THEMSE – 3D TECHNOLOGIES FOR MUSEUMS IN BERLIN

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ABSTRACT: The 3D Laboratory at the TU Berlin cooperates with several museums of regional and national relevance by developing 3D applications and by transferring 3D technologies with the intention to support both the scientific work of museums (3D digitisation, restoration, 3D replicas) and the improvement of the public presentation of the museums.

1. INTRODUCTION

The 3D Laboratory at the Institute of Mathematics at the TU Berlin was founded in 2004 initially with the intention to support the mathematical visualisation group of the institute by operating an immersive stereo projection system. In 2005 the equipment was extended significantly by 3D printing and 3D scanning facilities using grants of the EFRE (European Fund for Regional Development). The 3D Laboratory became an independent institution at the institute. It is characterised by a broad range of applications and it cooperates with numerous institutions. The current equipment includes four plaster printers from several generations, a fused deposition modelling (FDM) printer, a selective laser sintering system for polyamide, a 3D scanner, a static and a mobile stereoscopic immersive projection system as well as a comprehensive IT infrastructure.

Since a few months, the 3D Lab benefits from a new project funded by the BMBF (Bundesministerium für Bildung und Forschung) in its other main field of activity – medical applications, namely the research and development of tissue engineered scaffolds by using 3D printing technology. In that context its equipment and its team have been extended, in particular by a digital light processing 3D printing system and a micro computer tomograph. Additionally the 3D Lab will develop a 3D printing system with high accuracy for special materials. Currently the team consists of its professor, two fulltime and four temporary scientific assistants and seven student assistants. From the beginning the 3D Lab has pursued a strictly interdisciplinary approach as its staff originates from various disciplines – currently from architecture, materials science, engineering and fine arts as well as from mathematics. The student assistants originate from disciplines like media informatics, materials science, engineering, architecture or art history and complete the expertise of the 3D Lab. As a consequence it has been possible to cooperate with institutions that are not usually in the focus of a mathematical institute but which are involved in the dynamics of the rise of 3D technologies and the development of relevant uses and applications.

Besides the "typical" scientific, technical and industrial applications, the 3D Lab as involved in teaching especially with respect to the promotion of 3D technologies and cooperates, for example, also with artists and designers or architects: The fact that more and more students from the architectural departments of the TU Berlin and the nearby University of the Arts Berlin build their architectural models for their diploma or master thesis by using rapid prototyping at the 3D Lab can be understood as a turn to cultural issues. The cooperation with museums constitutes a rapidly growing activity field of the 3D Lab. Starting with the Gipsformerei (Art Manufacture) and the Egyptian Museum as institutions of the Staatliche Museen Berlin we noticed an obvious and increasing need for 3D applications. The main issues in this context are the 3D digitisation and therefore the digital conservation of cultural heritage, but as well the support of restoration or presentation of exhibits for different purposes.

Figure 1: *Plaster printers and show cases*

Figure 2: *SLS (selective laser sintering) machine with peripheral equipment*

2. 3D TECHNOLOGIES FOR MUSEUMS – PROJECT MOTIVATION

The use of 3D technologies on a professional level is still bound to costly equipment and material. Most museums cannot buy a 3D scanner or 3D printer. This equipment also needs skilled staff specialised in using 3D technology. These costs are too high to allow for experiments. Based on successful smaller pilot projects, the idea of knowledge transfer of 3D technologies to smaller museums at Berlin was born. This includes the definition and satisfaction of the individual needs of this museums as well as the determination of limits that still exist. The aim of this project is not only to support smaller museums with technical assistance and knowledge transfer, but also to give the partner institutions an overview on usage and perspectives of these technologies in their scientific work and public exhibitions. As the selected museums collect a very broad variety of objects with different characteristics and as they have different aims in the use of and the presentation with 3D technologies, the project is as well dedicated to demonstrate the bandwidth of possibilities. This report on a work in progress shows some first results of the cooperation project granted by EFRE and illustrates some other activities of the 3D Lab in the context of museum applications.

