VISUALISATION OF UNDISCOVERED BOŘIVOJ II PRINCE TOMB INTERIOR AT THE PRAGUE CASTLE

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ABSTRACT

There are many tombs of Czech kings and princes at the Prague Castle. Some remains of the Czech princes and their wives from the Přemysl epoch (9th century-1306 A.D.) were transported to a new cathedral of St.Vitus (1373) by the emperor and Czech king Charles IV (1316-1378) in the middle ages. The tombstones were made in the well-known stone workshop of the Parléř family. Some tombs were partly damaged and opened during the Thirty Years War. Majority of the tombs were investigated in the 19th and 20th centuries. The tombs of Bořivoj II (1100-1124) and Břetislav II (1092-1100) were restored in 2002. Mixed stones with lime were discovered under the upper part of the tomb; the space for the remains was been found under this layer and under the floor level. In the case of tomb Břetislav II, the prince, the last unknown opening has been stated in the 19th century (a small lead tablet with the date was found). In the case of Bořivoj II, the prince, the tomb has not been opened for more than 600 years (from the Charles IV time). It is a single undiscovered Přemysl´s tomb at the Prague Castle. This is because of large two stones (2x3m) shield the space over remains in the ground. The decision on status quo has been made after discussions. The reconnaissance using endoscopes has only been allowed. The 3D visualisation of the Bořivoj II tomb interior is the theme of this paper.

1. IMAGE DATA SET

In spring 2002, the sculptures on the tombs of Bořivoj II (1100-1124) and Břetislav II (1092-1100) were restored. Within this work, discovering of the space for the remains in both cases was planned. Mixed stones with lime were discovered under the sculptures; the lower part of the tomb located under the floor (cca 100x50x100cm) contains the remains of Czech princes. The decision on status quo has been made after discussions. The reconnaissance using endoscopes has only been allowed. Only the images from this device were used for possible creation of a 3D model. For a small camera input, the 2cm distance between two stones covering the tomb was prepared. Finally, two types of miniature cameras were used: the XL PRO VideoProbe (Everest-Vit) and the MTV-54C5P (Mintron) camera. In both cases, video sequences were obtained. From these video sequences singe images were generated with resolution 768x575 pixels.

The VideoProbe XL PRO™ is the most advanced remote viewing tool. It is especially designed to be easy to use and still offer unmatched imaging capabilities with options to suit virtually any applications. With number of accessories and options available, the XL PRO is ready to be adapted to any inspections situations, for example the using in archaeological purposes. The video bore scope consists of hand-piece buttons, joystick and on-board file manager, high resolution camera for true colour images, external monitor and recording device with S-video inputs. The image sensor contains from 1/6´´ colour CCD camera with resolution of 480 HTV lines S-video (440000 pixels PAL). Exposure from interval 1/60th seconds up to 12 seconds can be used. The XL PRO™ supports the use of interchangeable optical tips – the 3.9mm, 5mm, 6mm and 8mm diameter probe.

The second used camera was MTV-54C5P (Mintron Enterprise Co.,Ltd). This device uses interchangeable objectives (f=16,12,8,6,4,2.5mm). The objective with focal length 6mm was used for majority of acquired images. Camera is build in a tube; it contains 1/4-inch CCD Image Sensor (PAL, CCD total pixel 542 (H) x 586(V), electronic shutter,1/50~1/120,000 sec., scanning with 625 lines, 50 fields/sec). The camera MTV-54C5P is not a complex viewing tool; in this case, a special small halogen light source must be added. Video data were stored on digital video recorder.

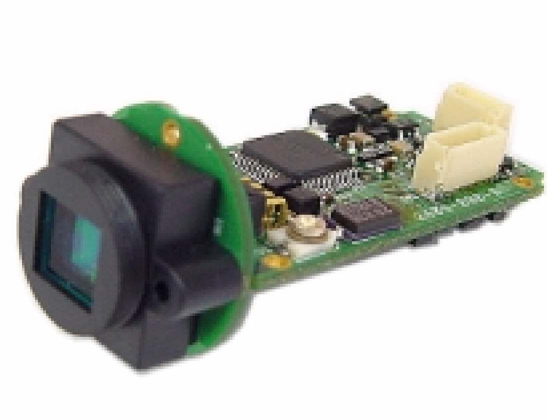

Figure 1. MTV-54C5P (Mintron) CCD camera

2. IMAGE PRE-PROCESSING

Both cameras are non-metric. In this case, for using in photogrammetry, it is necessary to make a camera calibration. We have made only simple camera calibration to decrease image distortion. A special method based on image calibration and self-made software was designed. As a reference image, the calibration field composed of a set of regular small crosses on a paper sheet was prepared.

