Donatas REKUS

PHOTOMETRIC CALIBRATION OF LEVELLING STAFFS SCALES

SUMMARY OF DOCTORAL DISSERTATION

TECHNOLOGICAL SCIENCES,
MEASUREMENT ENGINEERING (10T)

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Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2006–2010.
Scientific Supervisor

Assoc Prof Dr Vladislovas Česlovas AKSAMITAUSKAS (Vilnius Gediminas Technical University, Technological Sciences, Meausrement Engineering – 10T).

Consultant

Prof Dr Habil Vytautas GINIOTIS (Vilnius Gediminas Technical University, Technological Sciences, Measurement Engineering – 10T).

The dissertation is being defended at the Council of Scientific Field of Measurement Engineering at Vilnius Gediminas Technical University:

Chairman

Prof Dr Habil Vladas VEKTERIS (Vilnius Gediminas Technical University, Technological Sciences, Measurement Engineering – 10T).

Members:

Prof Dr Donatas ČYGAS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T),

Assoc Prof Dr Mindaugas JUREVIČIUS (Vilnius Gediminas Technical University, Technological Sciences, Measurement Engineering – 10T),

Prof Dr Habil Stanislavas SAKALAUSKAS (Vilnius University, Technological Sciences, Measurement Engineering – 10T),

Prof Dr Habil Vitalijus VOLKOVAS (Kaunas University of Technology, Technological Sciences, Measurement Engineering – 10T).

Opponents:

Assoc Prof Dr Mindaugas RYBOKAS (Vilnius Gediminas Technical University, Technological Sciences, Informatics Engineering – 07T),

Dr Pawel WIELGOSZ (University of Warmia and Mazury in Olsztyn, Technological Scienes, Measurement Engineering – 10T).

The dissertation will be defended at the public meeting of the Council of Scientific Field of Measurement Engineering in the Senate Hall of Vilnius Gediminas Technical University at 2 p. m. on 20 January 2011.
Address: Saulėtekio al. 11, LT-10223 Vilnius, Lithuania.
Tel.: +370 5 274 4952, +370 5 274 4956; fax +370 5 270 0112;
e-mail: doktor@vgtu.lt
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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Donatas REKUS

NIVELIAVIMO MATUOKLIŲ SKALIŲ FOTOMETRINIS KALIBRAVIMAS

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Mokslinis vadovas

doc. dr. Vladislovas Česlovas AKSAMITAUSKAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, matavimų inžinerija – 10T).

Konsultantas

prof. habil. dr. Vytautas GINIOTIS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, matavimų inžinerija – 10T).

Disertacija ginama Vilniaus Gedimino technikos universiteto Matavimų inžinerijos mokslo krypties taryboje:

Pirmininkas

prof. habil. dr. Vladas VEKTERIS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, matavimų inžinerija – 10T).

Nariai:

prof. dr. Donatas ČYGAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T),

doc. dr. Mindaugas JUREVIČIUS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, matavimų inžinerija – 10T),

prof. habil. dr. Stanislavas SAKALAUSKAS (Vilniaus universitetas, technologijos mokslai, matavimų inžinerija – 10T),

prof. habil. dr. Vitalijus VOLKOVAS (Kauno technologijos universitetas, technologijos mokslai, matavimų inžinerija – 10T).

Oponentai:

doc. dr. Mindaugas RYBOKAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, informatikos inžinerija – 07T),

dr. Pavel VIELGOSZ (Varmijos ir Mozūrų universitetas Olštyne, technologijos mokslai, matavimų inžinerija – 10T).

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Adresas: Saulėtekio al. 11, LT-10223 Vilnius, Lietuva.

Tel.: (8 5) 274 4952, (8 5) 274 4956; faksas (8 5) 270 0112;

el. paštas doktor@vgtu.lt

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Introduction

Research problem

The latest progress in the contemporary geodetic measurements technique upgrading made it possible in the provided digital levelling instruments equipped with a microprocessor which operates in accordance with the set in advance program, to sense not only the readings located on the screen of the leveling staffs scales but also to register the total sequence of operations executed. Thus enabled the personal errors made by an operator to be eliminated up to 100%. However, there have been recorded the other errors caused by some other sources to be additionally investigated. These could be considered the errors of the coded leveling staff's scales tags. Firstly, they could have appeared due to failures during the production process or they might be related to the applied conditions of maintenance. Moreover, when employed under the field conditions the instruments are regularly affected by humidity, sudden temperature changes, intensive solar radiation, mechanical shock and load. Because of the causes mentioned above, the levelling staffs scales are required to be calibrated on the regular basis.

The interferometer devices currently applied in the levelling staff's scales for the calibration procedures are considered to be complicated, expensive, high dimensional and time consuming.