3 STEP BY STEP – PRELIMINARY PROJECTS

Former smaller projects have led to the current project "3D technology for Berlin Museums". The first contacts with museums resulted from specific problems related to the scientific work of the Egyptian Museum of the Staatliche Museen zu Berlin. These problems could not be solved with standard methods in that application field. We outline two examples illustrating typical questions museums are faced with in their daily work.

3.1 HEAD OF QUEEN TIYE AND CROWN – ART MANUFACTURE AND EGYPTIAN MUSEUM OF THE STAATLICHE MUSEEN ZU BERLIN – STIFTUNG PREUSSISCHER KULTURBESITZ

In contrast to the habits of former times, the crown of this little sculpture of the Egyptian queen Tiye should not be moulded as this might damage it. The head was moulded at the beginning of the sixties of the 20th century by the Gipsformerei by gelatine casting. Thus, a replica of the head exists, but none of the crown, which had been added to the sculpture later.

Figure 3: *Crownless head sculpture of queen Tiye*

In cooperation with the Egyptian Museum and the Gipsformerei the 3D Lab produced a structured light scan of the crown and reproduced it as 3D print which can be moulded by traditional means. Meanwhile, the Gipsformerei produces and distributes replicas of the sculpture of Tiye with the crown based on this original mould. The application of 3D scanning and 3D printing has yielded two results. 3D scanning yields indestructible 3D data (if stored under adequate conditions) allowing for fabricating new moulds or real, reproducible copies using a 3D printer, for instance, if the production of scaled replicas or in small batches on demand is needed. Especially manufacturing small editions or on demand could enable a museum shop in a small museum to offer replicas of exhibits without the risk of investing into large production numbers as would be needed for inkjet moulding. The use of additive manufacturing also offers a larger variety and a better compliance with the needs of customers in museum shops. In some museum shops 3D printed objects are already available, but these products are more or less "design souvenirs" and do not use the larger potential that is implicated by 3D technologies.

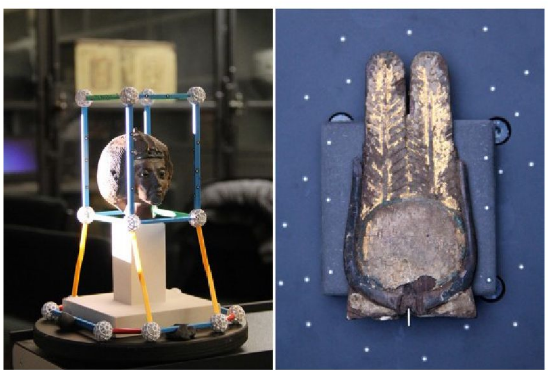

Figure 4: *3D scan setups for the head and the crown*

The original wooden crown of Tiye is so sensitive that it is not possible to produce a mould from the original. A 3D scan yields the necessary data without touching the original. 3D printing has even permitted to produce a “complete” model with head and crown. This illustrates the possibilities of 3D technologies to create very precise 3D digital data which preserve an object at least digitally, even if the original is lost. In addition, 3D printing allows for producing real “touchable” copies in any desired number at any moment. As already mentioned, the surface qualities delivered by professional 3D printing systems are much higher than those that can be expected from currently available cheap 3D printers for private users.

Figure 5: *3D printed, later painted and attached crown*

3.2 BUST OF PHARAOH AKHENATEN – EGYPTIAN MUSEUM OF THE STAATLICHE MUSEEN ZU BERLIN

In the exhibition “Im Licht von Amarna” (“in the light of Amarna“) the bust of Pharaoh Akhenaten has been presented for the first time after its last restoration. The 3D Lab was involved into this exhibition by a structured light scan and a 3D print in original size. The 3D printing had two main successfully fulfilled aims: The reproduction of the shape of the bust in the appearance of the first reconstruction after the discovery in order to present it in the exhibition, and the support of the reconstruction of the missing mouth, which is lost since the Second World War.

