ARCOS - A video-computer-documentation system for the use in Archaeology and Historic Sciences

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Chapter 1: Introduction

Archaeological excavations recover large quantities of artifacts, among which ceramics present a special point of interest. The documentation and scientific analysis of those objects require many steps and are time-consuming. Only by means of electronical data processing can those large quantities of ceramics, stone artifacts and other archaeological objects be reasonably registered, analysed and curated. Additionally, we observe in archaeological research the tendency to statistically analyse an increasing number of detail information about each object in order to obtain quantifiable and more precise results. In the scope of its archaeometrical program, the Volkswagen Foundation supports the design of a system for the automatic, optical recording of ceramics shapes. The system is being developed by the 'Fraunhofer-Institut für Informations- und Datenverarbeitung (IITB)' in cooperation with the 'Büro für Archäologie und Informatik in den Kulturwissenschaften (BAIK)', Karlsruhe, West Germany.

The system is part of the ARCOS-concept (Archaeology Computer System) designed to support the archaeologist and his work. ARCOS covers most aspects of archaeological documentation, leading from the registration of objects on the excavation site via the generation of drawings up to the curation of museum stocks. In order to fulfill this purpose, video and data processing technologies are combined, summarizing, shortening and optimizing several working steps.

ARCOS: concepts and goals

ARCOS is supposed to free the archaeologist from the recording, documentation, analysis, management and publication tasks. Those numerous aspects urge to distinguish between a recording system ('System for the automatic, optical recording of ceramics), and an analysis and administration system. During conception of the basic system, special importance was granted to the generation of ceramics drawings true to scale. Catalogues containing profile as well as reconstruction drawings constitute an important basis for subsequent scientific evaluation analysis.

The 'System for the automatic, optical recording of ceramics' is a mobile computer-equipped work station, registring and processing sherds and vessels by video camera (see also GATHMANN, KAMPFFMEYER, LÜBBERT and PARTMANN (1984)). Apart from the automatic generation of a reconstruction drawing, data are stored and made accessible for subsequent evaluation.

Special requirements have to be fulfilled:

a) both processing speed and accuracy have to be compatible with traditional recording and documentation methods.

b) unskilled users must be able to operate the system reliably and error-free.

c) programs and acquired information must be stored in a reliable and permanent way.

d) the system must be mobile and adequate for field use.

e) possibility should be given to coherently process and administrate the acquired views, drawings and characteristical information.

Chapter 2: The system ARCOS 1

In the following, the different configurations are described and attention is paid to the main features of the basic configuration in respect to their functions and particularities.

Special properties of ARCOS 1

The basic configuration of ARCOS 1 ('System for the automatic, optical recording of ceramics') has the following properties:

a) real-time video picture recording and processing

b) automatic determination of measured values out of the video picture

c) mobile, dialogue-oriented graphics work station

d) automatic generation of scale publication-quality reconstruction drawings

e) external program memories (e.g. floppy disks) are superfluous due to system-integrated programs

f) menue-driven manipulation by graphics tablet

g) fault-tolerant system programs which may reliably be used by unskilled collaborators

h) pictures, graphics (contour shapes) and numerical information are coherently stored on a single storage medium

The ARCOS 1 configuration

Distinction is made between two levels: the basic configuration (ARCOS 1) and an enlarged ARCOS 2. The actual basic configuration is the 'System for the automatic, optical recording of ceramics'.

The ARCOS basic configuration (ARCOS 1a) is a system which records, measures, processes, draws and stores sherds as well as complete vessels (see figure 1). For this purpose, a special mechanism to record ceramics true to scale by video camera has been developed. Sherds of 1 cm up to vessels with a height of 45 cm can be recorded. With some restrictions, this systems is also capable of recording other objects. The ARCOS basic configuration has been designed as a mobile work station which can be readily used on excavation sites. This system has mainly been designed for data acquisition.

The ARCOS basic configuration has the following capabilities:

a) scale-conserving recording of sherd and vessel contour shapes by video camera;

b) interactive contour-processing on the screen;

c) recording of the contour shape and automatic determination of measured values out of the profile;

d) generation of the profile view as labeled, publication-quality drawing with the possibility for automatic reconstruction and user-dependant scale selection;

e) dialogue-oriented acquisition of data which are not directly available from the picture;

f) automatic printing of labels for uniform lettering of the recorded artifacts;

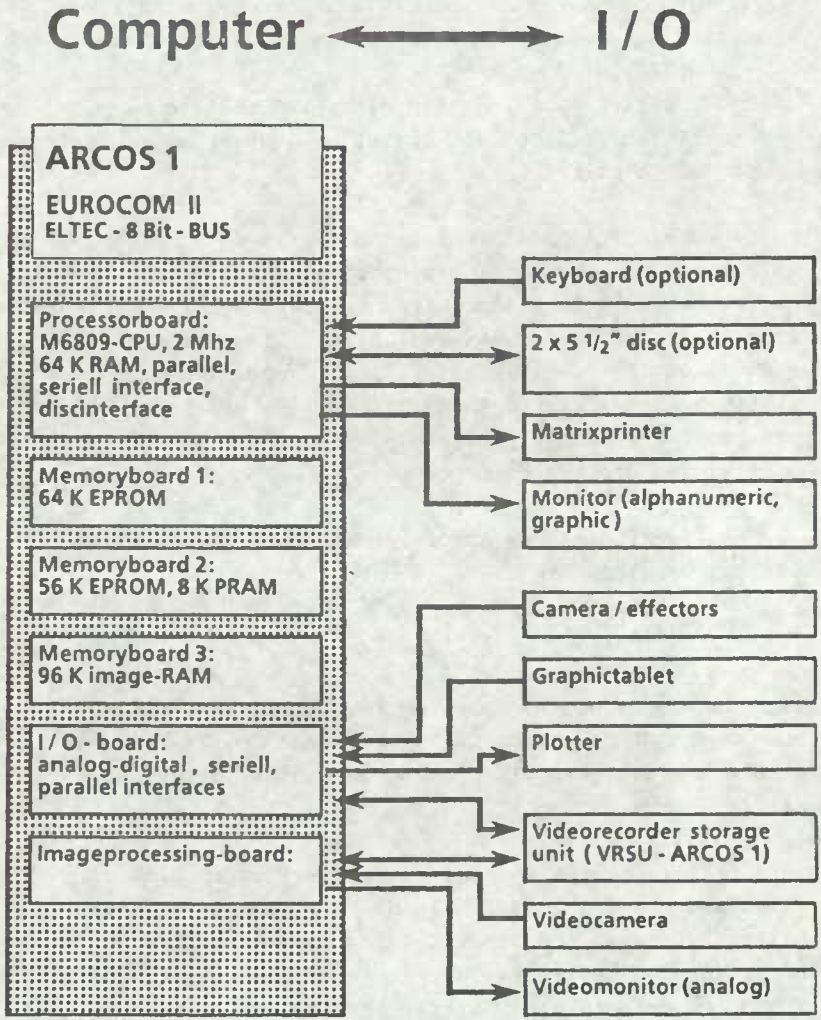

Fig. 1 ARCOS 1 - Prototype system configuration for the recording of views (object images), sherd profiles and descriptive data. The video camera films the sherd. System commands and data are enterd by the graphic tablet. The printer generates labels, lists and catalogues. The plotter produces drawings and maps. All information is stored with the video recorder storage unit.

g) storing and managing sherd view, contour shape and characteristical data on a single storage medium;

h) the acquired picture and digital information may readily be used for subsequent evaluation and curation of the objects.

During excavation and archivizing tasks, this system is able to record the total amount of ceramics and do the documentation job. All acquired information are coherently accessible for subsequent evaluation. Generation of excavation lists, catalogues, labels and drawings, statistical calculations and information management in a data base are directly possible without the data acquisition process to be repeated.

The development of the ARCOS 1 basic configuration was largely concluded in 1984.

Future configuration alternatives

By supplying another mechanism to computer and output components of the basic configuration ARCOS 1a, you can create a system capable of recording other ceramical artifacts.

This primarily applies to the survey and recording of flint and stone artifacts (arrow tips, strigils, scrapers, celts, hatchets, and so on), which have a similar importance as ceramics. They represent the major find group for certain ages (mainly the Neolithic and Paleolithic). Using this ARCOS 1b configuration, you can also process plots and photos as well as other objects. Only the programs require major alterations, as the ARCOS computer can also be connected to other measuring equipment.

During the development of the sherd measuring mechanism, the possibility to connect the optoelectrical sherd drawer 'EPROGRAPH' (designed in Berlin) to the ARCOS computer was taken into consideration, too. The EPROGRAPH probe contours the sherd without contact to the surface and issues a profile picture. Equipped with a standardized computer interface, EPROGRAPH II can communicate the measured shape data to another system for subsequent processing. This ARCOS 1c then offers similar capabilities as ARCOS 1a, but with the difference that no pictures can be stored due to this special contour acquisition method.

On a further extension level, the connection of a microscope equipped with a video camera is conceivable (ARCOS 1d). This would extend the scope of application of ARCOS from archeology to disciplines like biology, medicine or other scientific fields which require image processing combined with automatic measuring, and storage of video as well as digital information.

The ARCOS 1 work station

The work station of the basic configuration ARCOS 1 (see figures 2 and 3) consists of the mechanics table, the working table, the table for the printer and the automatic plotter, and a mobile table for the provision of ceramics. All components may be easily disassembled and reassembled for transportation convenience.

The upper level of the mechanics table contains the guide rails for the camera and the positioning platform, whereas the lower level has been designed for the encapsulated computer and the data storage medium (video recorder).

The larger one of the two orthogonally placed guide rails serves the mounting of the camera fixation. The camera is fit into a carriage and may be precisely pointed by means of an adjusting screw. At uneven intervals, the guide rail contains grooves in which the camera carriage snaps in. Upon this, a contact is closed and the exact camera position is communicated to the computer. This reveals the distance from the lens to the object, as well as the image scale to the computer, a prerequestion for pictures true to scale and the determination of measured values out of the video picture (see figure 5).

