Milan Nič, doc. Ing. PhD., Veronika Sojková, Ing.
Slovak university of technology Bratislava, Slovakia
Faculty of civil engineering

DOCUMENTATION OF BUILDING RESEARCH BY FOTOGRAMMETRY

This paper describes the creation of documentation of building exploration by close photogrammetry method. It describes the content and purpose of researches and it summarizes the development of graphic documentation researches. The introduction of digital photography has increased the possibility of using photogrammetry for the measurement of geometric parameters of existing buildings. This method can be effectively used in the case of unpreserved final building documentation.

Key words: building research, digital close-range photogrammetry.

Описано виготовлення матеріалів для обстеження будівель методом близької фотограмметрії. Розкрито зміст і мету обстеження будівлі і підсумовано процес підготовки графічної документації обстеження. Впровадження цифрової фотографії збільшило можливість використання фотограмметрії для вимірювання геометричних параметрів існуючих будівель. Цей метод ефективний особливо у тому випадку, коли не збереглася первинна документація будівлі.

Ключові слова: обстеження будівель, цифрова близька фотограмметрія.

1. Introduction

Renovations, modernizations and reconstructions of existing buildings represents an important part of building performance. This segment of construction market plays an important role especially in the current depression of new investments. To prepare the modernization and development of the project documentation is necessary to obtain complete information on the existing site. In the Slovak Republic, the owners of buildings do not own the actual building documentation. Therefore, the examination of existing building is made as a basis for designer of its modernization.

The purpose of the building exploration is obtaining a complete full range set of information about existing building structure and its relations to the surrounding area if it is required by the client.

A research of existing building typically includes:

a) a detailed visual and sensual exploration of a building, in particular: foundations, vertical support structures, horizontal supporting structures, roof construction, staircases, basements, building envelope and surroundings of existing building,

b) a detailed description of the state of individual elements of the building indicating the detected errors and faults or deficiencies in use and maintenance,

c) dimensional inspection of selected elements of construction compared to the built construction documentation,

d) data on the occurrence of increased humidity of the specific building elements (plaster, masonry, foundations, roof deck),

e) details of an incident in the course of use of the building (fire, floods, earthquakes, etc..).

2. Development of the building research documentation

Research documentation can be basically divided info: written and graphic research documentation.

2.1 Written research documentation

The basic document are the notes from the research. The structure of notation is managed by the purpose, for which is particular research performed. The notation in the contracts made for the state or public government should mention in particular these information:

a) location of the exploration, its reason, the time of commencement and completion, participants names,
b) the objectives and program of research,
c) method for searched objects identification,
d) description of the research obtained documents, measurement, sampling, etc..,
e) the method of research documentation and findings,

2.2 Graphic research documentation

Graphic research documentation is divided into hand drawings and photographs.

2.2.1 Hand-drawings

Hand drawn sketch in situ is the oldest, but always reliable evidence of the process and results of the inspection. It is usually made by the form of drawn sketches -out of real scale. An example of excellent graphic sketch from the exploration of existing cottage taken from the literature [1], is depicted in Fig. 1

