An Automated Pottery Fragment Classifier for Archaeological Studies

GULSEBNEM BISHOP, SUNG-HYUK CHA, CHARLES TAPPERT

School of Computer Science and Information Systems, Pace University

861 Bedford Rd. Pleasantville, NY 10570 USA

{gf44944w, scha, ctappert}@pace.edu

ABSTRACT

In this paper we propose an image-based pottery fragment identifier and classifier. We have successfully developed an automated, search engine system for pottery and pottery fragment images. This system is designed to assist archaeologists and students in identifying pottery shape, color convention, and other relevant information quickly and accurately. The purpose of this automated pottery fragment classifier is to make the matching task easier for archaeologists by providing them with a graphical user interface for matching and classification. We present several image retrieval and computer vision techniques and describe their applications within the domain of archaeological studies by utilizing a large digital library of pottery photographs. Pottery shapes such as amphora, kylix, hydria and lekythos, and pottery schools such as Red Figure, Black Figure, and White Ground are identified with shape and color-based image retrieval techniques, respectively. The system analyses and compares extracted features to determine the five closest database images, and then presents them to the user for final decision. This is the first pottery study to combine the two different techniques – regional property measurements and color-based image retrieval – to identify multiple characteristics of an unknown pottery image or a pottery fragment. The database contains one hundred sixty pottery images obtained from online digital libraries. Experiments on identifying the correct pottery shape, school, and cropped images yielded approximately 98% accuracy.

Keywords: image retrieval, pottery classification

INTRODUCTION

The study of pottery is one of the most important and complex tasks done by archaeologists. A significant amount of information about a culture can be gleaned from studying pottery. Analyzing the physical aspects of a pot or a fragment, can give us detailed information about the history behind the artefact. We can establish a date range by observing the shape and the size of the pottery, and we can narrow the date range of a pottery by observing the decorations. Pottery contains a great deal of information; therefore, new ways of taking a look into this area should be pursued [1].

This study has several *modus operandi*. First, it will serve as an educational tool for a novice archaeologist to identify and study artifacts or fragments. Second, it can serve as a valuable tool in excavations for identification, classification, and reconstruction of fragments. This may lead to significant archaeological discoveries. Third, thousands of pottery fragments are unearthed every year, and are usually discarded after being recorded. It is often impossible to photograph or record the measurements of these fragments, or even assign them a particular category or class. This system should provide a quick, inexpensive and objective way of documenting and classifying these fragments. It can also serve as a decoration detail finder.

Most of the studies in the field of pattern recognition and computer vision focus on three dimensional recreation of the images [1, 5, 6]. Some recent studies have concentrated on curve matching [2, 3, 4]. However, few studies have focused on making the task of matching, retrieving and classifying easier for the novice or field archaeologist by providing an image-based Graphical User Interface (GUI).

Identifying the shape and the school of pottery or a fragment, or detail of a decoration on the pottery, can be a challenging task for computer vision. Even though the shape of the pot is unique, the nuances vary and, of course, the pottery or fragment may belong to different schools. We will present a pottery shape and school recognition system that combines both regional property measurements and colour-based image retrieval techniques [8, 9].

In summary, the user will be asked to choose a whole pot or to crop a region of a pottery image. The task of the system is to retrieve five similar regions which are closest to the selected image. The system consists of three stages: segmentation, feature extraction and classification.

The subsequent sections of this paper are organized as follows. Section two discusses the pottery database. Section three describes the GUI called PIRS – Pottery Information Retrieval System. In section four, the test results are presented and examined. In section five, we discuss how this study may be applied to the field of archaeology, and how it can be developed further.

1. DATABASE

The database utilized in this system consists of two sections. The first section contains the images of pottery with shape and school information (spread sheet of Figure 1). The second section contains information about extracted features.

The digital images of pottery are kept in one folder. Our training database of eighty images, contains four distinct pottery shapes (Figure 2). There are also four distinct color conventions: Red Figure, Black Figure, Red Figure White Ground, and Black Figure White Ground (Figure 3) [10, 11, 12], and the database contains at least five samples of each shape.
The extracted data from the images are kept in a data file in a separate folder. In order to determine the shape of the pottery image, we first segmented the image (Figure 4) and then extracted regional properties measurement of the segmented image consisting of the Area, Centroid, BoundingBox, MajorAxisLength, MinorAxisLength, Eccentricity, Orientation, ConvexHull, ConvexArea, FilledArea, EulerNumber, EquivDiameter, Solidity, and Extent. Furthermore, we took the ratios of the raw regional features so that they are size invariant. Measuring the regional features of a segmented image is a different approach from the existing feature extractions methods [7]. It is these properties of the segmented image that is compared with those in our database to identify the similar images.
The aim of the template matching algorithm is to identify the top five matching pieces in the image database.
We went through a similar process with fragments. First, we obtained the images of the fragments. Second, we segmented the image of the fragment. Third, we put the fragments through a jigsaw puzzle like algorithm. Finally, we ran the feature values through our database and presented the user with the five top matches. We used 2D images of whole pots and randomly broke them into pieces. We then matched the pieces using regional properties and template matching algorithms (Figure 5). After reconstructing the whole pot, we ran this image through our database to find the top five matches.

