

## MODELING THE GOLDEN MADONNA

J. Peipe <sup>a</sup>, H.-J. Przybilla <sup>b</sup>

<sup>a</sup> Bundeswehr University Munich, D-85577 Neubiberg/Germany - email: [j-k.peipe@unibw-muenchen.de](mailto:j-k.peipe@unibw-muenchen.de)

<sup>b</sup> Universität Duisburg-Essen, D-45131 Essen/Germany, Henri-Dunant-Str. 65 – email: [przybilla@uni-essen.de](mailto:przybilla@uni-essen.de)

**KEY WORDS:** Close-range photogrammetry, digitizing, fringe projection technique, modeling, visualization

### ABSTRACT

In this paper, the 3-D digitization and modeling of the *Golden Madonna* preserved in the Essen cathedral in Germany is reported on. This outstanding work of art was documented by means of a fringe projection system, close-range photogrammetry and 3-D modeling software.

### 1. INTRODUCTION

Optical metrology systems based on techniques such as laser scanning, fringe projection, photogrammetry etc. are successfully being applied for the 3-D measurement and virtual reconstruction of object surfaces, e.g., in art and cultural heritage recording. All the methods have specific pros and cons, but can also support each other. With a fringe projection system, a very fast and precise digitization of an object surface can be performed resulting in a dense point cloud. To combine several acquired sections of the object the overlapping parts of these sections can be matched by means of more or less sophisticated procedures. Photogrammetry can be used to generate an accurate and reliable network of reference points on or near to the object to merge the point clouds measured by the fringe projection system.

In this paper the 3-D reconstruction and visualization of the so-called *Golden Madonna* (chapter 2) was carried out by using an optoTOP 3-D digitizing system (Breuckmann GmbH), a Kodak DCS 760 digital camera, and RapidForm modeling software (INUS Technology).



Figure 1. optoTOP-HE-600 fringe projection measurement system

### 2. THE GOLDEN MADONNA

The Golden Madonna (Fig. 2) is the oldest known statue of Virgin Mary dating from around the year 990 A.D. The famous, 70 cm high object made of linden-wood is covered with golden foils. The statue preserved in the Essen cathedral in Germany needs to be restored and repaired due to some stability problems of its wooden core resulting from ageing and wood-worm's activities. The restoration work is based on the

documentation and analysis of the actual state of the Golden Madonna including the generation of a high resolution 3-D model.



Figure 2. The Golden Madonna positioned on a turning table and the measuring system in the restoration workshop of the Essen cathedral

### 3. DATA ACQUISITION

To digitize the Golden Madonna the Breuckmann optoTOP-HE-600 measuring system was used (Figs. 1 & 2; Breuckmann, 2003 & 2005). The system includes a mechanically stable carbon fiber base connecting a 1280 x 1024 pixel camera and the fringe projection unit, and a highperformance PC or notebook with the operating software. The measuring principle is characterized by determining the order and phase of the fringe pattern projected onto the object surface and imaged by the camera. The light and dark fringes are deformed depending on the surface shape. A combination of graycode and phase-shift techniques is used to analyze the projected light structure in order to finally calculate the 3-D coordinates of the object (Breuckmann, 2003).

The configuration of the optoTOP-HE-600 provides 1.2 m operation distance and a 480 mm x 360 mm field of view with 320 mm measuring depth. About 1 Mio. 3-D coordinates can be acquired within a second. The distance between the measured points on the surface amounts to 0.36 mm, the X,Y-resolution to 0.18 mm and the feature accuracy to 0.05 mm.



Figure 3. Digital images of the Golden Madonna



Figure 4. Combining the single views (screenshot)

Approx. 60 scans were generated to cover the entire statue which was positioned on a turning table whilst the measuring system remained stationary (Fig. 2). Included were a lot of additional detailed views to acquire some hidden areas. The single views can be combined by means of the object geometry, finally by an automatic best fit approach (Fig. 4). The procedure is suitable for relatively small objects, but leads to a reduced accuracy for large objects. In this case, a reference network can be established by photogrammetry to transform the single point clouds to each other. For this reason and for the purpose of texture mapping (chapter 4) approx. 200 digital color images were taken with a Kodak DCS 760 camera (Fig. 3).

#### 4. DATA PROCESSING AND VISUALIZATION

The 3-D reconstruction using the fringe projection data was performed within the optoTOP software. A wire frame model was generated (Fig. 5) and, finally, texture mapping was done by means of the digital images and the RapidForm software

(Fig. 6; INUS, 2005).

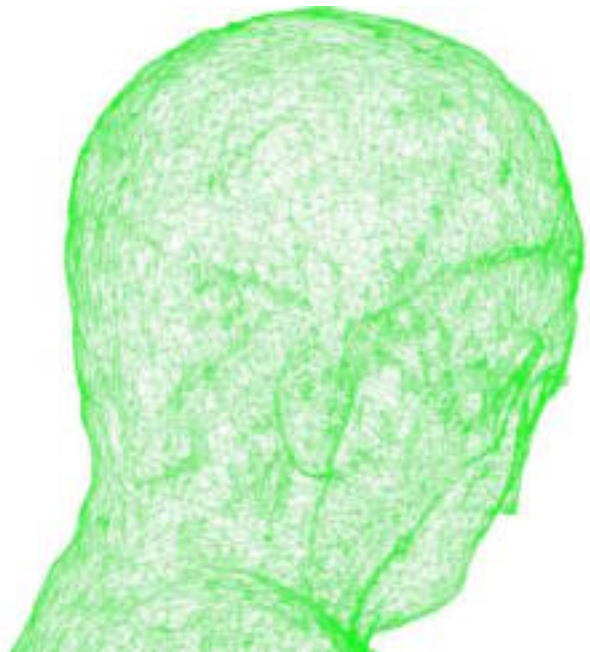


Figure 5. Wire frame model of the head of the Madonna

#### 5. CONCLUDING REMARKS

The digitization and modeling of the Golden Madonna by means of optical measurement techniques facilitates the documentation and analysis of the current status of this prominent cultural object. The mobile and flexible measurement system allows the complete and precise on-site capture of the geometry of the statue without any preparation of the surface. The 3-D model resulting from the visualization process is of high benefit to the user, e.g. the art historian or restoration expert.



Figure 6. Virtual model of the Golden Madonna

#### **REFERENCES**

- Breuckmann, B., 2003. State of the art of topometric 3D-metrology. In: Optical 3-D Measurement Techniques VI (eds. A. Grün & H.Kahmen), Chair of Photogrammetry & Rem. Sensing, Inst. of Geodesy and Photogrammetry, ETH Zurich, pp. 152-158.
- Breuckmann, 2005: Product information optoTOP , [www.breuckmann.com](http://www.breuckmann.com)
- INUS, 2005: Product information RapidForm , [www.rapidform.com](http://www.rapidform.com)

#### **ACKNOWLEDGEMENTS**

The authors wish to express their thanks to the Breuckmann GmbH for comprehensive and valuable support.