Figure 2. XL PRO VideoProbe (Everest-Vit) bore scope

The equations of collinear transformation (1) are completed with correction part for expression of image distortion (2):

$$X = \frac{ax+by+c}{gx+hy+1} \qquad (1)$$

$$Y = \frac{dx+ey+f}{gx+hy+1}$$

$$x_d - R'(x_d - x_0) = \frac{ax+by+c}{gx+hy+1} \qquad (2)$$

$$y_d - R'(y_d - y_0) = \frac{dx+ey+f}{gx+hy+1}$$

$$x_b = x_d - R' \cdot (x_d - x_0) \qquad (3)$$

$$y_b = y_d - R' \cdot (y_d - y_0)$$

$$R' = R'(x_d, y_d, r(x_d, y_d)) = k_0 \cdot r^2 + k_1 \cdot r^4 + k_2 \cdot r^6$$

$$r(x_d, y_d) = \sqrt{(x_d - x_0)^2 + (y_d - y_0)^2}$$

x_d, y_d are the coordinates with distortion, x_b, y_b are the coordinates without distortion, x_0, y_0 are the coordinates of principal point, k_0, k_1, k_2 are the coefficients of radial distortion. These equations are used in the software for distortion parameters calculation. As a data input, the set of true coordinates from calibration field and the set of image coordinates of crosses are used.

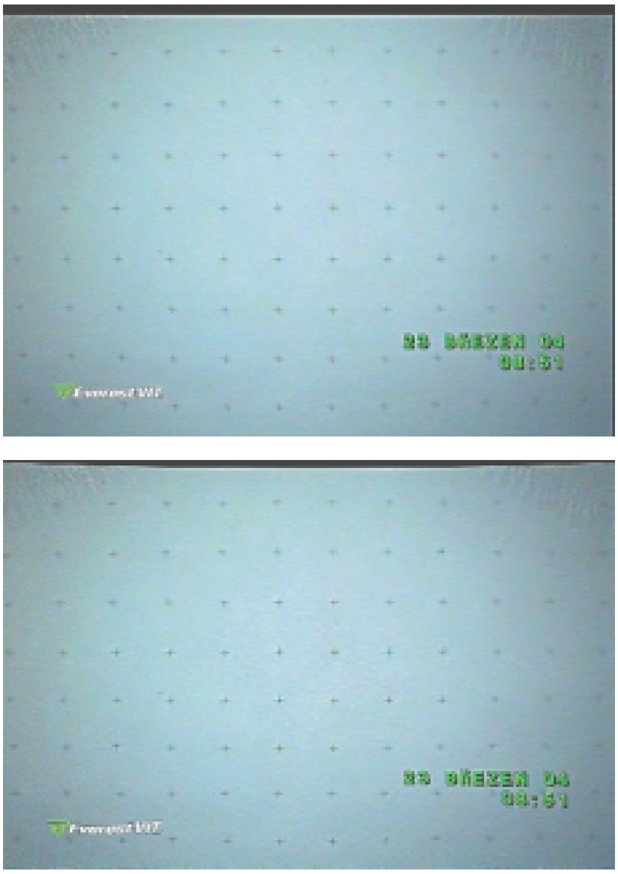

Figure 3. Simple radial image distortion suppressing (original image and processed image)

The next step is the elimination of known radial distortion from images by using of another software. This software uses inverse equation to equation (3) and iteration:

$$x_d = x_b + R' \cdot (x_d - x_0) \qquad (4)$$

$$y_d = y_b + R' \cdot (y_d - y_0)$$

Nearest neighbour method is used for determination of final RGB value in a new image. Finally, the images with suppressed image distortion are produced.

3. DATA PROCESSING

For a 3D model creating, the Photomodeler software was used. From video sequences, the suitable images must be selected. From the set of about 150 images only about 30 images were used as an input for Photomodeler software. It was not possible to make a complete model from all images; all the images were not suitable for intersection photogrammetry. For this reason, several partial models were created and the final model was made as a joining of model parts. Final model is an experiment for 3D visualisation of the tomb interior.

4. CONCLUSION

Technology of close range photogrammetry by using non-metric devices for discovering of archaeological artefacts is discussed in the paper. In this project, small digital cameras and endoscopes as imaging devices were used. After simple image distortion repairing, the photomodeler software for data processing and model creating was used.

Figure 4. The tomb Sculpture of Borivoj II.

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Figure 5. The tomb of Borivoj II.

