3D Modelling and Database of Indian archaeological Pottery Assemblages-HNBGU-NDSU Collaborative Initiative

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Indian archaeological ceramics have been considered the most useful cultural resource for reconstructing various aspects of ancient society. Scanning technology has not been used effectively in India for rapid documentation of collections and there is no centralized or easily accessible archive of pottery available for comparative analysis. With this in mind, the authors have initiated collaborative work for the development of computing technology for 3D modeling and an Internet-accessible database of Indian archaeological pottery.

Introduction: Indian Pottery Collections and Indian Heritage

Pottery constitutes the major proportion of all material recovered from archaeological excavations in India. The mosaic of Indian history and archaeology, spanning 5,000 years, is reflected through the different and diverse pottery traditions, commencing in the Neolithic and continuing throughout the Indian archaeological sequence. The different ceramic traditions and cultural phases are reflected through specific, diagnostic pottery types. In addition, pottery defines the cultural, social, economic, and technological status of the people who developed the different cultures and phases over time and space. In short, pottery collections in India serve as one of the primary sources of historical reconstruction. Therefore, a large number of studies focusing on the importance of pottery have been done in India (e.g. see Pant and Jayaswal 1997). Indeed, the cross-cultural associations of the different Indian protohistoric sites have been reconstructed based upon the relationships of pottery types (Srivastva 1979). However, the pottery assemblages from a wide range of sites are stored at distantly located institutions throughout India. Access to these preserved materials and the associated documentation is often difficult and expensive. No centralized or otherwise easily accessible archive of the corpus is available for comparative analysis. Also, in spite of the well-established classification of Indian pottery collections in terms of shape, color, fabric, paintings and designs, etc., there has not been a concerted effort to develop or introduce an automated system for fast documentation of pottery shapes. Nor has there been an effort to exploit the advances in computing, software, 3D modeling, and Internet technology to develop a Web-based database to access the detailed information on Indian archaeological pottery collections.

In order to fill this gap, the first major challenge has been to introduce some form of automated device and to make use of computers and other graphics tools to develop the technique further. To some extent, Dr. Nautiyal, along with students and staff, at HNB Garhwal University (HNBGU) has been able to address partially that goal (Nautiyal et al. 2000, 2001), but there is still great need to advance and develop their work on 3D ceramic modeling. Due to limitations of equipment and technological expertise, however, that advancement has been difficult. Therefore, a collaborative project was initiated by Drs. Nautiyal and Clark and their teams that will link the eff-

orts at HNBGU with the work being done at the Archaeology Technologies Lab at North Dakota State University (NDSU). With joint funding from the DST (India) and NSF (USA) programs, the digital database of Indian pottery being developed at HNBGU will be made accessible through the Digital Archive Network for Anthropology and World Heritage (DANA-WH). Furthermore, NDSU will assist HNBGU with the application of the latest 3D scanning technology and a host of 3D graphics and database software. The present paper summarizes the work at HNBGU and describes the preliminary results of the collaboration between HNBGU and the NDSU.

RELATED RESEARCH

Pottery is one of the most conventional sources of data for understanding and reconstructing the past. Typically, a ceramic assemblage from an archaeological site is collected, catalogued, and documented through traditional means for research purposes as well as for museum display. However, in recent years, with the advancement of computing technology, 3D graphics software, and innovative imaging and analytical techniques, there has been a shift towards the investigation of the various complex attributes of pottery through the application of geometrical 3D shape modeling, 3D reconstruction of axially symmetric pots from fragments, texture mapping, and more. While a comprehensive review of recent literature about computer based visualization of ceramics and virtual reconstructions of vessels cannot be presented here, there is clearly an increase in the number and sophistication of such efforts, as illustrated by several papers at the CAA 2003 and other publications (e.g. Schurmans et al. 2001, PRIP 2000, Cooper et al. 2001).

HNBGU SYSTEM: OPTICAL PLOTTING - EXTRACTION OF 2D AND 3D PROFILE AND DIAMETER

In view of the latest advances in the field of computers and various software applications, HNBGU has exploited the tools of AutoCAD for manipulating 2D outlines generated through an optical plotter (called Reflex Metrograph). These 2D outlines are then used to produce 3D rendered images of the archaeological ceramics (Nautiyal et al. 2000). The development of this AutoCAD-based technique opens many new possibilities in the areas of visualization, shape modeling, and use in digital archives for dissemination of pottery collections and other cultural heritage resources via the Internet. However, a lack of more advanced technology at HNBGU has hindered further developments in these areas.

