. Wilckens and R. Kratz *Synoptisches Arbeitsbuch zu den Evangelien* Benziger Verlag/Güterlsoher Verlagshaus, 1980

[Pier] P. Pierrou. *Literate Programming in XML.* Markup Technologies, Philadelphia, Pensylvania, US, Dec. 1999, http://www.literateprogramming.com/farticles.html

[PKCS5] RSA Laboratories, *PKCS #5 v2.0: Password-Based Cryptography Standard* available at:http://www.rsasecurity.com/rsalabs/pkcs/

[PS] Adobe Systems Incorporated *PostScript Language Reference Manual* Addison-Wesley, 1985 available at: http://partners.adobe.com/asn/developer/technotes/postscript.html

[Ram] Norman Ramsey *Literate Programming Simplified* IEEE Software, Sep. 1994, p. 97 http://www.eecs.harvard.edu/~nr/noweb/intro.html

[RamMar] N. Ramsey and C. Marceau *Literate Programming on a Team Project* Software - Practice & Experience, 21(7), Jul. 1991, http://www.literateprogramming.com/farticles.html

[RDF] Beckett, Brickley, Manola, Klyne, Hayes, et.al (eds.) *Resource Description Framework (RDF)* W3C Consortium available at: http://www.w3.org/RDF/

[Relax] ISO/IEC FDIS 19757-2 James Clark, MURATA Makoto (ed.) *RELAX NG Specification* online at: http://www.relaxng.org/spec-20011203.html

[ReMyDu] Allen Renear, Elli Mylonas, David Durand *Refining our Notion of What Text Really Is: The Problem of Overlapping Hierarchies* Research in Humanities Computing, Oxford University Press, 1996 available at: http://www.stg.brown.edu/resources/stg/monographs/ohco.html

[RFC2413] S. Weibel, J. Kunze, C. Lagoze, M. Wolf *Dublin Core Metadata for Resource Discovery*, RFC 2413, Sep. 1998. http://www.ietf.org/rfc/rfc2413.txt

[RFC2046] N. Freed and N. Borenstein *Multipurpose Internet Mail Extensions (MIME) Part Two: Media Types*, RFC 2046, Nov. 1996. http://www.ietf.org/rfc/rfc2046.txt

[RTF] Microsoft Corporation *Rich Text Format (RTF) Specification* available at: msdn.microsoft.com/library/en-us/dnrtfspec/html/rtfspec.asp

[Samet] J. Samtinger *DOgMA: A Tool for the Documentation & Maintenance of Software Systems.* Tech. Report, 1991, Inst. f¨ur Wirtschaftsinformatik, J. Kepler Univ., Linz, Austria

[SamPom] J. Samtinger and G. Pomberger *A Hypertext System for Literate C++ Programming.* JOOP, Vol. 4, No. 8, SIGS Publications, New York, 1992

[San] S. E. Sandø, The Software Development Foundation *CSF Specification.* http://sds.sourceforge.net

[SAFKKC] S. Shavor, J. D'Anjou, S. Fairbrother, D. Kehn, J. Kellerman, P. McCarthy *The Java Developer's Guide to Eclipse* http://www.eclipse.org

[SHA] National Institute of Standards and Technology (NIST), *Secure Hash Standard* Federal Information Processing Standards Publication 180-2, Aug. 2002 available at: http://csrc.nist.gov/publications/fips/fips180-2/fips180-2.pdf

[ShuCo] Stephan Shum and Curtis Cook *Using Literate Programming to Teach Good Programming Practices* 25th. SIGCSE Symp. on Computer Science Education, 1994, p. 66-70

[Sim] Volker Simonis *The ProgDOC Program Documentation System* http://www.progdoc.org

[Sim02] Volker Simonis *International Swinging: Making Swing Components Locale-Sensitive*, Java Solutions, "C/C++ Users Journal", Vol 20/No 8, August 2002, available at: http://www.cuj.com/documents/s=7961/cujjsup2008simonis/ sourcecode at: ftp://ftp.cuj.com/pub/2002/2008_java/simonis.zip

[Sim04] Volker Simonis *Scrolling on demand - A scrollable toolbar component*, "Java Developer Journal", Volume 9/Issue 7, July 2004 http://sys-con.com/java

[Sim03] Volker Simonis and Roland Weiss *ProgDOC - A New Program Documentation System*, LNCS 2890, Andrei Ershov 5rd. Intern. Conf. "Perspectives of System Informatics", July 9-12, 2003, Novosibirsk, Russia

[SiPl96] M. Simard and P. Plamondon. *Bilingual Sentence Alignment: Balancing Robustness and Accuracy.* In Proceedings of AMTA-96, Montréal, Canada, 1996 available at: http://www-rali.iro.umontreal.ca/Publications/spAMTA96.ps

