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Exploring Archaeological Information through an Open Hypermedia System

This paper presents the principles which guide the authors' research in creating an open learning environment in archaeology. The environment can serve as a flexible book (and notebook) where the user can systematically include personal extensions (text, images, sound) to the initially provided archaeological multimedia database.

The presented representation scheme is a specialisation of a more general knowledge representation form, guided by archaeological goals and priorities. It supports mapping from the world of archaeological objects onto the programmed microworld.

The environment is programmable; classes containing definitions of structure and behaviour act as conceptual templates which allow the definition and interconnection of all objects-instances in the implementation. The initial library of classes included in the system can be extended by the users, who can create their own worlds, to cover specific needs. Links with content and condition enforcement support the implementation of composite objects, while they preclude fundamentally unacceptable associations. Information can be explored either at the knowledge level (i.e. the conceptual definitions of the classes) or at the specific object level (i.e. information about specific instances – persons, places, artefacts, etc.).

Navigation within the representation scheme is supported by 'intelligent' viewing and accessing mechanisms within user-defined contexts. Furthermore, the structure of the system allows interfacing with programs for specialised evaluation tasks, hypotheses testing, etc.

1 Introduction

This paper presents the principles which guide the authors' research in creating an open learning environment in archaeology. The dual objective is to support free and creative exploration of information and to contribute to computer literacy, by introducing concepts of the object-oriented paradigm for the non-expert user. The focus is on supporting the exploration of information across non-predefined paths. The user can thus formulate his own conceptual model of the presented data, identify semantic relationships among information pieces, materialise the respective interconnections, extend the original environment and gain familiarity with the programming aspects of its structure.

The description in this paper covers technical issues; this infrastructure is needed to support domain specific knowledge of various archaeological areas.

1.1 Motivation

An intelligent repository of archaeological information can serve at many levels: It can help the teacher organise and present a lecture, the student compose and document an assignment, the researcher combine information of the system with personal notes, and the generally interested individual explore the historical space through an unconstrained promenade in a virtual museum. Although there are large-scale systems in that domain, such as KLEIO (Dionysiadou 1994), there is a need for software suitable for smaller domains as in school courses, tourist information or for a rapid search, i.e. for less demanding use by non-specialists, while maintaining the openness of the environment. The courses intended for archaeology students require special attention, as the objective is not solely the presentation of the course material, but the usage of the material representation as a mechanism to improve the expertise of the student on computer science principles, as the importance of computer technology in archaeological research and archiving becomes paramount.

The fundamental representational problem in this domain is to adequately reflect the actual world in a collection of data, so that someone exploring those data can re-construct, as easily as possible, a mental model of the represented actual world, suitable for his needs. We assume here that the user has the necessary background and common sense for the interpretation of such data. The problem is both a modelling and a communication issue. A representation scheme is sought, to accommodate a good part of the data handled by archaeologists, in a structured and manageable way. Information processing tools are needed to access and manipulate this data, as well as to support the user's navigation within the environment.

The representation draws on ideas from Geographic Information Systems, CAD models, object-oriented programming, databases, computer graphics and multimedia. The value of such constituents for archaeology has been recognised, from their relatively early stages (Eiteljorg 1988; Guimier-Sorbets 1990; Kvamme 1986; Reily 1991).

Hundreds of publications (Ryan 1988) prove the keen interest for computer applications in archaeology. Between the studies on the guiding principles for the construction of such environments, the most relevant for this work are those examining the conceptual modelling under principles that permit a 'hyper' exploitation of the implemented semantics (Burnard 1991).

Despite the huge work presented sofar, the everyday's technological advancement as well as the immensity of the conceptual space of archaeology, keep open the question of 'the appropriate computer environment for representing archaeological data'. A computer environment for storage and manipulation of the complex, hyperlinked and multimedia information required in an interdisciplinary approach, and easy to use in an ordinary computer such as an MPC, is now much more feasible than a few years ago.