The second, shorter rail carries the positioning platform for the ceramics artifacts. This rotary platform contains concentric circles on its surface, enabling the user to place vessel sherds upside down, but with their correct angle of inclination and original vessel diameter. The guidance rail presents a lock-point at the place where the optical axis of the camera coincides with the platform's centre of rotation, respectively with the original vessel axis when dealing with sherds originating from rotation-symmetrical vessels. The position of the rotary platform is continuously monitored by an indicator, and it may be moved in both directions. This allows the full-screen displaying of very small sherds as well as preserved, larger vessels (see also the paragraph 'Camera and picture acquisition). In continuation of the small precision-rail's axis with the rotative platform, there is a floodlight which illuminates the sherd's profile in the sectional plane. A second, mobile light source is placed on the platform in order to permit an optimal illumination of the sherd's point of fracture. Both lamps may be arbitrarily and independently dimmed from the working table by rotary switches.

The working table consists of two parts which are adjustable in height and inclination. That one in the rear is equipped with a fixture containing the master switch, the power supply, the power distribution, two light intensity controllers and the camera's threshold controller. It supports a black-and-white video monitor (left) reproducing the camera picture, and a green data

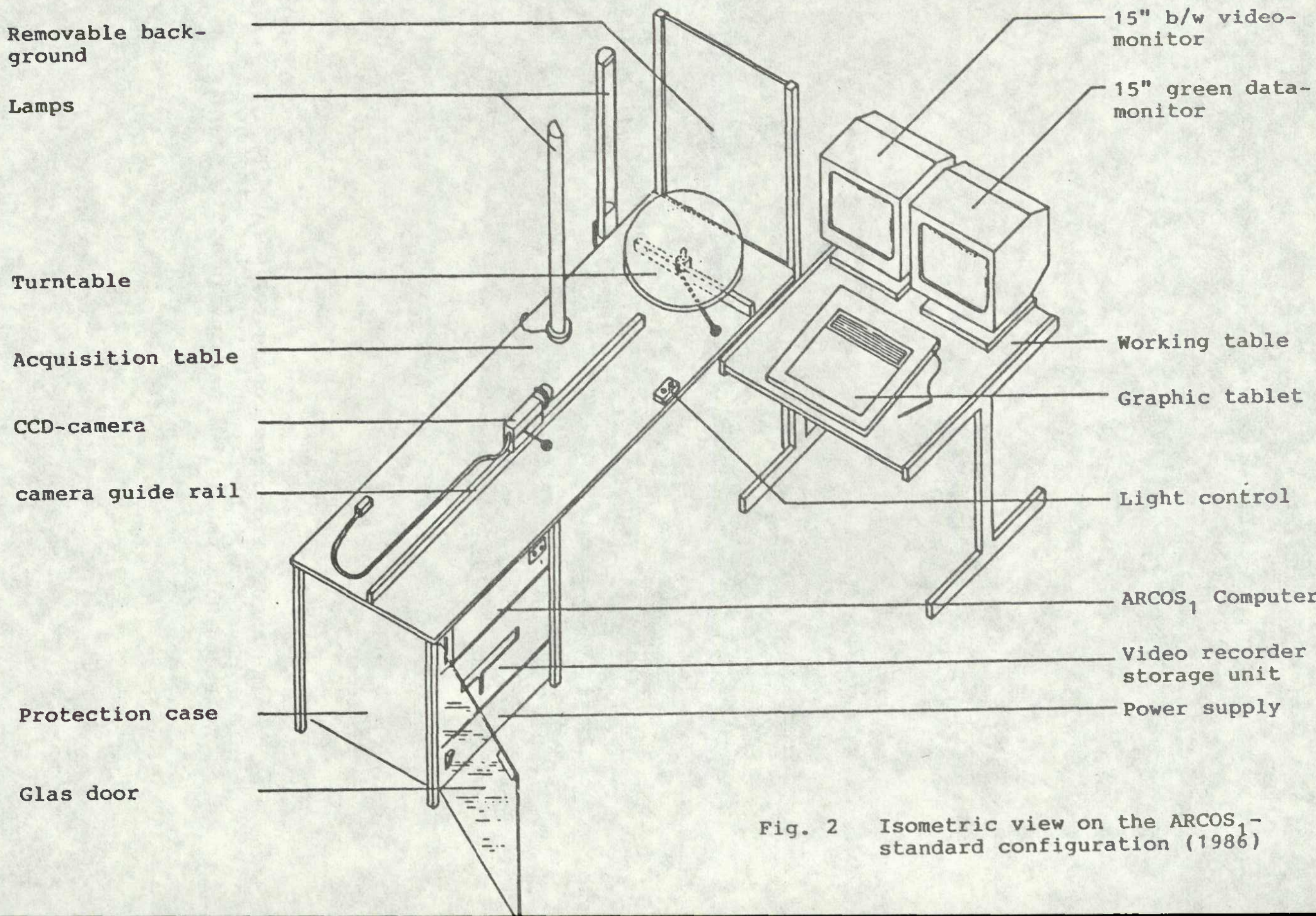

Fig. 2 Isometric view on the $ARCOS_1$-standard configuration (1986)

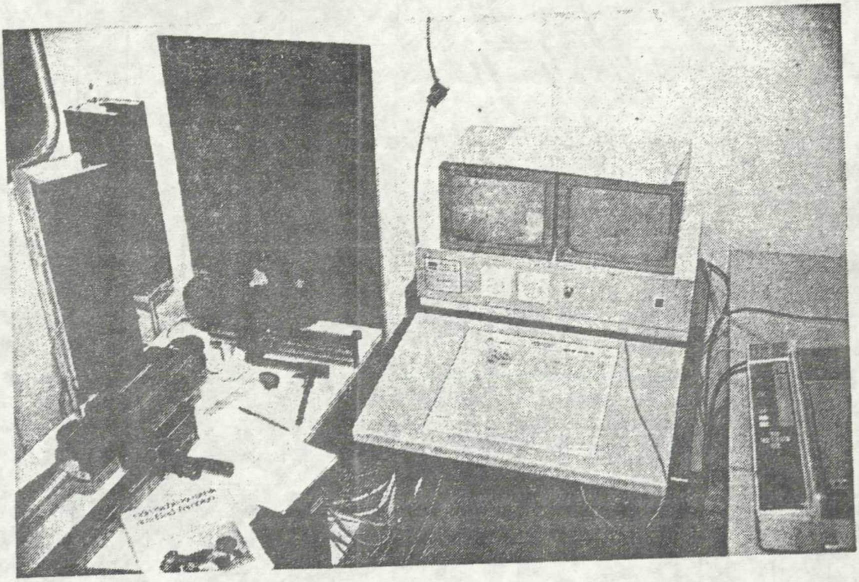

Fig. 3 The $ARCOS_1$-Prototype configuration at the excavation in the roman city of Bad Wimpfen, Baden-Württemberg, W. Germany in 1984.

display screen which enhances both the dialogue with the computer and the graphical editing of video pictures.

The graphic tablet is encastrated in the front part of the working table. An electronic pen is connected to it, being used for selecting function fields, entering numerical values and editing graphics on the screen.

The computer control and graphical editing functions as well as all other switches and control elements are easily reached from the working table. It is placed close enough to the mechanics table for the user to position the artifacts on the rotative platform and manipulate the camera without having to leave his chair.

On a mobile table, we find the printer for the generation of adhesive labels and artifact lists, and the plotter.

The mobile ceramics table with double bottom is equipped with two standardized boxes. The unprocessed objects are placed in the upper one, whereas the lower one contains the analysed artifacts, packed up in plastic bags sealed by a label.

The ARCOS 1 computing system

The basic configuration is assembled around an industrial bus system which may be upgraded by adding different modules. The Motorola 6809 CPU has an external 8-bit bus, but internally presents a 16-bit architecture. 64 kb of memory are directly adressable, expandable to up to 394 kb when using a MMU (Memory Management Unit). The system supports a 3-level 192 kb video memory, enhancing a 256 x 512 pixel resolution. Another module contains 120 kb of read-only memory with the resident programs. 8 kb of buffered memory save the system parameters (e.g. last used serial number, date of the last memory access, and so on) and the characteristics defintion (see paragraph

'Characteristics definition'). Additional I/O-modules permit reading the video picture, getting the positions of both the camera and the rotative platform, and operating the parallel and serial interfaces for keyboard, graphics tablet, printer and plotter. Connections for floppy disk drives as well as a control interface for the video recorder are also provided.

The computer is encapsulated in a splash-proof and shock-resistent case. A fan system with exchangeable filters guarantees a correct operating of the system even in a hot and dusty environment.

Originally, the operating system consisted of the not widely spread, but very comfortable FLEX OS. Being fully integrated into the system program BARCOS, it remains transparent to the user. BARCOS supplies him with menues containing all required functions (see paragraph 'The ARCOS 1 programs').

Camera and picture acquisition

The selected video camera is a high-grade measuring camera with high linearity, also utilized for robot control. It is movably mounted on a sturdy guide (see also paragraph 'work station'). The guide guarantees that the optical axis always points to the vertical axis of the rotative platform when moving the camera away from the platform. This is a prerequisite for determinating measured values out of the video picture. As the distance target-camera is well known, the video picture may be processed true to scale.

Due to the optical properties of lenses and the distortion of video pictures, problems showed up when displaying the object. A lens provides best sharpness at its centre, close to the optical axis. The angle of view and thus also the distortions are small here (see figure 4, left (A)).

The distortions radially increase from the centre to the edge, the highest inaccuracies being in the corners of a rectangular monitor screen.

