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COMPUTER MODELLING IN VISUALISATION AND RECONSTRUCTION OF ARCHEOLOGICAL RELICTS

WYKORZYSTANIE METOD MODELOWANIA KOMPUTEROWEGO DLA WIZUALIZACJI REKONSTRUKCJI ZABYTKÓW ARCHEOLOGICZNYCH

The paper presents a number of issues associated with applying modern digital techniques in relicts visualisation and conservation. Archaeological research performed in 2005–2008 in the Market Square, Krakow, resulted in discovering of many metal objects, all of great historical value. Relicts are in need of conservation; some also require reconstructing. The key aim of these activities is exhibiting artistic and aesthetic value of relicts; this entails supplementing or reconstructing missing parts. Proper restoration should bring back real qualities of objects, yet not falsify their original appearance, all supplements being discreet and reversible. This task can be fully achieved with the use of computer supported monument reconstruction.

The authors of the paper touch upon the most significant discoveries made in the Krakow's Market Square, all of them associated with production and trade of metal objects. There has been presented a variety of digital techniques used in museum collection documenting, preparing, conservating and popularising. Based on the example of an unusual relict, a lead ingot, the object virtual reconstruction with the help of multimedia 3D graphic programmes has been described.

Keywords: Relict, Reconstruction, Modelling, Visualisation

W pracy przedstawiono zagadnienia związane z wykorzystaniem współczesnych technik cyfrowych dla wizualizacji i rekonstrukcji zabytków. Badania archeologiczne na Rynku Głównym w Krakowie, prowadzone w latach 2005–2008, pozwoliły na odkrycie wielu obiektów metalowych o dużym znaczeniu historycznym. Zabytki te wymagają konserwacji, a niekiedy również rekonstrukcji. Głównym celem tych działań jest wyeksponowanie wartości artystycznych i estetycznych zabytków, obejmujące także uzupełnienie lub odtworzenie ich brakujących części. Prawidłowa restauracja winna przywracać rzeczywiste walory obiektów, nie fałszując ich prawdziwego obrazu, a wszelkie uzupełnienia powinny być dyskretne i odwracalne. Zadanie to w pełni realizuje wspomagana komputerowo wirtualna rekonstrukcja zabytków.

Autorzy skrótowo omówili najważniejsze odkrycia z krakowskiego rynku, związane z produkcją i handlem wyrobów metalowych. Zaprezentowano także różnorodne techniki cyfrowe, które mogą być wykorzystane w zagadnieniach towarzyszących dokumentowaniu, opracowywaniu, konserwacji i popularyzacji zbiorów muzealnych. Na przykładzie osobliwego zabytku - tzw. bochna ołowiu - szczegółowo omówiono wirtualną rekonstrukcję obiektów z wykorzystaniem multimedialnych programów graficznych 3D.

1. Archeological metal relics found in the market square in Kraków

In years 2005–2008 complex research works were performed on the east side of the Market Square in Krakow. They resulted in exposing of many cultural layers and traces of human existence and activity, some of which date back to the 10^{th} century. The range of performed archaeological research entitles us to list the research among the biggest undertakings of this kind in Europe. It resulted in exposing many relicts of forgotten medieval architecture of Krakow. There has been acquired a complex of movable objects associated with both functioning of an early medieval cemetery, a settlement and a medieval city. Found among these, a collection of metal products has a great historical, scientific and exhibit value. One should appreciate numerous specimens of medieval jewellery, all of great artistic quality: mostly rings, some embroideries, pendants and other elements of dress. Similarly, relicts found in graves including artefacts, earrings (also ring-type loops) and temple rings of the 10^{th} – -11^{th} century have an unusual val-

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ue. Leaden seals attached to goods imported to Krakow from whole Europe comprise a unique set of finds (Fig. 1). Coins originating from different historical periods are another group. Such samples attest to far-reaching trade and cultural contacts of Krakow and a high level of manufacture in a medieval city. Their in-depth analysis, which uses modern research methods, will allow supplementing of the existing source material.

Fig. 1. A merchant's lead seal excavated in the Market Square, Krakow. Photo by P. Guzik

Another group of metal finds comprises historical relicts associated with the history of industry, of lesser artistic value but still historically important. The authors of this article focused mostly on objects preserved in the form of semiproducts and cast products, intended for trade and further processing, which now are remainings of early metallurgy and casting processes.