Archaeological information management requires linking of information which exceeds the capacity of Hypercard-like environments, where a small number of 'buttons' links the presentation of related entities, but there is no semantic content of the linkage within the link. So it is not possible for the user to examine deeper relationships, to make hypotheses and to test them. The necessity of links with explicit conceptual meaning is examined here, mainly from a technical point of view, but also from the point of view of the conceptual space (Rigopoulos 1991).

For that purpose, the design principles are conceived at two levels: the first level aims to help the 'author' implement a specific conceptual space, as a universe; the second level aims to help the end user concretise the context of his work, i.e. explore the contained information, formulate personal ideas, express them as an integral part of the program and test them.

1.2 Objectives for the environment

The hypermedia environment under development, adheres to the object-oriented paradigm, with the dual aim of:

a. providing a fundamental template for the organisation of archaeological courses' material, virtual museum visits, navigation through archaeological sites etc.;
b. introducing non-computer experts to object-oriented data modelling, because they will increasingly face the need for advanced computing applications in their careers.

The environment will undergo two major development phases:

a. an initial phase performed by the author(s) who will provide the archaeological information and organise it with the assistance of an application designer;
b. a 'tailoring' phase undertaken by the teacher/tutor/museum guide, who will customise the material according to the envisaged interests and expertise of the end user.

The process of authoring and tailoring are described in Kibby *et al.* (1989).

The following fundamental requirements are taken into account in the design of this environment:

Interactivity, allowing the user to communicate with the system at the level of Predicate Calculus objects, (i.e. to obtain or to implement simple or composite objects, patterns, rules and methods of manipulation). Obviously, the existence of a graphical user interface allowing the user to exploit interactivity is taken for granted.

Concept management tools, allowing the user (researcher, tourist, learner, teacher, etc.) to include in the system any additional information or ideas, and interconnect them. Consistency and redundancy checking are also required.

Context definition tools, supporting the user's navigation over the retained information. Contexts are established with specification of constraints that result in subsets of the database material. Contexts are established dynamically and evolve with the user's interests and understanding.

Schema management tools, allowing restructuring of information with reformulation of any part of the hierarchical structure, and the redefinition of functions. Although most users are expected to be satisfied by the initial information templates (as organised by the author and tailor), some may want to modify the environment. Schema management requires an efficient monitoring mechanism to prevent the user from destroying the structure of the already existing material and to disallow conceptual discrepancies in the formulation of new abstract object and relationship templates.

2 Technical approach

2.1 Principles

The model combines principles of the hypermedia and the object-oriented paradigm, with the objective to create a flexible archaeological hypermedia environment with a rich underlying database, that can serve as an electronic book and notebook. The user should be allowed to systematically extend the initially provided environment with personal annotations (not necessarily limited to text) as well as with hyperlinks. The extensions of the original environment should be incorporated in a seamless way, enabling the user to consistently exploit them for the exploration of the new environment.

The general idea of almost any hypermedia environment, i.e. of applying a 1-to-1 mapping from the actual world onto the programmed microworld to reflect thinking has been thoroughly examined (Beeman *et al.* 1987; Jonassen

1986; Kibby *et al.* 1989). This idea is treated here within the frame of the above considerations and of archaeological goals and priorities. Archaeological concepts (more or less concrete) are implemented as computational objects, under the following directives:

a. the observed relationships among concepts in the actual world are represented as links between entities;
b. the nature of the information process applied by the program must be analogous to the one applied by the archaeologist in the actual world;
c. the actual world is always in change and thus there is a need for continuous adaptation of the program to the actual demands;
d. the user can extend the environment by adding computational objects and relationships, and lessen the environment by imposing rules restricting the space.

Essential points in that process are:

– the creation of conceptual objects as information clusters (of any type and kind of media carrying them) and their nomination;
– the interconnection of any objects with links bearing semantic information;
– the classification of objects and the possibility to reorganise that classification;
– the analysis of any object into components, which can be examined as self-standing entities.

