THE APPLICATION OF A TRUE 3D MEDICAL STEREOPHOTOGRAMMETRY MEASURING SYSTEM IN ARCHEOLOGY

3D SZTEREOFOTOGRAMMETRIAI ORVOSI MÉRŐRENDSZER ALKALMAZÁSI LEHETŐSÉGEI A RÉGÉSZETBEN

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Abstract

Recently, in the digitization of works of art, the application of fusion optic (white light) scanners and the identification of picture elements have shown a rising trend, besides laser procedures. In most cases, these procedures use the digital 2D photos of the objects for presentations and to create the surface texture of the models. They visualise the processed data in 3D perspective, which is a reason why they require a tool fleet and huge storage capacity. One of the most important characteristics of the 3D measuring system presented by us is that it enables data collection, measurement and visualisation directly in 3D. This method has adapted the methods applied by a branch of geodesy mainly to conduct a spatial measure the digital and microscopic photographs. The output device of the system is compatible with the real photo making processes either anaglyph, or stereoscopic, or polarized or shuttered. In the present paper, some fields of application of the cluster of programmes of the medical microscopic system have been analysed from an archaeological point of view.

Kivonat

A műtárgyak digitalizálásában az utóbbi időkben egyre inkább teret nyer a lézeres eljárások mellett, a fúziós optikai (pl. fehér fény) szkennerek alkalmazása, illetve a képelemek azonosítása. Az eljárások a legtöbb esetben a tárgyról készült digitális 2D fotófelvételeket prezentációs célra, a modellek felületi textúrájának kialakítására használják. Eszközpark és nagy tárolókapacitás igényük egyik oka, hogy perspektivikus 3D-ben jelenítik meg a feldolgozott adatokat. Az általunk bemutatott valódi 3D mérőrendszer legfőbb jellemzője, hogy lehetővé teszi az adatgyűjtést, mérést, és megjelenítést közvetlenül 3D-ben. A metódus a geodézia egyik ágának módszereit adaptálta – elsősorban - digitális, mikroszkópos fotófelvételek térbeli mérésére. A rendszer kimenete anaglif, sztereoszkópos, polarizációs, shutteres valódi 3D képalkotó eljárásokkal egyaránt kompatibilis. A dolgozatban az orvosi-mikroszkópos rendszer programcsomagjának néhány alkalmazási területét mértük fel, a régészet szemszögéből.

KEYWORDS: STEREO CONVERTER, 3D DATA RECORDING, 3D MEASURING SYSTEM, DIGITIZATION, MODELLING, CLOSE-RANGE STEREOPHOTOGRAMMETRY

KULCSSZAVAK: SZTEREO KONVERTER, 3D ADATFELVÉTEL, 3D MÉRŐRENDSZER, DIGITALIZÁCIÓ, MODELLEZÉS, KÖZEL – SZTEREOFOTOGRAMMETRIA

Introduction

The Three-Dimensional Morphological and Movement Analysis Laboratory of Semmelweis University Faculty of Physical Sciences and Sport Sciences led by Dr. Stuber István have been developing a spatial visualization system that features measuring, modelling and navigation. This system enables the display of micro- and macroscopic structures in the form of stereo-image pairs. Thus a true 3D view is achieved, with which it is possible to conduct highly accurate spatial measurements, mathematical analysis and modelling. Via 3D graphics the results can be presented in homogeneous, shaded and animated surfaces (Detrekői et al. 2004 102-105.).

The working mechanism of the system

The system is based on an optical device, invented by Stuber (Reference date of the patent: P0800650): the stereo converter, which, besides being capable of increasing any optical magnification by an additional five times, overcomes a major obstacle in optics: it parallely extends the depth of field of the given magnification by twenty-thirty times.

