Vassilios Tsioukas*

Free software solutions for the creation and manipulation of 3D representations of historical maps.

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Summary: Whatever the carrier of a map is (paper, fabric, wall, stone, wood) even if it is representing 2D information of the real or imaginary world it still remains a 3D object that should be treated appropriately.
The state of the art in electronic media and visualizing devices is shifting from 2D to 3D. Even in the movies and the game industry the more advanced products include either anaglyph or stereo projections. This technology can be very easily adopted to record, map and represent the 3D characteristics of valuable objects such as historical maps.
Creating 3D models of small objects including historical maps printed on paper or fabric material or found in books and atlases is nowadays more than easy and affordable to accomplish. The current paper is presenting solutions to create such 3D models using off-the-shelf hardware and free software.

Introduction

The historical maps are important cultural heritage artifacts with particular characteristics and should be treated as important samples of the human civilization and evolution. The historical maps have specific characteristics and three of them must be taken into account when a process for digitizing them is applied. Specifically:
1) a large amount of the historical maps' carrier is paper and therefore it is highly volatile and prone to damage of their image and geometry due to inadequate conditions (e.g. humidity, heat) and the over time storage
2) although they depict two-dimensional information and their geometric information is quite vague, after proper documentation and georeference of their digital copy, they can be used with great success in identifying toponyms no longer existing or assist the historical study. Therefore, the mapping and digitization process should be almost completely accurate so that digitizing errors will not deteriorate additionally the already unclear geographical background.
3) In many cases, historical maps are part of books or atlases. The placement of the atlas in a scanning device is different every time an effort is made to digitize it.
All three of the above mentioned characteristics lead to the conclusion that historical maps need to be digitized like all other 3D objects, and there should be a process of restoring them to a digital form that should be independent of the time of documentation. This "new" rectified form should be equivalent to the original image of the map when it was first generated on paper on top of a completely flat subject. This new rectified version could derive via the implementation of digital process by applying a stretching deformation so that body-surface of the paper will cover the largest extent.

* Associate Professor, School of Rural and Surveying Engineering, Aristotle University of Thessaloniki [tsioukas@topo.auth.gr]

This paper is concerned only with the part of the 3D documentation of the historical maps as valuable objects of cultural heritage e.g. a statue of great historical, artistic or archaeological value and is not addressing the process of virtually stretching a map to its original situation; however, an important step to implement this procedure is the creation of its real 3D model.
In order to generate the 3D model of small items of great cultural and historical value many solutions are available, using special software and appropriate hardware and applying no contact on the material but acting remotely. These are usually structured light scanners or stereoscopic photogrammetric configurations. The cost of the overall solution can range from a few hundred to hundreds of thousands of euros. The use of a freeware software solution is proposed here. The reason is not because of its low cost but mainly due to the extremely accurate results it generates. For the application of the methodology and the testing of digitizing historical maps, a case study was carried out, using old maps from an historival Atlas of the Koventareios maplibrary of Kozani dating back to the 17th-18th century.

3D digitization of historical maps

Our object of study is a centerfold map of Utopia the imaginary state of Plato's myth produced by J. B. Homann, a 17^{th}-18^{th} century German geographer, cartographer and atlas publisher. The map is rather deformed and its relief extends more than 2-3 centimeters (Fig. 1a and 1b). This is producing gross errors when measuring points on the top view scanned image produced by the Bookeye special scanning device that has been used to generate the digital copy of the map (Tsioukas et al, 2012). In order to have the correct geometry of the map, a 3D documentation procedure should be applied. One optimal (in terms of value for money) solution is 123D Catch.

Figure 1a and 1b. The deformation of the map is visible on both topview and oblique images.

123D Catch is a freeware application created by AutoDesk working over the Web. The software uses the structure from motion (Structure from motion - Wikipedia, the free encyclopedia) technique to indentify a big number of points on the outer surface of an object in several images (at least three to map every 3D point) and through the colinearity equations produces a scale-free 3D model of the imaged object. The images that are taken using a conventional digital camera need no special configuration (knowledge of calibration procedures and photogrammetric algorithms) and even a novice user can acquire them. Images should be acquired under natural lighting conditions and using the same focal distance. As mentioned earlier all points that need to be recorded must be captured from at least three different camera locations and should present high color texture. Points lacking (or of low) texture are not reliable and in such cases artificial texture patterns could be applied using either optical laser devices or video projectors. Our aim is mainly to create the 3D model of the historical map and not its pictorial information. The pictorial information must be captured using high resolution non-contact scanners (e.g. Bookeye, the Cruse Digital Imaging Equipment) and should be combined with the 3D model generated by 123D Catch.

