Reconstruction of 3D Images of Archaeological Objects Using RTI Dome Method

Vahid Pourreza Ghoushchi [1], Aysel Arslan [2] , Osman Furkan Kar*, Mahmut Sami Yazıcı*, Rana Özbal [2] and Hakan Ürey [1] .

1. Koç University, Electrical Engineering Department, Optical Microsystems Laboratory (OML), Istanbul, Turkey.
2. Koç University, Archaeology and History of Art Department , Istanbul, Turkey.

1. Motivation

Virtual reconstruction of archaeological artifacts has been a challenge in archaeology. Common reconstruction methods include photography and 3D drawings of the objects from various perspectives. However, these methods are time consuming and often lack the depth perception needed. Reflectance Transformation Imaging (RTI) is a novel technique to overcome these obstacles [1], [2]. This easy and inexpensive technique produces high-resolution 3D images[3], enabling archaeologists to examine artifacts in fine details.

RTI technique includes two methods: using a dome [4] or using highlights. In this work the dome method was employed for the first time in Turkey. We imaged various stone, metal, clay, and bone objects from different perspectives (LEDs in different positions and angles). Processing these LEDs images using the RTI builder program produces a single 3D image that combines all of the obtained images. Altering the light positions on the program allows for greater detail and increased depth perception. For example, by analyzing the RTI images of clay artifacts we could distinguish the fingerprints left by the people who made and used these objects. The RTI method has the potential to reveal new information about ancient societies.

2. Control Unit And Setup

Figure 1 – Experimental Setup

- The RTI device (Figure 1) includes:

1. An aluminum dome with radius of 30 cm.
2. 56 white LEDs
3. A tripod
4. Nikon d7100 24.1 MP DSLR Camera.
5. Nikon 105 mm Macro lens - f/2.8 with 15 degrees FOV
6. Electronics control unit employs an Arduino Mega chip without any extra shield.

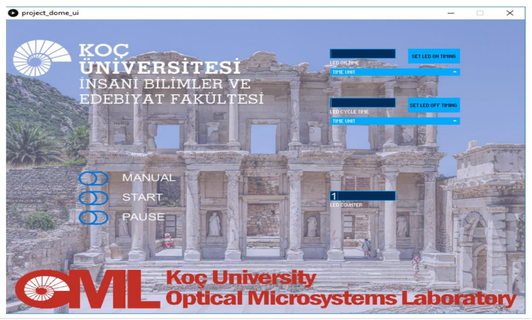

Figure 2 – GUI of the RTI device

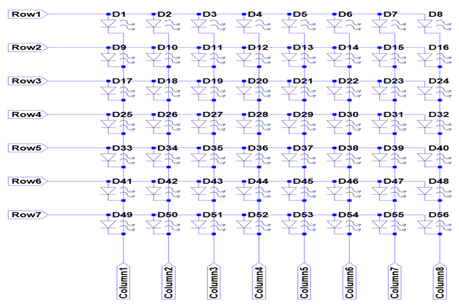

Figure 3 – LED matrix design of the dome

- White LEDs in four rows consequently illuminates an object in different lighting angles (15 to 58 degrees).
- Two Nikon macro lenses are used for capturing images: 105 mm, f/2.8 and 60 mm, f/2.8. Lenses were capable of reproduction ratio of 1:1 and had 15 and 22 degrees field of view on a crop sensor camera, respectively. The maximum resolving power of the device using 105mm lens is 2320 LW/PH[5].
- A customized Graphical User Interface (GUI) was developed (figure 2) to control LEDs in different locations and their illumination time.
- The LED array is constructed in form of a matrix(figure 3).
- A time shutter was used to capture the images(3 seconds for each image).