2.2 The object-oriented data model and the fundamental schema

The object-oriented paradigm was selected as a basis for the model, because it supports encapsulated structure and behaviour of conceptual entities in their type definitions; it is therefore particularly suitable for information modelling and the understanding of its principles even for the non-expert computer user.

Classes are generative templates of instances which contain definitions of structure and behaviour; they determine the potential interconnections of all instances in the implementation. The initial library of classes provided by the model can be extended by the user.

Within the object-oriented environment, the actual world of archaeology is reflected in a semantic network, where the nodes represent specific objects (mapping more or less abstract objects or conceptions in the actual world) and their connections represent their relationships (as they are considered in the actual world). The objects may be considered as instances of some fundamental types, defined according to the semantics and considerations of archaeology. For example, the node types can be:

Person, Idea, Place, Event, Artefact, Animal, and Group,

and of their subtypes, as for example, for ‘artefact’ are ‘building’, ‘statue’, ‘container’, ‘tool’ etc. These subtypes can be further subtyped, as for example for ‘building’ are ‘temple’, ‘house’, ‘theatre’, etc. This semantic organisation of the network is the basis on which the functions and rules are defined. But it should be viewed as an example for organising these semantics and not as a rigid form to which the construction and any usage must conform.

A separate class hierarchy reflects the representation and handling of information through different media (i.e. types as ‘image’, ‘text’, ‘sound’, ‘video’, etc.).

An initial set of fundamental object types holds the basic (archaeological) type definitions. All other types are described as specialisation (subtypes) of the fundamental types and their subtypes. Of course, the openness of the environment combined with the inherent extensibility of the object-oriented data model, allows the addition of more fundamental types and/or properties when necessary.

Properties are inherited through subtyping. The selection or definition of the appropriate types is a fundamental task, recommended only for experienced users. The network organisation can change, when additional types and sub-types are defined or when the hierarchy is restructured, to more accurately reflect the user’s mental model of the domain. Extensibility of the base model is addressed in the next subsection.

The network nodes are interconnected by directed links with semantic content. The links are objects in their own right instantiated from a relatively large number of link types (human relationships, ownership, part-of, logical relationships as implication and contradiction, etc.). The content of a link is expressed as a series of properties with corresponding value (context sensitive or non context sensitive).

No knowledge of the network structure is needed for its exploration; on the contrary thorough knowledge of the class hierarchy and the network of instances is needed for successful interventions to its structure.

2.3 Using and extending the fundamental environment

The user is allowed to attach personal annotations to the fundamental environment, and to add links materialising relationships that he observes. New classes are defined when the object types originally provided to express the semantics of entities (nodes) and relationships (links) do not suffice to express the user’s concepts.

From the aspect of computer programming, it should be mentioned that most computer languages are not yet easily accessed by non expert users. However, there are many indications that programming languages will be a common expression mean in the future; nowadays children can handle deep programming meanings from very early ages, by using Logo and Logo-like environments. In addition, visual editions of programming languages make their usage much simpler and more efficient; Hypercard-like environments can be easily handled by non-experienced users.

From the modelling principles viewpoint, it should be noted that the archaeology student (as the student of any discipline) follows modelling principles that do not necessarily (nor usually) coincide with the principles of database data models. The object-oriented data model permits more free modelling. The student who wishes to reflect his mental model to the fundamental environment should consult the existing scheme and identify analogies. This understanding of the environment will allow the student to extend it, and also will gradually make him familiar with the principles of its computerised organisation.

2.4 Preserving the consistency of the extended environment

The hypermedia environment in which the user is working is not a passive repository of information. Rather, the user's extensions are integrated with the already existing information: new information pieces and annotations must be connected with already existing ones to depict the relationship of new and old information; new links will reveal relationships among existing objects.