2. GRAPHICAL USER INTERFACE

The Graphical User Interface makes the analysis, comparison, and classification simple and efficient. For this purpose we created a Pottery Information Retrieval System – PIRS. This system uses five screens. The first screen prompts the user to select an image. After choosing the desired image, the user crops the image. The next screen analyzes the cropped image. After analyzing the regional property measurements and color histograms, the system displays the five closest matched images (Figure 6).
After the user chooses the most appropriate of the five images, the information about that image is displayed on the last screen. This screen gives information about the chosen vase, including shape, ware, date, painter, potter, and decoration.

3. TEST RESULTS

We tested the system with one hundred and sixty images, which involves four different pottery shapes and four different colour conventions. Attention was given to the accuracy of the system on three important issues: the accuracy of matching the pottery fragments, the accuracy of matching images from the database, and the accuracy of matching images for cropped pieces.
The system matched the fragments of a randomly dissected image at a 97% rate of accuracy and it returned the five matching images with 99% accuracy. When we tested the system using manually-created two-dimensional fragments, the accuracy rate depended on the area of cropping. If it was an obviously easy-to-identify area, the rate of accuracy was 99%. If the area was a difficult-to-identify region, such as the middle of the pot, the match was less accurate. As a result our template matching algorithm identified the cropped pieces with 85% accuracy. The identification process takes about 2-3 minutes for each cropped pieces. The colour convention in all images was detected with 98% accuracy.
After getting high return rates we tried our system with a three dimensional paper cup. This gave us more challenge because of the curved nature of the pieces. (Figure 7).
We put the cup together with a jigsaw puzzle like algorithm. Colour coded the pieces for identification. Finally, constructed a three dimensional cylinder of the fragments that we searched for the matching shape and colour convention. The jigsaw puzzle problem was treated like an artificial intelligence search problem. The fragment patterns, decorations, and colours help tremendously in locating the matching pieces, greatly reducing the search space.

CONCLUSION

In this paper, we have presented a pottery fragment matching and classifying system using regional properties measurement and template matching algorithm. Thousands of pottery fragments are unearthed every year in excavations and often discarded without being recorded because it is tedious to record these fragments yet alone try to assign them to a certain category. Even with a trained craftsman it is often impossible to identify and record an object manually without interpretation. This system will provide the much needed objectivity and can significantly facilitate archaeological studies.
Extensions of this study can be seen in three areas. The most important one is working with less identifiable and subtle fragments of the pots. Second, is the speed of the identification process, and third is testing the system with real fragments. Finally, the system can also be ported to an interactive handheld computer for direct use in the field, making the fragment matching and recording of artifacts or fragments vastly more efficient.

REFERENCES

KAMPEL, M.; SABLATNIG, R. (2003) – Virtual Reconstruction of Broken and Unbroken Pottery. In Proceedings of the Fourth International Conference on *3-D Digital Imaging and Modeling*, p. 318-325.

.LEITÃO, H. C. G.; STOLFI, J. (2002) – Multiscale Method for Reassembly of Two-Dimensional Fragmented Objects. In IEEE Trans. On Pattern Analysis and Machine Intelligence, 24 (9), p. 1239-1251.

McBRIDE, J. C.; KIMIA, B. B. (2003) – *Archaeological Fragment Reconstruction Using Curve Matching*. In Proceedings of the 2003 Conference on Computer Vision and Pattern Recognition Workshop, p. 1-8.

KONG, W.; KIMIA, B. B. (2001) – *On Solving 2D & 3D Puzzles Using Curve Matching*. In Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, p. 583-591.

De NAPOLI, L., *et al.* (2002) – *Semi-Automated Procedure for the Recognition and the Classification of Archaeological Artefacts*. In Proceedings of Computer Applications and Quantitative Methods in Archaeology Conference, 2002.

KAMPEL, M.; SABLATNIG, R. (2004) – *On 3D Mosaicing of Rotationally Symmetric Ceramic Fragments*. In the Proceedings of the 17th International Conference on pattern Recognition (ICPR 2004)

SMEULDERS, A. M. W, *et al.* (2000) – *Content-Based Image Retrieval at the End of the Early Years*. In IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 22, no. 12, p. 1348-1380, December 2000.

CHA, S. H.; MURIRATHNAM, S. (2000) – *Comparing Color Images Using Angular Histogram Measures*. In Proceedings of 5th Joint Conference in Information Sciences, vol. II, CVPRIP, p. 139-142.

SAWHNEY, H. S.; HAFNER, J. L. (1994) – *Efficient Color Histogram Indexing*. In International Conference on Image Processing, vol. 1, p. 66-70.

BOARDMAN, J. (1974) – *Athenian Black Figure Vases*. Thames and Hudson, Inc. 1974.

BOARDMAN, J. (1975) – *Athenian Red Figure Vases: The Archaic Period*. Thames and Hudson, Inc. 1975.

