# ACCURACY ASSESSMENT OF LEVELLING STAFFS MARKING USING DIGITAL PHOTOCAMERAS

**Vilma Kriaučiūnaitė-Neklejonovienė[2,1], Donatas Rekus[2,1], Giedrius Balevičius[1], Gabrielė Šuliokaitė[1].**

[1]Aleksandras Stulginskis University, [2]Kaunas University of Technology

**Abstract**

The article analyses the determination of accuracy of code levelling staff edges by using their digital photos. The accuracy of the position of graduated lines of levelling staffs is established by comparing reference and test digital photos of levelling staff stored in digital photo camera or in a computer memory. In this case, the position of lines of a calibrated levelling staff is compared to the position of lines of a photogrametric image of a reference levelling staff. Firstly, the digital camera calibration is performed. The aim of the research is to perform the analysis of accuracy of levelling staffs marking's edges by applying lenses of different focal length and to determine which of them provide the most accurate results of calibration. Digital photo camera *Canon-EOS-7D,* with which digital pictures of levelling staffs scales marking were taken, was chosen for the research and calibrated. The pictures of levelling staffs scales marking were taken with different camera lenses (20, 50 mm) and with different camera modes *(auto, macro)*. Having analysed the obtained results, it was assumed that the focal length of lenses of a photo camera and partially the choice of a camera mode have an influence on final results of calibration. The most accurate results were obtained by taking pictures and calibrating the levelling staffs scales with a 50 mm fixed-focus camera lens.

Key words: levelling staffs, calibration, error, digital photo.

## Introduction

As the modern geodetic measurement equipment progresses, a microprocessor built-in digital levels captures levelling gauges and the sequence of actions, according to a chosen program, in this way eliminating errors made by a person performing measuring activity by 100%. However, other sources of error, which must be additionally analysed, occur. It might be errors of code levelling staffs scales marking. They might occur due to fault in manufacturing and due to operating conditions of levelling staffs. When working outdoors, they are effected by humidity, sudden changes in temperature, intense solar radiation, mechanical shocks and loads. Due to these reasons, levelling staffs must be periodically calibrated. Presently used interferometric devices for calibration of levelling staffs are complicated, expensive, big, and the process of calibration takes a long time. This could be avoided by using photometric calibration of levelling staffs.

The results of levelling are obtained with unavoidable errors which might be resulted by the equipment used, the environmental impact or the person performing levelling. In order to obtain reliable levelling results, the equipment must be calibrated. New calibration methods, calibration equipment based on flexible digital technology and simple calibration technology are necessary for improvement of calibration of levelling staffs. This would ensure timely control of levelling staffs quality, would allow to control and eliminate systematic errors in levelling which result from errors of graduation of scales of levelling staffs.

Each element of matrix of digital images is called pixel, which means the area of raster cell. (Robinson et al., 1995., Linder 2006). Their significance also depends on the qualities of a registered piece of equipment and (or) of software. When the pixel significance is 0 - completely black; when it is 225 - white (Richards et al., 2006). A relevant configuration stand with marked points is used during the calibration of a photo camera. Photos of a prepared calibration stand are taken horizontally and vertically, the calibration parameters of a photo camera are obtained by solving (Abraham, 2004; Visockienė, 2007) polynomials.

The aim of the research is to perform the analysis of accuracy of levelling staffs marking's edges by applying lenses of different focal length and to determine which of them provide the most accurate results of calibration.

## Methodology of research and materials

Photometric calibration of levelling staffs marking's edges is based on application of elements of matrix of digital images.. These methods are used to change the characteristics of digital photos and the points in digital images are recognised by principles of computer vision. Each element of matrix of

digital images is called pixel (a pixel is a picture element), which means the area of raster cell. When the area of element is very small, pixels are called dots (Linder 2006, Robinson 1995).
When performing photometric calibration, special parameters of a digital photo camera must be checked first, its distortion parameters must be determined. The photo camera *Canon-EOS-7D* used for the research was calibrated with the demo version of *PhotoModeler* software. A template of software package presented in Fig. 1 was used for calibration.

