ArcImage: A Computer System for Generating Archaeological Floor Plans and Profile Walls

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ABSTRACT

Many archaeologists still rely predominately on string, line level, tape measure, pen and paper to draw floor plans and profile walls. This is a time consuming and labor intensive process that can suffer greatly from human error. This paper describes a software system for generating archaeological floor plans and profile walls that minimizes the error inherent in traditional methods and reduces the manual labor required to generate such drawings.
Keywords: computer assisted archaeology, excavation drawing

INTRODUCTION

Archaeology is one of the few pursuits of science in which the objects of study, the features within the site, are destroyed in the process of studying them. Due to the vital importance of contextual information in interpreting the meaning of archaeological artifacts and the destructive nature of the excavation process, accurate archiving of the excavations context is necessary. While the digital revolution is slowly working its way into excavation, much of the work is still performed using 19th century technology. Many archaeologists still rely predominately on string, line level, tape measure, pen and paper to draw floor plans and profile walls. This is a time consuming and labor intensive process that can suffer greatly from human error.

One source of error with the current method is accuracy. When mapping a feature by hand, an archaeologist measures and maps a series of points of the outline of the feature and then free hands the connections between them, making the accuracy of the resulting map dependent on the artistic ability of the individual who drew it. Furthermore, a 1 mm thick line on a 1:20 scale map scales to 2 cm in full scale, confounding the error brought on by free handing (Avern 2001: 3). Another source of error is that what is recorded on the maps is biased to what the archaeologist believes to be important while the rest is ignored.

One method employed to help minimize these errors is to take photographs; however, since many still use film cameras, the number of photographs taken during the excavation is limited due to the cost of film, its development, and the space required to store the negatives, images, and/or slides. It can also be difficult to super-impose the maps drawn at the site onto the image taken of the same feature, making it difficult to compare the drawing to the photograph and to visualize non-photographic elements within the image (i.e. changes in soil texture).

RELATED WORK

To address these problems, several projects aimed at bringing the digital revolution into the excavation process have been developed.

Arkeoplan is a system designed to improve the drawing of floor plans and profile walls. It allows the user to draw freehand over an image of an excavation level. It also allows the user to make measurements and label different objects of interest with respect to the digital image. When capturing the image, the archaeologist uses a large tripod to position a remote control camera five to ten meters above the excavation (Gruel et. al. 1993: 81-84). This physical arrangement makes it difficult to use in remote areas and, in freehand mode, it suffers from the same problems that pen and paper do.

Archo is another tool similar to Arkeoplan. This software was developed to work on pen-based computers in the field. Such computers are shockproof, waterproof, and resistant to dust, rain, and other open air conditions. It uses a mobile local area network to instantaneously send information back to the lab. While Archo is able to attach digital photos to the drawings, the option of drawing on top of a digital image is unavailable.   As a result, the system suffers from the limitations of drawing floor plans and profile walls as described before (Ancona et. al. 1999: 117-121).

Nathan Craig has proposed using off-the-shelf GIS software and digital photos to correct the problems associated with drawing floor plans and profile walls. During the excavation he takes a digital picture with the features etched into the soil, rectifies and rubbersheets the image, then draws on it with ArcView. Rubbersheeting is the process in which a coordinate system is imposed upon an image that did not have one. While Craig's process of rubbersheeting takes approximately 45 minutes for a single map, the result is very accurate. He suggests that the amount of time taken could be decreased by automating some of the steps, processing a batch of images and completing some of it in the lab (Craig 2000).

Another approach taken to solve the problem of recording excavations is to replace floor plans and profile wall maps with a 3D recording of information. In Geoffrey John Avern's (2001: 3-8) article, several such methods are discussed. The first one is Eytronics' ShapeSnatcher. This method uses a digital camera, tripod, and a projector that projects a slide with a grid. In order to calibrate the camera, a picture is taken of a box on the floor of a unit. After the floor has been calibrated another image is taken with the projector projecting a grid onto the floor. The resulting image is then combined with the calibration data to create a 3D representation of the floor. Data obtained from multiple perspectives can be combined to alleviate blind spots. The ShapeSnatcher system costs about $4500.

Laser scanners are also used to generate 3D recordings of archeological excavations (Avern 2001:3-8). The first one is ModelMaker which has a laser unit on an articulated arm and must be moved manually. The size of the area that can be scanned is only limited by the length of the arm. The device however is difficult to bring to the field and costs about $107,000. FastSCAN is another scanning laser system which is portable and robust. It can scan an area of 3m from a fixed position. Since it uses magnetic tracking for positioning, it is affected by metal and it does not capture color. It is also expensive, costing about $40,000.

