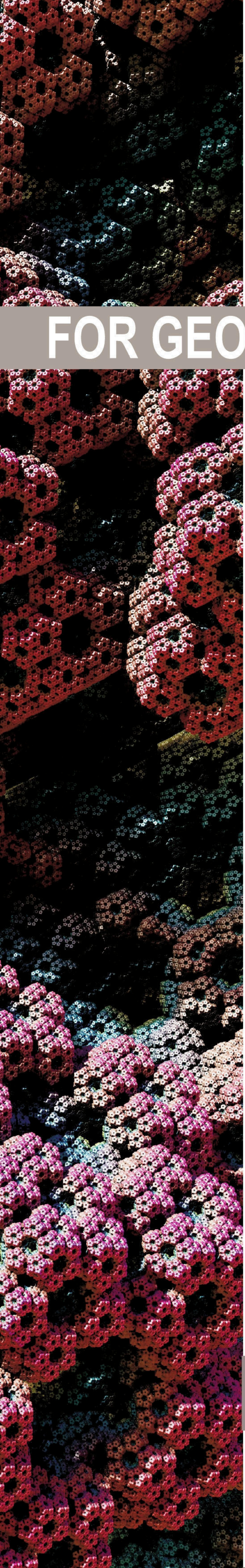

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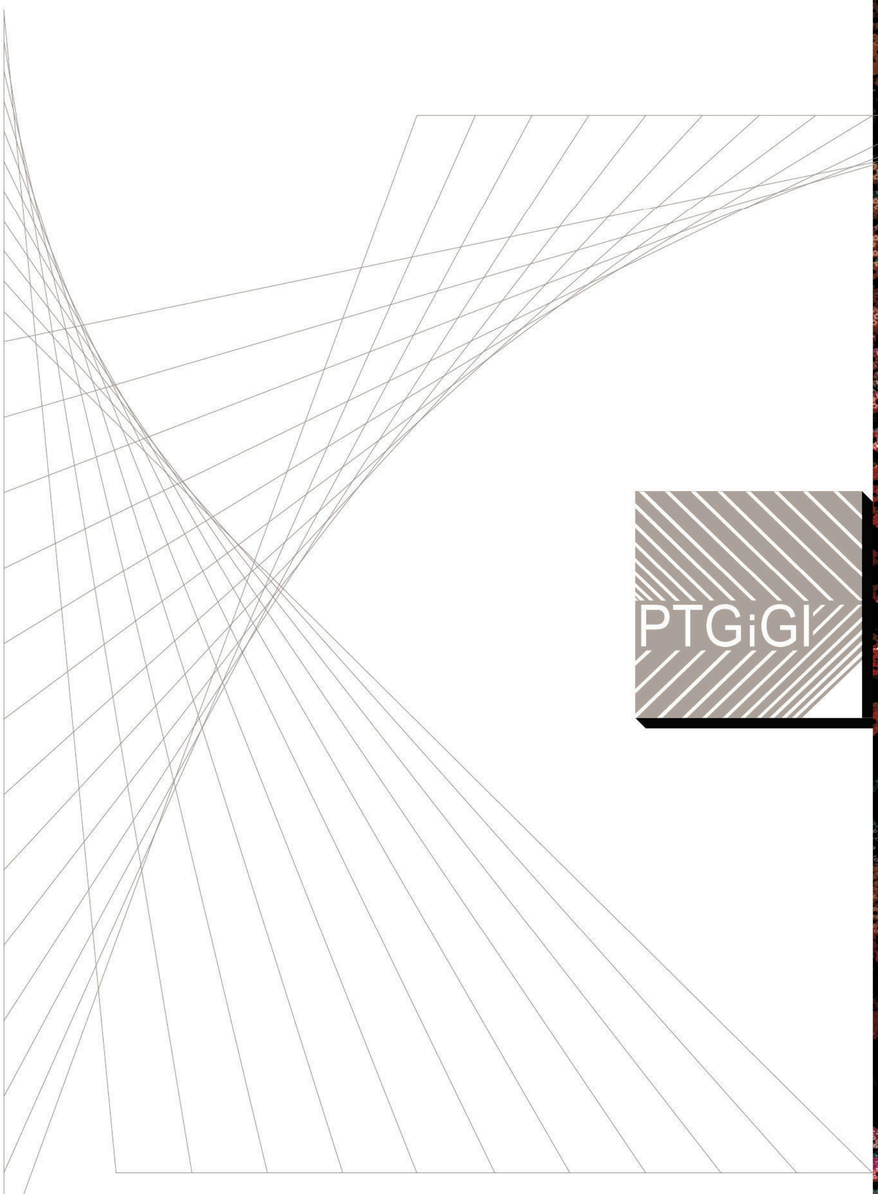