Upon pointing the optical axis of the camera equipped with a normal lens to the centre of rotation and the rim of the specimen holder, more than half op the picture remains unused. Therefore, a special lens made by ZUIKO is used. This 'shift lens' moves the optical axis to a corner of the picture section. This corner is pointed to the assembly level and the centre of rotation of the specimen holder (see figure 4, right (B), and figure 5). Several advantages for picture measurement result out of this:

a) The point with the highest accuracy is situated in the corner of the picture section, in the plane of the rotative platform. High precision is urged for in this area, as rim sherds often play important a role when classifying and dating an artifact.

b) The computation of optical errors is less difficult, because only a quarter of the circle segment has to be taken care of.

c) The optical axis remains at the same place, independently of the camera position.

d) The picture size is optimally used. Furthermore, complete vessels only require the processing of one half of them, the other half being automatically supplemented. Thus the utilization of the screen resolution is doubled.

e) Interferences and unused picture space are avoided, as the surface of the specimen holder exactly is at the same height as the camera's optical axis.

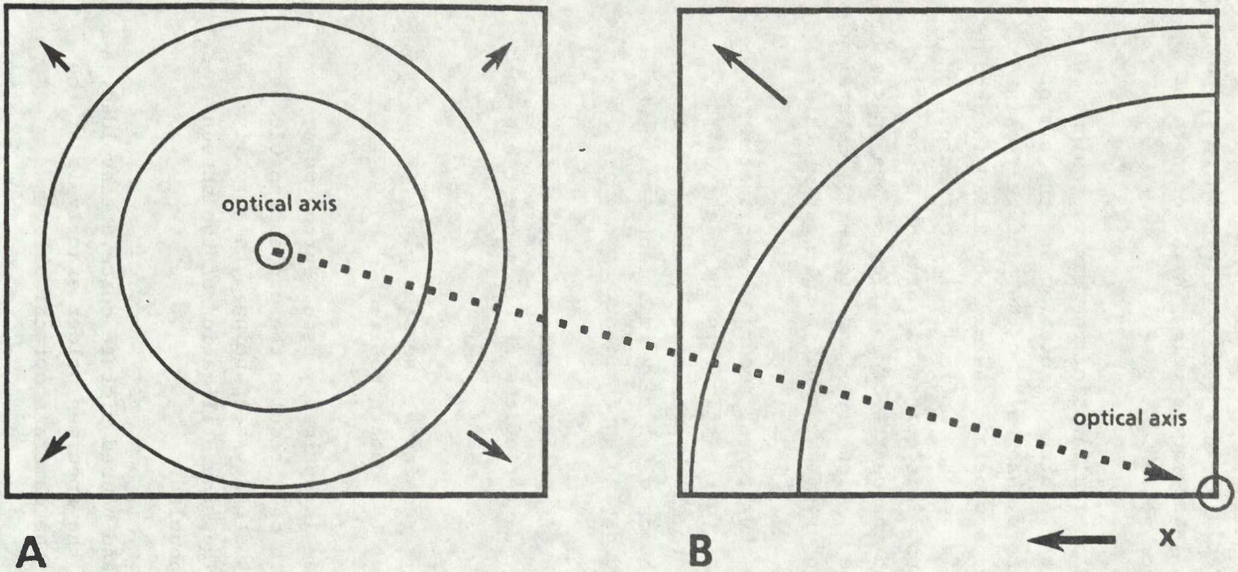

Fig. 4 $ARCOS_1$ - measuring with a shift-lens. When measuring geometric entitities in video pictures, it is especially important to us distortionless representations. Therefore ARCOS is equipped with a special shift lens. In Fig. A, the optical axis is situated in the centre of the picture, as it is common with photography and filming. Distortions increase when getting closer to the rim. By using a shift lens the optical axis is moved from the centre of the image to the right below corner. The point with the highest measuring accurancy is situated in the right corner (Fig. B), distortions now only increase in two directions and can be mathematically corrected by a simple x/y matrix, as the system knows the optical data of the lens and the position of the target. By using a high-precision measuring camera with high linearity, the errors become even smaller.

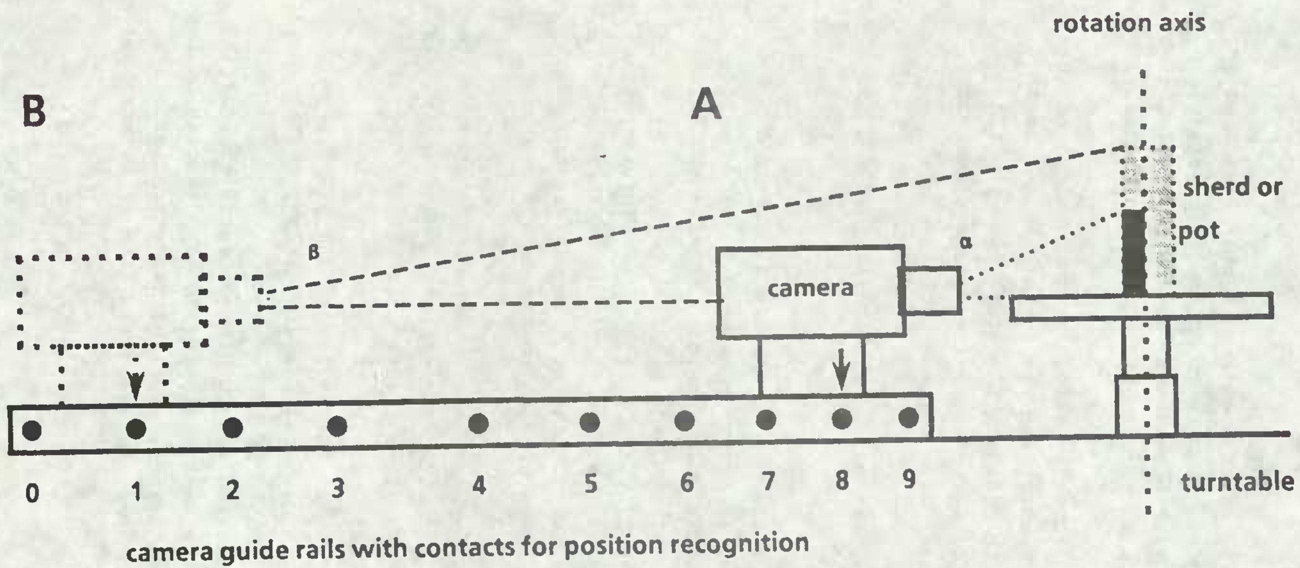

Fig. 5 ARCOS$_1$ - data acquisition with a special measuring tabe. Lens position, object distance and angle of view are especially important for measuring geometrical entities true to scale. By positionning the lens close to the object (A), vaulted solids become distorted and overhangs can falsify height measurements. Detecting elements in the camera guide always provide information about the lens position, so that the angles of view become computable and optical distortions compensable. The angle is smaller in position (B), the distortions less important, but the resolution of the computerimage is lower. Position 0 permits images of entire vessels up to the height of 45 cm. Objects about 3 cm height will occupy the whole screen when seen from position No. 9. The mechanical accurcy of the measurement unit is better than 0.5 mm.

Under ideal conditions, a precision better than 1 mm is possible with objects high up to 30 cm. This permits to automatically acquire a series of vessel and sherd data. Up to now, those measurements had to be done manually:

rim and neck diameter, overall height, height of the narrowest place under the rim (neck), height of the position with the largest diameter below the rim (bulge), side diameter below the rim, average side diameter and side diameter at the bulge.

Other measuring points may be arbitrarily defined (see figure 6).

It is especially difficult to measure the sherd's thickness, as this is severely related to the illumination. Especially thin sides of large sherds, seen from greater distance and the point of fraction being over-illuminated, are subject to errors. Test measurements with Roman pottery showed that the deviation regarding thickness amounts to 1-2 pixels. This corresponds to an error of 0.3-2.5 mm, according to the camera position.

By using reserved keywords of the definition program, the user can directly transfer the mentioned measured values into the data record. During data acquisition, the measured values are displayed on screen and stored together with the other information. This gives the possibility to print several measured values on the label.

Apart from the measured values, the integral contour is available for subsequent analysis. It may directly be used for classification purposes, or further characteristics and measured values may be extracted from it by means of a special program.

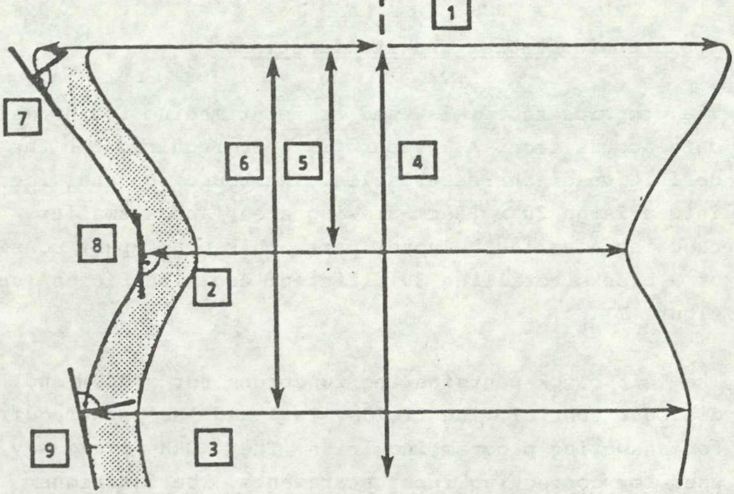

Fig. 6 ARCOS$_1$ - automatically determinated measured values. Terms into brackets are predifined keywords used in the definition program.

1 Rim diameter, measured at the highest point of the rim (RANDDM).
2 Diameter of the vessel at the narrowest position below the rim (HALSDM)
3 Diameter of the vessel at the widest position below the rim (BAUCHDM)
4 Overall height of the sherd or vessel (HOEHE)
5 Distance if the position with the narrowest diameter (2) to the orifice (HOEHE E)
6 Distance from the position with the widest diameter (3) to the orifice (HOEHE W)
7 Thickness of the sherd at the rim, measured orthogonally to the outlinecontour (DICKE R)
8 Thickness of the sherd at position (2) (DICKE H)
9 Thickness of the sherd at position (3) (DICKE B)
10 Footdiameter of the vessel when the function "Reconstruction" is not used (FUSSDM)

Further automatic measurement positions may be defined. All numerical values are taken in 1/10 mm steps.