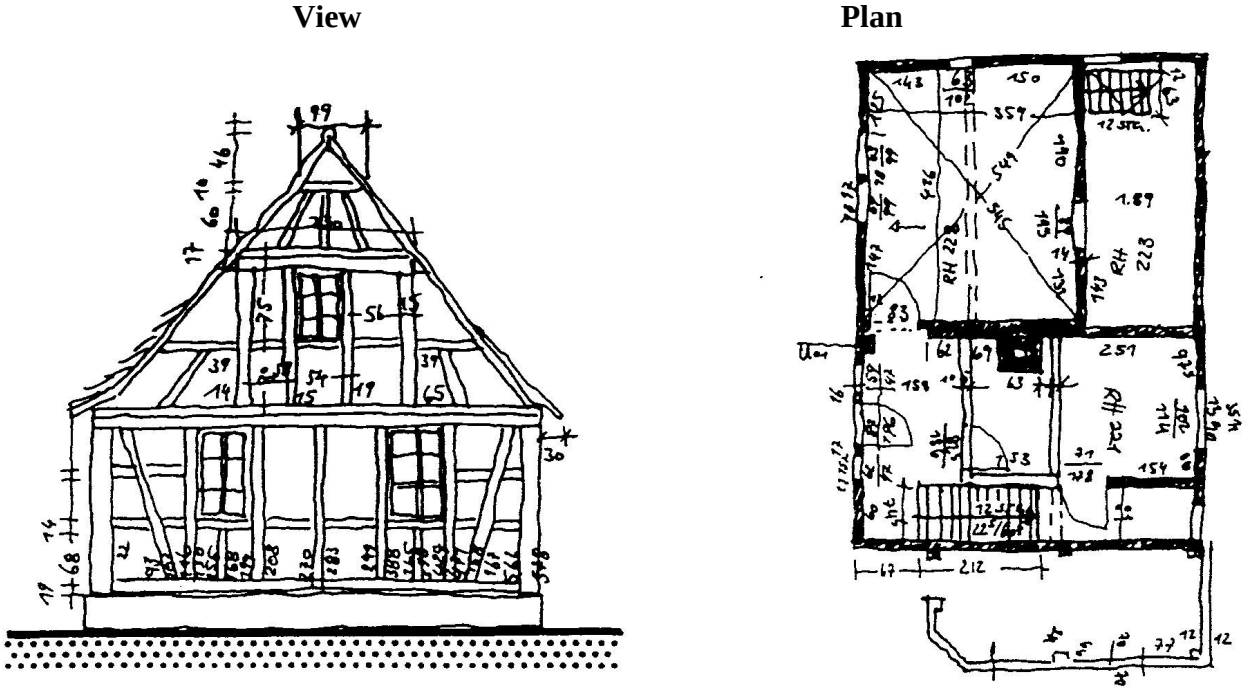

Fig. 1. Handdrawn sketch from the exploration of existing building [1]

2.2.2 Classic photograph

The discovery of photography in the 19th century enabled its application in technical fields. In construction, black & white and later also color photography was also used to document the condition of structures found during their examinations.

Lens focal length determines the angle of photography's picture view. Therefore, sufficient distance from the camera to the subject is generally needed for capturing the entire object on one photography. In the past, if necessary distance to capture one image of the object couldn't be obtained, the panoramic images composed of two or more individual photos were taken.

The process of taking panoramic image from three successive photographs (labeled I, II, III), reproduced from Bradáč [2], is shown in Figures 2 and 3. The first image (I) is carried out at the left edge of the scanned segment. The control point A was marked on its right edge (corner of the house). On the second photo (II) the camera was turned to such position, that the point A was visible on the photo and new control point B (tree) was set on the left edge of the picture. Similar way was used to finish the whole panoramic image.

