IMAGE ACQUISITION AND IMAGE ANALYSIS OF ARCHAEOLOGICAL FRAGMENTS

INTRODUCTION

This paper pursues three aims. First to draw the attention of the reader on the wide field of application of image processing and its relation to archaeology. Second to transfer some investigations and results of the EG-ESPRIT-project VASARI. Third to get the reader familiar with a project under way for puzzling of archaeological potsherds.

WHY IMAGE PROCESSING IN ARCHAEOLOGY?

Image processing as the manipulation of computerized images of real objects is a common applied technology in various scientific fields, also in archaeology. Image processing systems can aid the work of archaeologists by help of various functions as:
— to have a reproduceable computerized image of the objects under investigation
— to manipulate and analyse (images of) objects without touching them
— to compare and to transfer (images of) objects even if the real objects are not available
— to archive and to document (images of) objects in an easy way, preparation for publication; quick overview on collections of images
— to prepare a computerized 3D-modelling of archaeological objects
— others.

HOW TO GET IMAGES INTO THE COMPUTER?

Two very simple truths characterize the problem:
— without light we cannot see anything
— we cannot analyse, what is not stored in the computer.
First of all we have to define, what we want to see in the images of the objects of art. If we know that, we have to choose an appropriate lighting (white, coloured, structured etc.). A good lighting can (help to) solve the recognition problem. There is a wide spectrum of lighting systems from diffuse sources for normal image acquisition [Hab] up to special laser sources [Ost] for detection of surface profiles by help of interferometric methods.

To analyse details of an object we must see these details in an image. To analyse colour, the colour information must be stored in the computer. For the importance of image acquisition a wide range of image acquisition systems for different purposes is developed. In [VAS] high performance special colour scanning devices are described. A classification of image acquisition systems is done in [VER]; from this, good recommendations also for archaeological purposes can be derivated. Among other excellent mobile image acquisition systems, "MESySx000" and "Jenscan 4000" come from the tradition of Carl Zeiss Jena and provide high resolution (3.500 x 4.500 pixels) as well as metric and colour capabilities [VER].

How an image processing system looks?

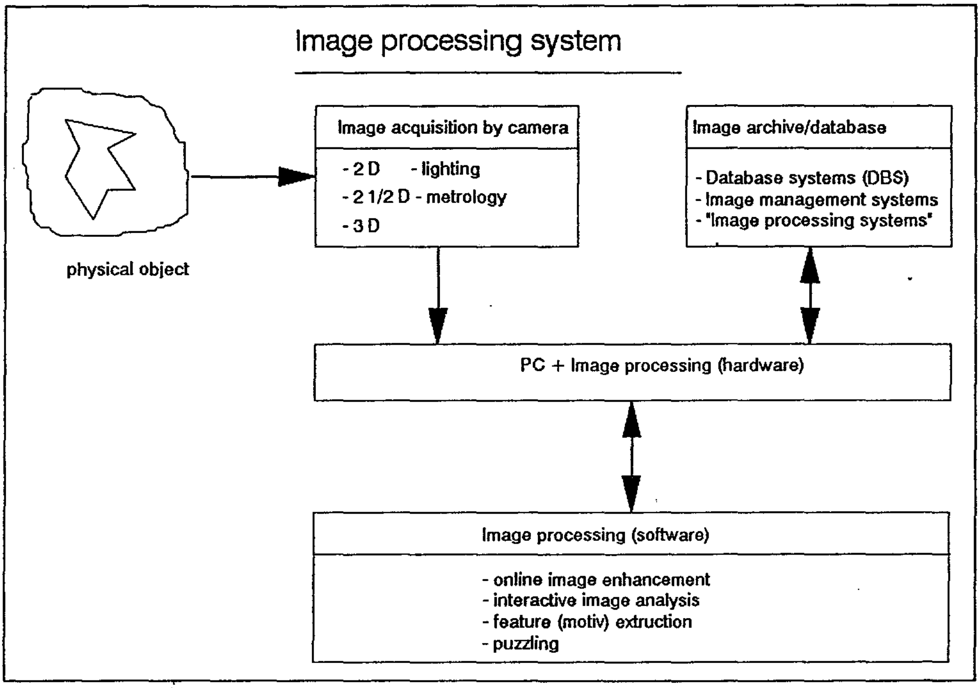

Fig. 1 — Main blocks of an image processing system with some characterizing features.

