Historical Coins in 3D: Acquisition and Numismatic Applications

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Abstract

This paper addresses the 3D acquisition of historical coins and evaluates its benefits over the current documentation method by means of 2D images. We present preliminary results on creating full 3D models of coins from the Roman and medieval times using a state-of-the-art active stereo scanning device. Furthermore, we discuss the results from numismatic point of view and highlight the different fields of numismatic research where a 3D analysis is of high value, including documentation, measurement and identification. The results show that accurate 3D models can be obtained despite the small size (typical diameter of about 15-30 mm) and specular surface of historical coins.

Categories and Subject Descriptors (according to ACM CCS): I.4.1 [Image Processing and Computer Vision]: Digitization and Image Capture—

1. Introduction

Numismatics deals with the historical study of the phenomenon money. As a consequence, central objects of numismatic work are coins and nowadays their digital capturing is a major issue. In digital coin databases usually images are added to the text-based descriptions to increase the informative value. Besides collection purposes, the digital capturing of coins has also the potential to automate and improve their analysis.

An overview and discussion of useful applications for automatic image-based analysis in Numismatics was recently given in [ZKS08]. First attempts for the image-based recognition of ancient coins were made on coin identification [KHMZ09] and coin classification [KZ08]. These methods were applied on 2D images since 2D acquisition is simple and cheap and large inventories exist already. However, although the results of the image-based methods for coin recognition are promising, they suffer from the loss of information due to the 2D image acquisition. Ancient coin surfaces are reliefs visualizing inscriptions and symbols. Therefore, the appearance of coins in 2D images is highly influenced by the lighting conditions. Different lighting directions make small patterns on the coin look very different which limits, for instance, the use of local image features for coin recognition. 3D scans of coins would lead to new perspectives for processing and studying historical coins as well as new strategies for representing them.

In the past, there have not been many attempts to develop a reliable method for the 3D documentation of coins. Hossfeld et. al [HCEA07] presented the so called Three-Color Selective Stereo Gradient method: the objective is to classify EURO coins based on a comparison of specially measured and processed 3D surface information with characteristic topographical data stored in a database. On historical coins, initial research for an improved visualization was conducted by Mudge et al. [MVSL05] by applying Polynomial Texture Mapping (PTM) [MGW01]. They used a setup able to photograph a coin 24 times with different illumination directions to obtain the according PTMs. With interactive viewing software the assembled PTMs are used to obtain a photorealistic visualization of the coin. PTM imaging can also be combined with shape from structured light to acquire more accurate 3D coin models.

In this paper we present preliminary results on creating full 3D models of historical coins using a state-of-the-art scanning device and discuss their possible use for numismatic research and documentation. 25 coins from both the Roman and the medieval age were scanned using an active stereo vision scanner providing high-accuracy models of the coins despite of the challenging constitution of this kind of objects. Typically, historical coins have a diameter of about 15-30 *mm* and highly specular surface since they were made of metal.

The remainder of the paper is organized as follows: Section 2 describes the scanner and the acquisition process used for obtaining our 3D coin models. In Section 3 the final results are presented and discussed from a numismatic point of view and the fields of application for 3D coin acquisition are identified. A conclusion is finally given in Section 4.

2. 3D Acquisition

Difficulties in the acquisition of coins are mainly caused by the reflectance of the metallic surface. For 3D coin acquisition synchronous acquisition of 3D data and texture/color information is needed. This allows the subsequent combination of 2D and 3D image analysis. Furthermore texture mapping of high quality 2D images leads to a realistic representation of a coin and fulfills numismatists' needs. Portability of the equipment is essential since coin acquisition has to take place at the museum where the coins are kept.

Because of these demanding requirements we scanned coins with the *Breuckmann stereoSCAN 3D* [SSc], shown in Figure 1. The scanner uses an active stereo approach, i.e. it combines the shape from structured light and stereo vision approach [SAB*07]. For stereo vision two cameras are used for simulation of the human vision system. A point in 3D space and the projections of this point in the left and the right camera build a triangle. If the angles of the projected light rays and the distance between the cameras are known, it is possible to calculate the coordinates of the point in 3D space. This is called triangulation. In active stereo vision, a light source projects artificial features. This features are easy to extract as their properties are known and they can be matched unambiguously.

As can be seen in in Figure 1 the main components of the system are two CCD cameras and a light projector which is projecting structured light. The use of structured light introduces known visual features which can be uniquely identified and matched in both images of the stereo system, i.e. finding corresponding points for triangulation is trivial. In the setup used for coin acquisition, the scanner provides a theoretical x-y resolution of 20 μm and a theoretical z-resolution limit of 1 μm.