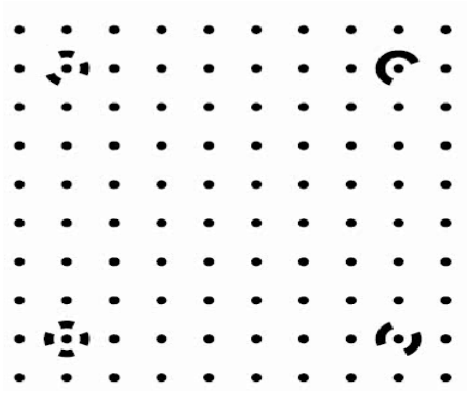

**Fig. 1**. *PhotoModeler* photographed template

This template is fixed on a horizontal surface, so that it could not be moved when taking pictures. The pictures of the template were taken eight times, from all four sides. First four photographic images were taken horizontally, at 90° angle, the rest when rotated vertically. Having taken pictures of the template, the calibration was started by using Photomodeler software. It is advised to take 6-12 pictures for calibration. In this research, eight digital photographs were used.
Different fixed-focus lenses (20 mm, 50 mm), different distances from levelling staffs and different position of taking of pictures (horizontal, tilted) were chosen when taking photographs.
The parts of pictures of levelling staffs were converted to digital information by means of PIKSELIS software. 21-bit digital photography format was used in this research.
Having carried out the analysis, the results of accuracy were analysed by applying the comparative analysis method. The differences of obtained results were compared with each other and shown in a graph.

**Discussions and results**
The decision to take pictures with different camera lenses (20 mm and 50 mm) was taken during the research. 21-BMP bit format was chosen for determination and analysis of levelling staffs marking's edges.
Comparison of Pixel values of 20 mm (green), 50 mm (blue) lenses of code levelling staff of the obtained results are presented in figures 2 - 3.

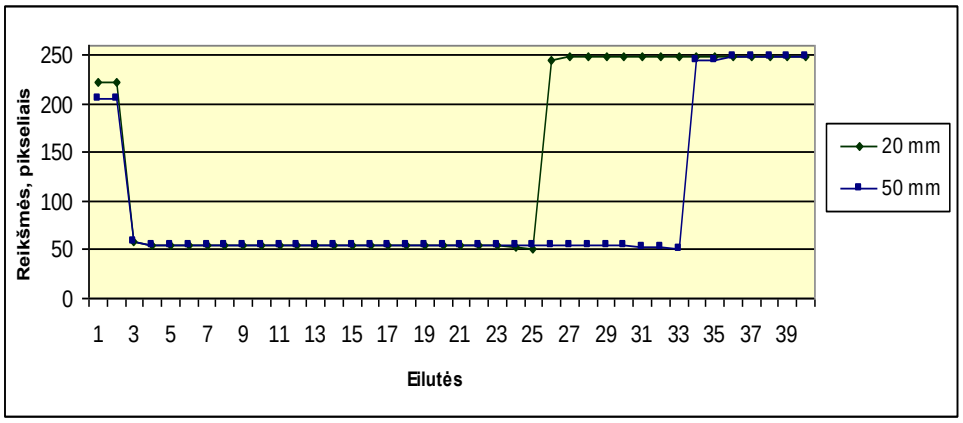


**Fig. 2.** Fragment values of coded scale (1) by means of 20 mm and 50 mm camera lenses

Figure 2 represents a fragment of a coded scale (1), when pictures are taken horizontally. It can be noted that darker colour captured by a 50 mm camera lens in lines 1 - 2, does not have a significantly

noticeable defect in lines 3 - 25. Starting from lines 26 - 33, it can be noticed that 20 mm camera lens captures a lighter colour, when 50 mm camera lens captures a darker colour.