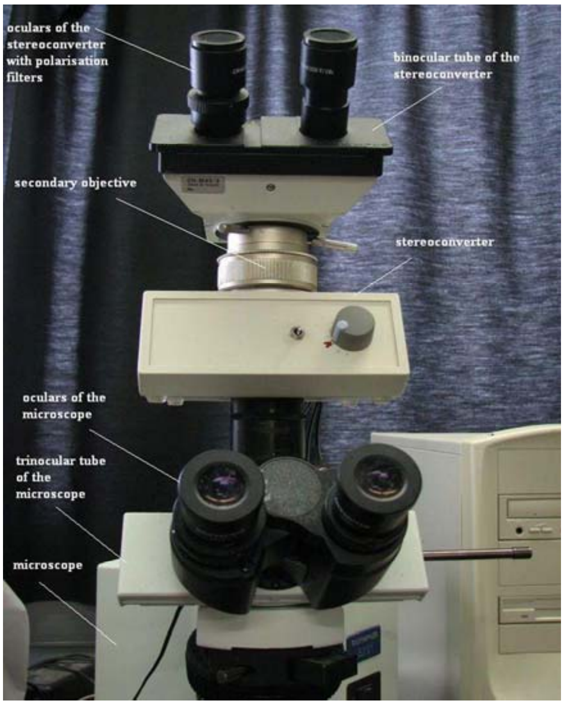

Fig. 1.: The stereo converter

1. ábra: A sztereo konverter

In other words, the width of the displayed layer is enhanced: as a result, it is possible to study the spatial morphology of spatial light microscopic structures (**Fig. 1**).

In case of the 3D measuring system a branch of geodesy, the stereophotogrammetry's data processing method – which is mainly employed to analyze aerial photographs – was adapted to the spatial measuring of micro- and macroscopic stereo-images (Kraus 1998 13-14, 177, 329-360.; Fekete 2006 2-9, 39-41, 53-54.). Our 3D computer workstation and the related software package basically simulate the data evaluation mechanism of optical and precision engineering appraisal tools.

The system works as a stereoscope: it displays stereo-image pairs obtained from two different angles. It facilitates work with a perfectly life-like virtual object and it's possible to carry out precise measurements. The cursors appearing on the left and right image function as a crosshair. The cursors can be moved simultaneously and freely in virtual space, can be placed at any point of the spatial structure. At this stage the cursors in the stereo-image pair overlap with the right and left projection of a given point (the so called identical points) (Alhusain et al. 2003 11-14.). This method can be applied in case of video records – in this case the process has to be repeated screenshot by screenshot in order to describe a moving object's spatial plane.

In the following, the 'traditional' 3D modelling and displaying methods will be called 2.5 D in contrast to the lifelike, true 3D view of the stereoscope. Although it is not the accurate use of the term, it reflects the fact that 3D programs primarily aim to generate a picture suitable to be displayed on a graphical output device (e. g. monitor screen); meanwhile the mathematical modelling of a 3D item is a relatively simple and fast process. Employing a stereoscope – as this system does – offers to work directly in 3D and to avoid the numerous difficulties of generating a 2.5 D view.

As a result of measuring, a 3D point cloud is formed, which is overlapped with a mathematical cover (by the software) and is displayed via a stereoscope in the form of homogeneous, shaded, three-dimensional virtual objects. These objects can be rotated, moved, deformed as a colour animation (Alhusain et al. 2003 12.). Mathematical analysis and modelling can be executed on the texture achieved by mathematical approximation.

The system can be adapted to various fields of archaeological research; in the following you will see some possible applications and their benefits. Please note that the pictures in the current paper present only one side of the stereo-images in the stereoscope, so one might see unfitting lines on object surfaces.

Digitalizing collections

Following the appearance of 3D modelling a considerable demand was expressed to digitalize collections. Thus the preservation of artefacts has arrived at a new stage, objects can be easily accessed and studied worldwide, and virtual museums are established (e. g. Balázsik et al. 2009 41-42. Szerdahelyi 2008 31.). Among the difficulties arising around digitalization, the problem of storing data files could be solved by the Stuber system.

The size of a database containing the images of an artefact captured from different viewpoints is minimal, because only 4 to 8 images are necessary. All the information required to measure and to create 3D models are contained in the photos and can be transformed at will into a 3D or 2.5 D model. The model can be displayed polygonally, and various textures (image of a real object, shaded texture, surfaces selected freely) can be added. For scientific purposes it is excellent as measuring can be carried out without generating the 2.5 D model of a given object, that would require expertise and a considerable amount of time (**Fig. 4**).

