

Voxel and STL-Data in Service of Archaeology - Digital Celts

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Abstract. Archeologists are curious people and so it is no wonder that they often – in order to research antiquity – use the newest and most modern methods to trace the silent witnesses of the past. To see very precisely into archeological objects, to microscopically analyze their interiors without actually damaging them through cuts, sondages or other interventions, has always been a great issue in research. Now an interdisciplinary project has turned this long held desire into reality. Object of the investigations were three oak wood Celtic cult figures, the cell structures and so also the annular tree-rings which for the first time were successfully and without contact three dimensionally imaged.

1 The archaeological Site

The figures originate from the Fellbach-Schmiden square enclosure east of Stuttgart. As a clay pit was extended there in 1977, the remains of the once around one hectare structure were stumbled upon, a square of around 104 m length of side. In the center of the excavations performed to 1980 by the State Office for Historical Monuments of Baden-Württemberg was an approx. 20 m deep well. The picture developed through the excavations pointed to the end of its useful life. The shaft was probably quickly filled with charred timbers, animal dung, earth and other settlement rubble after a catastrophic fire [fig.1]. Deep below organic remains were preserved in the ground water conveying area. The dendrochronological investigations of the oak well structure already performed at that time by the University of Hohenheim showed that it was erected in the year 123 BC. Particularly the clear discovery of the water supply serving well, which was in no way was to be interpreted as a cult shaft, linked with the knowledge that its filling primarily originated from agricultural usage, gave rise to a new evaluation of the square enclosure phenomenon. Viewed up to then as sacred, a paradigm shift now set in which has in the meantime led to a new interpretation paraphrased with the “chieftain’s farmstead” phenomenon.



[fig.1] The 2 100 year old well with organic materials, preserved in the ground water layers. Fellbach-Schmidien, Baden-Württemberg.



[fig.2] The stag. Carved oak wood. H. 87 cm.

Three Devotional Works - The Animal Sculptures

The stag and the two Billy goats, outstanding animal figures from the Latene period, also belong to the finds from the Schmidien well [fig.2,3]. They lay in the water conveying area between the timbers. Carved from oak, they were still covered with so-called royal yellow (arsenic trisulfide). They have remained to today unique and incomparable. It is seen as certain that they only fragmentarily preserved; the two antithetically posed billy goats were once part of a now mostly lost sculpture. This is supported by the outstretched hands and arms of an otherwise no longer present human figure on both billies. They once encompassed the two animals on the left and right as central representation. The intention was clearly to represent a lord or mistress of the animals - a motif originally adopted from

the Middle East. Which deity was represented by the two billy goats can no longer be discerned. The stag, damaged on the hindquarters, antlers and snout, was originally also part of a much more complex work, although it long remained speculative as to whether it belonged to the same or a different devotional image. Here only the current investigations helped any further. An allocation comes closer with comparison of later works, but there is only limited information on Celtic deities available from Roman texts and inscriptions on Gallo-Roman pencil-stones: here we find the stag allocated to Cernunnos (Hern). It is certainly possible that this was already so for the square enclosure period.



Fig. 3: The celtic billy goats, once part of a more complexe representation with a godess in the center.
Figurine on the left side H 76 cm; on the right side H 87 cm.

Problems with Wet Wood

After preservation of the three moist wood sculptures in the Landesmuseum Württemberg they were displayed in a specially constructed acclimatized glass cabinet in the Celtic collection. They are some of the most valuable objects that the Landesmuseum possesses from this period.

The problem now lay however in precisely this exclusivity. Before all else was now the pressing question from year to year of whether the polyethylene-glycol preservative had homogeneously penetrated into the depths of the object to provide long-term stabilization. How stable each of the figures was, whether there were large internally collapsed areas with cracks through where progressive damage could occur could not be reliably determined. For prehistoric lake-dwelling pilework-posts such issues are no problem – a cut is simply made or a sample taken. This is however scorned upon for artworks.

Another, museum specific problem resulted from the fragility of the pieces, as lending demands represented an important part of the work with the objects. The condition of the wood made lending indeed impossible on preservation grounds, however good copies can often helping such cases. Not however here; no responsible restorer takes a silicon mould for a replica from porous, over 2000 year old weak oak wood with scaling surface.