The optical plotter that is being used by Dr. Nautiyal was designed for orthodontics. However, its simple application was also found to be useful in archaeology by Scott (1981). At HNBGU, an optical plotter was used to make drawings of pottery fragments and full vessels to demonstrate the inaccuracies present in the manual method of pottery drawing

(Nautiyal et al. 1995). The details of the system have been described elsewhere (Scott 1982), therefore only a brief description is given here.

The optical plotter (Fig.1) is used to digitize the x-, y-, and z-coordinates of an object through the semi-reflecting mirror in ASCII format. The light source is moved over the reflection of the object to generate an outline of the object. Rplot2 software is used to convert the RPT files into DXF format, which allows the HNBGU team to manipulate and modify the files using more recent releases of AutoCAD, such as R14 and 2000. A 3D virtual reconstruction of the vessel to the lowest point of the vertical profile line is then generated by a series of AutoCAD commands: Rimdiameter, DView, Mirror, Resurf, and Render. This technique has been successful for generating 2D images and rendered 3D models of pottery.

Texture mapping, or the projection of a surface image onto an object, has been added to the HNBGU system as a result of the collaboration with NDSU. In addition to shape reconstruction, the surface texture (color) of pottery is as equally important for generating a realistic impression. In earlier work at HNBGU (Nautiyal et al. 2000) attempts had not been made to texture map the pottery assemblage. Following discussions between our teams, the materials library tools in AutoCAD have now been effectively used for texture mapping at HNBGU. These tools provide a workable solution to generate the closest possible photo-realistic model of the vessel. In this study, the digital image (JPEG and BMP) of the pottery fragment is imported into the materials library and the color captured during this stage is wrapped to the object. It is then rendered to create a textured full model.
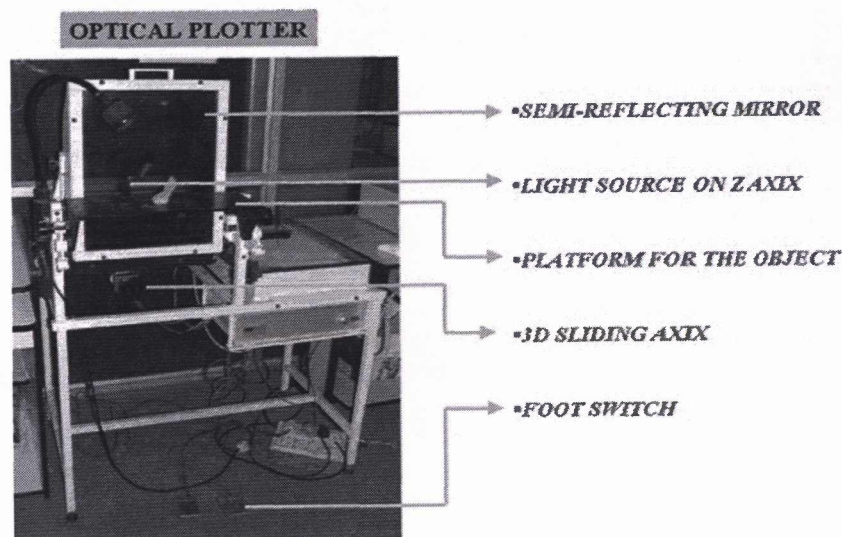

Figure 1 Optical plotter used by HNBGU

Thus, optical plotting hardware coupled with AutoCAD software has provided an inexpensive technique for drawing archaeological sherd profiles and for creating partial virtual reconstructions of vessels. To these reconstructions, textures can be added based on digital photographs of the original sherd. These reconstructions significantly improve efforts to classify pottery from archeological collections. This technique opened up new possibilities for Dr. Nautiyal to begin

working with Dr. Clark on laser-based techniques of modeling, texture mapping, and Web-enabled digital archives.