The other problem to be solved is that 2. 5 D models do not reflect the original characteristics of the ceramics, among others, in a satisfactory quality (Boon et al. 2007 153-54., 156.). In this system the digital object can be presented not as merely a textured surface but as a true 3D space, with optionally detailed resolution and digital storing place.

For demonstration and educational presentations a projector set is available with which the recorded object can be presented to a large audience. The projector system has been set up in the Cardiological Institute of Debrecen, Hungary.

3D modelling on artefact level

On the level of artefacts, efforts are directed primarily on the rapid and accurate digitalization of ceramic fragments that are unearthed in abundance. On the one hand digital databases can facilitate new approaches; on the other hand it can substitute for the time-consuming drawing. In the overwhelming proportion of cases the data acquisition is executed with an optical or laser scanner that is more suitable for obtaining surfaces and geometric information (Lambers & Remondino 2007 31.).

An advantage of range based methods is that direct 3D points are produced; therefore modelling is significantly faster compared to using photogrammetry. Its drawback is its high cost, the required high level expertise and technological background. The final result can be influenced by the characteristics of the fabric and by the reduction of the scanned points. Methods based on distance measuring demand that a vast number of points should be measured; otherwise the edges of the object cannot be detected. Consequently, at the end of the process the point cloud has to be decreased (El-Hakim et al. 2007 43.).

The main problem that researchers had to face is related to the orientation of sherds that was lately successfully automatized (Kampel et al. 2005 570-72.). A software has been devised that generates a figure from the scanned data meeting the standards of publication. Running the program does not require expertise and it allows the user to orientate the fragment on-demand. The generated 3D model, which is presented through 2.5 D, is convenient for further measurements and typology.

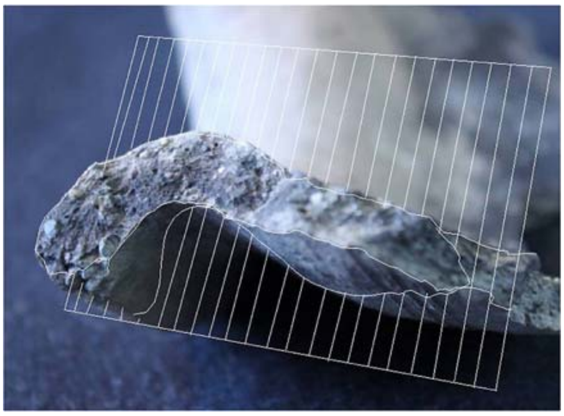

Fig. 2.: Early Avar coarse ware made by slow-turning wheel (Daruszentmiklós, F-005)

2. ábra: Adatfelvétel, lassú korongolt avar házi kerámiáról (Daruszentmiklós, F-005)

Our ongoing project strives to capture photographs of ceramic fragments carrying valuable archaeological data and generating profile lines that deliver professional standards. During the documentation the requirements of capturing stereo-image pairs have to be fulfilled: two identical cameras with appropriate settings and angles. To be able to make measurements the angle of the cameras has to be known and etalons have to appear on the photos. The etalon is an object with known metrical data.

The program of the system is not aimed at excluding the human factor but it promotes and corrects the user's work. Based on the methodology of photogrammetry the developed program is able to calibrate the pictures automatically. Following the calibration the measuring can begin in the images displayed in the stereoscope. For the computer the data of the 3D objects are defined by these measurements. Other measurements and calculations can be carried out on the 3D model: e. g. the diameter of the rim (**Figs. 2 and 4)**.

We have not yet succeeded to find the profile line automatically; however, the program is capable of generating a 3D model based on the profile line. In other words the 3D reconstruction is possible, but requires high amount of human interference at the moment (**Fig. 3**). In the case of the Stuber system the possibility of fully automatic ceramic documentation is uncertain.

New approaches can be explored in the field of morphological survey of artefacts. In case of lithic assemblages an increasing demand can be detected to study the physical data of stone objects: e. g. the flaking angle, the proportion of length and width and to examine the correlation between metric data and the applied knapping technique (Inizan et al. 1999 73-78.). The relationship between them also has been proven by experiments (e. g. Mateiciucová 2004).