2 The Interdisciplinary Project - Archeology and High Technology

It was thus the unresolved questions of current condition and preservation prognosis and the desire to make precisely detailed copies with non-contact processes which led in 2003 to cooperation of the Landesmuseum Württemberg with the Hochschule für Technik Aalen. The school's industrial 3D computer tomogram (3D-CT) was here the focus, which with a resolution of maximum 5 µm promised a very precise three dimensional and primarily undamaging view into the interior of the artworks [fig4,5].



Fig 4: 3D-computer tomogram from the Wälischmiller company at the Hochschule für Technik Aalen, performed by: Dr. Ing. Irmgard-Pfeifer-Schäller.

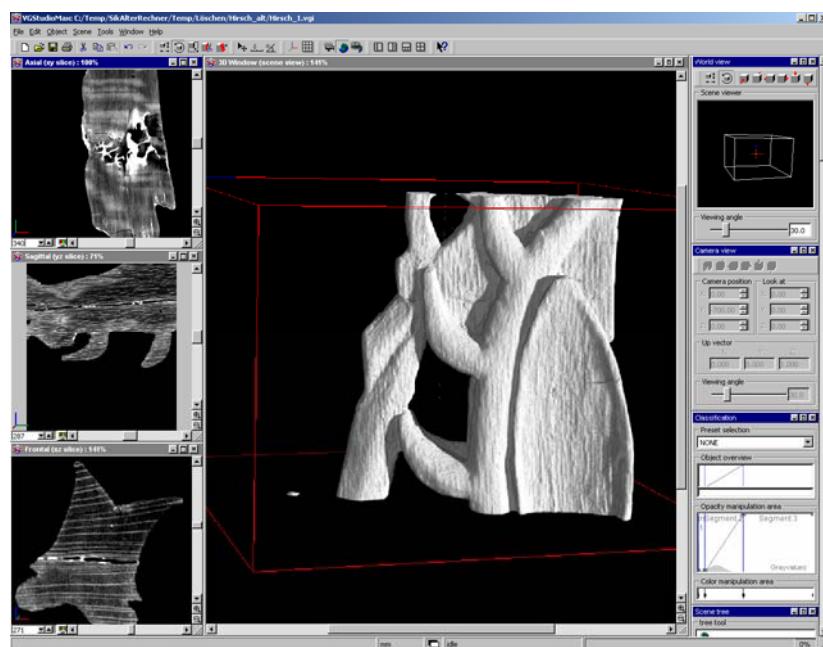


Fig. 5: Screenshot. Detail of the stag.

Additionally the Hochschule Aalen has a modern stereo lithography facility for research and teaching. On the basis of the data produced with the 3D-CT it was now actually possible to produce exact plastic replicas of the Celtic artworks without contact using this “rapid-prototyping-process”. (Hochschule für Technik Aalen, Rapid Prototyping Dept., Prof. Dr. Uwe Berger in the “Virtual Laboratory association” with Prof. Dr. Dietmar Schmid)

On the Trail of Preservation

The 3D computer tomography analyses produced a multitude of interesting observations. The interior view primarily revealed old and new, narrow and wide drying cracks. Differences in density were also visible as gray scales – indications of differing concentrations of the penetrating preservation medium. Also visible are support constructions inside the stag added at the very beginning of the preservation and also a glued joint probably made soon after the recovery and initial preservation in 1980. Here the wood had begun to tear; the widening split had to be fixed with wood glue. It was clear that the preservation had fortunately been thoroughly successful and that with appropriate climatization the stability of the pieces is also ensured for the future. In how far this now precisely measured, described, and databased condition will remain stable or alter will have to be shown by coming status analyses. With the currently foreseeable, routine non-contact long-term monitoring of the entire inner and outer geometry of archeological objects with 3D computer tomography, completely new standards in object preservation and preventive measures open up particularly in the area of preservation/restoration.

