Sławomir Mikrut*

Photogrammetric and Laser Scanning Data Integration**

1. Introduction

In recent years we have seen an increased demand for data to be provided not only in the two-dimensional format, but also in the 3D one. Moreover, there is a need for graphic visualization of a good quality, and for the resulting 3D models, which are true reconstructions of reality, i.e. models with correct radiometry and geometry parameters.

Photogrammetry is one of more popular methods of quick and exact data acquisition. However, it is the technique of laser scanning that is recently becoming more and more popular. Scanned data have their merits, but they also have their disadvantages. One of those disadvantages is the resolution of images obtained in the course of scanning.

Therefore, it seems sensible to supplement that method with high-resolution image data, obtained with the use of photogrammetric methods. Mutual integration of those two sets of data seems to be purposeful. Actually, having laser scanning data and a photogrammetric model, we have at the same time certain information that keeps repeating itself, and this can be utilized as an element of control.

The technology in question dominates, to a largest extent, in surveys of historic buildings and structures. Nevertheless, it can be expected that the technology will quickly develop in such other fields, as construction, industry, or transportation infrastructure survey projects.

* Department of Geoinformation, Photogrammetry and Remote Sensing of Environment, Faculty of Mining Surveying and Environmental Engineering, AGH University of Science and Technology, Krakow

** The work was completed within own research framework of the AGH University of Science and Technology, no. 10.10.150.962

2. The Problem of Data Integration in Literature

The integration of photogrammetric and laser scanning data is an issue which, for several years, has been studied in numerous scientific research and development centres. Lee and Choi presented their concept of integrating data based on a proposed pattern of distribution of sensors, and processing an object in certain lots by grouping the data in polyhedron models [2]. An interesting proposal was presented in another publication on the subject [1], in which the authors utilized a truck-mounted scanner with a camera for data integration. Another interesting solution is that based on the combination of scanning with images made from a balloon [9].

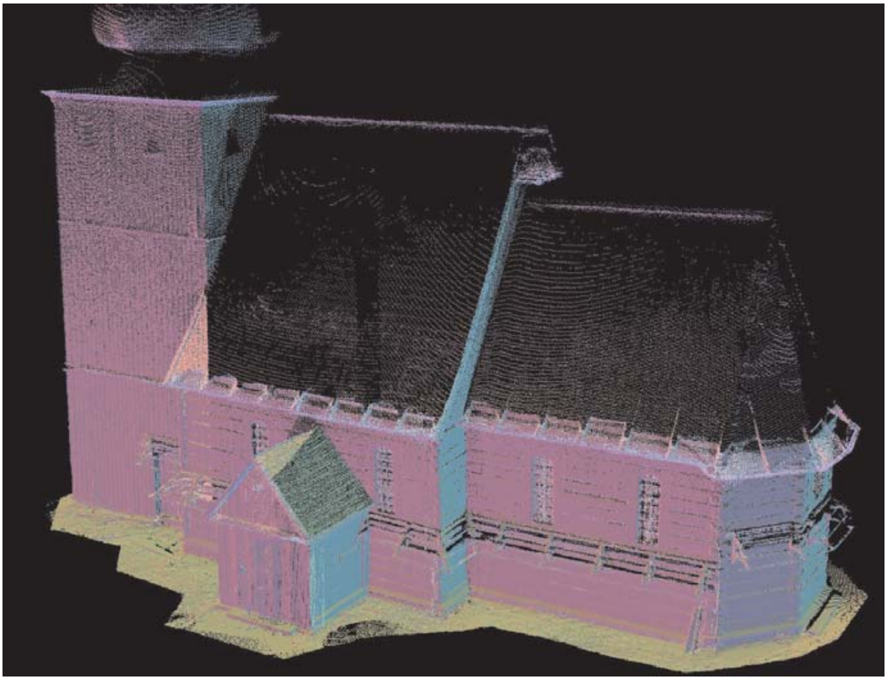

Fig. 1. The point cloud: a perspective view Church at Michalice, processed by Dephos
Source: [6]

In Poland, we also have had first experiences in the field. One of the first companies to become involved in laser scanning in Poland is the Kraków-based company of Dephos. First projects, integrating laser scanning data with those photogrammetric ones, were described in numerous publications [3, 5, 6]. One of the very first, exemplary projects was that, which concerned the church at Michalice (Fig. 1).

The literature on the subject clearly shows that scanning, in addition to its many merits, such as the speed of measurement of a large number of inaccessible points, has also its disadvantages. The laser beam, which records the points of an object, can supply false information resulting from beam slides or additional reflexes. Another difficulty concerns a very accurate determination of edges on the basis of the point cloud. The edges can only be approximated, therefore the higher the measurement density, the more accurately determined edges. However, another risk appears in that place. If there are too many points, they cannot be processed simply because the available computers are not able to process such a large amount of data [6].

