SOFTWARE TOOLS FOR ANALYSIS AND VISUALIZATION OF THE ANTIKYTHERA MECHANISM

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ABSTRACT

The Antikythera Mechanism is not only an artifact. It is the first known geared computer that spurs interest of archaeologists, astronomers, mechanical engineers and software developers. Its high level of corrosion, make very difficult its further studies. Although, the generated data which have been produced during an international research project for the Antikythera Mechanism, are going to be public. On the other hand, the fast evolution in computer graphics area, both in hardware and software, offers to users more possibilities than a few years ago in analysis, visualization and representation. In this paper, powerful and non-commercial software packages are presented, suitable for the study of the Antikythera Mechanism, and generally, for similar artifacts of Cultural Heritage.

Index Terms — Antikythera Mechanism, visualization, volumetric analysis, computer tomography, cultural heritage

1. INTRODUCTION

The Antikythera Mechanism is a unique greek and the oldest surviving geared device, constructed around the end of the 2nd Century BC. From the ongoing research, it is known that it calculated and displayed celestial information, particularly cycles such as the phases of the moon and a luni-solar calendar [1]. It is certainly one of the earliest intricate scientific instruments known [2].

The Antikythera Mechanism is exhibited in National Archaeological Museum of Athens. However, the high level of corrosion, prevents researchers from studying the physical artifact. Although, radiographies and Computer Tomographies (CTs) are the only type of data that can contribute to future studies. Moreover, the data of an international research project are going to be shared free in near future. This paper acts as a tutorial, presenting software tools that can manipulate these data and export useful information in analysis and visualization of this unique artifact. In other words, this paper presents pioneer and non-commercial software packages, for encoding the most sophisticated computer of the ancient world.

The rest of the paper is organized as follows. Section 2 reviews the early and recent studies in Antikythera Mechanism. Section 3 describes Drishti software package for structural analysis and visualization of the first known computer. In Section 4 is presented a solution for decoding the inscriptions of the Mechanism. Finally, Section 5 presents the conclusion and challenges for future research.

2. THE ANTIKYTHERA MECHANISM

The Antikythera Mechanism is the oldest, the only and in fact the very best known example of a complex astronomical device, a dedicated analogue astronomical computer, possibly a planetarium, a device made with gears [3]. The first great discovery in maritime archaeology yielded not only a fine collection of art treasures but also the most enigmatic, most complicated piece of scientific machinery known from antiquity [4].

The Antikythera Mechanism was found by chance close to the small island of Antikythera in April 1900 by sponge divers, who were stranded there, due to bad weather [5]. This singular artifact is now identified as an astronomical or calendrical calculating device involving a very sophisticated arrangement of more than thirty gear-wheel [4].

2.1. Early studies

In Table 1 a brief history of early studies in Antikythera Mechanism is presented, focusing on the relation between type of data for research, and type of representation as result. Thus, illustrations, accurate analog reconstructions [6], animations and simulations [7] [8], are the basic type of representation.

Time Period	Type of data	Type of representation
1901 - 1930	physical artifact	-
1931 - 1974	photographs	illustrations
1931 - 1974	radiographies	analog reconstruction
1975 - 2005	-//-	animations, simulations analog replicas
2005 - 2017	tomographies	-//-

Table 1. Milestones in the research of the Antikythera Mechanism

2.2. Recent studies

In recent studies the authors, as members of an interdisciplinary research team from University of Macedonia and Aristotle's University of Thessaloniki, aim to make a synthesis of the research results about the Antikythera Mechanism in new type of representation, using virtual reality technologies. Specifically, designing and developing an educational, and full of immersion serious game in virtual environment,is our major target. Although, an intermediate milestone is the analysis and visualization of the CTs dataset of Antikythera Mechanism, and this presentation is part of it.