Stereo-Lithographic Replicas

The data from the computer tomogram were used in the “rapid-prototyping process” for non-contact replica creation. The meanwhile high data resolution also played the decisive role in this stereo-lithographic process. With the now achieved slices of just 1/10 mm, the process proves to be well suited for the production of high quality museums replicas [fig.6]. The so produced synthetic resin copies of the stag and two billy goats serve as masters for the production of further conventionally made pieces. For this were casts made in the workshops of the Württembergisches Landesmuseum using the silicon molding process and then colored to match the original and can now be used for lending.



Fig. 6: The STL resin copies of the stag

Non-Intrusive Dendrochronology

The first topographies to provide information on the preservation condition of the figures already revealed striations and also faintly visible annular ring structures in the oak wood.[fig.7,8]. This led to involvement of the University Hohenheim with its renowned annular ring laboratory under the direction of Michael Friedrich. The high set goal was now to clear up continuative wood-anatomic issues with further measurements in higher resolutions and for the first time attempt virtual dendrochronological dating using computer tomography] As it was already macroscopically clear that sapwood was still present at some points, the chances were also good for finding relevant felling data for the wood. The virtual sectional images produced by Irmgard Pfeifer-Schäller in Aalen then also led in the Hohenheim University tree ring laboratory indeed to the first purely digitally derived dendrochronological dating worldwide [fig.9]. Further consequences also resulted for the evaluation of the figures, their origins, and the wood used, and also for growth conditions, questions of location or the condition of the forests.

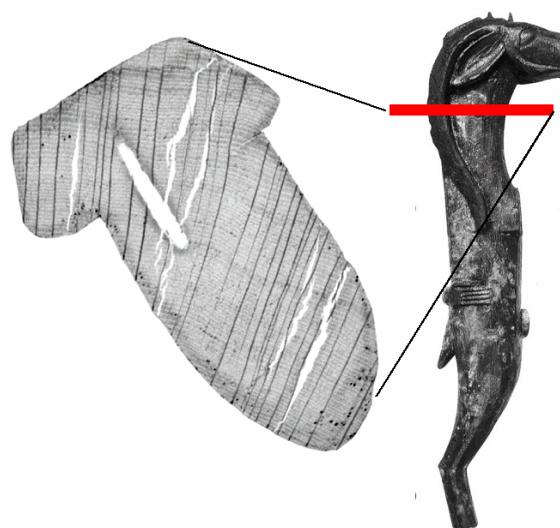


Fig. 7: One of the billy-goats with widening splits and the negative of a modern nail. Resolution 138 um.