What can be done by interactive image processing software?

Common used image processing systems provide a wide range of functions on how to improve the visibility and how to analyse objects. Such functions are:
— manipulation of contrast
— zooming details

— combining and mosaicking parts of images for an overview
— stressing of details
— cleaning the image from noise
— sharpening the image
— detection and measuring of contours
— extraction of regularities/irregularities from images for analysis
— extraction of features for an appropriate description
— analysis of colour and texture as well as profile of surfaces
— archiving, combining and comparison of images
— others.

All this and even more is running on common available PC's (also laptops) partially enhanced by special hardware with a good interactive support.

Only two examples for image processing function will be given. Fig. 2 illustrates in a quite clear manner the improvement reached by a simple contrast manipulation.

As a second example can serve the process of manipulating coins of the same type but issued at different times and places. By combining and overlapping of parts of various coins an ideal image of the coin can be reconstructed. For this and further details see [VER].

WHAT ABOUT ARCHIVING AND IMAGE DATA BASE SYSTEMS?

With the possibility of image acquisition and digital storage of images, amounts of images are produced which have to be managed. Furthermore an indexing of these images has to be done and retrieval procedures must be provided.

Some of these needs can be fulfilled by common available data base systems, extended by functions for storing and handling of images. In the VASARI—extension study [VER] about 20 database systems are considered. A categorisation into three classes can be made:

1. Information retrieval systems for managing of features and text
   Programm-packet GOS of British Museum Documentation / UNIFY of Unify / ADABAS of Software AG / AIDOS/M of Dataprint / Witt Computer Index / CLIO of SYSECA
2. DBS extended for managing of images
   INFORMIX / SYBASE / ORACLE / INGRES
3. Image processing systems involving DBS-functions
   NEXUS / Bild-Datenbank BIAS / Picture Power / ODIN / HI-Vision Galery / PC Album / Screen-Machine

There are also included recommendations on how to select an image data base system in dependence of the application purposes. The scale treated ranges

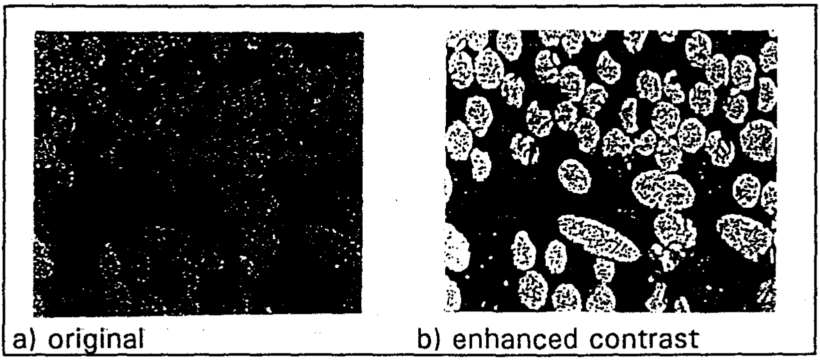

Fig. 2 — Glas fibers in a matrix.

from home applications up to archiving systems for museums.

A common feature of all data bases mentioned is the leak of content driven access to images. The retrieval procedures use only textual information added to the images. There may be some image describing information but it must be extracted by an expert and typed into the computer by an operator. There is no possibility to come with an image to the data base and try to find all images in the data base with a certain degree of similarity. Therefore automated feature extraction for image data bases is a growing need.

Automated feature extraction for image data bases

Surely, to describe the content of an image is a problem which has been tackled by many groups working in scene analysis for many years and cannot be solved in general. But, if we know the spectrum of objects to be stored in the data base, we can define a limited number of characterizing features. These features serve as the basis for the measurement of similarity between (images of) objects and in consequence for retrieval.

In regard to the VASARI-extension report [VER] two hypothetic examples for content driven access to image data bases will be mentioned.