2.3. The challenge

As mentioned before, the dataset of the Antikythera Mechanism Project [10] is going to be published for free. The main challenge for this presentation is the opportunity that many volume rendering libraries and frameworks have been made available to the users to build applications in [11]. Moreover, complete volume rendering systems provide visualization and analysis capabilities such as

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Figure 1. Photograph of fragment A

Figure 2. Radiography of fragment A [4]

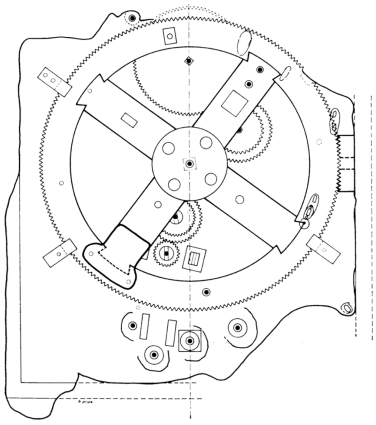

Figure 3. Illustration of fragment A [4]

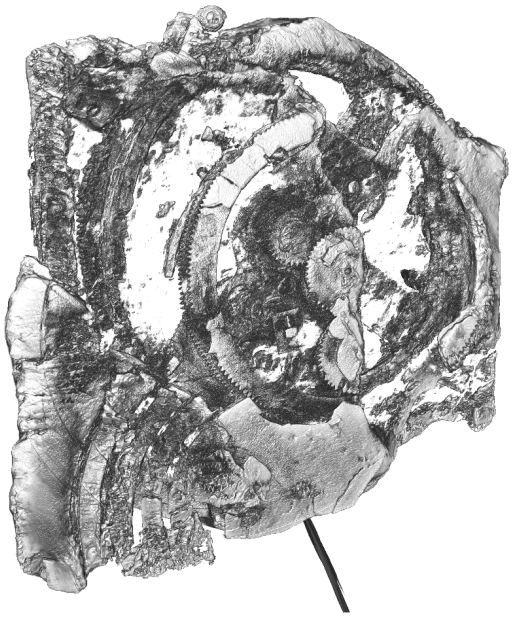

Figure 4. Tomography of fragment A of Antikythera Mechanism. This image is captured by the author in Computer and Network Systems Technology Laboratory (CNST-Lab), Department of Applied Informatics in University of Macedonia (Thessaloniki, Greece), using the "ImageVis3D" software package [9]

Drishti [12], and ImageVis3D [9]. This presentation tries to combine the Antikythera Mechanism dataset, with powerful software packages for analysis and visualization.

3. VOLUMETRIC DATA ANALYSIS

During the Antikythera Mechanism Research project [10], the technique of CTs was applied on Mechanism's fragments. The sample was in effect digitized into billions of volume elements, known as voxels. Computer software was used to reconstruct the 3D volume from all these projection images. What was created was a 3D map of the linear X-ray attenuation within the sample [13].

In this section we present a group of software packages, which will be useful tools in data analysis and visualization of the structure for the first known analog computer in humanity. As the dataset is going to be open to public, we decided to present non-commercial software tools, for spinning off the forthcoming research evolution for the Antikythera Mechanism. The one and only limitation, it will be the low hardware capabilities of researchers' computer systems. Drishti software handles scalar data over rectilinear grid and is written using OpenGL with Qt for the user interface. The software runs on OpenGL 2.0 capable graphics hardware. The package has three modules: (1) DrishtiImport, (2) Drishti, and (3) DrisghtiPaint tool [11].

3.1. Importing data

Importing an image file into Drishti is an easy procedure. User needs to execute the "DrishtiImport" application, which come with the whole Drishti software package. Type of folders and files, that can be imported in Drishti software, is: DICOM image, Analyze 7.6, GRD, Standard Image, MetaImage, NetCDF, NIFTI, NRRD, RAW, RAW Slab, RAW Slice, Grayscale TIFF Image, QMUL Tom, TXM, VGI.

Users have to save their imported image file under an appropriate name and needs to select the destination they want, the file to be saved into. The default "pvl.nc" format, which is selected when the window appears, is the file type that is able to be loaded into the "DrishtiRender" program.

3.2. Clip planes

In Drishti renderer [12], clip plane can be added when three points are specified. Press space-bar to bring up command dialog and enter "clip" to add a clip plane passing through those 3 points. The points will be removed when the clip plane is added. When the mouse is on either of the X, Y, or Z axis, left mouse drag can be used for rotation and right for translation. When mouse is on one of X or Y axis, then ctrl+right mouse drag can be used, for scaling the clip plane in the respective direction. Users can issue single key commands while hovering over a clip plane. Clip planes can also be manipulates using keyboard shortcuts.