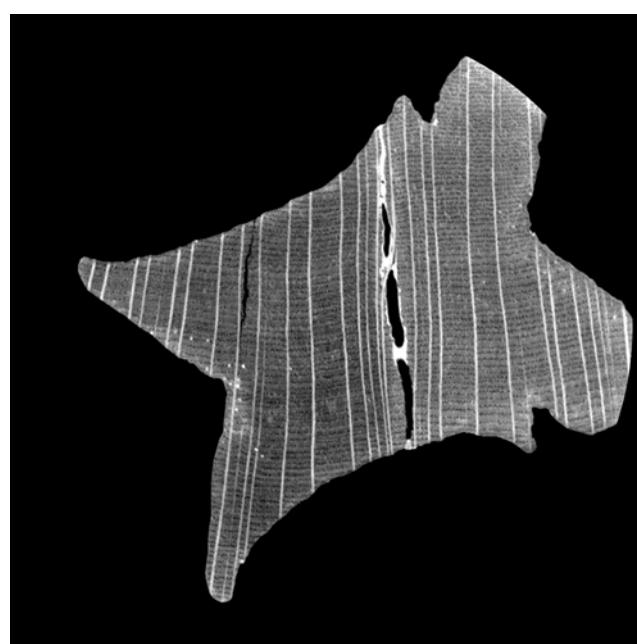


Fig. 8: The ear of the stag with wood-rays, res.116,9 um

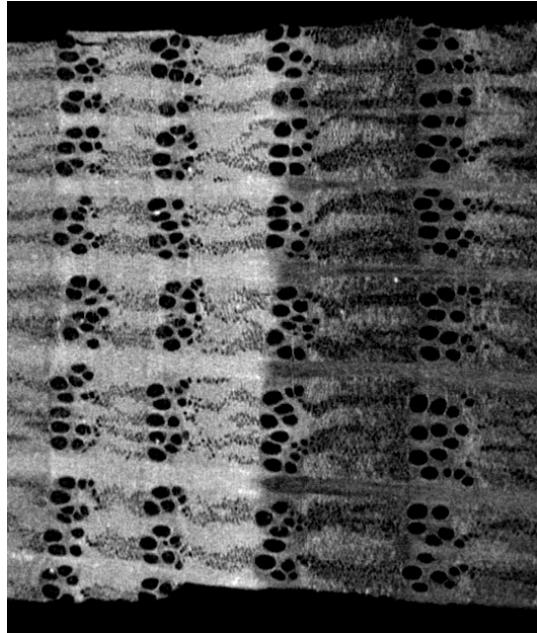


Fig. 9: High-resolution tomogram on the edge of sapwood and core.18,6 um

More than a Date

All three figures stem from the year 127 BC. Sapwood could indeed still be counted to within a few years and the missing rings up to the bark only estimated. This date is therefore only accurate to plus/minus 10 years. Certain is that both billy-goats and stag stem from one and the same tree, an around 250 year old, very regularly grown oak. From this we can very well assume that they originally belonged to a common figurative ensemble and were additionally made in the same workshop. The position of the figures in the trunk derived from the striations makes additionally clear that the former devotional image was put together from several parts and not carved from a single block of wood [fig.10]. The growth characteristics of this old, approx. 1m thick oak lead us to conclude that the tree was deliberately selected by the carver from an old wood near the square enclosure.

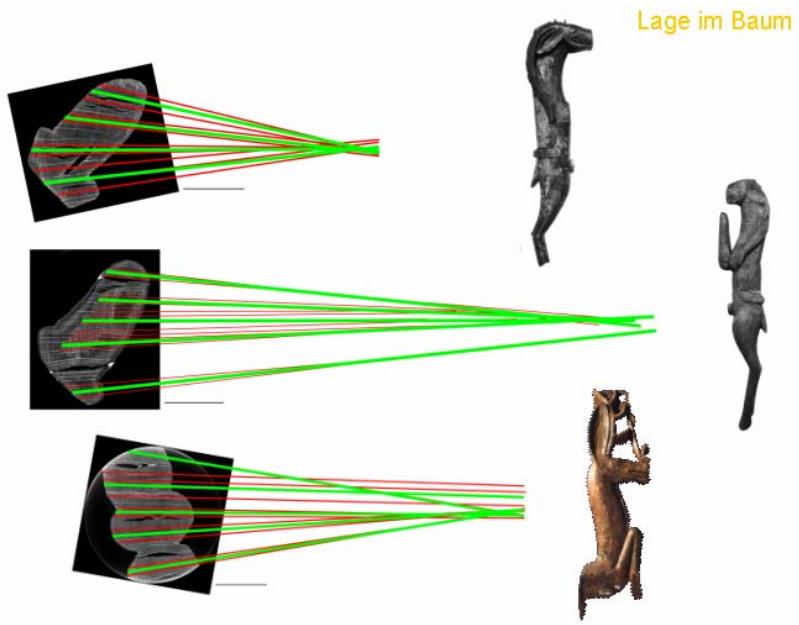


Fig. 10: The high similarity of the tree-ring curves and the position of the wood rays proof the origine of all figurines from a single oak tree. Tree-ring work was done at the Tree-Ring-Lab of the Hohenheim University by Michael Friedrich.

The simulated section through the wood prepared on the basis of the 3D-X-ray data allows a continuative evaluation of the square enclosure itself and also its surroundings. As we already know, the well was built in the early summer of the year 123 BC. The data determined from the figures are close, so that they were made at least close to the same time if not simultaneously. A sanctum in the ring was probably adorned with the multi-piece devotional image. The origins of the Schmiden square enclosure may however be older: the ring growth in the wood indicates wide clearances of the forests around 240 BC. This is the time at which the building of square enclosures begins in southern Germany. The end of the enclosure at Fellbach-Schmiden came at most 25 - 30 years after building of the well; all finds are from this period.