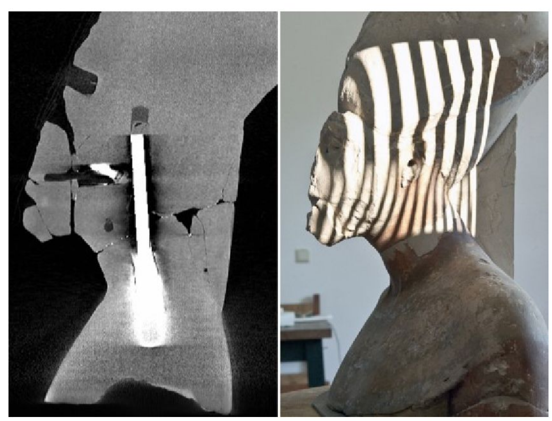

Figure 6: *CT scan image and surface scan process*

Figure 7: *The bust before and after 3D printing*

In a first step the bust was passed through a computer tomograph normally used for human patients at the Imaging Science Institute of the Charité, the university hospital at Berlin. The CT images enabled the Egyptian Museum to determine the current “internal” condition of the bust, which had been damaged and restored several times. This information has ben indispensible for further restoration work. The 3D Lab used the CT data together with the data from a 3D scan to produce a 3D model of original size. The model was first used by the conservator to plan and to test further restoration works before touching the original. In the exhibition, the temporarily restored original (the missing mouth was added), our 3D model of the unrestored original and another 3D print copy from the second bust of Akhenaten from the Louvre at Paris were shown. From the point of view of 3D technology, we tested for the first time the combination of CT data and 3D scan data. On the one hand, data form human CTs usually have an unsatisfactory image resolution due to the limited radiation intensity of these machines. This drawback can be remediated by the very precise surface data yielded by a 3D scan. On the other hand, the 3D scan of complicated and detailed structures requires sometimes hundreds of measurements leading to hundreds of overlapping digital “2.5D images” which have to be combined to a single digital 3D model. The combination of many overlapping image data sets yields to an inevitable, sometimes significant error propagation leading to shape deformations. The latter can, however, be drastically reduced by the more precise shape information from the CT data.

4 CURRENT PROJECT – 3D TECHNOLOGY FOR MUSEUMS AT BERLIN

Our current, larger project granted by EFRE consists of four subprojects with museums at Berlin. Each subproject is dedicated to a specific application of one of the cooperating museums where one or more 3D techniques of general interest are applied.

4.1 GIPSFORMEREI – ART MANUFACTURE OF THE STAATLICHE MUSEEN ZU BERLIN

In this subproject it is mainly intended to produce 3D scans and 3D prints of sculptures from the large collection of plaster replicas of the Gipsformerei. In contrast to former projects with this partner the digitisation of objects is more important than the solution of isolated problems. As planned, the 3D Lab is about to complete the 3D digitisation of a single group of sculptures in the collection of the Plaster Replica workshop: Sixteen sculptures of Greek legendary figures by Friedrich Tieck, originally sculpted for the tea room of the Berlin City Castle that is aimed to be partially reconstructed in the next years. The Gipsformerei aims to build a scaled model of the tea room for public exhibition. As the shape of these sculptures is in some details very complex, they yield a good example for a problem the 3D Lab is frequently faced with when sculptural objects had to be scanned: Structured light scanners cannot really reach every detail in complex shapes. Even by scanning objects with more than a thousand single scans it is sometimes impossible to depict every detail of a shape. Strong undercuts or holes have to be reconstructed in the post-processing of a 3D scan. As this problem can usually be neglected in the case of small replicas from large sculptures it is still an aim to reproduce a shape completely instead of using automatically generated or handmade reconstructions.

In the context of the research accompanying the ongoing 3D scanning campaigns, the Gipsformerei has become aware of an additional sculpture not yet represented in its collection. This casted sculpture of “Achilles”, that was found out to be part of collections of – amongst other institutions – at Sanssouci castle in Potsdam. Meanwhile the Potsdam version of "Achilles" has been scanned and will complete –

first of all digitally – the group of scaled models of sculptures.