The graphics tablet and its functions

The graphics tablet is used as input medium for normal data acquisition. A keyboard is only required for the definition of characteristics. The board is subdivided into a large 20 x 28 cm drawing area, and a smaller function area in the upper part. This upper part consists of 3 blocks totalling 30 different decision fields (see figure 7).

The left block contains the functions for system and dialogue control. The fields 'Yes' and 'No' are required for answering program inquiries. The 'KORR'-field may be used for correcting input statements. The functions 'START' and 'NEU' (NEW) lead back to the starting point of programs. 'DRUCK' (PRINT) selects the connected printer. 3 fields are left blank for further functions ('F1', 'F2', 'F3').

The second block consists of 9 fields for controlling image-processing and graphical functions (see also the paragraph about image-processing and graphics programs). The fields 'DIGIT' (digitize the picture) and the special function '*' are used for picture acquisition, whereas the fields 'L-LIN' (continuous deletion of points), 'Z-LIN' (continuous drawing of points) and 'Z-GER' (automatic insertion of horizontal structure lines) provide basic delete and supplement functions. A section of the picture may be enlarged with the 'ZOOM' function. The field 'REKON' mirrors and complements the profile view of the vessel. Possibility to fade inscriptions and graphics into the video picture is given by the 'BLEND' field.

The right block ist made up of a 10-digit numerical field, the decimal point and an 'enter' field. Different programs also use the decimal point for flow control. The somewhat larger 'enter'-field ('INPUT') completes data and command entry, and corresponds to the classic 'RETURN' key.

Fig. 7 $ARCOS_1$ - function fields on the graphic tablet (translations and explanation):

JA	= Yes
NEIN	= No
F1	= Special function 1
KORR	= Correction
START	= Begin of a program
F2	= Special function 2
DRUCK	= Printing
ENDE	= Concluding a function
F3	= Special function 3
DIGIT	= Binarize a picture
*	= Special function for image processing
REKON	= Reconstruction and mirroring the the image
Z-LIN	= Continous drawing of lines
Z-GER	= Insertation of structure lines
ZOOM	= Enlarging a selected section
L-LIN	= Continous deletion of points
L-FLA	= Deletion of enclosed areas
BLEND	= Fading the data monitor image on to the video image
1 - 0	= Numeric values
.	= Decimal point, special function
EINGABE	= Return function

Further fields may also be defined in the drawing area. Thus, the characteristics acquisition may be done by laying a questionaire onto the tablet; desired items only have to be ticked. A program determinates the position of the chosen item, and takes over the information. Thus, overlays in different foreign languages may be used without having to patch the existing programs. Error control and handling is done via monitor. Such programs for data acquisition with additional decision fields must be user-specifically developed. Normally, the characteristics acquisition is made in dialogue (see paragraph 'characteristics acquisition').

<u>The storage principle</u>

ARCOS's special feature is the ability to coherently store video pictures, processed contour shapes as well as characteristical data on the same medium

A normal video recorder is used for this purpose. Storing digitized image data on magnetic media like floppy disks is quite memory-consuming. On the video recorder, the sherd view is stored as a 'small film' (a series of semi-images).

In order to mark the artifact, the picture processing program's function field 'BLEND' allows to fade the serial number, the test name, the date and the scale into the picture. The picture's position is marked on one of the sound tracks and is also used for counting. Consecutively, the video tape contains the sherd's contour view, one or several artifact pictures and the data acquired by the characteristics acquisition program.

All three kinds of information are accessible via the same serial number. Thus, a piece of information may be looked up in the characteristical data part, while the video picture is being displayed. This function is not implemented with the current version, as the ARCOS basic configuration is mainly meant for data acquisition.

The video tape should not be used as final storage medium. Especially when frequently in search mode, the tape is expanded; when analysing captured frames, the tape surface is worn out, and the superposed tape layers magnetically affect themselves in the course of time. Therefore, the data should be transferred onto a more secure medium, e.g. an optical disc, after the acquistion part being completed.

Chapter III

The ARCOS 1 Software

All programs are integrated into the basic configuration by means of read-only-memories. They are embedded into the operating program (BARCOS), and are mostly formulated in the programming language PASCAL (ISO Standard).

The Operating Program BARCOS

The ARCOS basic configuration has been designed as turn-key-system. This means that the programs are automatically loaded and are ready to be used upon activating the system; no knowledge about operating systems and no handling of external storage media (e.g. floppy disks) is required. The program which shows up upon activating the system, and which forms the operating system environment for the user programs is called BARCOS.

First, the user is urged to enter the date. This entry, as well as all other, is done via graphics tablet. The date is stored together with the data sets, used in the annotation of the pictures and printed on the label. This permits control during subsequent evaluation, e.g. when different users have operated the system and have referred the characteristics to in different fashions.

Then, a menue showing the different programs is displayed:

(1) characteristics definition
(2) image processing
(3) image processing and characteristics acquisition
(4) characteristics acquisition
(5) video file management

The selected program is started by entering the corresponding number. Programs 2, 3 and 4 keep on running until the system is switched off.

When choosing program 3 (standard), image processing starts, followed by the generation of a drawing (facultative), and the possibility to store the curve and the sherd view. Then, characteristics acquisition is activated, the label is printed and the characteristics data are saved. The program loops to its beginning until an explicit abortion is desired. This formalized work cycle prevents steps from being forgotten, and the user is thus forced to make all entries in a steady and complete way. Program 3 consists of the programs 2 and 4 described later on. If 2 or 4 is chosen, only this program part is executed. This enables the system to be used solely for the generation of drawings or for the conventional acquisition of characteristical information.

Every program contains plausibility control features and has well-defined restart points; therefore, a system crash is only possible if the current breaks down or the system is damaged. Even then, system parameters like last serial number, definitions of characteristics, tape position and so on are saved in a special memory.

The program for defining the characteristics

It is used once before the beginning of an analysis, and is the only program which requires a keyboard as input medium, as alphanumerical entries are to be handled.

The program enables the user to define a list of characteristics or a key according to which the artifact will be analysed. This pays tribute to the fact that vessels from a Roman castellum, medieval ceramics from a latrin or neolithic sherds from a survey present different important characteristics. Information like find location, details about quadrant, depth and soil are important for documentation. Additionally, there are all the data that can't be derived from the picture, e.g. vessel type, lean material, colour, ornaments, dating and so on. Before starting the program for defining the characteristics, the user should ponder about systematically defining his characteristics and their importance (see test in Bad Wimpfen, chapter IV). Once the systematic manner of characterization has been defined, it must be used throughout the analysis, and can only in a limited way be enlarged by additional characteristics. The characteristics should be defined in a way enabling them to be effectively evaluated by electronic data processing. Too many characteristics may be as bad as too less. Unprecise subjective formulations make any data collection useless for later evaluation.

The definition program first enables the user to define a title which is automatically printed on the drawings and the labels. Second, the number of characteristics was to be entered. The processor needs this in order to create the data structure for storing the information. The characteristics' names and dimensions are then interactively asked. As for the dimension, an entry precising the number of decimals and the highest acceptable value is urged. This is used for plausibility control during data acquisition.

The program for the definition of characteristics recognizes a series of predefined characteristic names, such as 'RANDDM', 'HOEHE' (keywords for vessel diameter and height), and so on. If those are used during the definition of characteristics, no value has to be entered later on when acquiring data, but the corresponding numerical values are automatically retrieved from the picture. For example, 'RANDDM' computes the double vessel radius, and 'HOEHE' the overall object height (see figure 6). In this situation, the dimension value determines the decimal precision of the measure. Theoretically, a precision of 1/10 mm is possible, but a resolution of 0.5 mm is practically used.

Several data entry corrections are possible. Any characteristics may be added, inserted, changed or deleted. As soon as the user is of the opinion that his key is correct and complete, a hardcopy is produced. Then, the key is stored in a buffered memory. For this operation, a mechanical memory safety device has to be disabled, and again enabled after the saving. Any existing key is overwritten by the new one, and the counter reset to zero. No changes are possible now, but a new definition of characteristics may be done by keeping the original systematic manner and adding any number of new characteristics. Data acquired up to then remain valid. Label generating includes printing the title, the date and the serial number, as well as the first 10 defined characteristics together with their actual values (see figure 8). During definition of characteristics, attention should be paid to the fact that the identification information are among the 10 first characteristics. By changing the program, an exhaustive list of characteristics may be printed instead of a label.

The programs for image processing, graphics and plotting

The programs for image processing and graphics are also in non-volatile memories (EPROMs); they are all menue-driven, and have mostly been written in PASCAL. Only time- and storage-critical parts are constructed in 6809 assembler code. Each program is started and controlled via graphics tablet. Selectable subroutines and active function fields are shown in the left corner of the data monitor. The diagram displays the same abbreviations and symbols as the function fields on the graphics tablet (see figure 7). Faulty entries are rejected. The following programs and functions may be used.

Picture acquisition and image processing

By ticking the function field 'DIGIT', the camera's video picture is digitized by the processor and displayed on the data monitor; this is a real-time operation. Activating the function field '*' shifts the digitized shape contour for further processing into a second picture memory level. The original profile view remains in the first level. Changes in the rotative platform's position, illumination, camera sharpness, lens aperture or regulization of the digitizing threshold are always possible and may be traced on the monitor.

Sherds often present irregular points of fracture. In order to get a clean and complete cross-section, it is possible to superpose different profile views. By ticking the function field '*', the next profile view is entered and processed together with the preceding contour shape resident in the second level. The outer left contour is always kept. This procedure may be repeated until the monitor shows a good and complete profile.

Changing the sherd's position by turning the rotative platform enables to control whether it corresponds to the original position in the vessel. The left rim of ceramics with a centre of rotation must not shift when turning the platform. If this happens, the sherd has to be readjusted.