4. Reconstruction of 3D Images

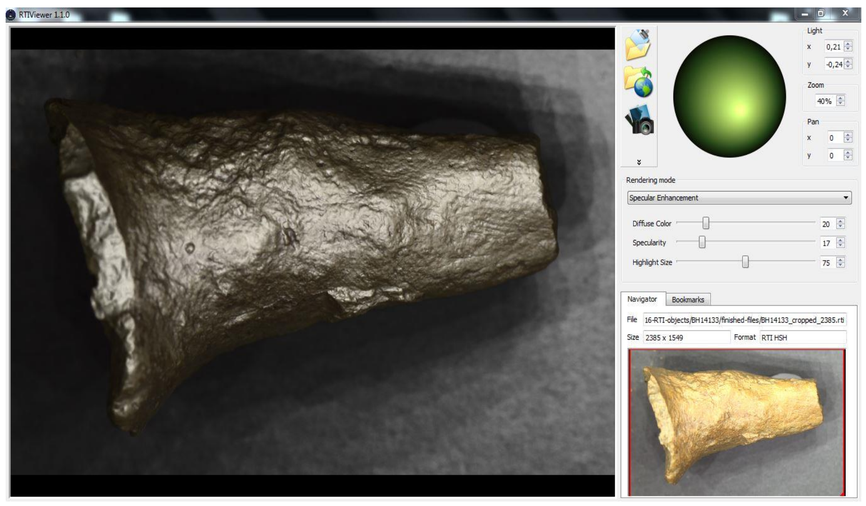

Figure 4 – Screenshot of RTIViewer software

- Images that were captured by the camera were imported to RTI builder program.
- This program uses reflectance transformation methods to calculate shadow, color and shape information and export it into a single file.
- Lighting can be changed in the program.
- This program offers various rendering modes, Such as normal visualization and specular enhancement.
- Specular mode, emphasizes the reflectivity of an artifact and ignores the color information. For example, in figure 10 by applying this rendering mode the fingerprints on the clay ball were clearly visible.
- Normal visualization mode produces a false-color representation that indicates how surface orientation changes.
- Since images were captured with a high resolution camera, it is possible to zoom in on the image and inspect the without significant resolution loss.

5. Other Methods For inspecting Archaeological Objects

Figure 5 – Bone scraper and its Drawings.

Figure 6 – The process of drawing an archaeological object (source http://pbs.bento.storage.s3.amazonaws.com).

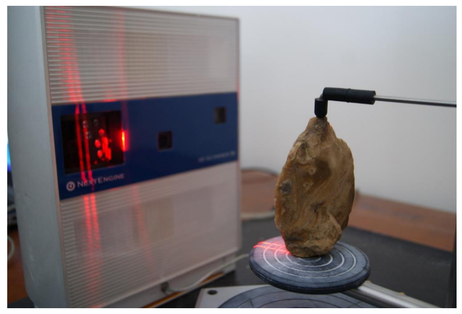

Figure 7 – 3D scanning of an archaeological object. (source https://sha.org).

- Documenting archaeological artifacts includes: visual observation with the naked eye, general photography and drawing the objects.
- General photography provides limited interpretations.
- Drawing method is very time consuming.
- Only a limited number of archaeological artifacts are selected and drawn at the excavations.
- 3D scanning method:
  - Requires a relatively long time
  - The color of the object affects the results
  - Even the high quality processing does not yield the minute details such as fingerprints.

Experimental Results

Figure 8 – Bone spoon fragment , normal image(top) and constructed image(bottom).

Figure 9 – Byzantine metal seal normal image (top) and constructed image(bottom).

Figure 10 – Magnified clay ball, normal image(top) and constructed image (bottom).

- We captured images of the metal seal from a Byzantine grave and a bone spoon and various clay objects from the Neolithic period dating to 6600-6000 BC.
- Some of the artifacts had been subjected to fire, however, it did not affect the constructed images.
- The technique yielded high quality images in a very short time (3 minutes).
- The bone spoon has quite an even surface. Scratch marks were visible to some extent to the naked eye. These marks make it possible for researchers to interpret how the bone spoon was made and how it was used. Thanks to the angle of illumination in RTI and a shallow depth of field, use and production marks were emphasized.
- Visual examination with magnifying glass or microscope were helpful, but it is difficult to see the complete fingerprints due to limited FOV, but RTI technique, overcame this problem

Conclusion

- RTI can be used in archaeology, conservation and museums.
- It is a non-destructive and time efficient method and yields more data than other visual examinations.
- As the lighting positions can be altered in the RTIViewer software, data loss due to shadows and specular lighting is minimal.
- Compared to 3D scanners, object surface can be examined in higher resolution.
- Considering the difficulties to transport archaeological objects, the RTI provides data that can be shared easily.

References

1. Willems, G., et al. "K. Van Lerberghe en L. Van Gool 2005: Easy and cost-effective cuneiform digitizing." M. Mudge, N. Ryan en R. Scopigno (red.) The 6th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST 2005), Pisa,. 2005. 73-80.
2. Earl, Graeme, et al. "Reflectance transformation imaging systems for ancient documentary artefacts." BCS, 2011. 1-9.
3. Kinsman, Ted. "An Easy to Build Reflectance Transformation Imaging (RTI) System." Journal of Biocommunication Demo 40.1, 2015. 10-14
4. Happa, Jassim, et al. "Illuminating the past: state of the art." Virtual reality14.3 (2010): 155-182.
5. http://www.photozone.de/Reviews/224-micro-nikkor-af-s-105mm-f28g-if-ed-vr-review--test-report?star

[*] Osman Furkan Kar and Mahmut Sami Yazıcı were summer interns at Optical Microsystems Laboratory, Koc University.

Koç University, Electrical Engineering Department, Optical Microsystems Laboratory, Rumeli Feneri Road, Sariyer, Istanbul 34450 Turkey, Email: vghoushchi13@ku.edu.tr