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Figure 6. Images from tomb made by MTV-54C5P (Mintron) CCD camera

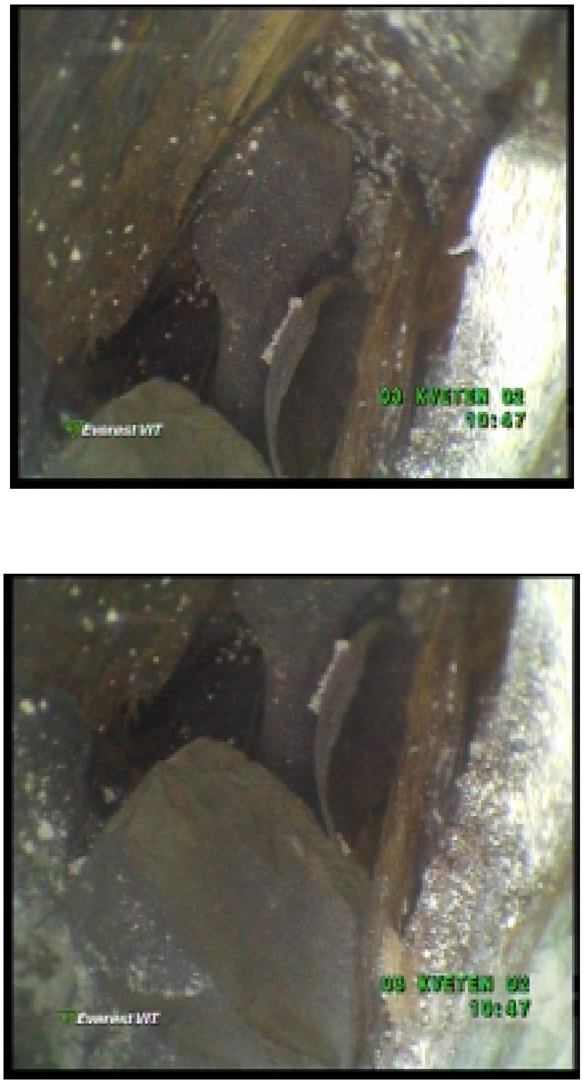

Figure 7. Images from tomb made by XL PRO VideoProbe

Figure 8. Detail of the tomb interior

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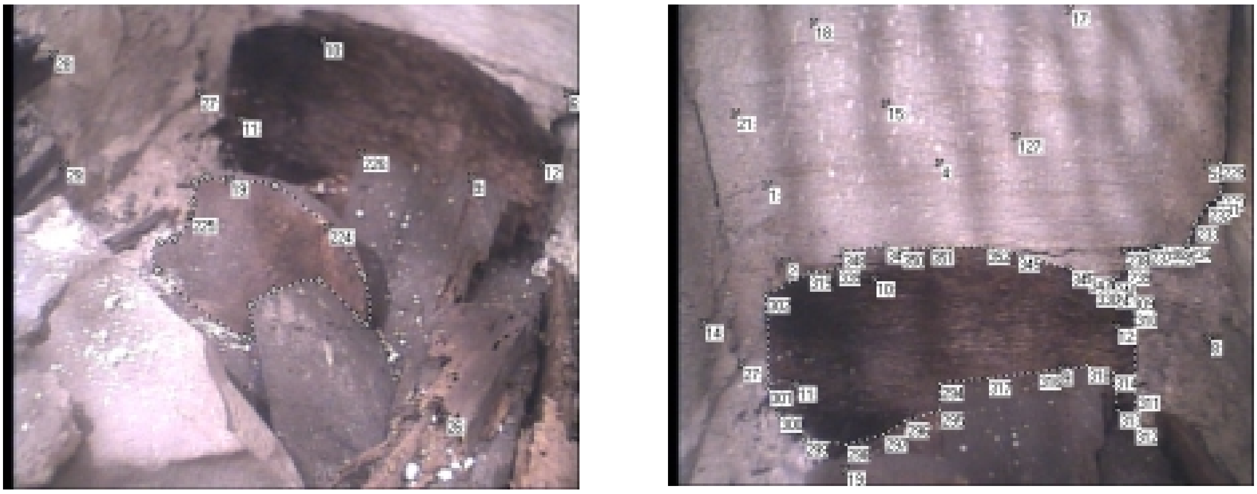

Figure 9. Object points processing, Photomodelert

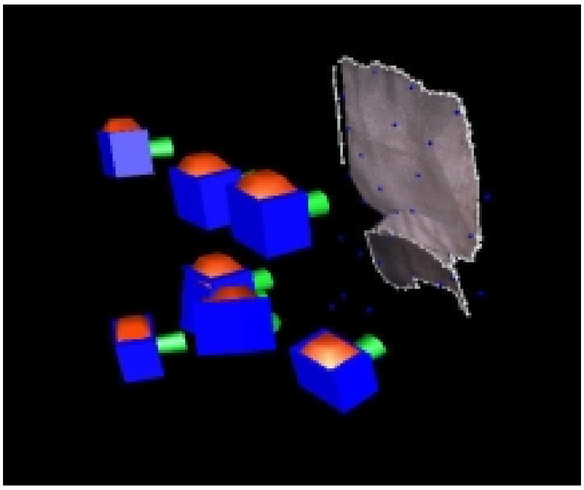

Figure 10. Image orientation using Photomodeler