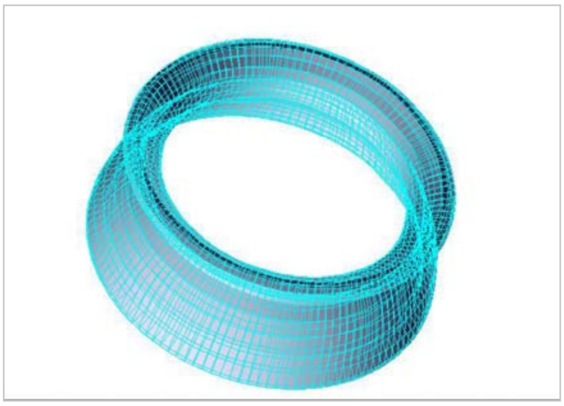

Fig. 3.: 2.5 D model generated from the profile line of a sherd

3. ábra: A kerámiatöredék profilvonalából generált egyik perspektivikus 2.5 D modell

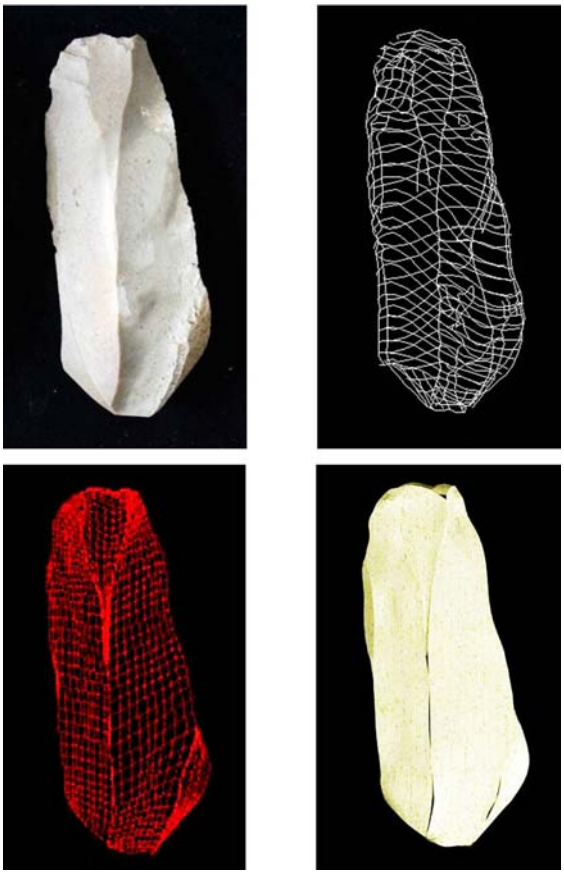

Fig. 4.: Neolithic blade, stray find, Linear Band Pottery Culture. Steps of creating a 2.5 D model: photo, measured points, polygon mesh and the final model (on this last step we used AutoCAD)

4. ábra: Szórvány neolit penge az alföldi vonaldíszes kerámia kultúrájából. A 2.5 D modell készítésének lépései ebben az esetben: (sztereo) fotó, mérőpontok, poligon háló, és a kész modell. (Az utolsó lépésnél AutoCAD-et használtunk.)

Drawing in the discussed system enables the user to measure the angles between surfaces and compare physical data. For instance, in case of a blank it is possible to determine the flaking angle or the angle du chasse, in case of a core the angle between the striking platform and the débitage surface can be calculated (**Figs. 4, 5 and 6**).

The advantages of the three-dimensional measuring system

The main benefit of the introduced measuring system derives from the fact that here measuring is not restricted to one plane; therefore a significant number of points can be defined in the course of the same operation. This way the outcome is also more accurate compared to the process of measuring the subsequent planes separately.