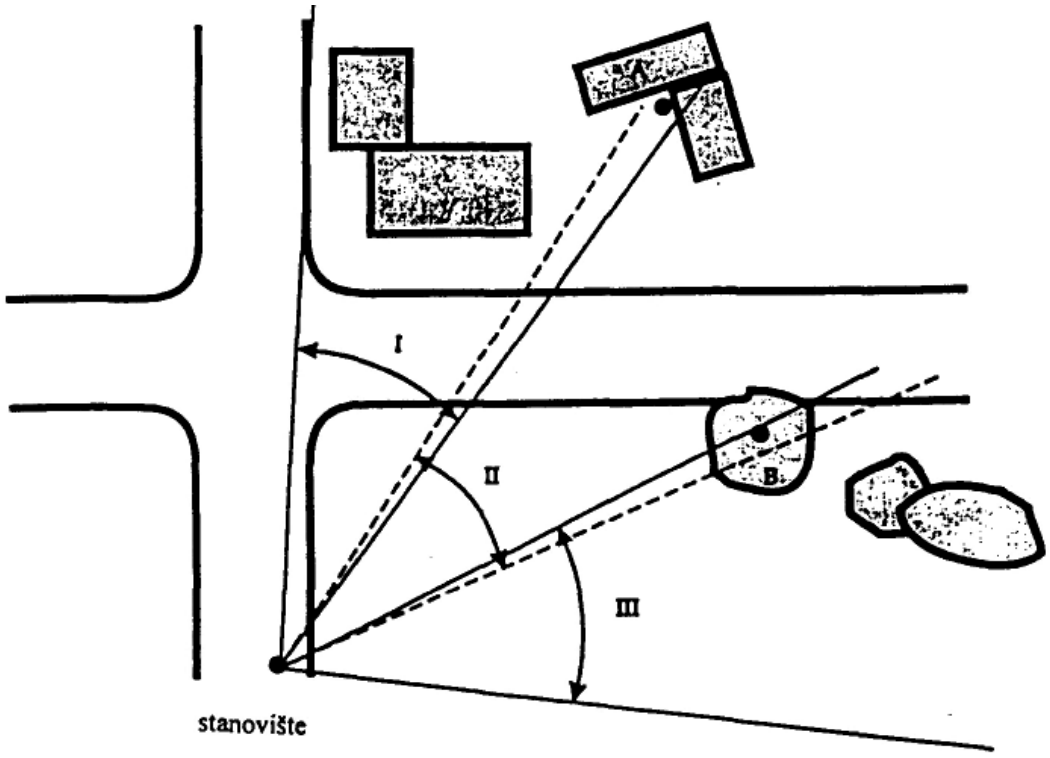

Fig. 2. Plan of individual pictutes (I to III) taken during the creation of panoramic photography

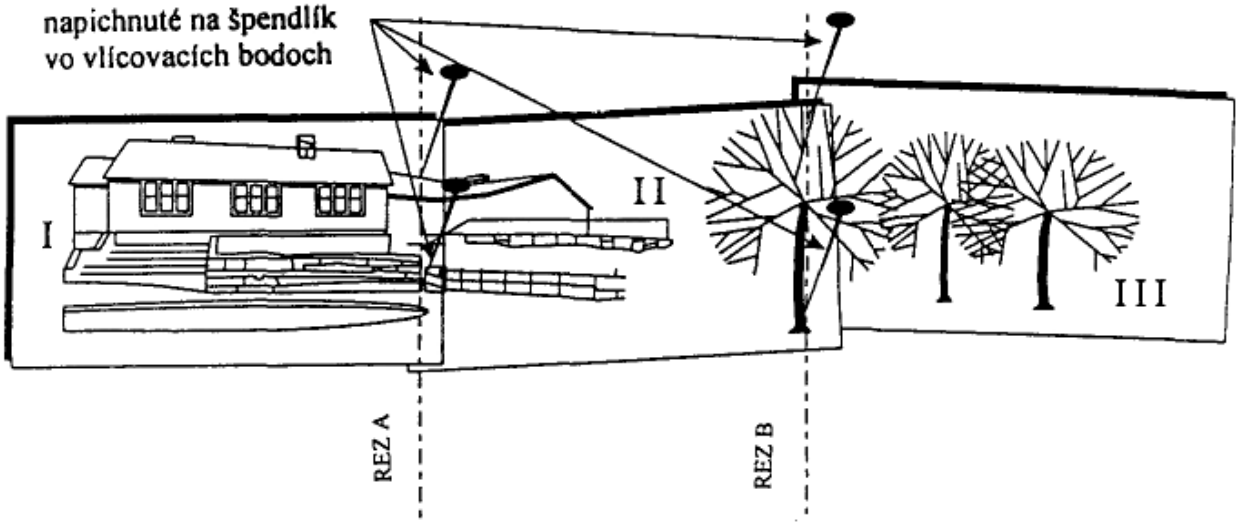

Fig. 3. Scheme of panoramatic photo assamblage out of three pictures (I to III)

2.2.2 Digital photography

Digital photography uses electronic devices to record images in binary form. The system of digital photography allows to view, save, print, edit, transfer and archive the data on personal computers.

Digital photos saved in binary form can be adapted by software to the required shape. The simplest case of digital photography modification is plane object redrawing into the orthogonal position identical with the drawing, plan or map.

A photography itself cannot be considered as a metric base, because the image contains several distortions (projective, radial, geometric), which significantly deformed the orthogonal projection (Fig. 4). However, after software's removal of distortions, the image has an exact nature of the orthogonal projection in a certain scale (Fig. 5) [3].