Figure 8: *Cassandra statue with reference points*

As it is intended to build a scaled model of the complete tea room for an exhibition, the quality of the plaster replicas of sculptures must be rather high. While the surface details can be reproduced in high precision by careful 3D scanning, additional post-processing and a careful 3D print, the problem that the specific plaster and the necessary infiltration with epoxy resin yield colours which are not appropriate for all purposes remains. We are, therefore, adding supplementary colour pigments to the plaster. In the present case, the addition of titanium white pigments resulted in a rather pure white.

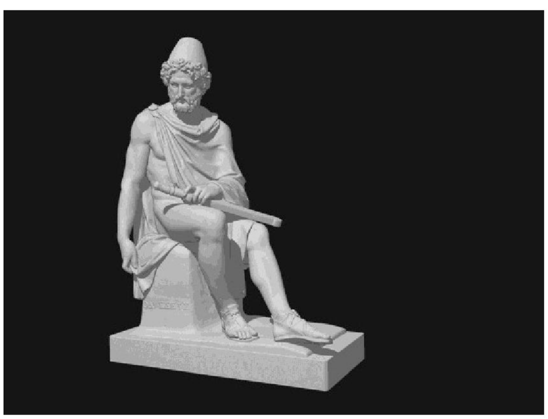

Figure 9: *A computer rendered image of the 3D scanned Odysseus statue*

Although there is the problem of missing data mentioned above, copying via 3D scanning yields an obvious benefit compared to the usual way: the ability to easily scale or mirror the sculpture, to add or remove parts and to reconstruct a model from its scattered parts. In addition to these constructive aspects, 3D data allow for a vast amount of applications for education and entertainment.

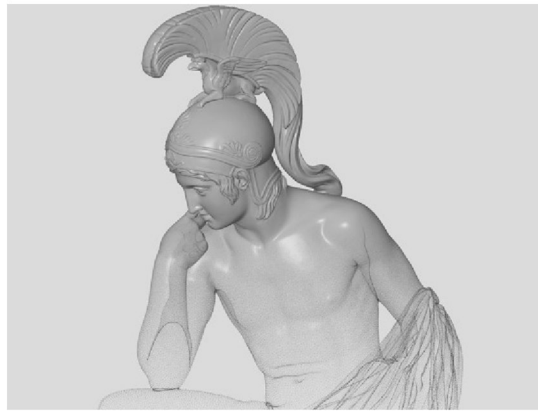

Figure 10: *The still unfinished Achilles 3D scan data dissolving into vertices*

4.2 STIFTUNG STADTMUSEUM BERLIN

The main issue in this cooperation is the 3D scan of architectural models of the cityscape of Berlin from different centuries. The models themselves, carved in wood, date from the 20th or even 19th century and cannot be disassembled. The detailed geometry of the models, depicting houses, churches and little yards on a surface of several square metres is causing problems in the attempt to grasp the complete information as mentioned before: In principle, a high resolution model of a size up to several metres is required.

Previous experiments had revealed that our current scanning equipment is overstrained with this task. The 3D scan at the Stadtmuseum was realized with a more modern 3D scanner than that which is available at the 3D Lab (dating from 2005). One of the main problems, that had to be solved, was the size of the city model with a diameter of more than 3.5 meters in relation not only to its resolution, but primarily to the weight of the 3D scanning system. As the scanner had to be positioned above the model at as many positions as possible to get a complete view from enough perspectives, the weight of the scanner at the 3D Lab lead to vibrations in the arm of the tripod. With an up-to-date scanning system it was possible to minimize these vibrations to allow the scan as well from the viewpoint of safety in general as also from the perspective of the accessible quality of the results. The used scanning system had, as all systems do, its advantages and disadvantages. For the huge city model the advantages were dominant: a big field of vision while still maintaining a proper scanning quality. This did not only save a lot of time, it also provided material for the next steps.

After scanning the architectural models, the post-processed data will be the basis for their digital reconstruction. A 3D scan would provide accurate but too large data files for the purpose of the intended use. The purpose of this digitisation consists in a virtual interactive presentation for a walk through the space and time of the cityscape of Berlin.