ATL- NDSU

In November 2001, the Archaeology Technologies Laboratory (ATL) (http://atl.ndsu.edu) at NDSU received funding from the National Science Foundation's Digital Libraries (NSDL) program, for a two-year project designed to create and implement a Digital Archive Network for Anthropology (DANA). This network is being designed to function as a federation of distributed, interoperable databases, each with specific content of value to anthropology (Clark et al. 2002). With the realization that a network such as DANA could grow larger than first conceived, the scope of its content grew to cover all domains that have as their focus the study of cultural and biological human heritage. This new vision also included expanding the content beyond US-based institutions to include international participants. As a result, DANA was enlarged in name as well as content, and is now the Digital Archive Network for Anthropology and World Heritage (DANA-WH, http://www.dana-wh.net). DANA-WH is also accessible through the NSDL portal (http://nsdl.org) and the ATL Web page (http://atl.ndsu.edu/archive/).

DANA-WH differs from other digital heritage archives; in addition to textual and two-dimensional (2D) graphical (digital photos, sketches, etc.) content, it includes accurate, 3D models of artifacts and fossils. The 3D models are surrogates of the real objects that can be variously manipulated to be viewed from all angles, and they are sufficiently precise to allow for a range of detailed measurements and analyses. The ATL has developed a customized 3D viewer for DANA-WH that includes virtual tools that enable users to take and record basic measurements of the 3D objects for individual research and analysis or group studies. As an online distributed network, DANA-WH will allow "anytime, anywhere" access to content and services. Users can take advantage of the digital library for formal research, as an educational resource, or simply to satisfy curiosity.

The ATL is equipped with three non-contact laser digitizers/scanners and an array of software for 3D modeling and graphics. Each of the scanners captures a point cloud that represents the surface of the object. Point clouds are merged using third party software, either PolyWorks (http://www.innovmetric.com/) or Geomagic (http://www.geomagic.com/). One of these digitizers, a Minolta Vivid 900 (http://www.minoltausa.com/vivid/default.asp), captures color-per-vertex information, thus eliminating the need for a separate step for texture mapping. The 3D surrogates are available for viewing and a range of measures through DANA-WH, which also presents a range of metric and non-metric associated data.

As a further result of the HNBGU-NDSU collaboration, we are now working to integrate knowledge and methods to develop a more efficient system for vessel reconstruction from single sherds. Rather than optical plotting, the ATL employs its laser scanners to create highly accurate 3D models of the entire sherd. From this sherd surrogate, we can define a profile by a plane through the sherd. We are working to further define the vessel profile, to the extent possible from size of the sherd, based on a series of slices through the digital surrogate. The advantages of this technique over that used at HNBGU is that the basis for the vessel reconstruction then becomes the entire sherd rather than a single linear profile of one slice of the sherd, and therefore the profile is more precise. Furthermore, the Minolta Vivid 900 scanner allows for the automatic texture mapping of the sherd, which greatly facilitates the simulation of full-vessel surface color.

Certainly there are limits to how much one can reconstruct, or model, based upon one sherd; for example, if the lower portion of the vessel is missing, particularly the base portion, then reconstruction will typically be most problematic. This limitation can be ameliorated somewhat, however, in situations where the ceramic assemblage is reasonably well known for a given temporal and cultural period. In such a situation, a series of templates of characteristic vessel forms can be developed to serve as the basis for shape comparisons. That is, the sherd form is used to reconstruct the vessel shape as far down as the sherd size allows; extensions of the walls are then projected beyond that area. New software will be developed that will be used to compare the simulated form to the set of vessel templates for a best-fit match to some specified level of confidence. The template form parameters can then be used to create an idealized model of the full vessel shape. We are still far from developing the shape comparison capability, but software for similar types of shape analysis is being developed at Arizona State University (e.g. Schurmans et al. 2002) and elsewhere. Whatever the extent of the vessel reconstruction, though, the sherd can be viewed in an appropriate place on the whole pot, and the real sherd can be distinguished from the proposed reconstruction.

DIGITAL DATABASE OF ARCHAEOLOGICAL POTTERY FROM INDIA

The primary objective of our collaboration is the development of a pilot program and proof-of-concept for the Indian ceramic comparative collection delivery through DANA-WH. The inclusion of the HNBGU database of Indian pottery in DANA-WH will allow it to be networked with other databases and to make it available to a global audience of researchers. In return, DANA-WH will be enriched in terms of its content. Furthermore, HNBGU will be the first international participant in DANA-WH. In addition, our collaboration will provide mutual benefits for distributed database network development, 3D modeling, and pottery vessel reconstruction.