In this evolving environment, the incorporation of incompatible associations can destroy the semantics of the network; the incorporation of logically compatible but redundant or trivial associations can rapidly make the environment intractable for any practical purpose. Hence, the extension of the environment with information provided by the user must be subject to an internal control mechanism that detects and prohibits contradictory associations and redundant information. For that purpose, the partial ordering of link types is utilised by a mechanism that compares the semantics of the new link with those of existing ones among the connected nodes, identifies links that contradict or are semantically subsumed by already existing ones and undertakes prohibiting/repairing actions. This mechanism is analysed in Gyftodimos/Spiliopoulou (1994).

The annexation of new link types can be supported by a mechanism that asks the user to place each new type inside the partially ordered set of link types and to describe its relationships to the other link types; the user thus is expected to identify the types subsumed and those subsuming the new type, as well as types that are logically incompatible with the new one.

3 Exploring the hypermedia network

3.1 Navigation, creation of new elements and exploration

Navigation within the representation scheme is the action of visiting nodes by following links (not necessarily in their direction) (Nielsen 1990). It is supported by 'intelligent' viewing and accessing mechanisms within user-defined contexts.

The software under development aims to be an open exploratory environment for the end user. Exploration can be performed by traversing links and by issuing queries; during exploration, the user may add links and nodes as necessary, being subject to the monitoring mechanism that preserves correctness.

Query processing of information organised in a database is a well-known technique from database theory. We hereafter focus on the navigational paradigm of information retrieval, as it is more widespread in hypermedia applications. We mention though that the expressiveness of a query language permitting non-procedural associative access cannot be matched by a simple navigational mechanism, so that both paradigms are necessary, especially as the user becomes more experienced and is interested in sophisticated data associations.

3.2 Navigation and disorientation

A hypermedia system can assist the learning process significantly, by keeping parts of the work which the learner would like to temporarily leave aside and recapture later. It can also assist him when he gets lost.

A problem occurring when hypermedia systems are used in an exploratory manner, is disorientation; the user does not know how and why he reached the currently visited node, or has a wrong impression about that. In a learning environment, the problem is even more acute, because the learner has not yet created in his mind all semantic relationships among the visited information pieces (Gyftodimos/Spiliopoulou 1991).

Many commercial systems assist the user in getting oriented again, by storing the traversed path; examples are the 'history of cards' in Hypercard™ and the 'footprints on maps' of the hypermedia network used in NoteCards™. However, most of those systems do not use multiple types of links and therefore do not face the possibility of many links connecting two nodes under different contexts, which is frequent in learning. Furthermore, they overlook that 'history' grows fast, thus becoming practically unusable.

The learner constructs a route in the non-sequential hypermedia network. Disorientation occurs when the learner forgets parts of this route or even the reason for visiting some nodes across it. An 'intelligent' tool is designed, which assists the user in exploring the hypermedia network,