Clip planes can be textured with transfer functions using "tf-set" option. This facility allows for viewing of slices along any orientation. Users can edit changes made to the clip planes. Moreover, view-port functionality translate the camera at clip plane's position. Viewing direction is along the clip normal. Near and far cutting planes are controlled by the thickness parameter. Users can press space-bar while in view-port window, to bring up the clip plane dialog [12].

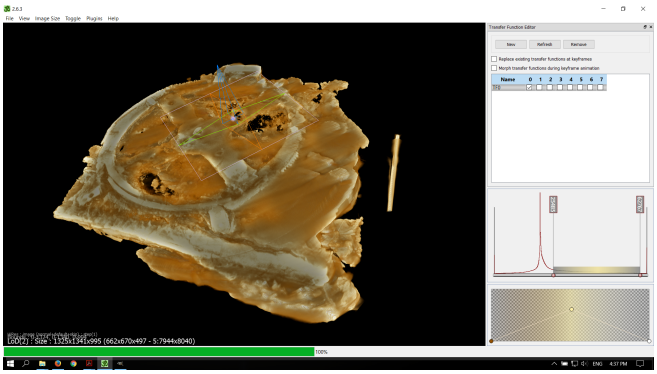

Figure 5. A clip plane crosses vertically the fragment A (1 by 4)

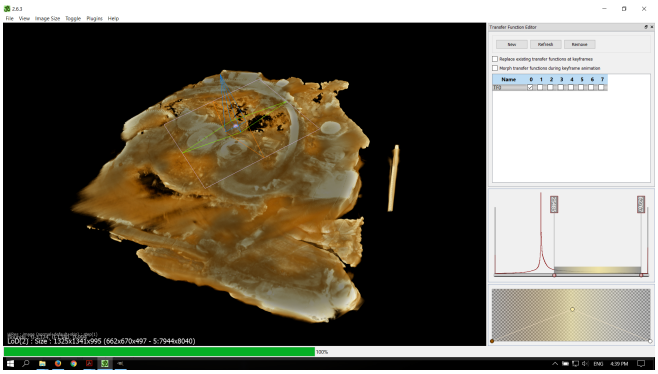

Figure 6. A clip plane crosses vertically the fragment A (2 by 4)

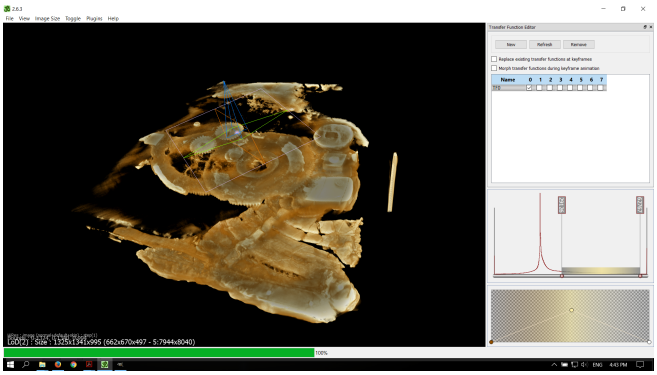

Figure 7. A clip plane crosses vertically the fragment A (3 by 4)

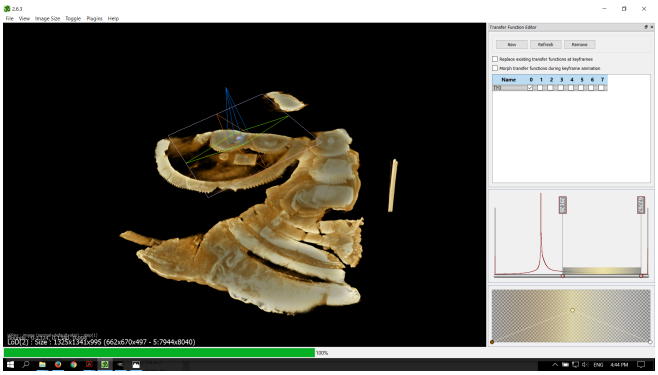

Figure 8. A clip plane crosses vertically the fragment A (4 by 4)

Figures 5, 6, 7, and 8 present a sequence into the density of fragment A of Antikythra Mechanism, by using a defined clip plane in Drishti software. The structure of the fragment is revealed. Gears, and axes are now clearly visible.

3.3. Measurements

Paths are created using the ”addpath” command from the points. Paths can be created using all the points or the selected set of points. Once the path is created the points used to create the path are removed from the scene. The path can be modified after it has been created; points can be added, moved and removed from the path. A path consists of at least two points.