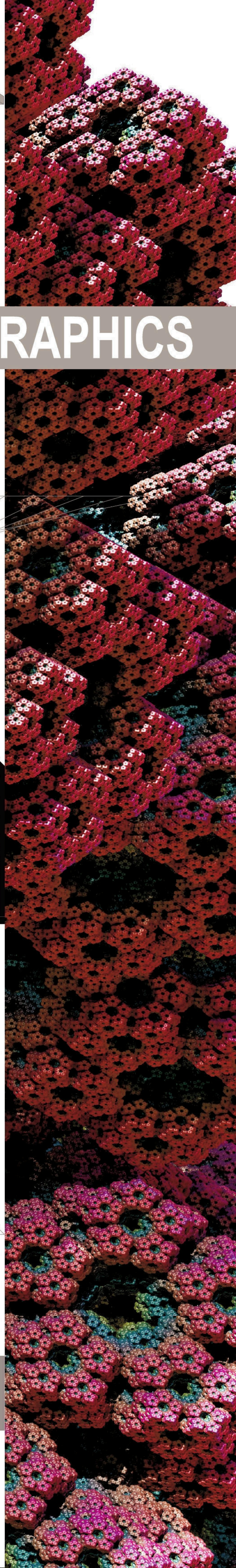

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ANALYSIS OF 3D PHOTOGRAMMETRIC RECONSTRUCTION

Daniela VELICHOVÁ

Slovak University of Technology, Faculty of Mechanical Engineering
Nám. slobody 17, 812 31 Bratislava, SLOVAKIA
daniela.velichova@stuba.sk

Abstract. Paper brings information about process of analytics reconstruction of 3D real data of objects selected from photographic images using software application CamWitt. Reconstruction algorithms are based on classical methods of photogrammetry and principles of epipolar geometry.

Keywords: Photogrammetry, epipolar geometry, 3D reconstruction.

1 1 Introduction

The paper brings information about process of analytic reconstruction of 3D real data of selected objects from photographic images using software application CamWitt. This interactive tool was developed for filtration of data recordings, automatic detection of objects in the images and exact determination of dimensional and positional characteristics that enable correct identification of recorded objects and their real dimensions. Algorithm for calculation of real dimensions is based on geometric principles of photogrammetry and epipolar geometry. Various solutions improving accuracy of the resulting real data are described and analysed, and 3D visualisation GeoGebra applet for understanding proposed corrections to algorithm and their geometric interpretation is presented. Methods of underlying principles of epipolar geometry are introduced in brief.

Presented facts are results of the project of the Slovak Research and Development Agency APVV-1061-12 entitled „Determination of geometric characteristics of objects obtained from criminological relevant image recordings“ and coordinated by the Slovak University of Technology in Bratislava. Partners are Criminological and Expertise Institute of Ministry of Defence of SR. Project aims to development of a correct and precise algorithms for processing of geometric characteristics and reconstruction of dimensions and position of selected objects in photographic images of 3D scenes. Its results will be used for practical applications in criminology, for detection of criminal acts, in collection and analysis of proofs of evidence recorded on images and during identification of suspected criminals.

2 Description of basic tasks

2.1.1 At many public spaces that have to be under constant surveillance due to various safety reasons, expensive security camera systems are installed at stable position, which are used for continuous recording of the 3D space within the camera vision cone. Obtained recordings have to be thoroughly analysed especially in case of emergency situation or when a crime has been committed, in order to deduce the reason of the event and search for proofs of evidence. In majority of situations these camera systems are of known calibration and therefore classical photogrammetric methods of reconstruction can be used.

2.1.2 An interactive tool CamWitt was developed during the project life for filtration of data recordings, automatic detection of objects in these images and exact determination of dimensional and positional characteristics that enabled correct identification of recorded objects and their real dimensions. Used methods are extensively tested before they can be applied in the criminological practise, in detection of criminal acts, in collection and analysis of proofs of evidence recorded on images and during identification of suspected criminals.