Based on the experience gained by Dephos company, one can state that the anticipated results of the combination of photogrammetry and laser scanning are promising. The company is successfully implementing other projects of the type, and not only in Poland, but also abroad (the survey of historic buildings in Atturaif, Saudi Arabia – a joint project with KPG, another Kraków-based company).

The problem of integration itself became the subject of the Ph.D. dissertation of A. Rzonca [7], in which the author proposed certain approaches to the integration.

2.1. Problems During the Integration

The existing experiences of many authors show several basic problems. The ever-growing number of data, resulting from the equipment manufacturers' desire to "overtake" their competitors and to supply equipment with higher and higher numbers of points that can be recorded within a second causes that data processing programmes prove to be low-effective. Loading of point clouds from several scanned images runs up against numerous difficulties. The author believes that the problem can be solved in near future through the application of a technology similar to NVIDIA CUDA, which is based on parallel processing, and through a shift to 64-bit systems. Concurrent programming will allow for a more efficient operation and quicker data processing.

Another problem of today, which calls for solution, is that of identifying edge lines on "detected" objects (feature extraction). The issue seems to be the more complicated due to the fact that in classic photogrammetry the whole operation comes down to the operation on an image, that is a 2D operation. The third dimension, if any, can be obtained through transferring (converting) two edges to a 3D space. In the event of laser scanning data, one can operate directly on the point cloud obtained in a 3D space.

Based on the knowledge possessed by production professionals and on the author's own knowledge of software, the author's conclusion is that there is no good software, which would enable complete automatisation of feature extraction from the point cloud. This problem shall be discussed to a larger extent in this paper.

3. Data Acquisition

3.1. Selection of Test Object

The test object selected was a windmill, located in the Ethnographic Park of the Village Museum at Tokarnia, Poland. The roller windmill was originally constructed in the village of Grzmucin in 1921. Following the death of its owner, it was sold and later transferred to the open-air ethnographic museum at Tokarnia. The windmill is one of typical objects in the museum. Its features include a very good location on the hill, as it was very well visible from all directions, and available for scanner and photogrammetric measurements.

3.2. Equipment

In the course of field works, a Z-F Zoller-Fröhlich, model IMAGER 5006 laser scanner was used (Fig. 2).

Fig. 2. IMAGER 5006 at work

The scanner operates within a range of up to 79 metres. It basic technical specifications are listed in table 1. This is a phase scanner of a very high accuracy (0.1 mm), and the speed of its operations constitutes one of its major merits (it can record 500,000 points per second). More features can be found in literature [8].

Table 1. Technical parameters of 3D IMAGER 5006 scanner

Data	Parameters
Scanning speed	500 000 points/sec
Maximum range	79 m
Minimum range	1 m
Resolution	0.1 mm
Field of view – vertically/horizontally	310/360

Images were made with the use of a Rollei 6008 digital camera (Fig. 3, tab. 2).

Fig. 3. RolleiMetric 6008 camera

The camera has a certificate with current data of calibration performed by its manufacturer (RolleiMetric).

Table 2. Technical parameters of RolleiMetric 6008AF camera

Data	Parameters
CCD size	4076 × 4080
Resolution	9 mm
Focal length	80 mm

The geodetic control network was measured with the use of a TCR 405 POWER prismless total station, with the angle measurement accuracy of 5" and a range of measurement without a reflector of up to 180 m. Points on the windmill, indicated by means of special marks, as well as natural photo points, were utilised to form the geodetic control network.

3.3. Software Selection

Laser scanning data in the form of the point cloud were processed using RealWorks Survey Advanced, version 6.1 software. The photogrammetric measurement data were adjusted using the Photomodeler software. 3D data were acquired from photogrammetric models with the use of Dephos digital station. The edging analyses, employing sub-pixel methods, were made using own feature extraction software.

4. Description of Experiments

The goal of experiments was to integrate laser scanning data with images obtained from digital cameras. The laser scanning data in the form of the point cloud were utilised to construct a model of the object's surface.

4.1. Methodology. Sequence of Actions

Based on the author's experience, and in the course of research, the following sequence of actions has been adopted:

1. Field inspection and design for measurement posts.
2. Indication and measurement of geodetic control network.
3. Acquisition of the point cloud from laser scanning.
4. Shooting images of a photogrammetric resolution (Rollei).

5. Utilizing the point cloud to generate a 3D model.
6. Imposition of images upon the generated and filtrated model.
7. Verifying the correctness of the created model on the basis of a stereoscopic observation.
8. Edge enhancing with the use of the feature extraction software.
9. 3D visualization.