Another popular method of capturing 3D information, though Avern argues against it, is Metric 3D reconstruction as described in Pollefey et. al (2003: 20-27). In this method a series of digital camera images are taken from various perspectives. The difference in angles of the viewpoints must not exceed 10 degrees, and a sequence of video frames can be used instead of images. The images are processed and a 3D model is produced with an error of about $1cm^2$ (20-26). Avern's argument against photogeometry is the probable presence of blind spots. John Williams has developed a system to eliminate (or greatly reduce) blind spots from photogeometric models (2001).

PROJECT GOALS

The long-term goal of this project is to create a convenient, accurate, and fast system for recording floor plans and profile walls. The ideal system will be able to display all pertinent information associated with the drawing. The system will be able to determine the Munsell colors (a color classification system) from the digital image. The archaeologist will be able to generate accurate dimensional information as well as impose a user-defined grid onto the map. The system will be scale independent; meaning it will be flexible enough to work for a large excavated area as well as focusing on small features, and to be able to allow for any shape of excavation area. Since maps can be drawn on a digital image, the archaeologist will be able to impose the map on the image thus making demonstration of information easier. The archaeologist will be able to display the floor maps and profile walls of a feature, unit, and/or site in a 3D world. With this 3D representation, the archaeologist will be able to add artifacts, display relationships, and show or hide features. Overall, this will improve the speed and accuracy of data collection during excavations as well as improve interpretation of the excavations. Because this system must work in the field, the system will be designed to work on mobile computing platforms like laptops, PDAs, and tablet PCs.

Some progress towards this ultimate goal has been realized. A baseline system, ArcImage, has been developed which currently incorporates a drawing program that displays a digital image and allows the archaeologist to draw on it. Each feature can be rotated, scaled, and moved. The archaeologist can calibrate the image and can impose a grid onto it or measure the distance between features and/or artifacts using the assumption that images are acquired via orthogonal projection from the surface. The archaeologist can place depth markers and save the resulting image allowing it to be opened on a later date. This baseline system serves as an extensible framework for later extension.

PROJECT DESCRIPTION

The ArcImage program is designed to work with mobile technology, PDA's in particular but also tablet and other pen based computers. The benefit of a PDA is that a digital camera can be built into the device and therefore, no connection to a desktop computer is required. Connecting a camera to a computer increases the chance of soil getting into the connections. The PDA, however, does have a very small screen.

Since screen space on a PDA is at a premium, the GUI is very basic. Tasks are selected from a menu bar. Several predefined shapes (ovals, rectangles, and rounded rectangles) can be placed onto a drawing. Arbitrarily shaped polygons can also be placed onto the drawing. Each shape can be rotated, moved, scaled, and filled with different patterns. Shapes can also be deleted from the drawing. These options are selected in a convenient pop up menu associated with the selected shape (Figure 1) which is displayed using a right mouse click on the shape.
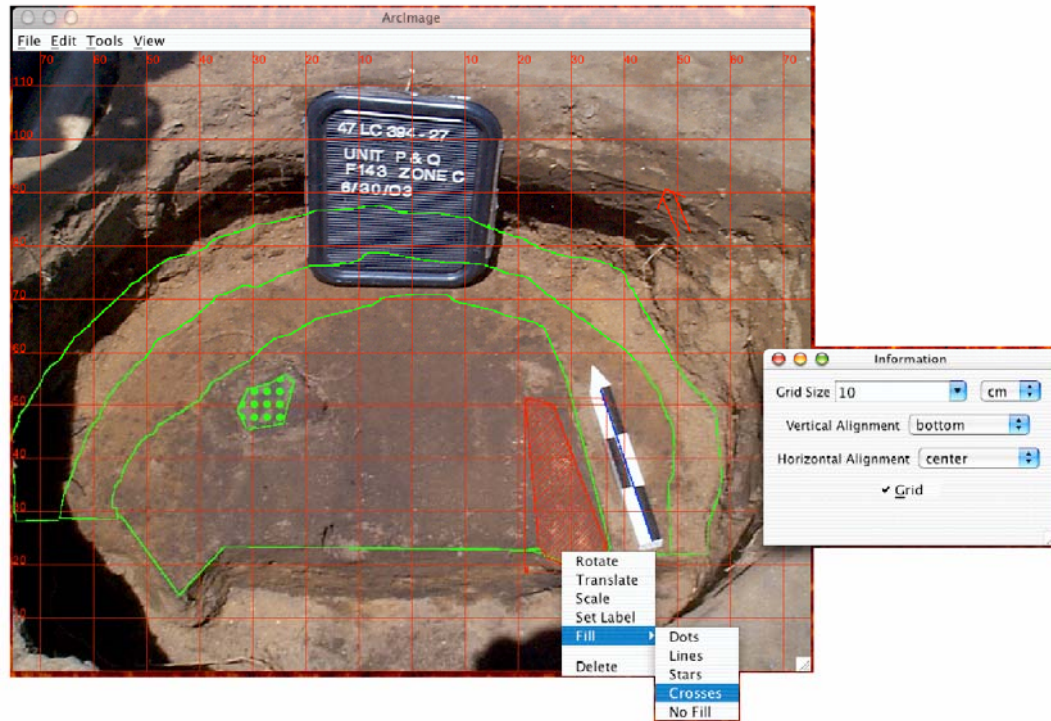

Figure 1. A screenshot of ArcImage showing the grid options and a pop-up menu showing the actions that can be performed on drawn elements. The dot fill object is a potsherd and the line fill object is an elk antler. The original image was taken from an actual excavation site in La Crosse County, Wisconsin.