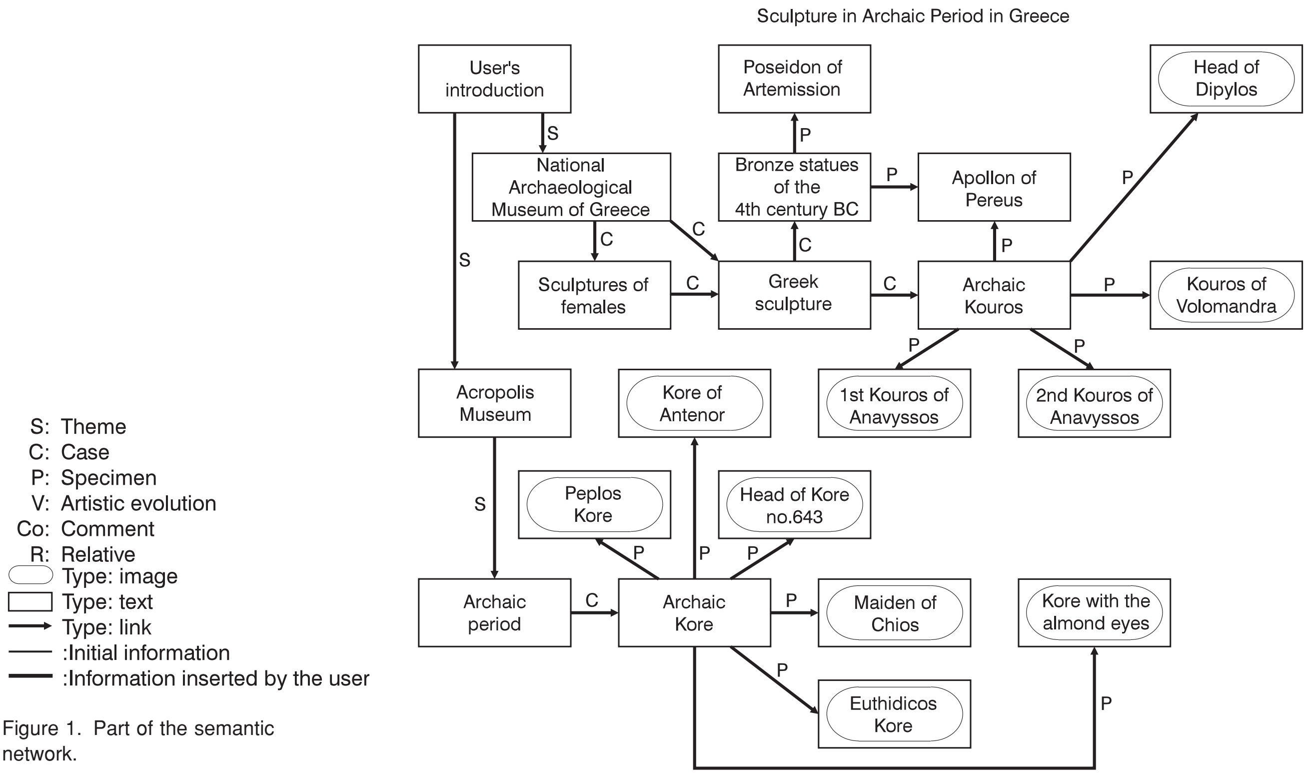

Figure 1. Part of the semantic network.

by maintaining and processing the route (nodes visited and links traversed sofar). This tool creates two lists, namely the 'history of traversed links' and the 'list of landmarks' which are visited, nodes having a particular importance for the learner.

The user explicitly declares important nodes, thus including them in the 'list of landmarks'; the computer also recognises landmarks by observing the user's moves. It must be noted, that the usage of landmarks has a direct impact on the learning process: a good selection of nodes to be characterised as landmarks by the learner both assists the learner in recapturing previously visited information and allows him to integrate the information explored sofar with already existing knowledge.

For the efficient maintenance of these lists, it is essential that their components (nodes and/or links) are periodically filtered, so that unnecessary or disrupting information is eliminated. However, the remaining objects should be adequate to help the learner recapture the route he followed during exploration of the hypermedia network and to connect new information with old knowledge. Filtering concerns the elimination of nodes or links that are no longer important for the learner's mental process. Although only the learner knows what is important for him, the tool may take the liberty to filter out information that apparently is redundant, such as the parts of the route (traversed links) which form cycles or build excursions around a landmark node. For more sophisticated filtering, both the co-operation with the user and the usage of artificial intelligence techniques is necessary. These manipulation tools are described in Gyftodimos/Spiliopoulou (1991).

'History of traversed links' and 'list of landmarks' may assist the user to:

- retrieve objects previously examined; the tool serves as an intelligent notepad, more flexible than a simple inspection of the walk;
- become reoriented whenever he gets lost; the tool maintains return tracks from long excursions;
- inspect walks of other users; this may serve the educational use of the network, by informing the teacher briefly on the progress of the pupils, or other members of the working group in the case of a collaborative study.