When, according to the user, the screen view and the original of the profile coincide, the digital picture may be processed. By ticking the 'INPUT'-field, the outer contour of the profile view is transformed into a series of line segments.

This representation already largely corresponds with ceramic profiles found in archaeological literature.

Graphics programs

The profile curve may be transformed applying several graphics programs to the resulting processed pictures. Faults and distortions due to the illumination, an uneven fracture or the superposition of different contour shapes are frequent. When very large objects are filmed from greater distance, significant details (like rim form, etc) sometimes have to be touched up, as the resolution of the picture not always renders them precisely.

The graphics programs are selected by ticking the desired function field. Generally, they are active until another function is selected, and are monitored on the display. In order to help the user, the position of the graphics pen is shown on screen by a blinking cursor. It may be moved by changing the pen's position slightly over the graphics tablet, without altering the picture. The selected function only becomes active when the pen's head touches the graphics tablet.

Deleting

The function 'L-FLA' enables to delete larger sections of the monitor picture. The area to be deleted must be encircled with the graphics pen. As soon as the surrounding curve touches itself, or has an overall length of 256 pixels, the encircled area is deleted. The function has to be reactivated for further deleting.

Continuous deleting of points, lines and surfaces is possible by using the function 'L-LIN'. It acts like an eraser and remains active until another function is activated.

Completing

The function 'Z-LIN' (continuous drawing of points) enables to draw points and lines. This way supplements may be added to the sherd, contour shapes may be touched up and erroneously deleted parts may be reassigned. A continuous comparison with the original is possible via video monitor.

Structure completing

Although the ARCOS basic configuration has not been designed for processing vessel surfaces, frequently appearing structures like grooves on the vessel, shoulders or ridges on the surface and other ones may be figured. This is especially important as such subtle details aren't often visible any longer on the profile. The function 'Z-GER' enables to interactively draw horizontal lines into the representation, the processor distinguishing between inside and outside structures. If the graphics pen selects a point of the external contour, the line originating from this point is regarded as part of the outside structure, and vice versa. The horizontal lines thus are accordingly drawn, and added only to the corresponding vessel part on later pictures (see figures 10 and 11). The line drawn last may be selected by marking it once again.

Zooming

In order to facilitate detail corrections, any section of the curve may be enlarged by the 'ZOOM' function. After selecting this function, the user is asked to mark with the graphics pen two points of the selected section. This is enlarged within one second and fills the whole screen. The section may then be processed with the functions 'L-LIN' (continuous deletion of lines), 'L-FLA' (deletion of enclosed areas) and 'Z-LIN' (continuous drawing of points). After processing, the original picture containing the changes is again displayed on the monitor.

Smoothing the profile curve

The system offers the possibility to smooth the profile with a spline function. By comparing neighbouring pixels, small irregularities originating from picture acquisition are compensated. On the other side, subtile structures and sharp edges get lost by using a spline function. The user himself must decide whether to use this utility or not, depending on the actual shape of the profile curve. Tests with Roman and medieval pottery revealed that different groups of ceramics need different spline functions with a varying smoothing factor. Therefore, differently marked functions have been implemented and are ready for use.

Fading the sherd graphics into the video picture

By using the function 'BLEND' at this moment, the curve representation may be faded over the sherd view on the video monitor. Thus, original and graphical representation may easily be compared.

Reconstructing

As soon as the processing of the curve is completed, the user may select different methods to reconstruct the vessel. If the analysed artifact is a rim sherd or a vessel standing upside-down, the function 'REKON' mirrors the representation, showing the sherd or vessel in the right position on the screen. After calling this function, it is possible to mirror the picture relatively to its vertical axis. When doing this, the mirrored right part only shows the outside contour shape. Thus, the impression of an archaeological vessel picture is created, showing a cut through profile on the left side of the vertical axis, and the outside view on the right side. The lines previously entered by using the function 'Z-GER' are displayed as inside structure on the left side, or as outside vessel structure on the right side, according to their starting-point.

If the artifact is a bottom sherd or a vessel standing in its original position on the platform, the function 'RECON' is not required. Inserting structure lines and mirroring relatively to the axis is done according to the same principle as with rim sherds. If the entire object is recorded, no mirroring is done, but the artifact is directly displayed with its outside contour shape.

Automatic generation of a reconstruction drawing

After completing the graphical processing, the user is interactively given the possibility to generate a picture. Different scales, profile hatching and representation methods may be consecutively selected. The scale may be adapted to subsequent publication dimensions. Theoretically, enlargments and reductions to any scale may be generated. The picture dimensions are only dependant on the size of the paper in the plotter, and the original scale is used, no constraints being imposed by the dimensions of the video picture. By using optical hatching, the profile is rendered in a clearer way. Many archaeological publications frequently make use of this. The hatching density in figure 8 is depending on the distance from the camera to the object. The figure has been realized with the first software version BARCOS 1.0. Two different representation methods of the sherd may be used. One of them is the total representation with mirrored outside. If the sherd is too small to permit a unequivocal reconstruction of the original vessel diameter, or if the publication space is confined, only the profile and the rim may be represented.

The picture is generated as vector graphics. It automatically includes a legend with serial number, analysis title, date and scale (see figure 8). When it is being assembled, the next processing steps may already be executed.

It is possible to generate several pictures from the same object, with different representation methods and scales. During the breaks between drawings, the pens of the plotter may be exchanged in order to adapt the line thickness to the size of the drawing. Ink pens (e.g. Rotring: ISOGRAPH, MICRONORM, and so on) may be used. The plotter can draw on single sheets, also overhead foils, as well as endless paper which is automatically supplied. If no plotter is available, the drawing can also be produced with raster graphics, if an appropriate printer is available. Nevertheless, it is of poorer quality than a plotter output, and not suited for publication.

After the generation of the drawing, the system automatically loops to the saving procedure, the characteristics acquisition, or again to the image processing program, as specified in the start program.

The characteristics acquisition program

Information not directly extractable from the picture of the sherd or the vessel are acquired in dialogue with the characteristics acquisition program. The characteristics, their dimensions and their sequence have to be previously defined in the characteristics definition program.

The following characteristics are common:

a) Identification:
Information about excavation site, coordinates, depth, circumstances, layers, strata, diverging registration, etc.

b) Documentation:
Archivation number, drawing number, restauration notes, photo number, whereabouts, etc.

c) Type:
Type, form, function, form of rim and bottom, structural characteristics, application, etc.

d) Dimensions:
They are mostly automatically determinated by the ARCOS system (e.g. length, diameter, thickness, etc) and do not need to be manually measured and entered in dialogue.

e) Technical data:
Material, handling, components, state of preservation proprieties, quality, etc.

f) Ornaments:
decorative elements, shapes, emplacement of the ornaments, style, quality, tool, manufacture, etc.

g) Dating:
Epoch, reference objects, etc.

h) Scientific analysis:
Results of ^{14}C-dating, pollen analysis etc.

This list may be arbitrarily enlarged or shortened, depending on the archaeological artifacts.

The characteristics acquisition program displays a list of the previously defined characteristics on screen. The user consequently enters the respective data via graphics tablet. As the tablet only permits numerical entries, the characteristics must be coded. Plausibility tests are executed. When an obvious error is encountered, the user is urged to enter the data once again. Corrections may be done screen-oriented. Measured values are automatically supplied, and the program branches to the next entry. After concluding data entry, a label is generated (see figure 9), and the values are saved.

The program permits to reuse the values of the previous data set; this is particularly useful when dealing with similar artifacts, as only few entries change. This saves much time.

Two status lines display information about the processing situation, e.g. date of the last data access, last serial number used, etc. Furthermore, the user is told what data to enter, when the printer is active, whether the system is in input or correction modus, or whether an erroneous entry has to be repeated.

The characteristics acquisition program may be independently used, or in conjunction with the image processing features.

The information management on video recorder

This program manages the pictures, profile curves and characteristical data, which are automatically saved onto video tape after their recording. All functions of the video recorder are automatically controlled by program. No manual attendance expect cartridge changing is required.

The video data management program fulfills the following functions:

a) determination of the last recording position for continuing an interrupted recording;

b) determination of the remaining tape capacity;

c) showing the number of recorded artifacts and their serial numbers (table of contents);

d) output of a list (catalogue) containing all the characteristics of the recorded artifacts;

e) searching profile curves according to their serial number for subsequent processing and drawing;

f) transferring the profile curves and the characteristical data to an evaluation computer (e.g. ARCOS 2, see chapter VI).

Chapter IV

ARCOS tests: Roman Terra Sigillata vessels in the museum of the Saalburg castellum

During 14 days, in spring 1984, the prototype of the ARCOS basic configuration without memorizing system was tested in the store of the Roman Saalburg castellum near Bad

Homburg. The test was supported by the manager of the Saalburg museum, Prof. Dr. D. Baatz, who did not only put the premises at disposition, but also promoted the trial with his personal experience.

The first test material consisted of Roman Terra Sigillata sherds, 2^{nd} to 3^{rd} century. Out of the store-rooms, boxes containing sherds identified by potter stamps were selected. Rim sherds, broken vessels with complete cross-sections and bottom sherds were recorded. Out of every box, all the objects processable by ARCOS (25-100 %) were recorded, automatically and manually measured, and drawn to different scales. As for sigillata with ornamented surface (relief-moulded decorations), only the profile was processed. Most of the test objects were of the Dragendorff types 18/31, 27, 31, 32, 33 and 40 (see DRAGENDORFF (1895). Figures 9 and 10 show examples of drawings. Figure 10 was already elaborated with the improved software version BARCOS 1.2. The option 'reconstruction of the right vessel side, hatching of the profile' was mostly used. The scale factor was 1:2. The computer drawings are similar to the Roman Terra Sigillata pictures to be found in literature. Up to now, the German Federal Republic has not yet elaborated uniform rules for acquiring characteristics and producing drawings of Roman ceramics (see ROTTLÄNDER (1971) and YOUNG (1980)).