BOARDMAN, J. (1989) – *Athenian Red Figure Vases: The Classical Period*. Thames and Hudson, Inc. 1989.

FIGURES

DBID#	MUSID	WARE	SHAPE	PAINTER	CONTEXT	DATE (BC)	HEIGHT (M)	DIAM.LIP (M)	WIDTH MAX (M)
0522	M11	W1	S4	P64	C30	D2	H105	DL79	WWH26
0185	M10	W1	S3	P78	C6	D36	H59	DL47	WWH8
0399	M10	W1	S3	P78	C6	D36	H59	DL47	WWH8
0519	M7	W1	S20	P100	C30	D36	H108	DL57	WWH16
0355	M1	W1	S2	P53	C24	D27	H142	DL79	WWH26
0525	M11	W1	S17	P120	C30	D31	H33	DL79	WWH26
0527	M11	W10	S8	P120	C30	D60	H142	DL79	WWH26
0528	M11	W10	S8	P120	C30	D63	H22	DL79	WWH26
0199	M8	W11	S1	P120	C30	D3	H142	DL79	WWH26

Fig. 1 – Coded Information.

Kylix **Amphora** **Hydria** **Lekythos**

Fig. 2 – Vase Shapes.

Black Figure (630-530 BC) **Red Figure (530-470 BC)** **White Ground (550-330 BC)**

Fig. 3 – Schools.

Fig. 4 – Segmented Image.

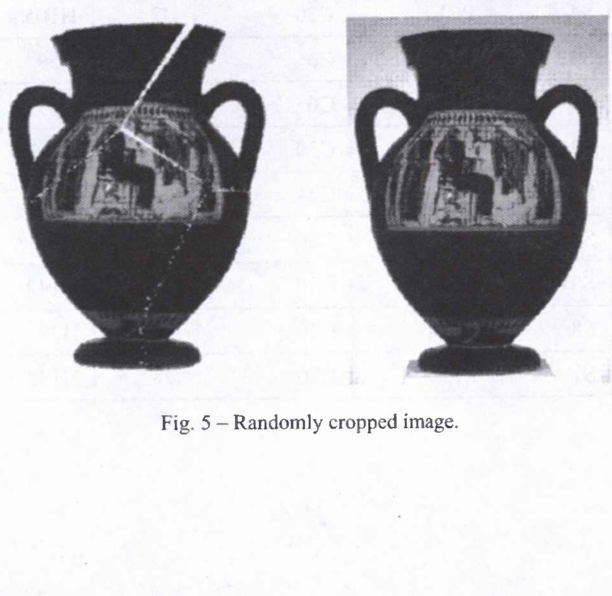

Fig. 5 – Randomly cropped image.

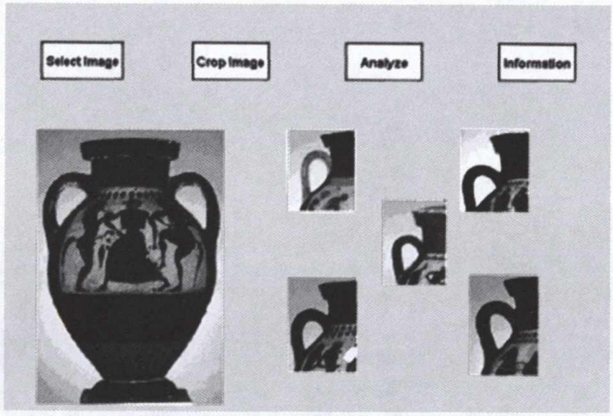

Fig 6 – Graphical User Interface.

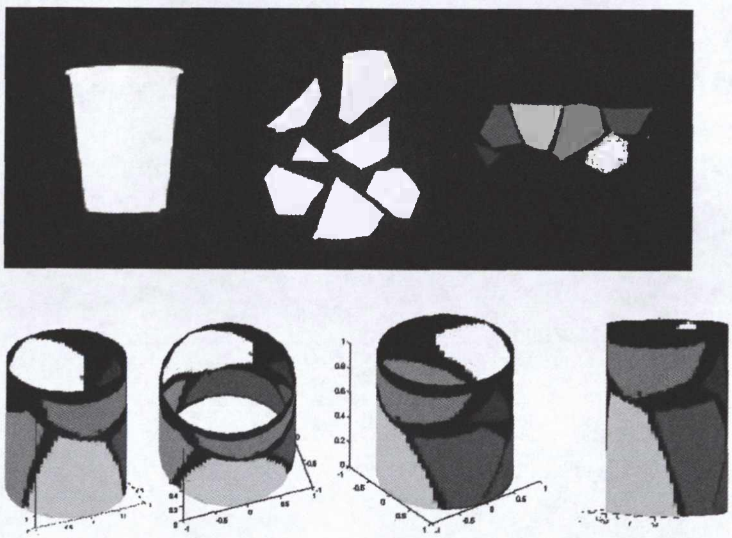

Fig. 7 – Dissected Paper Cup.