Remainings of trade workshops (in the form of melting crucibles or pieces of furnaces), which dealt with melting and casting non-ferrous metals, attest to production activity in the Market Square area. Conditions were favourable as metal raw materials were close at hand; these included exploitation of silver and lead deposits in the Bytom area, later also the Olkusz area, documented in 12th and 13th century. In the 13th century Krakow became a trade centre, mostly based on trading Hungarian copper (Fig. 2) and locally extracted lead.

a b

Fig. 2. Copper slices from the Market Square in Krakow (a) and the Bay of Gdansk (b), photo by the Authors

Trading of raw materials laid on merchants a duty of weighing goods; this in turn meant employing a city weighbridge. The earliest mention of the weighbridge in Krakow dates back to the year 1302 and it refers to the weight of lead. There used to be lead warehouse in proximity; there, the goods not only were weighed, but also sold in items (there were usually called ingots or slices, thanks to their shape). The items took the shape of casting moulds in which they cooled down at the last stage of metallurgical process in lead-works.

Fig. 3. Wood engraving, G. Argricola *De re metallica libri XII* publised in Basel in the year 1556, a fragment [1]

The weight of each piece was measured and the engraved, together with an owner's symbol. The bigges items were set aside for wholesale, and smaller one were sold in smaller parts (halves, quarters or smaller ir regular pieces) [3,4]. Found in the Market Square, a 69 kg lead ingot, is the only relict of its kind, preserved i one piece (Fig. 6). Similar but now non-existing relict were found in Gliwice and Bytom; their image inserte in a 18th – century manuscript indicates direct analogie with the Krakow object in both shape and dimension. In order to improve lifting and transportation, edges c the item were incised. The Krakow ingot bears a sym bol resembling the capital letter E, indicating its plac of origin, most likely the Olkusz lead-works (Elkosch). Additionally, there can be seen: 11 marks standing fc weight of 11 quintals, similar to one another; a sea depicting a crown; imprinted fourfold, a ducal seal or Władysław Łokietek, his coat of arms depicting half of the body of a lion and half of the body of an eagle with a crown upon their heads. This relict attests to active participation of Krakow and Lesser Poland in the European economy development which in medieval times based upon exploitation and smelting of ores as well as ore trade. One should bear in mind that Poland, from medieval times until the end of the17th century was one of the key players in Europe's lead production. Yearly output of mining and leadmaking activities in Silesian - Cracow deposits in the 14th and 15th century is estimated at a level of a few hundred tonnes. [3]

Many metal samples, particularly these associated with metallurgic production, were subject to devastation. They could have either been cut in technological activities run in the proximity of Great Weighbridge, or in such condition been brought along the trade route from Hungary to Krakow. One easily notices that the samples used to be more shapely and to render the contour of their casting moulds (Fig. 4). Reconstructing of samples' original contours and appearance would be an intriguing task, irrespective of their present condition.

Fig. 4. Semi-products found in the Great Weighbridge in the Market Square, Krakow. Photo by T. Kalarus

Bad condition of particular metal relicts results from long-term exposure to corrosive factors, such as moisture and high salinity soil. It may prove a difficult task for conservators to bring back due artistic and historic value to these samples. When restorating of a relict poses a threat of damaging its authenticity, coming back to its original state may take place in virtual reality; and likewise, when exhibiting of relicts entails specific difficulties of a conservation or technical nature. From the research and conservation perspective, visualisation and computer supported virtual reconstruction of relicts has many advantages. This work is the first of a few stages of a broader enterprise, which supports the scientific research and restoration of a set of metal relicts found in the Market Square, Krakow.

2. Computer modelling

Since computers are indispensable in many fields and each day there are implemented more and more applications. The foundry casting industry has long been successfully using a range of digital techniques. One of more interesting and quite new ideas is applying computers to the making of fillings, and even complete reconstructions of historical castings. An interesting example is casting of the bust of Friedrich Schiller, where digital techniques allowed ACTech company to use a 200 – year – old plaster model, a relic itself, in a non-invasive manner [6]. This was one of the examples which contributed to preparing a custom scheme of computer techniques application in virtual recontruction of archaeological castings (Fig. 5).