The profile curves were only slightly smoothed, or not at all (see the paragraph about 'Smoothing'), in order to keep the sharp edges of Roman ceramics.

Figures 10 and 11 are striking because of the fact that the bottoms are not drawn up to the vessel axis. The algorithms used in the BARCOS versions 1.0 up to 2.1 did not give the possibility to close arcs. But a new program version now also allows the processing of bottoms, complicated rims, handles, and other applications.

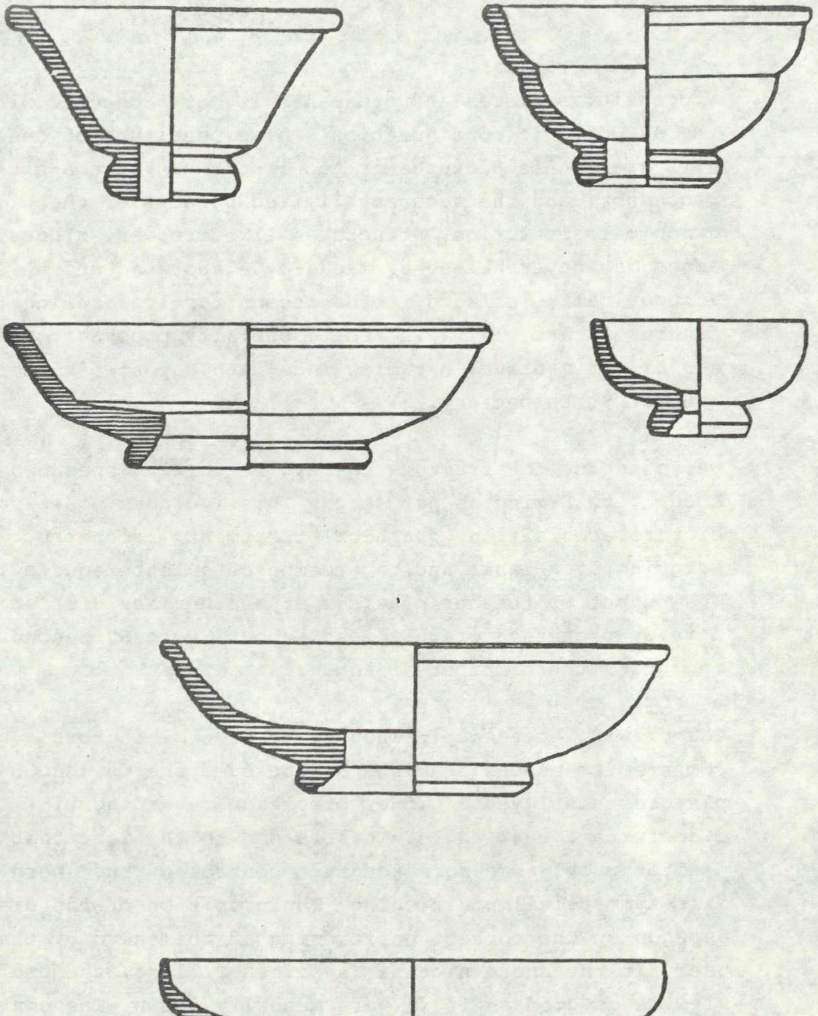

Fig. 8 ARCOS_1 - Test at the Saalburg castellum 1984. Roman sigillata, reconstructed and drawn with software version 1.0.

Processing surfaces and ornaments is not projected with the ARCOS basic configuration. The expenditure of dealing with grey-scale pictures is too important for a 8-bit processor, and the accuracy limited because of the graphical resolution. Structures like grooves, ridges, and edges may nevertheless be manually elaborated and automatically included in the reconstruction drawing (see figures 10 and 11). This tool especially prooves to be very useful for medieval ceramics made with a potter's wheel, and for Roman pottery.

Depending on the fracture shape, the working speed was about 4 to 8 minutes per sherd. This includes positioning, picture acquisition, graphical treatment, reconstruction, printing of a label and generation of a lettered drawing. The output of further drawings at another scale of an already processed graphic needs about 20 to 60 seconds, including the computer dialogue.

The drawing speed is influenced by several factors: compared to manual drawings of the same sherds, ARCOS pictures displayed a higher precision regarding rim diameter and neck angle. This is due to the fact that the monitor provides a more accurate control of the sherd's axis-symmetrical positioning. The precision of the drawing depends on the correct positioning of the sherd by the user. If the sherd picture is screen-filling, the profile view is as good as if it were manually drawn. The contact points between rim and platform and the sherd's inside contour, however, must often be touched up. This work normally lasts from 30 seconds to 6 minutes. 5 % of the sherds had to be retreated, as the picture was too inaccurate, or the touch up had changed to many original things so that the sherd view and the graphic view did not coincide any longer.

Comparing identical sherds recorded from different distances and drawn to different scales showed differences in rim diameter from 0.4 to 3 mm. The artifact's position on the turn-table had not been changed. These differences are due to the illumination and the distance object-lens. If too heavily illuminated, the edges appear emphasized and are reproduced in a thicker way on screen. The reverse phenomenon is encountered when handling very thin sherds from greater distance.

Upon recording small to medium sherds (height 1-10 cm), distortions may appear in the upper screen part. As the computer knows the position of the lens, its focal distance and the distortions, these minor height measurement errors (max. 3 mm) may be arithmetically compensated (see paragraph 'Camera and Picture Acquisition'). The maximum measurement accuracy is given by the 512 x 256 pixel resolution of the screen. Sherds not higher than 10 cm and a former vessel diameter of up to 25 cm are processed with an accuracy of 0.5 to 2.5 mm (height and diameter).

With sherds or vessels up to a height of 45 cm and a former rim diameter of 45 cm, the differences may be up to 5 mm. The theoretical accuracy of the mechanical system (linearity of the measuring system) is 0.5 mm. When taking into consideration that especially manually produced prehistoric ceramics offer differences of several centimeters in rim diameter and several millimeters in side thickness, regarding the same vessel, the accuracy of ARCOS is as good as that of manual measurements. The height of a sherd and partially also its thickness are dependent on the state of preservation and the fracture. Detectable picture acquisition errors (e.g. shadows) may be interactively compensated via monitor and are taken into account during the automatic measurement procedure.

During the following speed test with normal Roman ceramics (rim sherds of storage vessels), a maximum throughput of 94 objects per 8 hour working day was achieved, including adjustment, breaks, picture generation and manual operations.

Ceramics from the excavations in the Roman town of Bad Wimpfen

For this test, material from the pits of the first settlement phase was chosen, as it is relatively easy to survey it. These pits are cut by the foundation of the later town-wall. The finds coming from there, expecially coins and ceramics, present a 'terminus post quem' for the establishment of the Roman town-wall. Maybe the dating of the ceramics will provide information about the age and purpose of this wall, elucide the question whether it was built as protection against 'barbarian raids' or as 'representative feature of the main locality of a governmental district' (see FILGIS and PIETSCH (1985)). Up to now, no valuable answer to this question has been provided for any of the fortified settlements in the Limes region.

Computer-aided ceramics evaluation requires a systematic encoding of the different characteristics and their importance. This has already been done prior to data acquisition by means of the ARCOS definition program. The revised characteristics key of Bad Wimpfen encompasses all important information and has prooved to be adequate (see KAMPFFMEYER/PIETSCH (1985)). It bases upon a list of definitions and characteristics, as well as a collection of reference objects allowing a simplified and uniform approach. Characteristics 1 to 5 are related to the excavation origin of the artifact; 6 and 7, material and shape, roughly characterize the sherds; 8 to 10 classify the shapes according to already defined type divisions. The Terra Sigillata were first classified according to

Wimpfen2 13.12. 1984
Fund Nr. 35

1)	Inventarnummer	975	2)	Flaechennummer	788544
3)	Fundkomplex	688	4)	Schicht O.G.	2
5)	Schicht U.G.	2	6)	Ware	50
7)	Form	50	8)	DRAGENDORFF-TYP	0
9)	Leitform Wimpf.	413	10)	Wimpfenform	4121

Fig. 9 $ARCOS_1$ - automatically printed self-adhesive label with data from the excavation at Bad Wimpfen 1984.

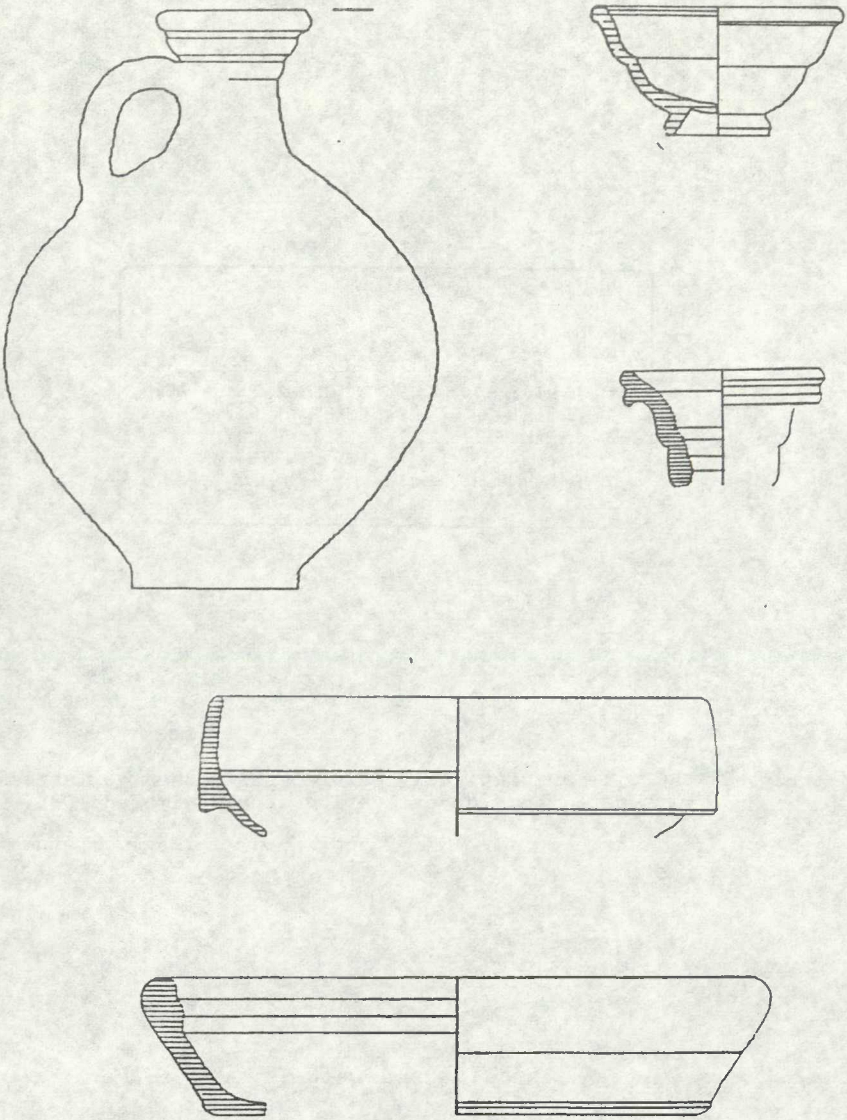

Fig. 10 $ARCOS_1$ - Drawings with inserted structure lines from the tests at the excavation at Bad Wimpfen 1984 and at the institute for the preservation of monuments in Mainz 1985 (software version 2.1).