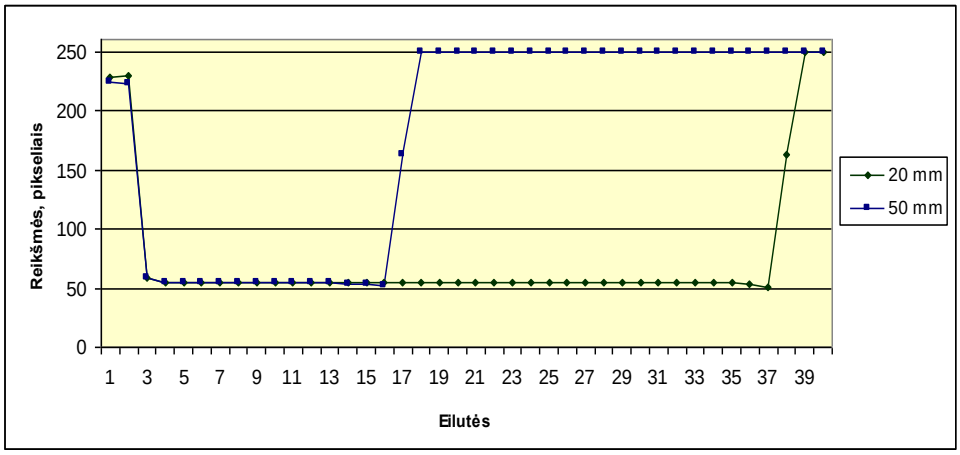


**Fig. 3.** Fragment values of coded scale (2) by means of 20 mm and 50 mm camera lenses

Figure 3 represents a fragment of a coded scale (2), when pictures are taken in a titled position. It can be noticed that a slight difference is visible in lines 1 - 3, a 50 mm camera lens captured a darker colour; it was not distinguished in lines 4 - 16, which means that a 20 mm and a 50 mm camera lenses recognise the same colours; a significant difference appeared in lines 17 - 38, which shows that a 50 mm camera captured white colour and a 20 mm camera captured a darker colour.

By using the obtained results, we determine the bandwidth of levelling staffs marking's edge, scratchings or other damages which will be relevant for further calibration of levelling staffs.

Other results were obtained by using a *Nikon* digital photo camera. A *Nikon* has a variable focal length camera lens, which a *Cannon* does not have. Different camera modes were used than before with a *Canon*. Several camera modes were used here (*auto* mode, *macro* mode, *portrait* mode) in order to facilitate the process of distinguishing between lighter and darker colours markings.

Figure 4 represents fragments of code levelling staffs scales marking 21-*BMP* digital format, photographs were taken by using different camera modes (*auto* (a), *portrait* (b) and *macro* (c).

a (*auto*) b (*portrait*) c (*macro*)

**Fig. 4**. 21-BMP bit fragments of code levelling staffs scales marking by using different camera modes

Obtained results of pixel values of code levelling staff in *auto* mode is represented in green, *macro* mode - in blue, *portrait* mode in red (Fig. 5).

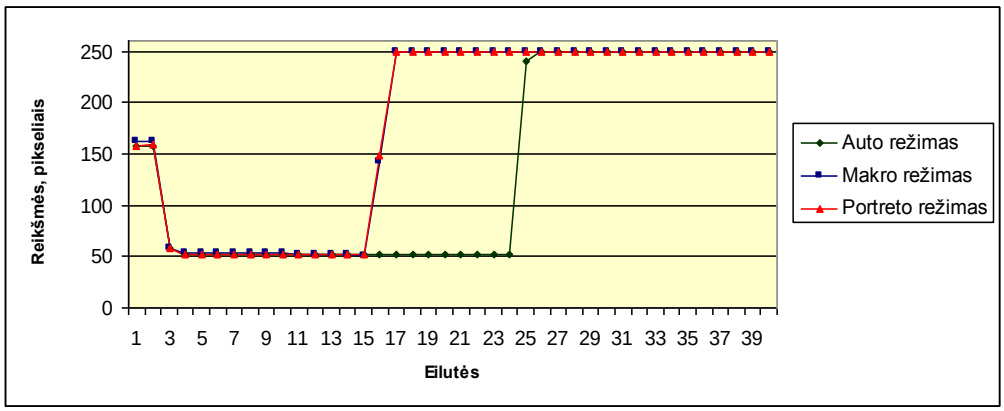


**Fig. 5**. Code scale's fragment values in different modes

The obtained results of a code levelling staff (fig. 5) show that *macro* and *portrait* modes are relatively equal, the *auto* mode distinguished itself in lines 16 -25. It is known that *macro* and *portrait* modes focus precisely on the object which is being photographed and that they blur the background. *Auto* mode captures a darker colour.
Numerical values (the lowest, the highest) are presented in Table 1.