They can also be used by the teacher, who can predetermine important routes, indicating relationships which he wants to emphasise.

3.3 An example of exploring the network

As an example, a part of such a semantic network (a view) and the interventions of the teacher and learner are presented here. The following schema represents a part of the semantic network, linking information concerning

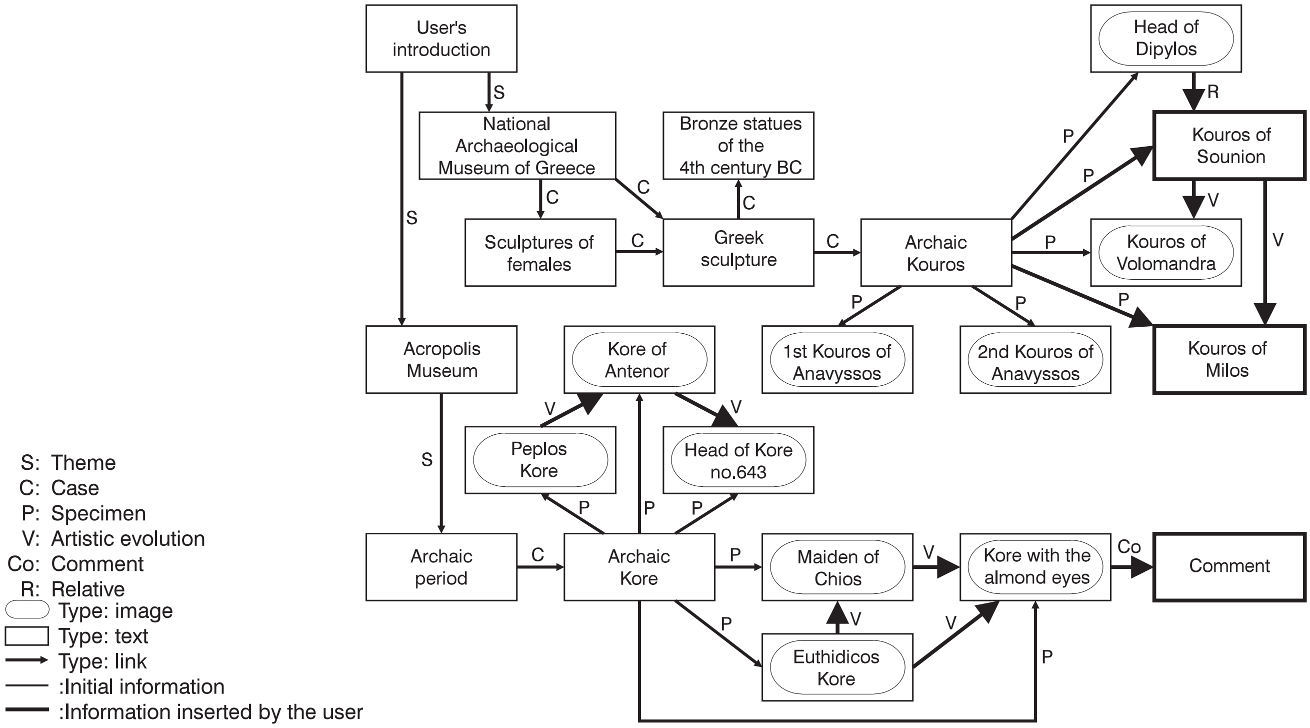

Figure 2. The tailored network.