DRAGENDORFF (1895). A further classification according to type and type variant was carried through, taking reference in the picture numbering of the publication from CZYSZ, HARTMANN, KAISER, MACKENSEN und ULBERT (1981). They exemplarily process part of the ceramics excavated in Bad Wimpfen during the years 1969-1971, and classify them in the catalogue part into 621 different shapes. Characteristics 11-15 supply the automatically acquired measured values (RANDDM, HOEHE, DICKE R, DICKE H). Then, the sherds are more precisely dealt with: surface treatment; material, density and size of the lean material; state of preservation as well as eventual ornaments and applications. The column 'Miscallaneous' at the end of the list is of non-neglectable importance, as there are always details which are not seizable by the given key systematic. Scale, date, serial number and other characteristics are automatically provided by the system.

The test first consisted of 10 a day field trial in October 1984. It was found out that the long characteristics key and the long time needed to learn to manipulate the system did not allow any performance comparison with traditional excavation documentation. The evaluation was rendered even more difficult by technical faults which prevented continuous working. However, these faults could be quickly corrected, and a second test was carried out in the office for the preservation of monuments in Stuttgart in December 1984. Here, the remainder of the Bad Wimpfen material was recorded. This test was executed by the staff of the office, without support by the system designers. Figure 11 dates back to this second test phase. The handling time became considerably shorter when getting more and more familiar with ARCOS. Manipulations were learned relatively quickly, but the user first had to get accustomed to the changed basic methodology.

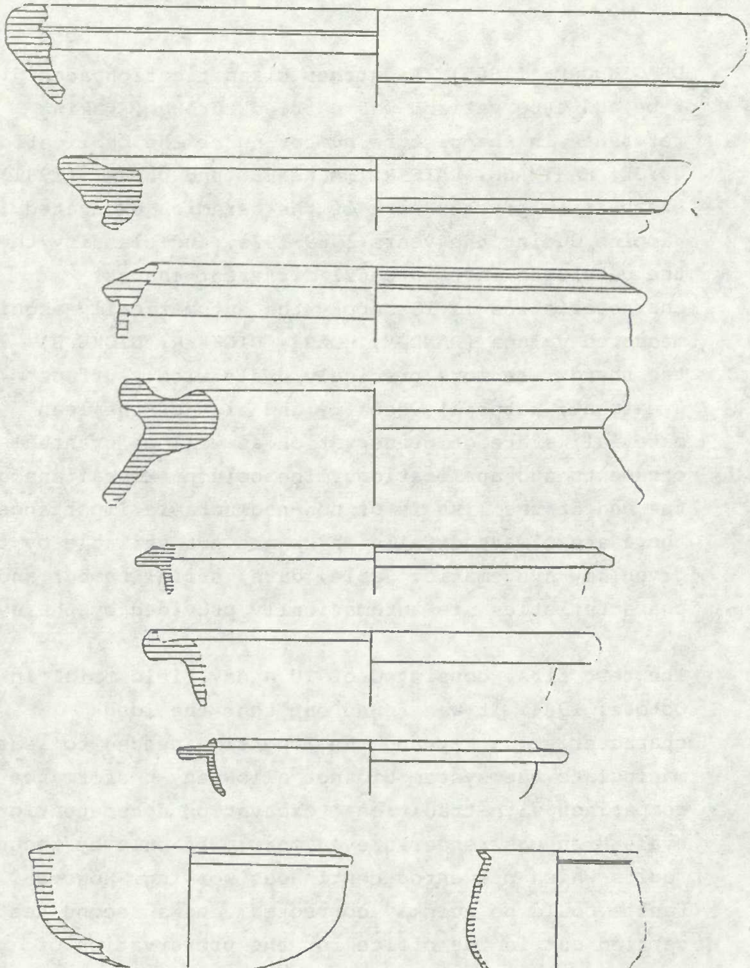

Fig. 11 ARCOS$_1$ - Drawings of roman pottery from the institute for the preservation of monuments at Mainz 1985 (software version 2.1).

The drawings nevertheless also show picture acquisition problems which made it impossible during the test to faultlessly record outturned overlapping rims, handles, footrings and other objects with optical hidden line problems. The new program version BARCOS 2.2 specially takes this problem into consideration. The contact point of the sherd with the turn-table is also problematic, as the program, due to reflections on the surface of the specimen holder, is inclined to take the rounded lip as a straight line. Subtle structures like those encountered on Roman cups with 'Cannies rim' are emphasized by the function 'Draw a straight structural line', as screen resolution is not high enough for such details. Smoothing curves by mathematical functions was also problematic. Here, a solution which generates smooth contours in the drawing, but preserves sharp fractures and edges is striven for.

The Bad Wimpfen tests have prooved despite the described problems that ARCOS 1 is a powerful archaeological tool. Coherent recording of finds was possible right on the excavation site. After a learning phase, picture generation could be executed by local users introduced to the system. Catalogging and documentation tasks were largely completed by the end of the recording. Acquired data can directly be used for statistical evaluation. The objects were archivized in the store-room without any further processing. This considerably shortened the amount of time required for evaluating and publishing results.

Chapter V

The Classification of Ceramics Shapes

Besides the current characteristics for statistical evaluation, ARCOS 1 also provides for the entire profile curves. The evaluation can't be executed with ARCOS 1, but several programs for processing profile curves as contour code exist for mainframes and larger minis. This leads to new possibilities for describing and evaluating usage and shape of ceramics.

Up to now, methods for analysing shapes of ceramics based on the following principles:

a) shape comparison according to visual resemblance, done by an archaeologist;

b) encoding of partial structures, e.g. rim, handle, neck or bottom shape, etc;

c) similitudes with geometric solids, or parts of them;

d) determination of measured values at prominent points, e.g. rim and overall diameter, height, inflection points and their coordination, angles, etc.

All these methods are more or less subjective, and reduce a vessel's total information contents to single particularities. The methods of SCHRÖDER (1969) or STEHLI and ZIMMERMANN (1980) are giving in this context the most complete vessel description by using measured values. The automatic and interactive-automatic classifications take all seizable informationa about the sherd profile into account. The complete profile curve with inside and outside contours from rim to centre of rotation at the bottom is used as closed series of line segments for comparisons. This method also considers the sherd's thickness at every point, all direction changes in the contour shape and other details.

A distinction will be made between automatic and interactive-automatic classification.

Automatic classification

Here, the vessel curves are compared point after point as polygonal connection or series of contour codes. Processing of contour code series is done by using several algorithms which are also employed for industrial pattern recognition (see ZAMPERONI (1980, 1982)). The SAM system, developed by the Fraunhofer-Institut für Informations- und Datenverarbeitung (IITB) in Karlsruhe and employed for workpiece recognition (e.g. screw checking), makes use of those comparison methods of video pictures, up to steering industrial manipulators. Procedures for automatic measuring, testing, steering and shape recognition were considered when designing ARCOS (see FREYTAG (1983), HÄTTICH (1981), IPA (1980), SCHWERDTMANN (1984), TROPF (1980), ZIMMERMANN (1984), WARNECKE and MELCHIOR (1980)).

When using ZAMPERONI's contour code method for comparing sherd profile shapes, profile curves of different length first have to be standardized. If need should be, the angle to the vessel's axis can be neglected for analysis of parts of curves; then, the pure curve shape is analysed (e.g. rim sherds).

After having compared the shapes by substracting the curve values, and a subsequent analysis, e.g. cluster analysis, the degree of dissimilitude between two curves is expressed by a numerical value between 0 and 2. The less differences, the smaller that value (method for processing contour code series). The values may be displayed by means of dendrograms or other graphics. Apart from the pure shape, other characteristics (e.g. height, technological characteristics, ornaments, etc) may be considered for evaluation.