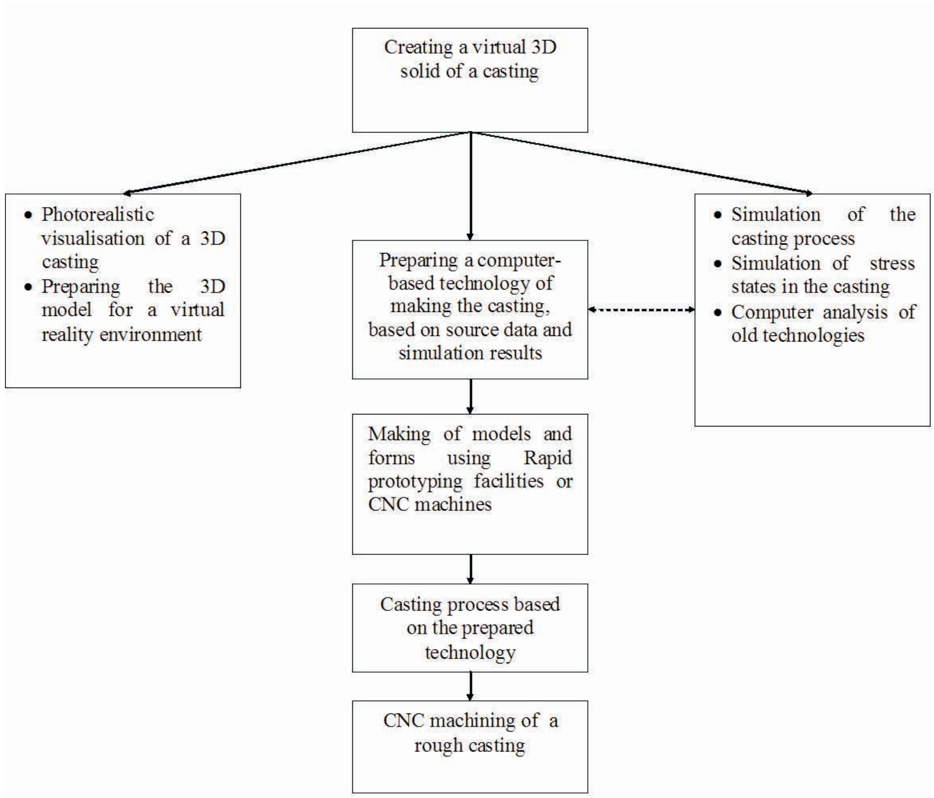

Fig. 5. A scheme of applying computer techniques to virtual reconstruction of archaeological cast objects prepared by authors

The first step in this process is creating a virtual 3D cast model. What differs this stage from typical industry practices is its complex, time-consuming and requiring much precision character. It is noteworthy that the process need not finish by making of a real object. While in industrial applications computer techniques can be used only to support the process of making faultless, high quality castings, in archaeological projects the virtual object is itself a value. One may refer here to extremely popular internet – based museums, experiments with computer reconstruction of historic relicts or works aiming at confronting old technologies with contemporary casting practices [7].

There are two ways to transform an existing object into a virtual 3D solid. The first method employs 3D scanners. The functioning of these devices is similar to the functioning of flat bed computer scanners, the only difference being a result of scanning: a 2D picture is replaced with a file containing a 3D virtual solid model. The primary advantage of that solution lies in a very high level of compatibility of a real object with its virtual model and quite a short time of creating the model. Furthermore, in modern scanners, the scanning process not only does give feedback on the shape of the object, but also on its texture and colouring of the surface; this simplifies visualisation significantly. The drawback of 3D scanners is their high price. One should bear in mind that, since most of these devices use a beam, particular complicated shape objects might not be recognized (at least the parts out of reach of light).

Another method of creating 3D virtual objects is using specialist software. The accuracy of solid modelling depends in that case on technical documentation (designs, photographs etc.) of the modelled object. Basically, these programmes will tend to fall into three categories: CAD modelling, graphic modelling and NURBS based modelling.

The first group consists of commonly known engineering tools such as AutoCAD, SolidWorks, Catia etc. A distinctive feature of these programmes lies in a high degree of parameterisation of the 3D solid modelling process. When shaping a particular solid, a user will employ predefined operations; here the drawing process is similar to the making of standard technical documentation on paper. Unfortunately, parameterisation hinders modelling objects of more complex or irregular shape; that basically rules out using these programmes for our purposes.

The authors of this article note that multimedia 3D graphic programmes such as 3ds Max or Maya prove more capable in that field. These are often very compound tools which not only enable 3D object modelling, but also animation and visualisation. They allow free manipulation of building elements of 3D solids such as:

polygons, vertices and sides; this in turn means that almost any shape can be built. Applications prove useful for modelling objects' irregular or expanded surfaces.

NURBS (*Non-Uniform Rational B-Spline*) is a popular name of two kinds of mathematical objects: curves and surfaces. NURBS – shapes are defined by control points. NURBS modelling has been now implemented in most of multimedia graphic programmes. However, there is specialist software such as Rhinoceros 3D which uses this method only for object modelling. NURBS would therefore compromise parameterization and freedom of 3D modelling. Programmes which use this method are widely applied to making cast pieces of jewellery as well as artistic engineering applications (e.g. industrial design).