To start this work we have selected a well documented and published pottery collection from Atranjikhera, an Indian archaeological site in District Etah, Uttar Pradesh, excavated by R. C. Gaur in 1964. The most noteworthy feature of this published material is that pottery from the earliest Ochre Color Pottery (OCP), to Painted Grey Ware (PGW), Northern Black Polished Ware (NBP), Black and Red Ware (B&R), through late Red Ware comes from a well-stratified deposit and comprises almost all the typological shapes of Indian pottery (Gaur 1983). In the development of the database,

Gaur's work has been used to demonstrate the real and future potential of digital archive technologies in archaeological research. In this case, the long-range goal is to establish an online Indian comparative ceramic collection for analysis and refinement of the Indian pottery typological classification system.

In our initial work, the HNBGU content was converted to more generic database formats that are compatible with a broader range of JDBC-compliant relational database management systems. Oracle 9i (http://www.oracle.com/) and PostgreSQL (http://www.postgresql .org/) were used for the initial implementation. A prototype of the Indian Ceramics Comparative Typology, comprised of 200 ceramic specimen records and associated 2D images of pottery profiles (adapted from RC Gaur 1983), is now available through DANA-WH (Fig.2).

A major challenge to our goal has been the insufficiency of the technology infrastructure that serves HNBGU, which is in a mountain valley in northern India. Due to a current lack of IT infrastructure at HNBGU, the ATL is hosting the Indian database and image archive during the pilot phase. Through the assistance of Dr. Franco Niccolucci, however, plans are currently underway to secure financial assistance from the Italian government to upgrade the IT infrastructure to HNBGU. When that upgrade is completed, the content will be relocated to HNBGU where it will continue to be accessible through DANA-WH.

CONCLUSION

The application of computer technology in Indian Archaeology has been little exploited compared to other scientific studies. Therefore, computer applications in archaeology, especially with regard to visualization of artifacts, has remained an undeveloped domain in India. The Indian team at HNBGU has tried to fill the gap by developing an AutoCAD based technique for pottery drawing in archaeology. In this paper we have given a detailed discussion on this technique, and preliminary results of work on 3D modeling, texture mapping, and the development of a web-enabled
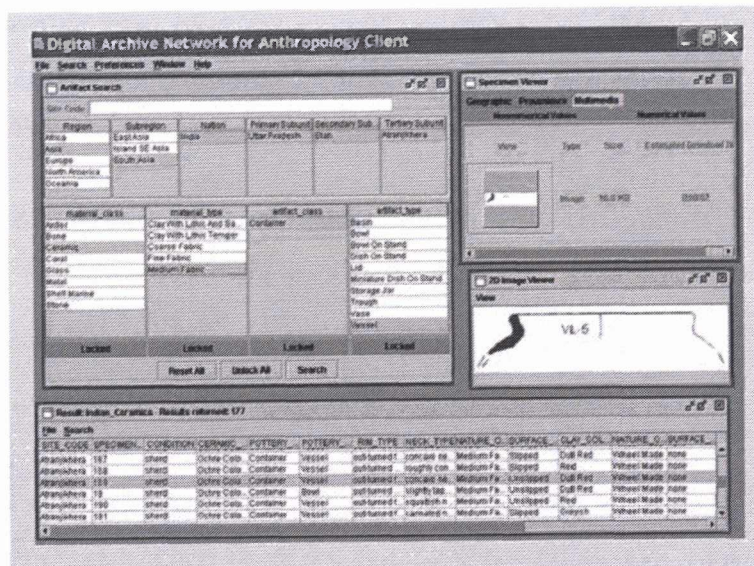

Figure 2 Compilation of screen captures from DANA-WH showing search interface with geographic and artifact type query (top left), list from query results with specific object selected (bottom), multimedia options for object (top right), and profile view f sherd and vessel (right center). Indian pottery vessel from HNBGU database

database of Indian pottery from the archaeological site of Atranjikhera under the DST-NSF collaborative project with the ATL.

The collaborative initiative will be extremely useful in facilitating Web-based access to a distributed network of database and multimedia archives with contents on Indian ceramics, through DANA-WH, for use in the comparative classification and typology of specimens. This will not only benefit Indian archaeologists but also various other scholars interested in South Asian Archaeology.

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