It should be emphasised that the goal of data integration includes the establishing of a correct 3D model of the object, both a skeleton model, and a one subjected to rendering.

The first stage includes field inspection and design for geodetic control network. The network points were designed; part of them was indicated, while the rest were used as natural points. Then followed measurement with a TCR 405 POWER prismless total station. The photogrammetric control network was adjusted, and the points were measured using Photomodeler programme (Fig. 4). During the next stage, data in the form of the point cloud were put together and processed. That was effected by means of the RealWorks Survey Advanced software.

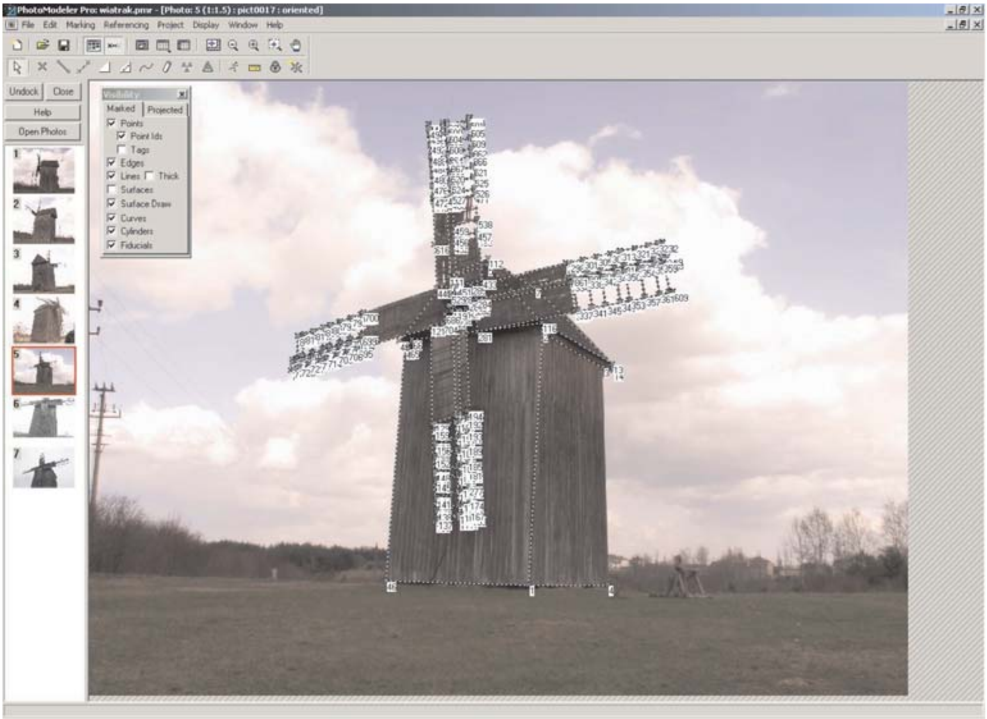

Fig. 4. Photomodeler measurement window

After the laser canning and photogrammetric data had been integrated, 3D skeleton, surface and textured models were generated (Fig. 5), and, finally, the windmill was visualized in 3D (Fig. 6).

The windmill from Grzmucin is a perfect example of creating a 3D model through a process of a simplified photogrammetric processing. The convenient location of the windmill made it possible to shoot correct images.

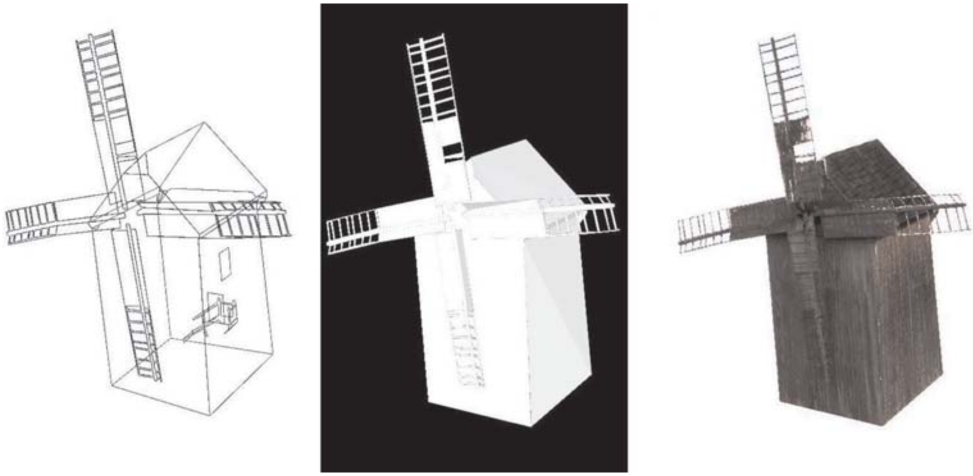

Fig. 5. 3D models of the windmill (from l to r): skeleton, surface, textured

Fig. 6. Visualization of the windmill fragment

Despite a complicated shape of the windmill and a necessity for an accurate measurement, it was possible to obtain a high-accuracy model. The lack of any objects that might obscure the windmill (plants, trees, electric poles, etc.) positively contributed not only to the raising of the measurement accuracy but also to a high quality of the model textures.