Figure 11: *3D scan setup for a wooden model of Berlin in 1680, courtesy of Ingenieurbüro Malige*

Figure 12: *The triangulated surface data of the Berlin city model 3D scan*

4.3 MUSEUM NEUKÖLLN

The Museum Neukölln is a regional museum focusing on the history of the Berlin quarter Neukölln. One of the central parts of its collection are exhibits from various times represented in combination with the history that they represent. The large variety of shapes and materials yield one of the characteristics of this cooperation, which has currently reached the phase of producing 3D scans with two different technologies. As in most museums, the exhibits are shown in glass cabinets and are not to be touched by the visitors. After the post-processing of the 3D scans, some exhibits will be reproduced as 3D printed scaled models which permit a better access for visitors with visual handicaps. In addition, models which can be touched increase the interest in visiting a museum. The presentation of touchable replicas of the exhibits in different scales is intended to make small details of objects better accessible to blind people. The usability and acceptance of this application will be evaluated in workshops later in 2014.

Among the exhibits to be scanned are an urn from the Bronze Age, a wax seal from a letter, a taxidermied bird (a large bustard) as well as sculptures, an amulet made by a Syrian prisoner and the lower jaw of a young mammoth from a time before this area was called Neukölln. Due to some restrictions in the allowed handling of the objects, two different technologies will be used. Besides the use of its own structured light scanning system, the 3D Lab continued its longterm cooperation with the Leibniz Institute for Zoo and Wildlife Research at Berlin, which will produce CT scans of the urn and the lower jaw of the mammoth and additionally of a radio from the early 20th century. Due to the surface and the fragility of the mammoth jaw, it must not be turned upside down as needed in order to produce surface scans from all perspectives to get the whole shape. Additionally, the surface is littered with small holes, which makes it improbable to generate a closed surface and, in the following, a 3D printable file. After having printed the jaw in three parts and joining them for presentations like EVA, the next task will be the creation of a surface and a weight corresponding to that of the original.

A more experimental scan will be the CT scan of a radio from the early 20th century. Scans like this one have the intention to demonstrate, what is possible and which quality of data is reachable. The generated data are intended to be used for different purposes, such as "fly-through animations" or digital representation with haptic devices.

Figure 13: *Bone comb from around 525-560 and its digitized counterpart*

Figure 14: *Carved peach seed amulet from around 1989*

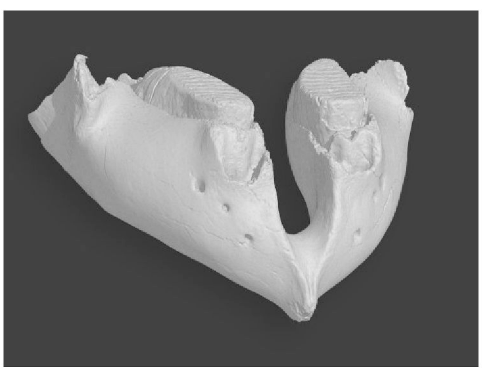

Figure 15: *The computer rendered image of a CT scanned mammoth lower jaw*

Figure 16: *A peach seed plaster print in a scale of 5:1 and an SLS print of the mammoth lower jaw scaled 1:5*

4.4 SPANDAU CITADEL

This pilot project differs from the others, as the results will be directly integrated into the exhibition "Berlin Enthüllt" ("Berlin Revealed") of the Spandau Citadel starting at the end of 2014. To this historical exhibition, the 3D Lab will contribute a virtual interactive representation of the so called "great hall" that was intended as a central building in the city "Germania" planned by the Nazi government and supposed to be built instead of Berlin.

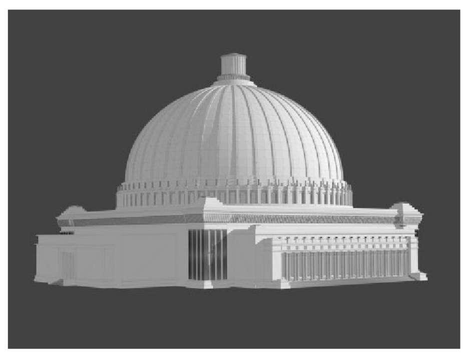

Figure 17: *The reconstructed Great Hall based on the model from the Landesarchiv Berlin*

Visualising the enormous size that this building would have had is difficult, as it is presumably beyond everyone's imagination. Using a scaled model will give an impression of the relation to other buildings but cannot communicate the discomfort that would have been produced by this building. Installing an immersive and interactive stereo projection system would have been far beyond the budget. The Spandau Citadel, advised by the 3D Lab with respect to possible technical solutions, decided to integrate a tool into the exhibition that revives the representation of virtual realities by using head mounted displays of the current state of the art. The first available version of the "Oculus Rift" has been in use at the 3D Lab for nearly one year and has been evaluated especially in relation to its acceptance by the audience.