The first tests were done with neolithic cups on a PDP-15 system. Figure 12 shows one of the dendrograms. Grouping was done with single-link cluster analysis basing on

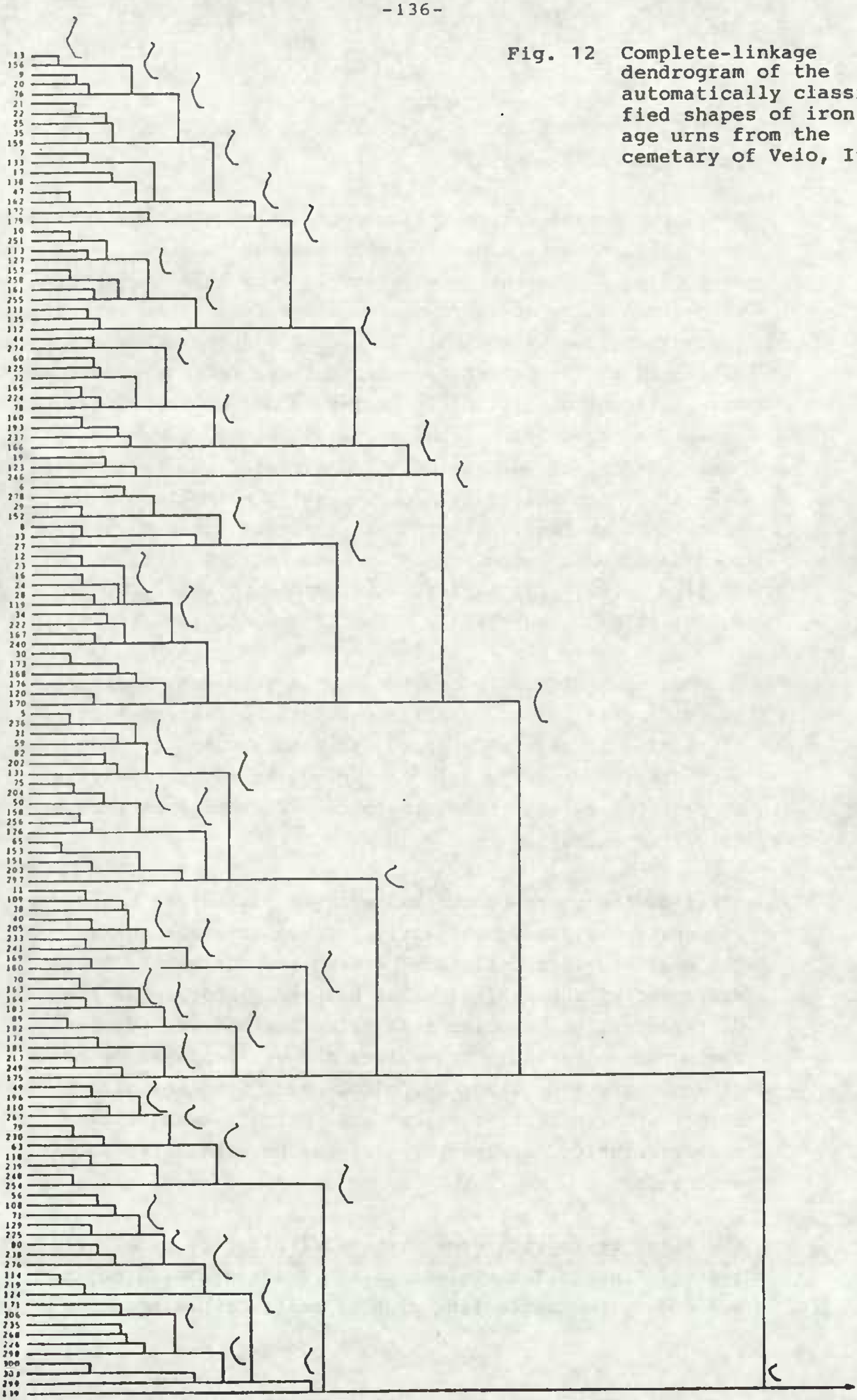

Fig. 12 Complete-linkage dendrogram of the automatically classified shapes of iron age urns from the cemetary of Veio, Italy.

contour codes. Other characteristics and their respective importance may be used for evaluation. Results will be discussed at another place (see GRAÇA (1985), GRACA, KAMPFFMEYER, TEEGEN and ZAMPERONI (1986)*).

The state of preservation of ceramics varies very much, and measured values can therefore not always be completely acquired. Incomplete profile curves are especially difficult to handle when having to compare rim sherds to complete curves of preserved vessels. This requires a standardization of the available data, that is, different partial curves must be extractable from entire vessel profile curves. The difficulty resides in the state of conservation of the reference object, as the processor must find out on its own whether to use solely the rim, rim and neck or even also a part of the shoulder. Here, formal criteria and the object's size have to be considered. Additional problems come from objects with handles and other applications, as these may suppress the vessel's actual profile shape. The recording of an artifact, once with and once without taking applications into consideration, may lead to a high degree of dissimilitude when comparing these two profile curves.

Interactive classification

First of all, a library with standard curves is created. It is constituted either of common original profiles, or theoretically defined ideal profiles. They are entered via video camera or graphics tablet. The reference curves are numbered.

During recording or subsequent evaluation of vessels, their profile curves are compared to those standard curves. This may be done by using the already described method ('Automatic Classification'). Nevertheless, comparisons are difficult. First, 'similitude areas' have to be defined, as curves fitting entirely onto the reference curve are practically never encontered. Second, it is necessary to enable the manipulation of fragments in order to assign the most similar preserved vessel to an incomplete sherd. Third, the reference curves have to be organized in a tree structure; thus, it is not necessary to compare every curve with every reference, and the quickest way leading to the most similar object can be determinated. The system expresses the degree of similitude with one or several reference curves in terms of percentages or numerical factors. It is then up to the user to accept the result, make modifications or declare the analysed profile to be an additional reference curve. This interactive classification method would offer several advantages for subsequent curation and evaluation:

a) It becomes possible to check the data acquired by unskilled personnel.

b) It isn't any longer necessary to store the entire curve, but only the reference number and the degree of similitude. The amount of data is thus considerably reduced, and it is easier to statistically evaluate them.

c) Incompletely preserved artifacts can automatically be completed and drawn offer having been classified.

Thus, interactive automatic classification is the first step leading from a tool for archaeological documentation to an 'expert system'. The ever increasing performance of small computers won't make archaeologists and drawers superfluous, but will be a benefit for efficient scientific research.

Chapter VI

ARCOS 2

ARCOS 2 is a step into this direction. Its development was started after completion of the first prototype of the ARCOS basic version.

This enhanced ARCOS system has been designed for managing and processing data acquired with ARCOS 1. It is equipped with a powerful CPU featuring a large memory and high processing speed. A bus system with a 16/32-bit processor (MOTOROLA 68000 CPU, 8 MHz clock rate and 16 Mb direct addressable memory) was selected, being flexible and upgradable. This enhanced ARCOS machine will support every function of the basic configuration, as well as archaeological software packages. Commercial programs may be used due to the presence of a standard operating system.

Museums, archivs and research institutes will be the main users of ARCOS 2. Modern storage technologies provide efficient management of a large number of stocked artifacts. A special interest presents the still being developed optical disc technology. The optical disc GIGADISQUE by Thomson/Alcatel is used as remote memory with ARCOS 2.

Up to now, the exchangeable optical discs are writable only once. Information are burnt by laser rays into the disc's surface and can't be deleted. This presents a very high data security for archivized objects of importance. The capacity for standard 12'' optical discs (THOMSON-CSF, CONTROL DATA, SHUGART, etc) is close to 1 GB (1.000 Megabytes correspond to 1.000.000.000 characters) per side. If double-side recording is used, one optical disk may store in random-access technology more than 100.000 graphics and drawings, or 1 million of type-written text pages. The processor interface allows the simultaneous connection of up to 8 optical disc drives.

This concept will give ARCOS 2 access to the following features:

A) Operating Systems:
Dedicated operating system environment for dialogue-oriented standard tasking, comfortable commercial operating systems (e.g. UNIX derivates, CP/M68K, etc).

b) Graphics:
Enhanced capabilities of the ARCOS basic configuration, handling other objects than ceramics, grey-scale image processing, tabular graphics for illustrating statistical results, evaluation and processing of antique scripts, combination of texts with graphics and pictures, implementation of GKS, viewdata standard ("Btx"), etc.

c) Photogrammetry:
Survey and redrawing of air-, façade-, excavation- and other pictures and plans may be executed by running the ARCGRAM photogrammetrical system. It uses one-eyed 9x9 Reseau-cameras.

d) Statistics and Classification:
Combinational statistics, serialization, automatic classification of vessel profiles, interactive classification, mapping, etc.

e) Data Bases:
Direct accessible files with pictural, graphical and alphanumerical information; management of large find quantities; generation of reference lists, catalogues and sorted indexes; selection of information for statistical research; management of archives containing excavation sites, aerial photos, slides. literature, or other.

f) Text processing and utility programs:
Combined text processing (access to pictures, graphics, data base information, tables generated by calculation programs, etc), calculation programs (projects, terms, means and funds, loans, etc), utilities.

g) High-level programming languages:
C, PASCAL, BASIC and other ones for writing user-specific programs which have access to the standard programs ant the data collections.

h) Communications:
Use of modems, eventually viewdata ("Btx"); transfer programs for exchanging data with other systems, already used in archaeology, etc.

The differences between the basic configuration and the enhanced system lie in the application scope and the hardware equipment. The basic system is nearly exclusively meant for acquiring data and simple image processing on the excavation site, whereas ARCOS 2 has been designed for subsequent processing, statistical evaluation and data management. The more sophisticated ARCOS 2 should be used as central computer for several mobile basic configurations on excavation sites or in stores. The configuration may be adapted to the respective requirements of the institutions which use it (e.g. universities, research institutions offices for preservation of monuments, museums, administrations, etc).

Chapter VII

Summary: Using ARCOS in Archeological Research

Working facilities and new cognition methods for archeology are the main achievements of the ARCOS concept:

a) objective, standardized and time-saving recording of archeological artifacts coming from excavations, archives or museums;

b) simplified and accelerated publication possibilities due to automatic techniques for drawing, catalogging, evaluating and documenting;

c) dealing with large amounts of material not yet published;

d) possibilities for statistical evaluation; analysis of many details, automatic shape classification and other techniques for answering archeological questions by means of quantitative methods;

e) simplified management of large data amounts and collections;

f) information exchange for comparison analysis between different research institutions;

g) use of graphics and drawings instead of thesauri and descriptions in data bases.

ARCOS may be used in every office for the preservation of monuments, museum, research and university institution, as well as administration.

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