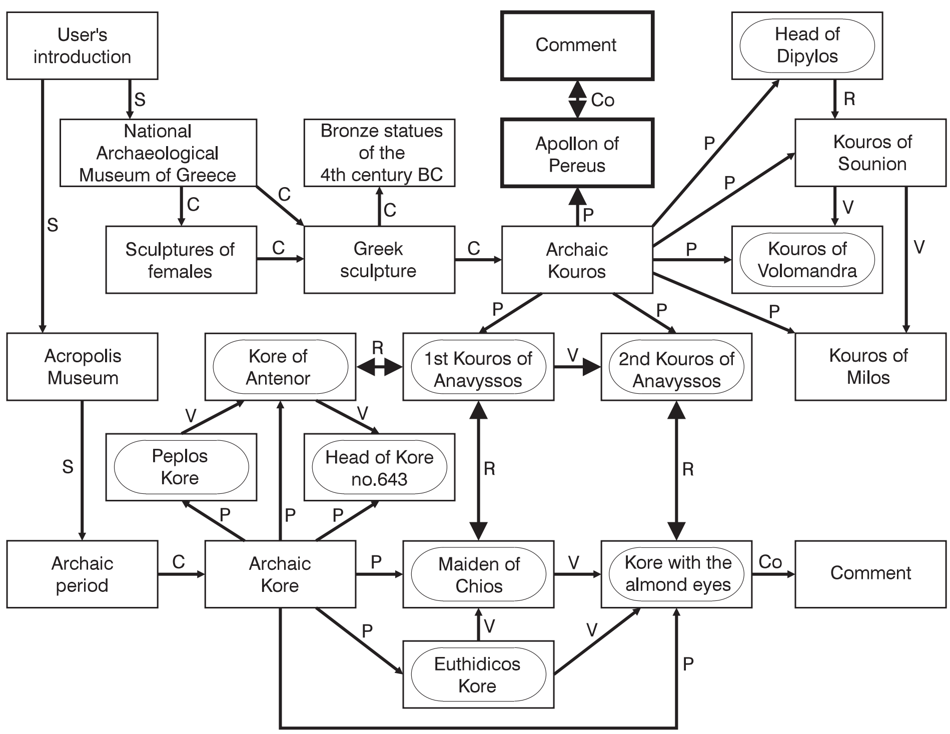

Figure 3. The network in the learning phase.

exhibits from different Greek museums (Andronikos *et al.* 1975). The user may observe analogies on the studied objects, and introduce his conclusions in the network for further study.

4 Conclusions

Completely fulfilling these specifications in a real scale environment is a rather ambitious task, because of the complexity of the domain and the consequently extended labour demands, high cost and heavy computational requirements. Currently one can realistically expect that related research can result in a prototype desk accessory for teachers, students and researchers. Such a prototype permits experimentation and evaluation of representation and manipulation issues, so that extension to real scale becomes easier when the technological advancement will allow it. The progress in the fields of object-oriented programming, databases and multimedia, and the drastic price reduction in hardware and software, set the frame for current and future research directions.

The study of historical facts, based on findings, demands the examination of a large number of relationships. In such a study, objective information is mixed with personal considerations. The computerised environment must be designed in a way allowing the expression of both, yet maintaining their distinction. The proposed hypermedia system permits this expression and it offers a number of tools evaluating the interventions and helping the navigation.

Such an environment is expected to serve as:

- A hypertext-type book, easy to use for independent study, flexible and adjustable; it may be used for tourist information. The search at this level is supposed to be performed by ‘clicking’ on predefined ‘buttons’, for observing museum exhibits or specimens in an archaeological place and reaching relative information.
- A hypertext-type book for a more advanced study, based on information from different museums, interesting for students; the search at this level may be improved by allowing the user to apply programming ideas. Programming is considered here as an expressive medium, permitting the formulation of composite meanings; thus it must be supported at least in the advanced levels of use. Of course, it requires that the user has an Computer Science background, which we may assume for all students in the near future.
- A flexible notebook, equipped with some ‘intelligence’ in order to collaborate effectively with the user for a comparative study, based on hypothetical reasoning; this requires *querying* capabilities within the knowledge space. This feature is useful for obtaining global information which can be further used as a new search space.
- A teaching book, equipped with facilities allowing the teacher to adjust the subject matter to the needs of the course, yet not obliging the student to limit his efforts in the proposed domain or to follow predefined paths. For that purpose, this environment may be essentially useful for inductive learning.

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