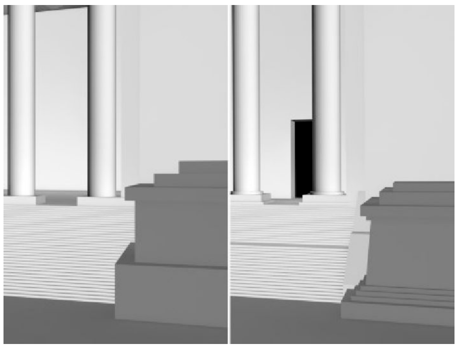

Figure 18: *The transition from the model scale to a virtually visitable scale based on plans from the Landesarchiv Berlin*

As the field of view of this device is much larger compared to earlier systems and the software, combined with a tracking system, is capable to provide a free view in all directions without latencies, these HMDs provide the viewer with a highly immersive, interactive view into the virtual realities that are represented. In order to visualise the dimensions of the building of 290 m in height and 315 m edge length at the basis, the visitor will approach the simulated building in the virtual environment with two different velocities – at first, similar to a car, starting from a larger virtual distance and, later, like a pedestrian on the last 500 m. The virtual environment is currently constructed in 3Dstudio max and will be completed with reconstructions using the original design drawings.

Figure 19: *Using the "Oculus Rift"*

5 RELATED ACTIVITIES

Due to the increasing interest in 3D printing the 3D Lab has been consulted by contemporary artists as well as by museums with collections in different areas of interest. In the following, we mention two examples of current projects in this context.

5.1 DIGITAL PREPARATION OF FOSSILS

In cooperation with the Natural History Museum Berlin and the Charité, the 3D Lab processed the CT data of a Plateosaurus vertebra and a hand which still remains enclosed in rock that hosted it for millions of years. The cooperation led to a publication in the medical journal "Radiology" in 2013. The benefit for the Natural History Museum Berlin consists in the possibility to identify the rows with embedded fossils, as the labels are lost because of a bomb impact during the Second World War. The second main benefit was that it was possible to get the shape of the fossils as a digital and also as a real object in a very short time compared to a preparation in the traditional way. This application requires in particular a careful image processing, more precisely image segmentation, when "extracting" the fossilised body parts virtually from the rock

Figure 20: *Presentation model of a Plateosaurus hand*

5.2 BIFACE

As the 3D Lab continues its experiments with possible uses of 3D technologies it realizes "in between" projects like this 3D print from a 3D scanned hand axe, bringing together one of the first tools of mankind with one of the newest. This tiny project was very instructive to the team in its results. A

3D print is not as irreplaceable as an archaeological artefact. In the 3D Lab this practical experience very quickly provided insight into the fact that this tool from the Stone Age was designed and produced with a deep knowledge of design and ergonomics, an insight which can be derived from the high comfort the reproductions offer, but as well from mirrored counterparts that fit perfectly for left-handed people as the original bifaces do for right-handers.These two projects of different complexity demonstrate again the potential of 3D technology in scientific and museum work.

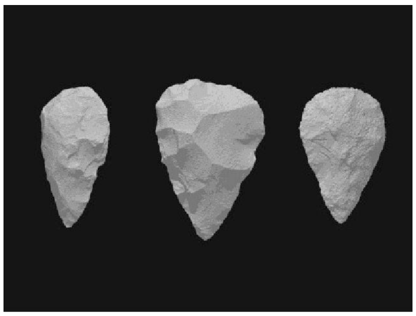

Figure 21: *Upper Paleolithic bifaces*

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