User interface of the CamWitt application is presented in Fig. 1, with uploaded two photographic images of a real 3D scene. Users are supposed to detect manually at least 9 pairs of corresponding points in the two windows with images taken by a non-calibrated camera from two different positions. System automatically calculates the camera calibration and inner picture calibration, and finds the inverse projection matrix, from which coordinates of the real points in 3D are calculated and appear in the pop-up window. Distances of selected points can be calculated as well.

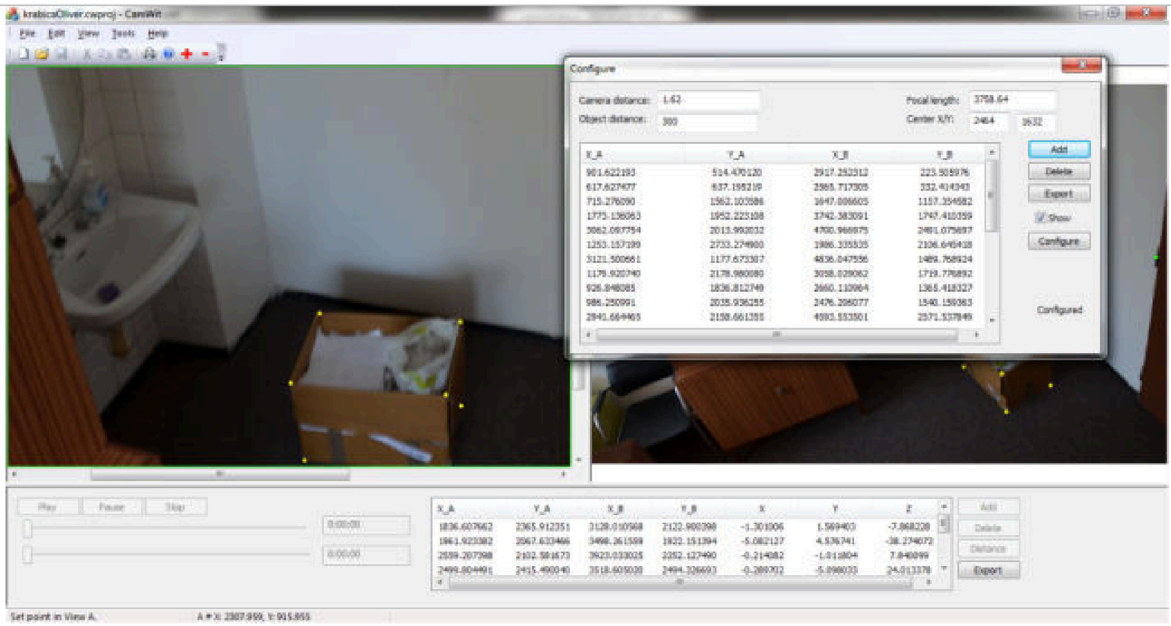

Figure 1: CamWitt application interface

3 Theoretical backgrounds

Calculation of real 3D Cartesian coordinates of points detected from photographic view is realized by means of algorithms based on properties of linear perspective, projective transformations represented in matrix form. Each central projection or photographic mapping defines a particular coordinate system in space, called the camera frame. Its origin is placed at the centre of projection, the principal ray of the camera is the z coordinate axis, and the principal directions in the photography image plane serve as x and y coordinate axes spanning the vanishing plane of this central projection. Central projection denoted in homogeneous coordinates $(x_0: x_1: x_2: x_3) = (1: x: y: z)$ is expressed as a linear mapping determined by the focal distance d.

$$\begin{pmatrix} x'_1 \\ x'_2 \\ x'_3 \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 1 \\ 0 & d & 0 & 0 \\ 0 & 0 & d & 0 \end{pmatrix} \begin{pmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{pmatrix} \qquad (1)$$

Inverse problem, in which coordinates of points on the real object in space are calculated from plane coordinates detected in the central images of the respective points, is the background of the analytic algorithm. Projection lines from the two given centres, so called epipolar lines of projection, are lines intersecting in the mapped points located in the space, see Fig. 2, on the left. Image coordinates are detected always with certain errors, due to various reasons (manual data collection, size of analysed picture and its precision, contrast and resolution, etc.), which are reflected in different position of epipolar lines that might be intersecting in points not corresponding to real original points mapped in the central images from which the views were detected. Lines can be either intersecting in points inside or outside the mapped object, as can be seen in Fig. 2, on the right. In the worst case these two lines can be skew and not intersecting in a real point at all.