There are stored e.g. a certain number of Roman coins in the computer. During the image acquisition process an analysis is done and image like features are defined as:

diameter
contour (circle or polygon)
roughness of the contour
deepness of the profile
colour
special signs as numbers on the surface
relation between such signs
others

If a new coin is added the same process for feature extraction can be carried out and on this base a comparison is made. Or, we can put the question for all coins with a polygonal contour a nearly flat profile and no numbers on the surface.

Another example would be a (thought) data base filled with microscopic images of brushes of Egyptian ceramics. We suppose that there is a link between the surface structure of such brushes and the places where the ceramics come from. Fig. 3 shows two such brushes. As a result of an automated feature extraction process we could get:

— the white part of the image is about 60% (a) or 50% (b)
— there are 10 large white objects in a certain area (b)
— there are many objects of unregular size and shape in the image (a)
— there are fiber like objects in the image (b) / no fiber like objects in the image(a)
— others.

In order link objects of arts to place, an image driven access to image data bases would be helpful even if the real objects are not available. The question to the image data base could be, pick out all similar brushes and give the statistics of the most significant places.

Image processing for puzzling of fragments (of potsherds)

During the discussion of the VASARI-extension-study the idea to use image processing technology for special tasks in archaeology came up. One reason was that in museum storehouses thousands and thousands of potsherds from excavations are stored and there is no possibility to piece them together. Even if there were an adequate labour capacity, the combinatorial problem would be too enormous for human capabilities. Image processing could help to automate or at least to reduce the problem to a manageable stage. As a result of this discussion a sponsored project for "puzzling of archaeological ceramic fragments/potsherds by means of image processing" started in 1992.

The aim is to build up a software system (running on PC extended with a colour frame grabber of Imaging Technology) for the interactive and automated puzzling. First 2-D-like objects are treated and in a second step 3-D-like objects, will be considered. The system to develop will run under windows, and can be divided into the following parts:

— image acquisition of single and multiple potsherds
— definition of characterizing features and derivation of these features for all single potsherds
— storage of describing features in a data base

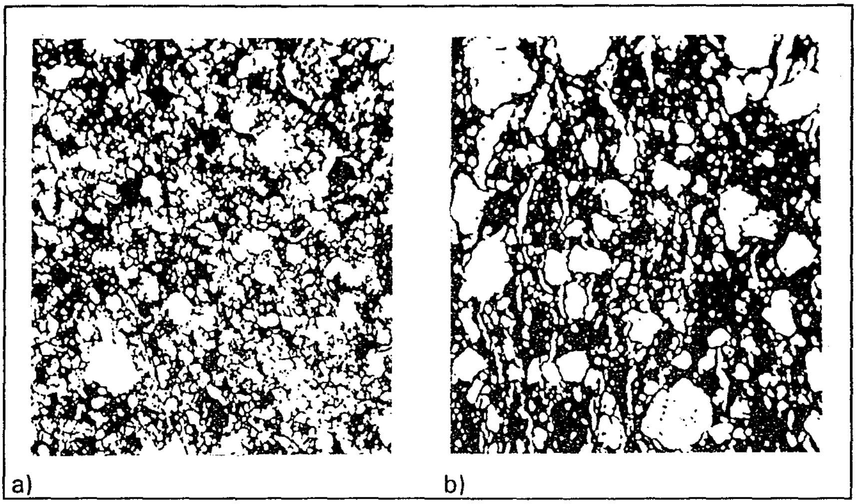

Fig. 3 — Brushes of Egyptian ceramics (source: Rathgen Institute Berlin).

— retrieval as an evaluation of similarity
— puzzling, on the screen
— interaction

The basic problem lies in the definition of the characterizing features. At the end, the unique information for joining is coded in the 3-dimensionality of the crack surface.

To reach a solution we follow a stepwise approach. As characterizing features are used (see also Fig. 4):

— edges lengths and angles of the contour
— texture of the surface
— patterns on the surface
— colour information (if useful)
— shape/flatness of the potsherd
— pattern of the supporting background (if existing)
— others.