Fig. 4. Extremely oblique image of building facade

Fig. 5. Redrawing oblique image to orthogonal projection

3. Usage of photogrammetry in building researches

Advantages of digital photography as: electronic displaying, storage, subsequent software modification are also used in photogrammetry. Photogrammetry is classified by quantitative (size, location, shape) and qualitative (structure, texture, color, reflectivity, ...) properties of objects from their perspective images.

Photogrammetry uses several methods for image processing, while for construction researches purposes of Forensic Engineering come into consideration projective photogrammetry, stereophotogrammetry and convergent photogrammetry [5].

3.1 Convergent photographing

It is the most precise photogrammetric method for determination of spatial objects. Based on the images of the same object taken from different positions, in a way that each point is displayed on at least two photos (Fig. 6) [4]. Achievable accuracy can be expressed in approximate equation assuming the quality geometry of camera position:

$$m_p = \frac{Y}{f} \cdot Pix \cdot m_{pix} \tag{1}$$

where: $\boldsymbol{m_p}$ – point spatial accuracy; $\boldsymbol{Y}$ – distance between object and position of taking photograph; $\boldsymbol{f}$ – focal length; $\boldsymbol{Pix}$ – the physical size of the picture element; $\boldsymbol{m_{pix}}$ – measurement precision in a digital image.

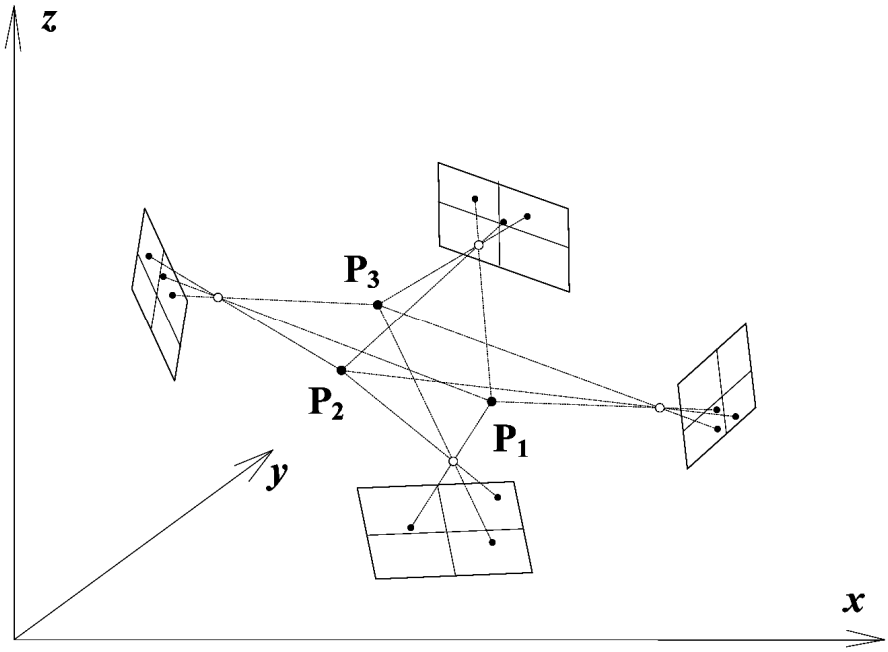

Fig. 6. The principle of convergent photographing

The basic supposition for the quality of the results is the determination of so called elements of camera's inside orientation, which are: focal length, the coordinates of the principal point, lens distortion. Process determining those parameters of the camera is generally called camera calibration. The more accurate are the elements of the inner orientation specified, the more accurate are the results [3], [4]. Use of converged photographing researches for construction is illustratively described in paragraphs 3.2 to 3.4

3.2 Determination of the building wall height

During the building examination it is sometimes necessary to determine the dimensions which are not available with direct measuring tools. An illustrative example is the determination of the height of residential building gable wall. For photogrammetric identification of the height pictures were taken from three different positions. (Fig 7) with a compact digital camera Canon A520 – 4 Mpix. Directly measured width of the building was used for determination of the height.