[Szy] Clemens Szyperski *Component Software, 2.ed.* Addison-Wesley, 2002

[Simo96] C. Simonyi. *Intentional Programming - Innovation in the Legacy Age.* IFIP WG 2.1 meeting, june 4th, 1996

[Simo99] C. Simonyi. *The future is intentional.* IEEE Computer Magazine, Vol. 32, No. 5, May 1999

[Sor] D. Soroker, M. Karasick, J. Barton and D. Streeter. *Extension Mechanisms in Montana.* Proc. of the 8th Israeli Conf. on Computer Based Systems and Software Engineering, 1997

[SouNav] Red Hat, Inc. *Source Navigator.* http://sourcenav.sourceforge.net

[SpHu99] C. M. Sperberg-McQueen and Claus Huitfeldt *Concurrent Document Hierarachies in MECS and SGML* Litarary and Linguistic Computing, Vol. 14, Issue 1, 1999 available at: http://lingua.arts.klte.hu/allcach98/abst/abs47.htm

[SpHu00] C. M. Sperberg-McQueen and Claus Huitfeldt *GODDAG: A Data Structure for Overlapping Hierarchies* Principles of Digital Document Processing, München, Sep. 2000 available at: http://www.hit.uib.no/claus/goddag.html

[SperBu] C. M. Sperberg-McQueen and Lou Burnard (eds) *Guidelines for Text Encoding and Interchange.* TEI Consortium and Humanities Computing Unit, University of Oxford, 2002, ISBN 0-952-33013-X available at: http://www.tei-c.org/

[Str] Bjarne Stroustrup, *The C++ Programming Language.* Addison-Wesley, Special Edition, 2000

[TEISO] David Durand (chair) *TEI Stand-Off Markup Workgroup.* TEI Consortium, available at: http://www.tei-c.org/Activities/SO/

[TeRe] T. Teitelbaum and T. Reps. *The Cornell Program Synthesizer: A Syntax-Directed Programming Environment.* Communications of the ACM, Vol. 24, No. 9, Sept. 1981

[ThMcK] Henry S. Thompson and David McKelvie *Hyperlink semantics for standoff markup of read-only documents* Proceedings of SGML Europe '97, Barcelona, Spain, 1997 available at: http://www.ltg.ed.ac.uk/~ht/sgmleu97.html

[TopMa] Michel Biezunski, Martin Bryan, Steve Newcomb *Topic Maps - 2nd edition* ISO/IEC 13250:1999, available at: http://www.y12.doe.gov/sgml/sc34/document/0058.htm

[Trex] James Clark *TREX - Tree Regular Expressions for XML* online at: http://www.thaiopensource.com/trex/

[TU01] Universität Tübingen, Zentrum für Datenverarbeitung, *TUSTEP - Das Handbuch*, 2001 online at: http://www.uni-tuebingen.de/zdv/tustep

[U30] The Unicode Consortium *The Unicode Standard 3.0* Addison-Wesley, 2000 available at: http://www.unicode.org

[UNI] The Unicode Consortium, online at: http://www.unicode.org

[URI] T. Berners-Lee, R. Fielding, L. Masinter *RFC 2396: Uniform Resource Identifiers (URI): Generic Syntax.* IETF (Internet Engineering Task Force), 1998 available at: http://www.ietf.org/rfc/rfc2396.txt

[UnReEx] The Unicode Consortium *Unicode Regular Expression Guidelines*, Unicode Technical Report #18, http://www.unicode.org/unicode/reports/tr18

[VanWyk] Christopher J. Van Wyk *Literate Programming Column.* Communications of the ACM, Volume 33, Nr. 3, March 1990. p. 361-362

[Ver] Jean Véronis (ed.) *Parallel Text Processing* Kluwer Academic Publishers, Dordrecht, 2000

[VisAge] IBM Corporation. *Visual Age C++.* http://www-3.ibm.com/software/ad/vacpp

[VisSt] Microsoft Corporation. *Visual Studio.* http://msdn.microsoft.com/vstudio

[Walsh] Norman Walsh *Literate Programming in XML.* XML 2002, Dec. 8-13, 2002, Baltimore, USA. http://www.nwalsh.com/docs/articles/xml2002/lp/

[Walsh2] Norman Walsh *DocBook XSL Stylesheets.* http://docbook.sourceforge.net/projects/xsl

[WaMu] Norman Walsh and Leonard Muellner *DocBook: The Definitive Guide* O'Reilly & Associates, 1999, available at: http://www.docbook.org