4.2. Enhancement of Edge Lines

In the course of research, experiments related to the automatic edge detection were carried out. To that purpose, own feature extraction software was utilised. The description of the programme and of its algorithms can be found in literature [4]. Here, the algorithms of approximation were extended by possibilities of the given point cloud analysis.

The FES programme allows detecting edges with the sub-pixel accuracy (even up to 0.02 pixels depending on the image quality).

Fig. 7. Detected points with adjusted edges on the example of a wall fragment

The detected edges serve as the enhancement of the skeleton model of the windmill. Irregularities in the windmill shape (Fig. 7), resulting from its age and actual condition will (owing to the algorithms applied) be automatically generalized and presented in reality as straight lines. The authorial design is to attempt at integrating data, based on skeleton lines detected in the point cloud but controlled through lines extracted from a digital image. Such an analysis, when completed in relation to several edges, will allow determining parameters for the whole processing project, which will considerably facilitate the process of extraction. This is an authorial approach, and research results will be presented in a separate publication.

5. Summary and Conclusions

This paper proposed a pattern of reconstruction of objects based on images and points acquired by "close range sensors". There were presented problems of laser scanning and photogrammetric image integration. Based on the available software, a spatial model of the windmill from Grzmucin was created, and later visualized. On the basis of that model, own feature extraction software was also tested. The software enables automatisation of the process, utilising both image data and the point cloud approximation.

The above-described methodology can be useful not only in surveys of spatial objects, but also in works related to construction, industrial, etc. surveys.

The completed experiments and literature data justify the conclusion that the results of the application of photogrammetry combined with laser scanning are promising. This is a quick and efficient technology. A scanner is a highly efficient piece of equipment, as the measurement of hundreds of thousands of points takes place within seconds. By supplementing the measurement of the point cloud with photogrammetric data, we can improve their quality.

The author would like to thank Mr Janusz Karpiński, the Head of the Village Museum for an unlimited possibility of using the test objects in the Ethnographic Park at Tokarnia. Also thanks to KPG Sp. z o.o. for making available a Z-F Zoller-Fröhlich, model IMAGER 5006 laser scanner, and to Geotronics Sp. z o.o. for making available the RealWorks Survey Advanced software.

References

[1] Jansa J., Studnicka N., Forkert G., Haring A., Kager H.: *Terrestrial laserscanning and photogrammetry – acquisition techniques complementing one another.* The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 34, Part XXX, Beijing 2008.

[2] Lee I., Cho I.: *Fusion of terrestrial laser scanner data and images for building reconstruction.* The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVII, Part B5, Beijing 2008.

[3] Mierzwa W., Rzonca A.: *Skanowanie powierzchni jako nowa metoda rejestracji i interpretacji szczegółów architektonicznych.* Archiwum Fotogrametrii, Kartografii i Teledetekcji, Vol. 13, 2003, pp. 427–434.

[4] Mikrut S.: *Wpływ skanowania i kompresji JPEG na wykrywanie obiektów liniowych i punktowych na obrazach cyfrowych*. AGH, Kraków 2003 (Ph.D. dissertation).

[5] Mitka B.: *Możliwości zastosowania naziemnych skanerów laserowych w procesie dokumentacji i modelowania obiektów zabytkowych*. Archiwum Fotogrametrii, Kartografii i Teledetekcji. Vol. 17a, 2007, pp. 525–534.

[6] Rzonca A.: *Współczesne metody kompleksowej inwentaryzacji zabytków na przykładzie parafialnego kościoła w Michalicach.* Archiwum Fotogrametrii, Kartografii i Teledetekcji, Vol. 14, 2004, pp. 499–506.

[7] Rzonca A.: *Integracja danych pozyskiwanych metodami fotogrametrycznymi i skanowania laserowego przy inwentaryzacji obiektów zabytkowych*. AGH, Kraków 2008 (Ph.D. dissertation).

[8] *Skanery laserowe* (a free supplement to *Geodeta* monthly). No. 4 (155), Warszawa, 2008.

[9] Tsingas V., Liapakis C., Xylia V., Mavromati D., Moulou D., Grammatikopoulos L., Stentoumis C.: *3D modelling of the acropolis of athens using balloon images and terrestrial laser scanning*. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVII, Part B5, Beijing 2008.