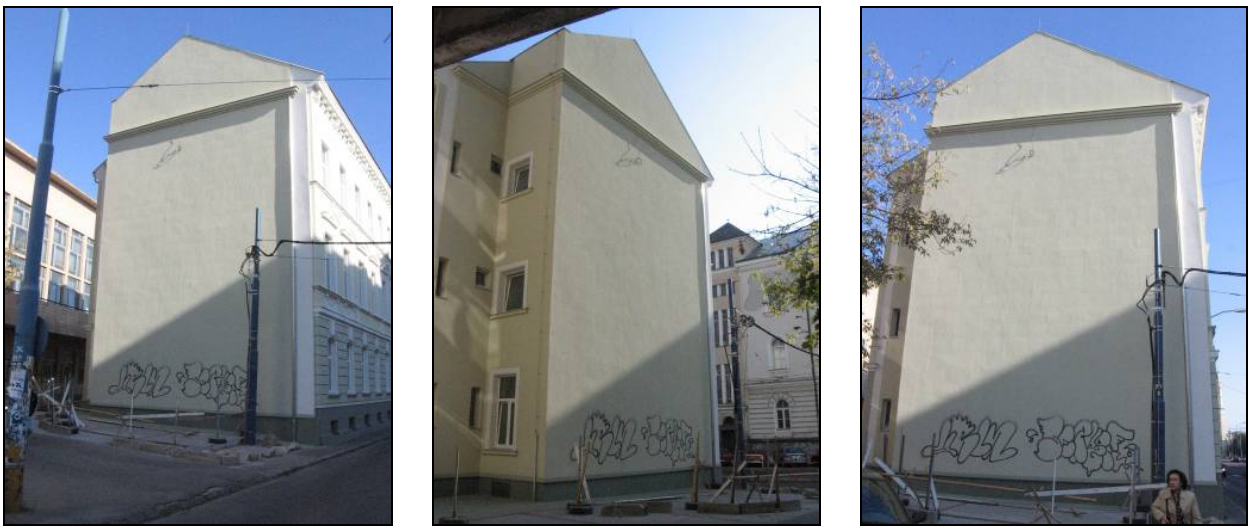

Fig. 7. Original photographs

Photograph processing took place in a software environment of system PhotoModeler Pro5, which enables photogrammetric evaluation of planar and spatial objects from their digital images. The evaluation is based on measurements of identical elements (points, lines, edges, curves) on all used images. The scale of the object is set in the next step by assigning of directly measured length in situ to the identical edge on the digital image. And the redefining of the coordinate reference system, which repositioned the wall to the vertical position in the XZ plane.

The origin of the coordinate system was inserted into the left lower corner of the wall. The system can then measure the spatial coordinates of each point, length of lines, areas and volumes. The software also provides the introduction of different conditions, such as verticality, horizontality, length conditions, conditions etc., which allow the processing of images for the purposes of redrawing of oblique image to orthogonal projections in selected projection plane. Like this, of course, only planar objects can be redrawn.

Outputs are the coordinates of points in the reference coordinate system with the standard errors in text form (Table 1), vector CAD output into *.DXF format and raster output of orthogonally redrawn images (Fig. 8). The accuracy of the measuring points is up to 26 mm.