The images are dropped in the 123D Catch window and overview images are generated to provide a coarse 3D model. The images are transferred to an internet computer farm and heuristic algorithms are creating the necessary matching between the conjugate points. The delivered product is a scale free triangulated wire mesh covered by the full resolution images. The user should define manually a reference distance as well as provide the rotation around the arbitrarily defined 3D axis (taken from the first image introduced in the project). The accuracy of the generated 3D model is quite good and for sure it is much better than any 2D scanning procedure that ignors deformation errors of the historical maps' image due to its relief. The generated 3D model is stored in AutoDesk DXF or 3DS files or can be extracted to common 3D file formats such as .OBJ which is suitable for the manipulation of the model in other freeware applications. For example, MeshLab can be used to navigate and measure the generated 3D model (Fig. 3).

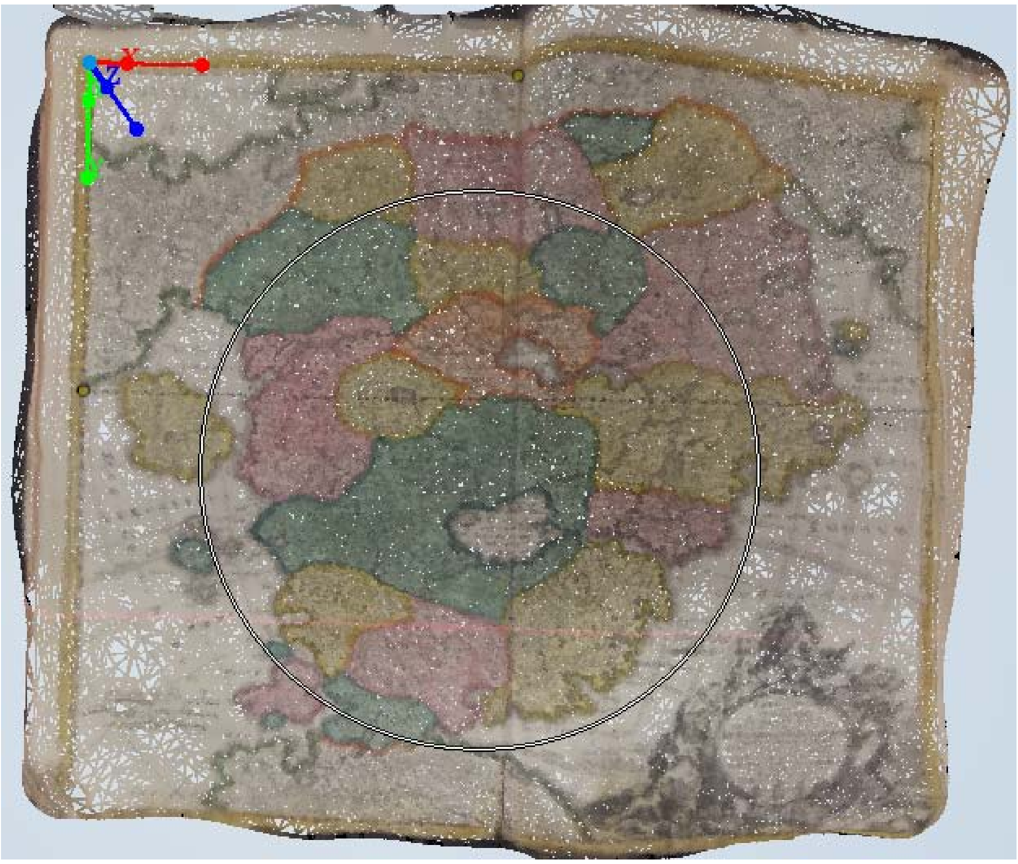

Figure 2. The Triangulated Irregular Network (TIN) after the extraction of the 3D model from 24 images of the historical map. Texture information has been applied on each point and line of the mesh.

Figure 3. The 3D model can be manipulated and measured in MeshLab.

Conclusions

Our proposal demonstrates the use of freeware software to generate the 3D model of paper historical maps. The models can be the basis to extract precise geometric information out of the historical maps and exploit fully the geometric content of these important historical documents. Future research will concentrate in the creation of software to rectify the digital copy of a historical map in a "stretched" form that is going to give the representation of the historical map at the time of its creation.

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