In order to illustrate the above, a 3D model of an archaeological object was prepared. It is the said 693 kg lead ingot – an object of great importance for the beginnings of metallurgy and foundry in Poland (Fig. 6). The exhibiting of such bulky objects poses a challenge to museum institutions. Applying of computer techniques allows to make photorealistic visualisation of the puddle-ball so that one can view the object from any angle at the same time, without the risk of damage.

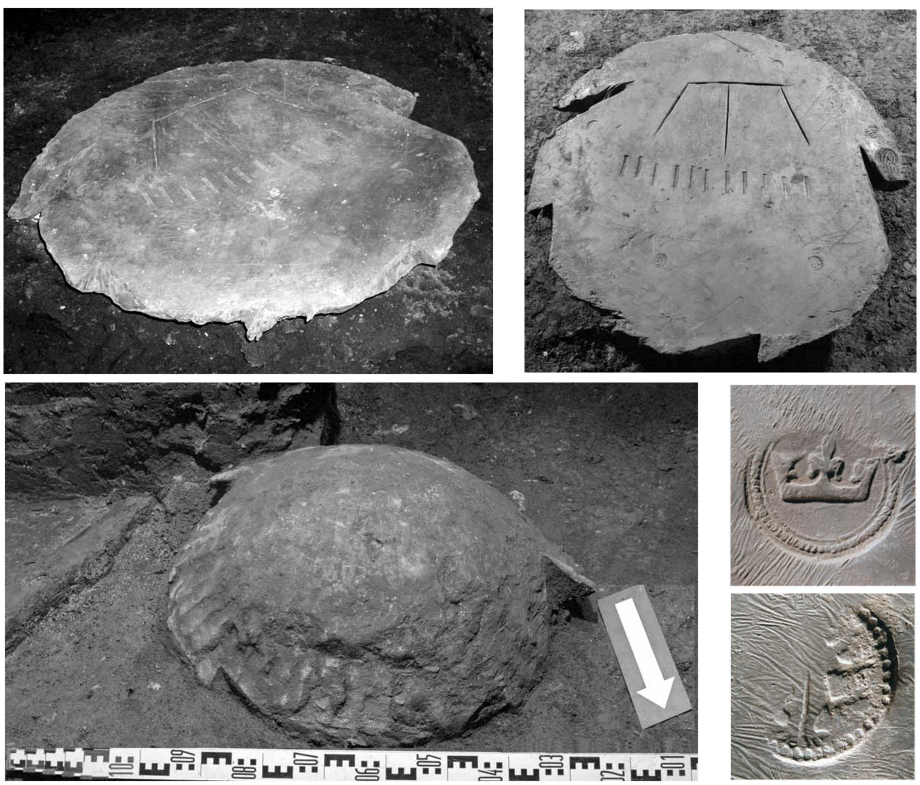

Fig. 6. A lead ingot, 16th century, found in the Market Square (weight: 693 kg, dimensions: 0,89 x 0,81x 0,19 m). Photo by T. Kalarus and the Authors

The considerable weight of the object as well as inability to turn it and/or move ruled out the use of 3D scanners. For purposes of preparing a 3D virtual model, a demo version of a popular 3D graphic programme (3ds Max) was used. Since the model in question is irregular shaped, so called Box modelling was used at this stage. The process was named after an initial 3D solid model, the beginning stage of creating of a particular object. This would mostly be a box (a cuboid). To model the ingot with greatest precision, extensive photographic documentation was used (Fig. 6).

The modeling process consisted in changing the position of the said building elements of 3D solid models. Then, the existing polygon mesh was compressed and further alterations were introduced until the required precision of the image was obtained (Fig. 7).