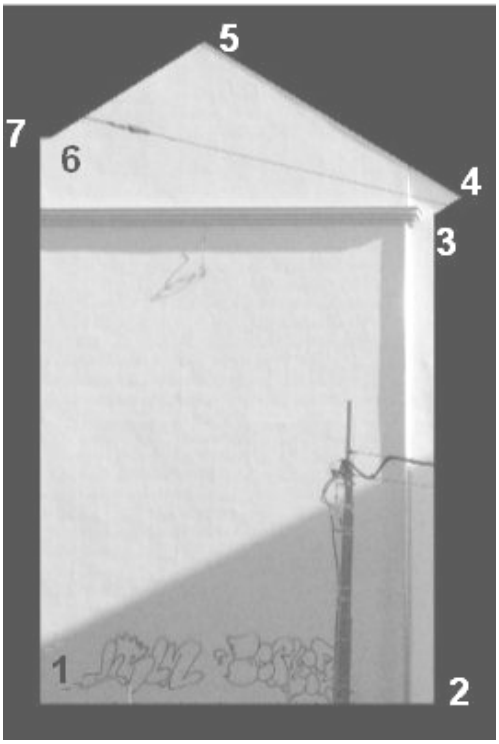

Fig. 8. Orthogonal projection of the measured building wall

Table I

Accuracy of observed points

Point	X [m]	Y [m]	Z [m]	Standard errors		
				X [m]	Y [m]	Z [m]
1	0,000	0,0	0,000	0,007	0,002	0,024
2	10,320	0,0	0,000	0,007	0,002	0,026
3	10,336	0,0	12,875	0,012	0,004	0,010
4	11,046	0,0	13,325	0,013	0,004	0,011
5	4,331	0,0	17,434	0,008	0,003	0,019
6	0,311	0,0	14,914	0,012	0,002	0,013
7	0,017	0,0	14,914	0,013	0,002	0,015

3.3 Determination of the building built volume

Kunsthaus in Piešťany, built in 1980, is an atypical building, serving multiple cultural purposes – theater, cinema, concerts, exhibitions, lectures so on. The building layout is divided into 2 parts: rooms for visitors (1 underground floor plus 4 floors) spaces for artists, service and building manager (3 floors).

Vector three – dimensional model of the building was constructed by convergent photogrammetry from photographic images made with the camera Canon 300 D (Fig. 9) and the ground plan measurements. (Fig. 10)

Accessible building dimensions (lengths and heights) were measured by laser rangefinder and compared with data obtained from convergent photographing. The differences between these two measurements ranged from 25 to 40 mm, at about 100 m length of the building. Convergent photographing with the arbitrary position of the optical axis was used as a photogrammetric method. All object points were naturally signalized and spatial accuracy of the model m_{XYZ} ranged up to 20 mm.

Fig. 9. Southwest view

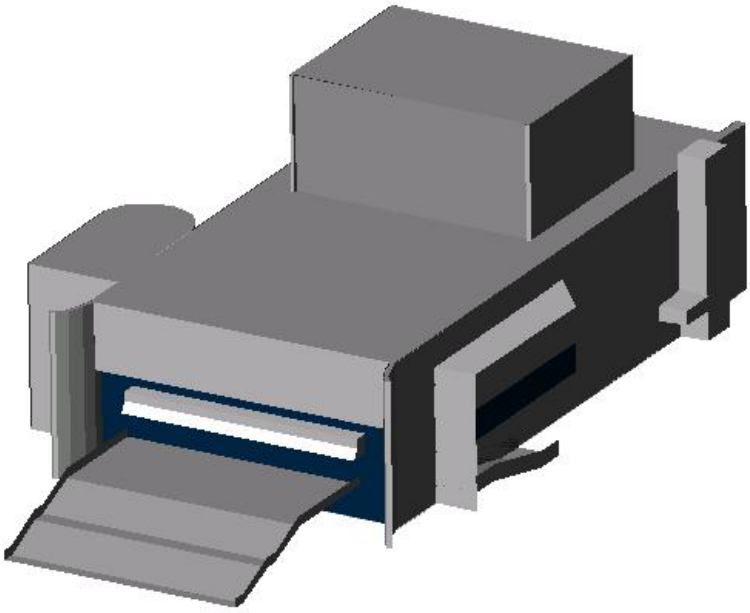

Fig. 10. Model of Kunsthaus of Piešťany made with convergent photogrammetry

3.4 Family house documentation made with spatial convergent photogrammetry

The term convergent photogrammetry is related to the orientation of the image axis (optical axis of the lens) of pictures, which means that the building to be spatially reconstructed is pictured in a wise angle with the largest overlap (Fig. 11). Then, the anticlastic points are marked on the pictures which are evaluated by a software. The spatial position of those points was obtained, from which was the digital model created (Fig. 12).

Time parameters were monitored at the same time as the investigation and documentation of family house geometric parameters.

Partial vector model documented in Fig. 12 was made in 1 min, with the precise determination of break points 10 mm. Exterior of the house would require about 8 photos and the total time for a creation of complete 3D model, about 1 hour. In a similar manner it is possible to reconstruct the interior, but it is a more difficult process due to the often inadequate distance of the camera from the walls and the consequent need for significantly larger number of pictures.