3. Results and Numismatic Discussion

In total 25 coins were scanned: 16 ancient coins from the Roman era and 9 tornese coins from medieval age. Views showing the obverse and reverse of five Roman and a tornese coin are shown in Figure 2. Please note that, for example, the Roman coin of Figure 2(a) and the tornese coin of 2(f)

Figure 1: *Active stereo scanner used for the 3D acquisition of the coins.*

have a maximum diameter of only $\sim 21mm$ and $\sim 25mm$, respectively.

In the subsequent sections we address the parts of numismatic work where high-accuracy coin models like the ones presented here can be used to improve the effectiveness and impact of research. This includes the fields of documentation, coin measuring and coin identification.

3.1. Documentation of Coins

Today the prevalent method for coin documentation in Numismatics is to capture images of both coin sides. However, the problem of this documentation method is that important features might get lost. For instance, highlights due to the metallic surface decrease the quality of the images and handicap any analysis where the real coin is not available. With 3D scans detailed models of both coin sides are obtained which allow for a more accurate analysis. As an example, a sufficient documentation of the coin edge is only possible by accurate 3D models. The edge of a coin is very important to recognize its production process or to identify counterfeits.

If real copies of the coins are needed for studying, nowadays numismatists usually produce plaster casts of certain coins of interest. In a second step a positive copy is produced which shows all details of the original except its color. However, 3D coin models allow a more realistic representation and can be reproduced and transferred electronically which gives them the potential to replace plaster casts in the future.

Another benefit of 3D coin models is that they allow a fast and easy visualization for publication and documentation. Once a coin model has been acquired, the coin or certain features of it can be made visible from any viewpoint and in any scale. For a comparison between a traditional 2D coin image and its 3D model see Figure 3: the view of the 3D model of a Roman Denarius shown in Figure 3(b) gives a

Figure 2: *Front and back views of six generated coin models: (a) Roman Antoninian of Valerianus II (253-255 AD), (b) Roman Antoninian of Traianus Decius (249-251 AD), (c) Roman Denarius of Septimius Severus (193-211 AD), (d) Roman Aureus of Herennius Etruscus (251 AD) (e) Roman Antoninian of Philippus I (244-249 AD), (f) French gros tournois (1290-1295 AD).*

more informative impression of the coin's 3D structures than the 2D image of the same coin shown in Figure 3(a).

Figure 3: *(a) 2D image of a Roman Denarius, (b) acquired 3D model of the same coin (visualized without texture).*

3.2. Measurement of Coins

3D coin models offer a simple way to accurately measure the diameter or other features like the thickness of the coin. However, the most useful aspect is the accurate measurement of the coin volume. The volume is relevant to calculate the density of the coin to identify differences between the theoretical and the real density when coins were plated (for instance, a silver over a copper core)

3D data is also useful to analyze changes on the coin surface. The example in Figure 4 shows a Roman coin which has been used as metal resource in a German settlement in Thuringia. You can see deep cuts to separate parts of the coin (Figure 4(a)). To show these cuts adequately a plot of the coin profile can be generated (Figure 4(b)).

3.3. Identification of Coins

3D coin models can be used also to identify ancient coins in a better way as traditional images or very small originals. To recognize all features of small coins a numismatist has to use a microscope on the real coin or a high-resolution image. Given a sufficient resolution of the acquisition device some details like inscriptions or symbols are potentially more visible on a close-up view of the model as in reality, as exemplarily shown in Figure 5. The 3D close-up view of