[Wil] Ross N. Williams. *funnelWeb.* http://www.ross.net/funnelweb/

[WiMue] Richard Widhalm und Thomas Mück, *Topic Maps* Springer-Verlag, Berlin Heidelberg, 2002

[Wir77] Niklaus Wirth, *What can we do about the unnecessary diversity of notation for syntactic definitions?* Communications of the ACM, Volume 20, Issue 11, November 1977

[WirGu] N. Wirth and J. Gutknecht. *The Oberon System.* Software - Practice & Experience, 19(9), 1989, p. 857-893

[WunZoe] R. Wunderling and M. Zöckler. *DOC++.* http://www.zib.de/Visual/software/doc++/

[WordNet] Piek Vossen and Christiane Fellbaum *The Global WordNet Association* available at: http://www.globalwordnet.org/

[WWW] The World Wide Web Consortium, online at: http://www.w3.org

[XEP] RenderX, Inc. *XEP Rendering Engine.* http://www.renderx.com/FO2PDF.html

[XHTML] *The Extensible HyperText Markup Language.* W3C Recommendation, Jan. 2000, available at: http://www.w3.org/MarkUp

[XInc] Jonathan Marsh, David Orchard (Editors), *XML Inclusions (XInclude) Version 1.0* W3C Working Draft, Nov. 2003, available at: http://www.w3.org/TR/xinclude

[XLink] Steve DeRose, Eve Maler and David Orchard (Editors) *XML Linking Language (XLink)* W3C Recommendation, June. 2001, available at: http://www.w3.org/TR/xlink

[XML] T. Bray, J. Paoli, C. M. Sperberg-McQueen, E. Maler (Editors), *Extensible Markup Language.* W3C Recommendation, Oct. 2000, available at: http://www.w3.org/XML

[XML-Na] T. Bray, D. Hollander, A. Layman (Editors), *Namespaces in XML.* W3C Recommendation, Jan. 1999, available at: http://www.w3.org/TR/REC-xml-names/

[XMLSch0] David C. Fallside (Editor) *XML Schema Part 0: Primer* W3C Recommendation, May 2001, available at: http://www.w3.org/TR/xmlschema-0/

[XMLSch1] Thompson, Beech, Maloney, Mendelsohn (Editors) *XML Schema Part 1: Structures* W3C Recommendation, May 2001, available at: http://www.w3.org/TR/xmlschema-1/

[XMLSch2] Biron, Malhotra (Editors) *XML Schema Part 2: Datatypes* W3C Recommendation, May 2001, available at: http://www.w3.org/TR/xmlschema-2/

[XPath] James Clark and Steve DeRose (Editors) *XML Path Language (XPath)* W3C Recommendation, Nov. 1999, available at: http://www.w3.org/TR/xpath

[XPoint] Grosso, Maler, Marsh, Walsh (Editors), *XPointer Framework* W3C Recommendation, Mar. 2003, available at: http://www.w3.org/TR/xptr-framework/

[XSL] S. Adler, A. Berglund, J. Caruso, et. al. *Extensible Stylesheet Language (XSL)* W3C Recommendation, Oct. 2001, available at: http://www.w3.org/TR/xsl

[XSLT] James Clark (Edt.) *XSL Transformations (XSLT)* Vers. 1.0, W3C Recommendation, Nov. 1999, available at: http://www.w3.org/TR/xslt

[XTM] Steve Peppe and Graham Moore (eds.) *XML Topic Maps (XTM) 1.0* available from: http://www.topicmaps.org/xtm/index.html

[Zuk97] John Zukowski *Java AWT Reference* Addison-Wesley, 1997

[Zuk] John Zukowski *"Magic with Merlin: Scrolling tabbed panes"*, available at: http://www-106.ibm.com/developerworks/java/library/j-mer0905/

[ZuStan] John Zukowski and Scott Stanchfield *Fundamentals of JFC/Swing, Part II*, MageLang Institute, available at: http://developer.java.sun.com/developer/onlineTraining/GUI/Swing2

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Colophon

This document has been typeset with pdfLaTeX at 10pt using a modified report style which typesets the chapter and section headings with a sans serif font. Headers and footers have been created with the help of the `fancyhdr` package and URLs have been typeset with the `url` package using the standard sans serif font. Palatino has been used as base font together with AvantGarde as sans serif and LetterGothic as mono-spaced font.

The figures have been created with `xfig`, the screen-shots with `xv` and the UML class diagrams with `PoseidonCE`. The small icon graphics used in the marginalia have been created with `xpaint` and `gimp`. The resulting postscript and encapsulated postscript files have been converted to pdf with the `epstopdf` and `ghostscript`.

Except for section 4.2 where the `fancyvrb` package has been used for source code inclusion, code examples have been pretty printed and included directly from the source files using the ProgDOC program documentation system.