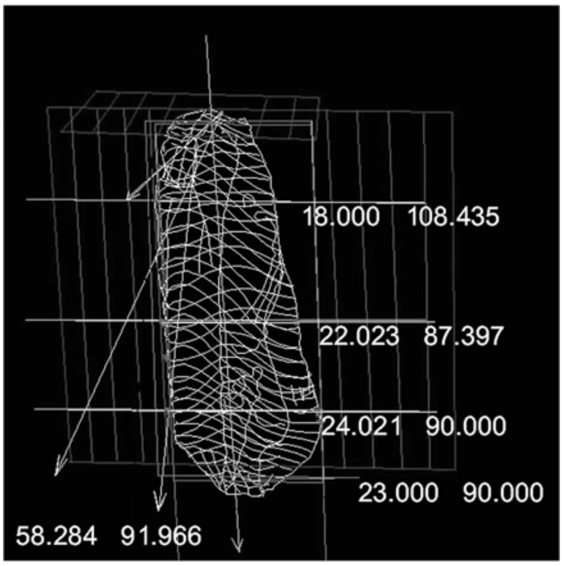

Fig. 5.: The metric data of the same blade appear in the picture: the maximum length (5. 8 cm), maximum width (2. 4 cm) and proximal (1. 8 cm), mesial (2. 2 cm), distal (2. 3 cm) width

5. ábra: A penge méretadatai leolvashatók: legnagyobb hosszúság (5,8 cm), legnagyobb szélesség (2,4 cm), proximális (1,8 cm), mediális (2,2 cm), és disztális (2,3 cm) szélesség

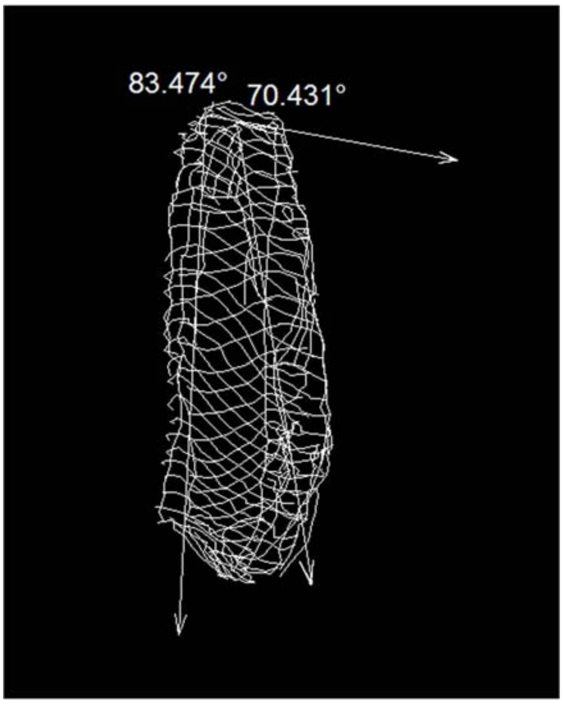

Fig. 6.: The program is capable of measuring angles: in this case the flaking angle and the '*angle du chasse*'

6. ábra: A program alkalmazása szögmérésre: ebben az esetben a leválasztási, és leütési szöget ('*angle du chasse*') mértük meg.

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A further advantage is that during measuring real shapes the software generates a virtual object to be utilized for calculations. By semi-automatizing the measuring time can be saved, nevertheless post-correction is also available. The gained data can be managed variously or can be transferred into processes already in use. Several measures of the same object can be merged, thus extending and specifying documentation.

From the viewpoint of archaeology a number of practical profits can be enlisted (e. g. Balázsik et al. 2009 43-44.). The system requirements for working with true 3D can be fulfilled with a standard computer.

Data acquisition is quite simple. The system is based on stereo-image pairs displayed in true 3D and enables data acquisition and measuring directly in 3D. The technical prerequisite for capturing stereo-images is to adjust two cameras in the appropriate angle, and an etalon demanded for calibration has to appear in the image.

Working with the measuring system basically does not call for computer expertise; the model can be manually drawn via a special tool. The data required for measuring refers to only two digital images that facilitate the handling of data: processing, storing and sharing.

Its flexibility, cost-efficiency and compatibility make this measurement system one of the picture element fitting methods that are to be used to an ever increasing extent in archaeological documentation and in the museological digitization of objects in the near future in accordance with the more and more possibilities of digital photo processing.

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