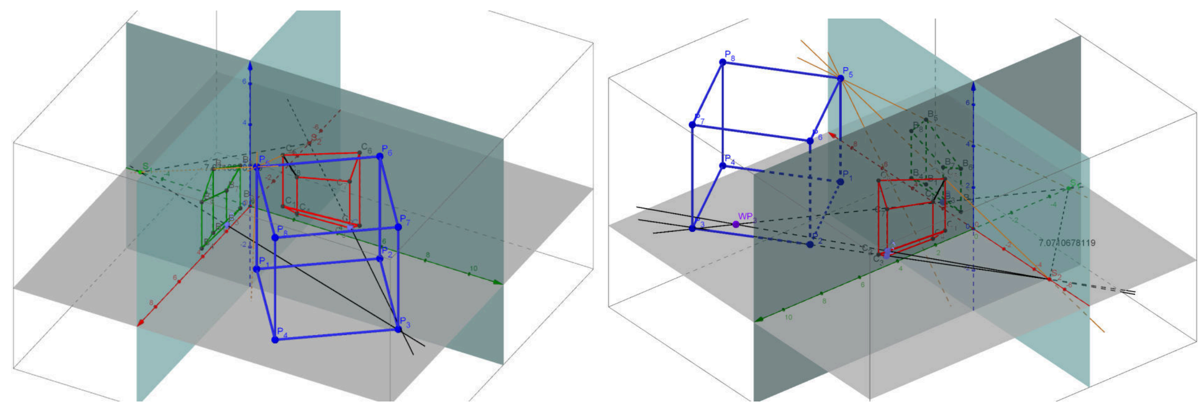

Figure 2 Left:Two central projections of a cube from two different centres. Right: Incorrectly meeting epipolar lines inside mapped cube.

For obtained skew lines, when there is no solution of the inverse problem, additional algorithm had to be implemented. Corresponding point is calculated as the centre of the axis of respective skew lines. This means that line perpendicular to both skew lines and intersecting both of them is determined, while centre of symmetry of the two intersection points on skew epipolar lines, i.e. point in the minimal distance to both of them is determined as the corresponding point at the reconstructed real space object.

Several other attempts to improve precision of calculation of the real coordinates of points on selected reconstructed objects were analysed, dealing with information on photographic images, as e.g. position of the principal point (view of the centre of projection) in the two images, distance of the two centres of projection, and others. Impact on achieved accuracy of results was analysed, namely relation to inaccurate dimensions in direction of different coordinated axis. On the basis of this analysis some further improvements to algorithm will be introduced.

4 Conclusions

Several supportive digital tools were developed in order to analyse inaccuracy that might occur in the calculations of real dimensions from image data. One of them is the 3D visualisation GeoGebra applet for performing two different central projections of an object from different centres located in given distance. Basic principles of epipolar geometry are presented here in their geometric representation, which are underlying the classical photogrammetric methods applied in analytic form in the developed algorithm, see in Fig. 2.

Analysis and results of the project „Determination of geometric characteristics of objects obtained from criminological relevant image recordings“ were presented. Based on photogrammetric methods represented in analytic form, an algorithm for calculation of real three dimensional data of selected objects on two photographic images was developed, aiming to precise reconstruction of object dimensions and position in the space. Several methods for improving the accuracy of obtained calculation results were presented.

The described methods are to be introduced in the criminological praxis, for investigation of acts of crimes, in collecting and analysis of proofs of evidence recorded on video-cameras or from two stable cameras, and from any other relevant image recordings, for the aims of identification of criminals and committed criminal acts. Results of project will be generalised on development of algorithms of videogrammetry, for reconstruction of objects in video-records for stable camera systems.

Acknowledgements
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METODA ANALITYCZNA REKONSTRUKCJI FOTOGRAMMETRYCZNEJ 3D

W pracy podano analityczną metodę odtwarzania rzeczywistych danych 3D obiektów wybranych z obrazów fotograficznych za pomocą aplikacji CamWitt. Algorytmy rekonstrukcji oparte są na klasycznych metodach fotogrametrii i zasadach geometrii epipolarnej.