**Table 1**

Numerical values of levelling staffs

| Image No. | Camera lenses/Camera modes | Values | |
|---|---|---|---|
| | | Lowest | Highest |
| Coded scale (1) | 20 mm | 51.00 | 249.475 |
| | 50 mm | 50.775 | 249.35 |
| Coded scale (2) | 20 mm | 54.4 | 249.325 |
| | 50 mm | 54.2 | 249.2 |
| Coded scale (different modes) | Auto | 51.25 | 249.575 |
| | Macro | 51.1 | 249.675 |
| | Portrait | 52.5 | 249.125 |

Having analysed variants of levelling staffs images processing, it was found that operational and other damages of levelling staffs scales markings can be seen when taking pictures by using different camera modes (or) camera lenses. Inacurracies are different because each camera mode and (or) camera lens have their own specifics when taking pictures.
The comparison of assessment of accuracy of calibration of levelling staffs markings is presented in a graph. The comparison was performed by using the results obtained from pixel values of a code levelling staff. The initial results were obtained by taking pictures with a *Canon EOS-7D* photo camera and its two camera lenses (20 mm and 50 mm).

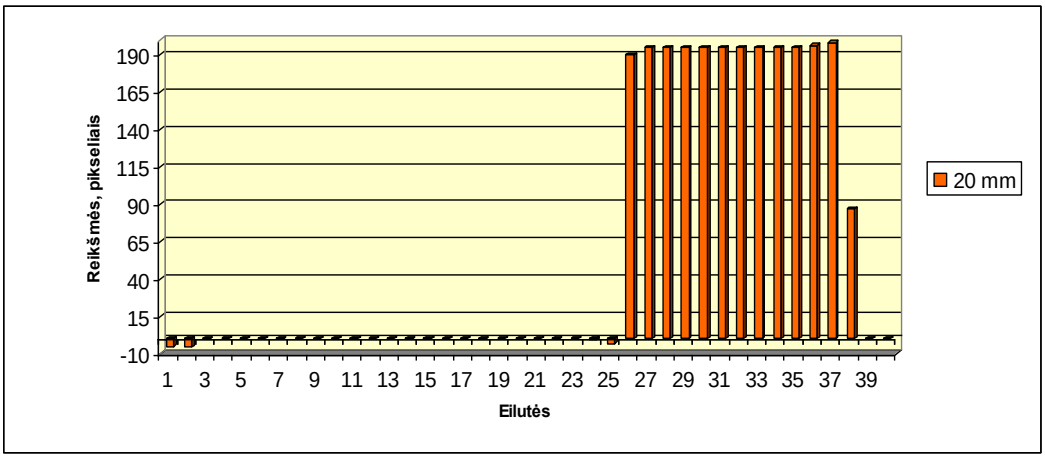


**Fig. 6**. Numerical values of 20 mm of a coded scale (1, 2)

Having assessed the results of pixel values of coded scales lines, having taken pictures with 20 mm lens camera, having taken pictures in different positions, and by means of photometric calibration, the assessment of accuracy in figure 6 shows that there is a slight difference in lines 1-3, lines 4-26 did not distinguish, and the biggest positive difference is visible in lines 27-39. The biggest difference is 198.275. This difference shows that when taking pictures horizontally, more operational scratches and (or) other changes in coded scale are captured.