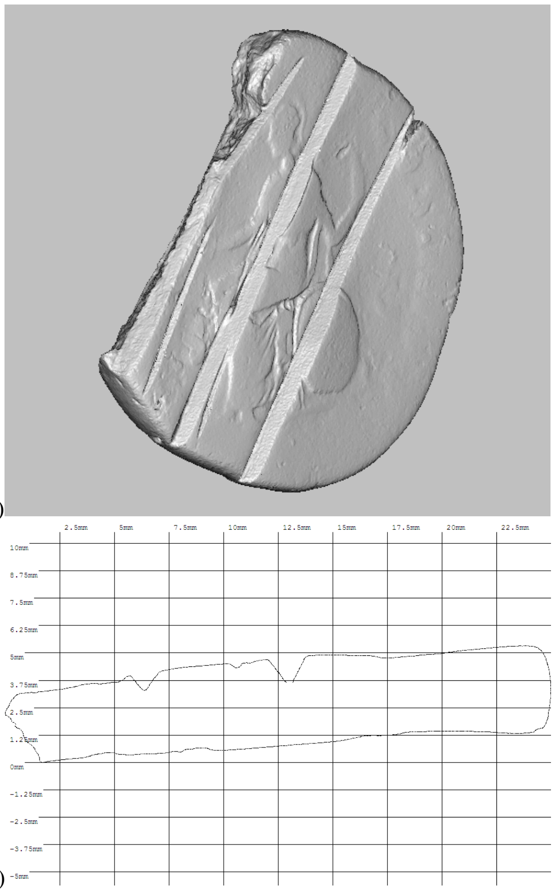

Figure 4: *(a) 3D model of a coin with cuts, (b) profile of the same coin.*

the letters shown in Figure 5(b) gives a better understanding how these letters have been created using punches of letter parts than the 2D image (Figure 5(a)).

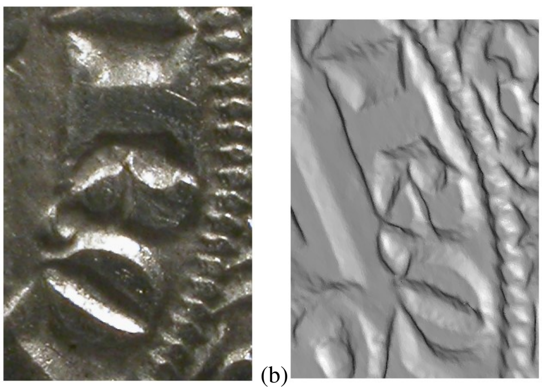

Figure 5: *Close-up view of letters on a tornese in a (a) 2D image and (b) 3D model (visualized without texture).*

Interactive 3D models help the numismatists to recognize the coins because the models, like the originals, can be viewed from any viewpoint and in any scale. Additionally, multiple light sources visualize the stamping better then a 2D image. Another important feature is that 3D models show the difference between the obverse and reverse axis. Ancient and medieval coins were hammered, thus obverse and reverse axis are not necessarily aligned.

4. Conclusion

In this paper preliminary results on the acquisition of high-accuracy 3D models of historical coins have been presented. We furthermore described the use of such models in the documentation, measuring and identification of coins. The achieved results suggest that accuracy of the active stereo scanner used is high enough to fulfill numismatist's needs for an improved scientific documentation and analysis of coins.

For future research, a more detailed evaluation of the results is planned. Additionally, techniques allowing an automatic analysis, e.g. coin identification, on the coin models will be investigated.

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References

[HCEA07] Hossfeld M., Chu W., Eich M., Adameck M.: Fast 3D-vision system to classify metallic coins by their embossed topography. *Electronic Letters on Computer Vision and Image Analysis 5*, 4 (2007), 47–63.

[KHMZ09] Kampel M., Huber-Mörk R., Zaharieva M.: Image-based retrieval and identification of ancient coins. *Intelligent Systems, IEEE 24*, 2 (March-April 2009), 26–34.

[KZ08] Kampel M., Zaharieva M.: Recognizing ancient coins based on local features. In *Advances in Visual Computing, 4th International Symposium, ISVC 2008, Las Vegas, NV, USA, December 1-3, 2008 Proceedings, Part I* (2008), pp. 11–22.

[MGW01] Malzbender T., Gelb D., Wolters H.: Polynomial texture maps. In *Proceedings of the 28th annual conference on Computer graphics and interactive techniques* (2001), ACM New York, NY, USA, pp. 519–528.

[MVSL05] Mudge M., Voutaz J.-P., Schroer C., Lum M.: Reflection transformation imaging and virtual representations of coins from the hospice of the grand st. bernard. In *Proc. of VAST'05* (2005), pp. 29–39.

[SAB*07] Stoykova E., Alatan A., Benzie P., Grammalidis N., Malassiotis S., Ostermann J., Piekh S., Sainov V., Theobalt C., Thevar T., et al.: 3-D Time-Varying Scene Capture Technologies - A Survey. *IEEE Transactions on Circuits and Systems for Video Technology 17*, 11 (2007), 1568–1586.

[SSc] http://www.breuckmann.com/index.php?id=stereoscan, last visited: 05/18/2009.

[ZKS08] Zambanini S., Kampel M., Schlapke M.: On the use of computer vision for numismatic research. In *Proc. of VAST'08* (2008), pp. 17–24.