Conclusion and Outlook

The aim of the research project “rapid prototyping in non-destructive archeology” performed from 2003 to March 2005 by the Hochschule Aalen and the Landesmuseum Württemberg, was intended to ensure

“...that future archeological finds can be three dimensionally measured without contact, non-destructively and in their original position and can be depicted both internally and externally both finely detailed and near to nature for analyses and exhibition purposes using VR technology...“ has succeeded . This is also true for the further aims formulated by Prof. Dr. Uwe Berger in 2003: “that replication through stereo lithography in the rapid-prototyping-process also allows the dimensional, objective and near to nature reproduction of fine surface structures.

On the part of the museums is the hope that respective research results from the above-mentioned technologies open the possibility in future of dispensing with the expensive and damaging international shipping of often-irreplaceable exhibition objects... “The new standard-process developed with significant involvement of the Hohenheim University, 3D-CT carving wood type determination leads far beyond continuative botanical wood research and primarily dendrochronology. From the Celtic animal figures at Fellbach-Schmidien it

has already become clear at the very beginning of the routine process that industrial 3D-computer tomography will provide numerous new possibilities and processes for non-contact dating and specific resolution of questions on growth and origins of the wood for important archeological and also art historical objects.

3 The Exhibition

To conclude the interdisciplinary project the Landesmuseum Stuttgart arranged a special exhibition in the Altes Schloss in Stuttgart under the title “Digital Celts -Archeology and High technology.” The Hochschule for Gestaltung Schwäbisch Gmünd was responsible as competent partner for this publicly related part of the digital Celts project. Correspondingly innovative was also the approach to the topic. Software had to be written and machines brought to production readiness for the exhibition to find the appropriate form of presentation for the high technology topic.

An example here is the “virtual window”- a seemingly empty glass display case with a side-mounted articulated arm with a screen mounted on the end. Grasping and moving the screen with both hands in the three available axes produces according to distance and positioning to the glass display case three-dimensional images of the digitalized stag nearer or farther up to delving into its previously hidden internal structures. This high resolution means of virtual observation opens futuristic methods for presenting unique objects or those not loaned, or only with great difficulty, to the general public. In the exhibition, this virtual viewing was the central unit for presenting the digital research methods and their surprising results [fig.11,12]. This along with another glass display case alongside formed the central axis – in this was the original wooden sculpture.



Fig. 11: Virtual window with 360 dg- screen. Exhibition at the Landesmuseum Württemberg 2005



Fig. 12: Digital Celts. Landesmuseum Württemberg 2005.

4 Ancient Egyptian Animal and Human Mummies

Industrial 3-D CT will continue to be operated at the Landesmuseum Württemberg. In the lead up to its Egyptian exhibition in 2007, a mummified and bandaged human hand was able to be analyzed there for research through the friendly cooperation of the Wälischmiller Company in Meersburg. The as yet not further distributed software very clearly reveals gray scales which can be identified as textile wrappings, mummy resin, sinews, muscle fibers and bones or cartilage.

These first views into the interior of a body led us to approach a Sacred Ibis with this non-damaging methodology, generously made available by the Hessische Landesmuseum Darmstadt who were very interested in the analyses [fig.13]. Aim of the analyses planned for June 2006 is to gain the maximum high-resolution data – particularly on the pathology of the animal - and also to more closely analyze the mummification process using 3D-CT. In connection with written and pictorial information from ancient Egypt, we hope to be able to better understand the clear mass stockpiling of the sacred ibises and their specific treatment as pilgrim devotionals, and also authoratively and impressively illuminate the associated complex religious backgrounds in the exhibition. From the he STL-data and using specific software applications, 3D-CT represents an excellent basis for the virtual resurrection of the three dimensional mummy packet into an individual quasi “living” bird.



Fig. 13: Next step to high resolution data: The Egyptian Mummy of a Sacred Ibis. Hessisches Landesmuseum Darmstadt

Literature

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