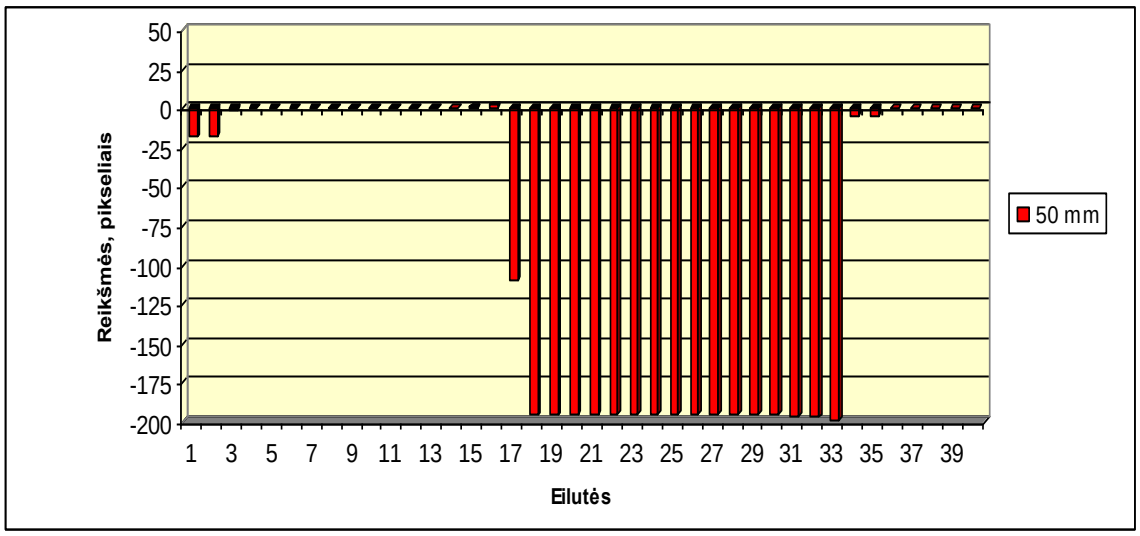


**Fig. 7.** Numerical values of 50mm of a coded scale (1, 2)

Having assessed the results of pixel values of coded scales lines, having taken pictures with 50 mm lens camera, having taken pictures in different positions, and by means of photometric calibration, the assessment of accuracy in figure 7 shows that there is a slight change in lines 1-3, there are no changes captured in lines 4-16, and the biggest negative difference is visible in lines 19-34. Their biggest negative difference - 195.95, which shows that when taking pictures in a titled position, more operational scratches and (or) other changes are captured.

Different results were obtained when taking pictures with a *Nikon* photo camera and its different camera modes. The results were discussed by means of pair analysis method. It is important to note that this camera has a variable focal length camera lens, contrary to the results obtained with a *Canon* photo camera.

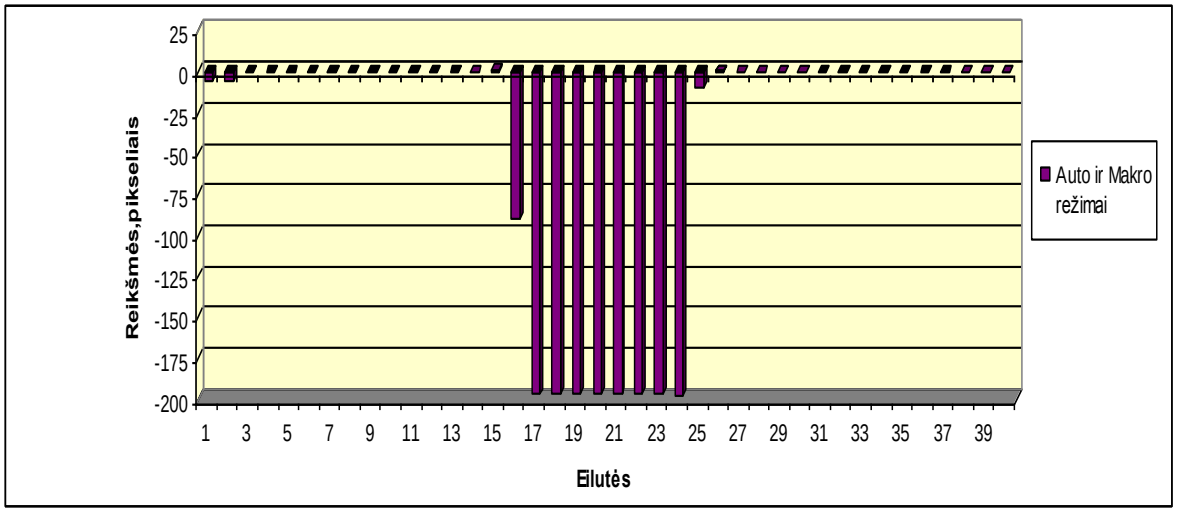


**Fig. 8.** Numerical values of a coded scale in *auto* and *macro* modes

Figure 8 shows results obtained after having performed the assessment of the results of pixel values of coded scales lines when taking pictures by using different camera modes, in this case in *auto* and *macro* camera modes, and by means of photometric calibration; the assessment of accuracy shows that there is a significant negative difference. Lines 1-3 show minimal scratches and (or) damages captured. Lines 4 - 16 show that when taking pictures in *macro* mode, more lighter colour is captured in darker colour. Lines 17 - 26 show that *auto* mode captured more darker colour than *macro* mode. Slight differences are captured in lines 27-40. The results of the research allow us to make an assumption that when taking pictures in *macro* mode, damages or scratches of a levelling staff are captured. The biggest negative difference – 197.775.