When a shape is selected, the shape is highlighted by either a surrounded rectangle or the display of two perpendicular lines running through its center depending on which manipulation option has been selected.

Calibration is performed by manually drawing a calibration line of known length on the image. The mapping between the image space and physical space is computed using the scaling factor ρ defined as:

$$\rho = \frac{\sqrt{(x_1 - x_2)^2 * (y_1 - y_2)^2}}{L}$$

where (X_1, Y_1) and (X_2, Y_2) are the image coordinates of the endpoints of the calibration line and L is the known physical length of the calibration line.

The ability to place depth markers is also supported by ArcImage. The archaeologist clicks on a location of known depth and the image is annotated. The archaeologist is also able to place a north arrow on the image.

Java, the language used to write the program, provided another benefit. One of the biggest benefits is portable allowing the same application to run a number of different platforms with out having to change the code. This will give the archaeologist flexibility in choose the types of computers that best suit his needs. The language also has PDA support, which will allow it to be used in the field. Another benefit of Java was that it simplified the design and implementation of the program since APIs for drawing and displaying 2D graphics are built into the language.

RESULTS

The ArcImage project exists as a drawing application that can be used in the field with mobile technology and digital cameras. As a result, it can produce drawings similar to those that are currently produced by hand (Figure 2). It uses digital camera pictures that have been demonstrated in Arkeoplan to speed up the drawing of floors. The archaeologist is able to fill in features to show basic relationships and have the ability to label different depths.

FUTURE DEVELOPMENT

Planned extensions to ArcImage include the registration of multiple images taken over large areas. The restriction of having to take the image straight down will be removed by developing appropriate interpolation algorithms and including photo-geometric techniques.
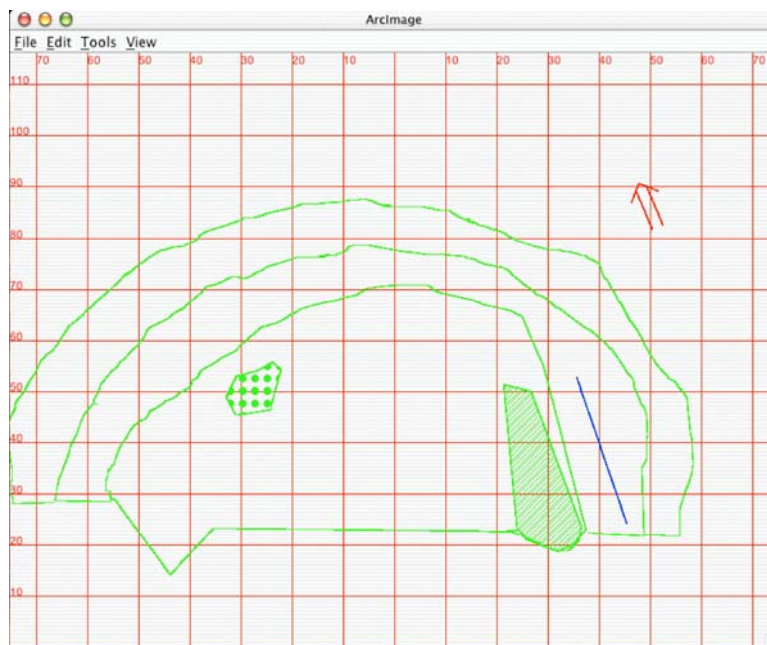

Figure 2. A sample floorplan generated by the ArcImage system.

Information about the 3D geometry of the excavation will also be culled from the image database. In this stage the sequence of floor plans that were drawn will be placed in a 3D environment based on their location and depth as well as placing profile walls vertically where they are located. The archaeologist will have the ability to add the location of artifacts and a representation of the artifact will be displayed. The ability to show and hide both artifacts and features will be incorporated.

To aid in interpretation, the archaeologist will have the ability to have features and artifacts displayed with certain colors and/or hidden based on selected properties of the feature or artifact. Eventually using the methods developed by Pollefey et. al (2003:20-27) to reconstruct the layers in 3D, the plan maps will be able to be placed on top of them to allow for levels of detail. All of this combined will help improve the speed and accuracy of data acquisition as well as interpretation and bring excavation into the 21st century.

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