Fig. 11. Convergent photographs

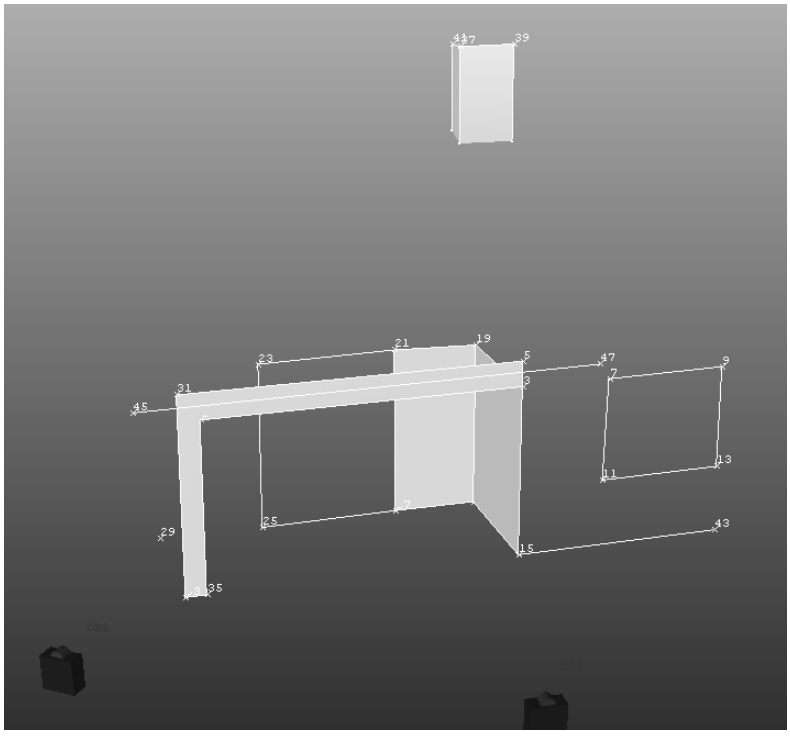

Fig. 12. Digital vector model

4. Conclusion

The aim of this paper is to present the use of close-range photogrammetry method for creating the graphic documentation of the building researches results. Originally, the land photogrammetry was used to document the visible failures and deficiencies of existing constructions such as: the development of cracks in reinforced concrete and masonry structures, documentation of leaking fluid traces, fungus traces and the similar.

The introduction of digital photography has increased the possibility of using close ground photogrammetry including for the efficient detection of geometrical parameters of existing constructions. This method is effective for use in case of not preserved actual built documentation of a building, or if it is determined that the building did not follow the declared design and the changes are not documented. In the future, we expect the extension of photogrammetry in civil engineering in the following areas:

- identification of the geometric dimensions of inaccessible parts of buildings, including the determination of selected sizes and shapes,
- making the actual built documentation of an existing building,
- making drawings of actual realization of the hidden constructions (the cables in ditches before backfilling, pipes in walls and ceilings before their covering, etc..).
- long-term monitoring of deformations of selected building elements,
- documentation of gradual reconstruction of historic buildings and similar.

1. Neufert, E.: Building designing. Prague: Publisher Consultinvest, 2000. ISBN 80-901486-6-6 2. (In Czech). 2. Bradáč, A. et al: Forensic engineering. Academic publisher CERM, s.r.o. Brno June 1997. ISBN 80-7204-057-X. (In Slovak). 3Fraštia, M.: Digital camera calibration and testing for close photogrammetry application. Bratislava: SUT in Bratislava, Faculty of civil engineering, 2008. 114p. (Edition of scientific works, no. 52. ISBN 978-80-227-2812-6.(In Slovak). 4. Fraštia, M: Close photogrammetry and its applications and tools. In: 19th Slovak geodetic days [electronic source]: Proceedings of papers. Žilina, SR, 3.-4. 11. 2011. Bratislava. Chamber of Geodesists and Cartographers- ISBN 978-80-969809-8-7.(In Slovak).