When performing experimental assessment of accuracy of levelling staffs margins by applying the photometric method, the most important thing is to choose the most appropriate focal length of lenses of a photo camera and relatively – camera modes.

## Conclusions

When applying the proposed calibration method, the calibration equipment is composed of a digital high resolution photo camera (no less than 8 million pixels), a computer and software designed for describing the photographic view of levelling staffs scales marking in a digital format and for the processing of the obtained information.

Having performed photometric calibration of levelling staffs using a digital SLR 20 and 50 mm fixed focus lenses photo camera *Canon EOS-7D*, by using different camera modes, we can claim that in this kind of calibration it is important to determine the limit between lighter and darker colours marking. This calibration method allows us to attribute numerical values to pixel values of digital photographs of the position of levelling staffs margins, which allows us to determine and assess damages and scratches made to levelling staffs scales.

Having performed the assessment of accuracy of calibration and analysed the obtained results (excluding various conditions of lightning and attachment of levelling staffs) we can claim that the focal length of a camera lens and partially camera modes have an influence on final results.

The most accurate results of calibration were obtained by taking pictures of levelling staffs scales with a 50 mm fixed camera lens.

## References


1. Abraham S. Tcc. 2004. A software for Test field based on self-Calibration of multi Camera-Systems. Institute für Photogrammetrie, Universität Bon, 39 p.
2. Krikštaponis B. 2000. Matavimų analoginiais ir skaitmeniniais nivelyrais tikslumo tyrimai. *Geodezija ir kartografija.* Volume 26, Issue 2, 69 – 72 p.
3. Krikštaponis B. 2001. Precizinio niveliavimo paklaidos ir jų įtaka matavimų rezultatams. Iš Kvalifikacinio mokslo darbo ataskaitos. Vilnius, 60 p.
4. Krikštaponis B. 2002. Skaitmeninio nivelyro Wild NA3003 atskaitos sistemos ypatumų tyrimai. *Geodezija ir kartografija*. Volume 28, Issue 2, 39–44 p.
5. Linder W. 2006. *Digital photogrametry*. Berlin:Springer–Verlag. 214 p.
6. Robinson A. H.; Morrison J. L.; Muehrcke P. C.; Kimerling A. J.; Guptill S. C. 1995. Elements of cartography. USA: John Wiley and Sons. 674 p.
7. Richards J.A.; Xiuping J. 2006. Remote sensing digital image analysis. Berlin: Springer – Verlag. 439 p.
8. Sužiedelytė-Visockienė J. 2007. Skaitmeninės matuojamosios fotokameros kalibravimo parametrų įtaka nuotraukas transformuojant į plokštumą. *Geodezija ir kartografija*, Volume 28, Issue 1, 26–30 p.



Information about author

**Kriaučiūnaitė-Neklejonovienė Vilma**. Associate professor, doctor. Aleksandras Stulginskis University, Institute of Land Management and Geomatics, Faculty of Land and Water Management. Address: Universiteto str. 10, LT – 53361 Akademija, Kaunas. Ph. (37) 752372. Lecturer, doctor. Kaunas University of Technology, Faculty of Civil Engineering and Architecture. Address: Studentų str. 48, Lt - 51367, Kaunas. Ph. 8(37) 300479. e-mail: vilma.kriauciunaite@ktu.lt

**Rekus Donatas.** Lecturer, doctor. Aleksandras Stulginskis University, Institute of Land Management and Geomatics, Faculty of Land and Water Management. Address: Universiteto str. 10, LT – 53361 Akademija, Kaunas. Ph. (37) 752372. Lecturer, doctor. Kaunas University of Technology, Faculty of Civil Engineering and Architecture. Address: Studentų str. 48, Kaunas. Ph. 8(37) 300479. e-mail: donatas.rekus@ktu.lt

**Balevičius Giedrius.** Lecturer. Aleksandras Stulginskis University, Institute of Land Management and Geomatics, Faculty of Land and Water Management. Address: Universiteto str. 10, LT – 53361 Akademija. Kaunas. Ph. (37) 752372. E-mail: giedrius.balevicius@asu.lt

**Šuliokaitė Gabrielė.** Master student. Aleksandras Stulginskis University, Institute of Land Management and Geomatics, Faculty of Land and Water Management. Address: Universiteto str. 10, LT – 53361 Akademija, Kaunas. Ph. (37) 752372.