The importance of paths, is the opportunity of accurate measurements in the fragments of Antikythera Mechanism. We can count the accurate distance between two gear teeth, and define the real radius of a gear. Moreover, we can estimate the length of an axis. Thus, we can reconstruct the structural parts of the artifact.

4. INSCRIPTIONS

About 3000 letters had been deciphered up to 2012. They all fall into three broad categories: astronomical inscriptions, technical inscriptions and geographical inscriptions. Several astronomical terms have been read referring to the Sun, the Moon, the ecliptic, the Metonic and Saros cycles and other astronomical phenomena [5]. Extended astronomical and technical inscriptions covered its front and back doors and plates [14].

In this section we present a unique method, developed by Hewlett Packard, that is very useful in research for cultural heritage. In our case, we describe a procedure for decoding the inscriptions of the Antikythera Mechanism.

4.1. PTM analysis

The Polynomial Texture Mapping (PTM) is a representation of varying luminance of pixels in a sampled image plane. The method uses a fixed camera and captured surface, frequently a single object, and varying light positions known either from creation of a fixed light orientation device. A series of photographs is produced each with a separate known light source. The variance in the pattern of light and shade across the object is calculated from them [15].

We present fragment 19, of the Antikythera Mechanism into the PTM viewer software. In series of Figures 9 to 14, user can see the user interface of the application. At the end, it is clearly the improvement in decoding the inscriptions in the front side of the fragment. Both in Figure 9 9 and Figure 14 14 the direction of the light comes from top, with the difference that the intensity is doubled. In Figure 10, 11, 12 and 13 we applied to source direction light, a clockwise rotation. This technique is suitable for rusty artifacts in Cultural Heritage.

4.2. Volume analysis

Drishti render provides sculpting facility via (1) clipping planes, (2) cropping, (3) blending, (4) dissection, (5) reveal, (6) path tools, and (7) bricks. These features, in combination with PTM viewer, can maximize the research result of the structural analysis of each fragment. Artifacts with inscriptions, such as the Antikythera Mechanism can be decoded with the use of cropping, which provides more flexible sculpting facility, compared to clip planes. Finally, blending of transfer functions allow users to display different information in a specific region, by using different transfer functions to the one that is applied to the whole data. [11].

Figure 9. Fragment 19 with no edit, in PTM viewer

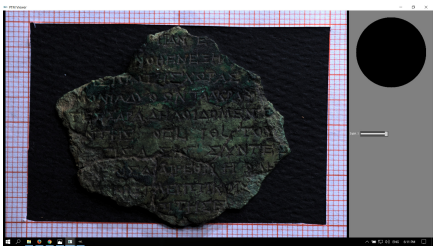

Figure 10. Light from top-right

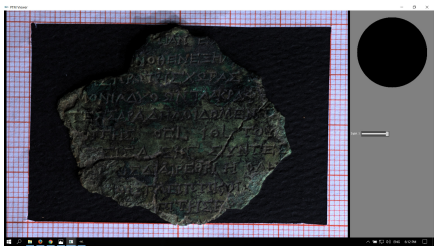

Figure 11. Light from bottom-right

Figure 12. Light from bottom-left

Figure 13. Light from top-left

Figure 14. Centered and double density light

5. CONCLUSION AND FUTURE WORK

The paper presented software packages, for the analysis and visualization of the Antikythera Mechanism. Specifically, we described the powerful, and open-source Drishti software, suitable for the analysis of raw data of the Antikythera Mechanism, which are going to be public. Moreover, we emphasized the use of PTM viewer, a useful tool for inscriptions' investigation.

This paper is helpful, not only for researchers and professionals in Astronomy, Engineering, Cultural Heritage, or Computer Science. This presentation will be practical to everyone, who likes to use the forthcoming open data, of Antikythera Mechanism project, to design and build physical and operational models, or more accurate and immersive animations and simulations.

In the future, we will gamify the Antikythera Mechanism. We are going to design and develop a serious game in virtual reality, embedding the knowledge for the artifact. This aims to communicate the Antikythera Mechanism with public, in an immersive, educational and entertainment way. The evaluation of the project will feed back the research in serious games and virtual reality.

6. REFERENCES

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