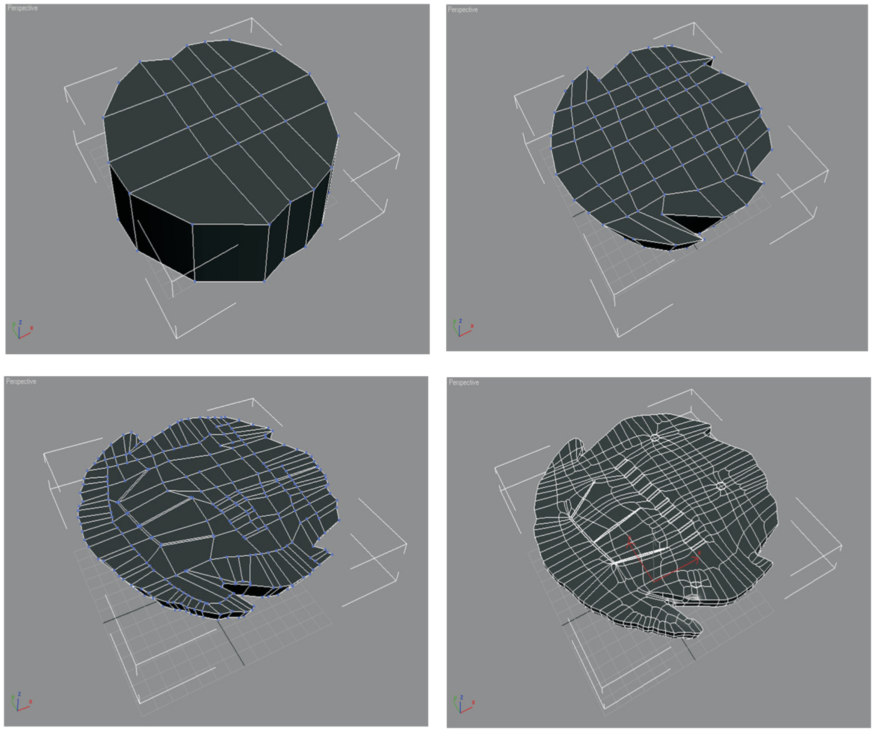

Fig. 7. A lead ingot, sequential stages of 3D modelling.

The next stage was overlaying 2D pictures (photographs) on a 3D model. This is called texturing and, apart from giving the required colouring, it allows to perform a number of operations: wrapping the appropriate texture onto a model, applying lights reflection and dispersion, transparency etc. Then, the 3D solid model was positioned within a scene; that consisted of a ground and elements of lighting.

The final step was the rendering of a ready image which resulted in turning 3D models to 2D graphic files and video files (Fig. 8, 9). The rendering process depends on the employed 3D modeling programme. Extended, commercial applications use techniques such as Ray tracing or Global Illumination which allow using photorealistic effects.

Fig. 8. A lead ingot, computer visualization

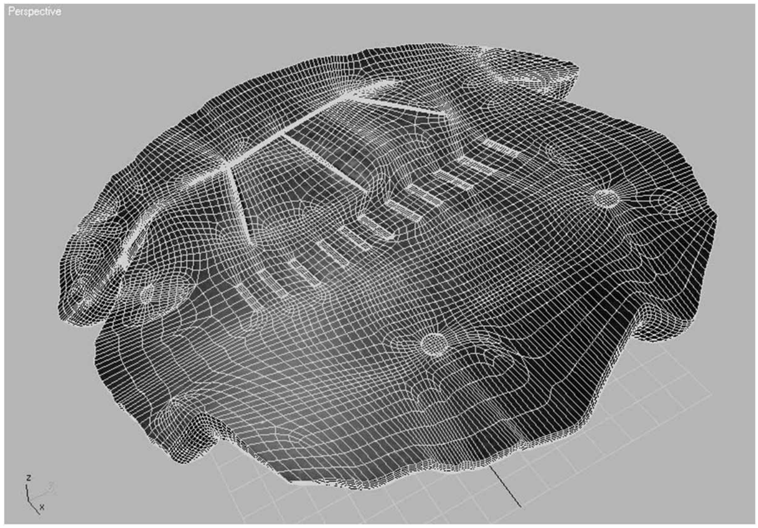

Fig. 9. A lead ingot, the final 3D model mesh

3. Conclusions

According to the heritage conservation theory, missing parts of a relict should not be reconstructed or replaced; and if the need of supplementing arises, the object should retain its original character. Computer reconstruction allows adding missing parts with no damage whatsoever to the object. However, it retains the so – called *memory of a relitc*, that is: traces of damage resulting from the object functioning and the influence of harmful external conditions; but at the same time reconstruction views the original appearance of a relict. Computer reconstruction helps envisage and understand the position of the object in a set of analogical relicts. It proves useful when an original relict is too big to be moved (as the said ingot) or in bad condition, and therefore cannot be exhibited.

Computer reconstruction enables virtual rendering of non-existing artefacts, with archival photographs and plans being the only source of information; it restores modelled objects to the contemporary recognition. It may also support further reconstruction of a relict using traditional methods.

Thanks to its significant educational qualities, virtual reconstruction enables valuable supplementation of didactic materials and museum exhibitions. It presents a chance of modern reception of a historic relict and an alternative approach to the cultural heritage.

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