When the characterizing features are defined retrieval procedures calculating the similarity between features must be developed. For a contour description by edge lengths and angles there is no problem. Figg. 5a and 5b show this process, in particular for a lot of fragments in Fig. 5a and an intermediate result after a procedure which compares edge lengths and angles in Fig. 5b.

When the puzzling system is confronted with real archaeological material/potsherds there will be a number of image processing and CAD-like problems to be solved:

- edges lenghts and angles of the contour
- texture of the surface
- patterns on the surface
- colour information (if useful)
- shape/flatness of the potsherd
- pattern of the supporting background (if existing)
- others.

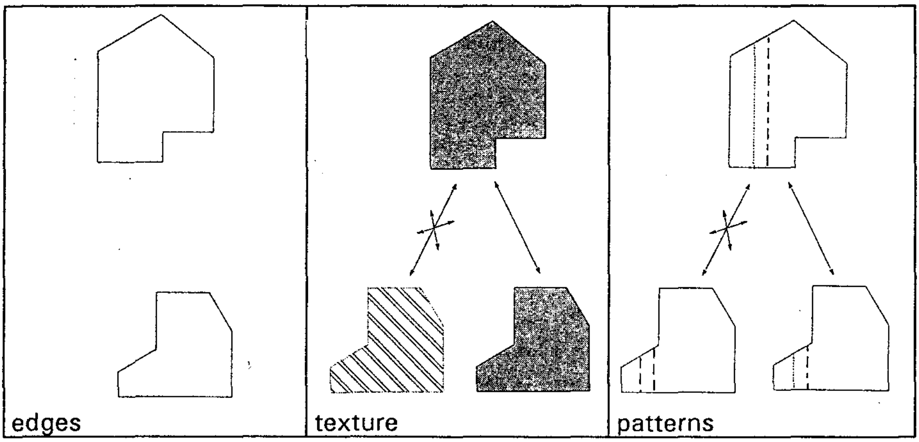

Fig. 4 — Examples of characterizing features of postsherds.

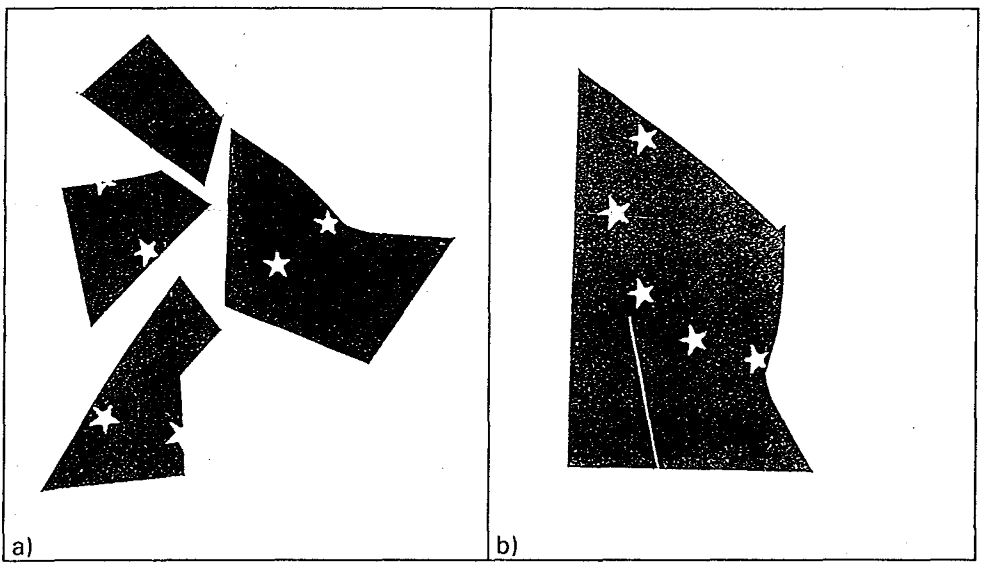

Fig. 5 — Fragments of the EG-flag (a); partially puzzled EG-flag (b).

— processing of 3-D shapes
— inferring of patterns and texture
— include/exclude colour information
— curvature as a feature
— others.

The system will be tested in 1992 and at a certain level finished in 1993.

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