Relevance of thesis

The received results of levelling tend to include errors, which could not be avoided; they are due to the geodetic instruments applied, because of the environmental impact or they are caused by the operator's personal mistakes. In order to obtain the accurate results of the measurements all the available geodetic instruments have to be calibrated. To perfect the calibration of the levelling staff's scales there have to be introduced the upgraded methods of calibration, the levelling instruments have to be based on the flexible digital technologies, the technology of calibration works have to be simplified. The measures taken would allow to ensure the quality assessment prescribed for the levelling staffs scales permitting to monitor and eliminate the systematic errors of levelling which occur as the result of the incorrectness of the graduation of the scales of the levelling instruments.

Research object

The object of the research is to determine the accuracy of the position of the tags for the levelling staff's scales.

Aim

To compile the new calibration method to be applied for the levelling staff's and to simplify the calibration appliances as well as the calibration process itself.

Objectives

The following tasks have to be solved in order to fulfil the objective of the investigation:

1. To analyse scientific publications regarding the structure, principle of operation on the interferometrical horizontal and vertical comparators.
2. To analyze and theoretically justify the selected digital techniques meant for the processing of the images received by the levelling staff's.
3. To derive the technique meant for the tags calibration of the photometric levelling staff's scales and based on the descriptions of the images of the levelling staff scales and to be supplied in a digital form.
4. To perform the assessment of the reliability of the technique chosen to be performed in determining the position of the photometric levelling staff's scales the pilot measurements have to be executed by means of the optical microscope.
5. To execute the comparative analysis to determine the accuracy of the position of the tags on the photometric levelling staff's scales when compared with the results derived in the certified geodetic calibration laboratories as well as compare with the results submitted by the manufacturers of the levelling staff's.

Research methodology

The research includes the application of the theoretical and experimental investigations on the principles of digital image processing and analysis, while carrying out the comparative measurements in order to determine the position of the levelling staff scales tags as well as the implementation of the methods of mathematical statistical analysis for the comparison of the derived values of the digital images of the levelling staff's.

Scientific novelty

When exploring the tasks of the dissertation there were obtained the following results :

1. The photometric calibration method of the levelling staff's scales tags was compiled, based on the correlation analysis of the digital images of the edges of both the etalon and calibrated levelling staff's scale tags.
2. The patent right was issued on the basis of the invention made while carrying out the research.
3. The methodology was developed enabling to provide numeric values for the pixel values regarding the digital photos taken on the position of the levelling staff's scale tags.
4. The results of the analysis on the accuracy of the calibration method concerning the position of the photometric levelling staff's tags were submitted which justify the possibility of the implementation of the technique in practice when determining the position of the edges of the tags of the photometric levelling staff's scales.

Practical meaning of the results

The application of the prepared method of the calibration of the photometric levelling staffs considerably simplifies the levelling staff's calibration process. It turns out to be cheaper, requires less time and it is costs saving when compared with the other calibration methods recently applied.

Defensive arguments

1. There has been compiled a new photometric calibration method meant for determining the position of the levelling staff's scales tags based on the correlation analysis of the digital photo-images of the edges of both the etalon and the calibrated levelling staff scale tags.
2. The methodology developed allows to provide the digital values to the pixel values of the digital photos regarding the position of the levelling staff scale tags.
3. The grounding of the practical implementation possibilities concerning the new compiled calibration method meant for the levelling staff has been indicated.

The scope of the scientific work. The scientific work consist of the introduction, three chapters, conclusions, three appendixes, list of literature, list

of publications. The total scope of dissertation is 109 pages, 38 figures, 8 tables, 26 numbered formulas. There were made use of 101 scientific literature sources available.

1. Analysis of development and accuracy analysis of digital levelling devices improvement

The article describes the characteristics of digital levels, levelling staffs types, calibration of levelling staff's. Schlemer was the first who suggested using standard sizes and optical methods in the process of staff's calibration.

The comparator of staff's calibration partly corresponds the measurement operations performed during levelling.

Digital levellers operate in a semi-automatic way because the instrument – leveller – is directed to the staff and the accurate determining of values is performed automatically. Electronic system provides the reading of the staff height as well as the distance to it. The results of levelling are obtained in the digital indicator. They can be captured and stored in an electronic form. The microprocessor with the programs installed into the instrument is used to capture the readings and distances of the staff, to level the routes and spaces, to mark the designed heights and to check the leveller. The traditional method may also be used for the measurement in accordance with the centimetre grades marked on the other side of the staff.

All grades of coded staffs can be calibrated by traditional interferometric comparators. Usually it is enough to measure separate elements (grades) of 2.025 mm width) by a chosen method. For the calibration of the produced scale a vertical comparator of staffs is used. The distances between the coded staffs are always considered as the product 2.025 mm of coded steps. The resistance of staffs to the thermal extension is measured by horizontal comparators. The staffs are calibrated at 0, 10, 20, 30 and 40 ^{o}C temperature.

The comparator of staff's calibration partly repeats the measurement operations performed during levelling. The main principle of system calibration is to observe the readings of laser interferometer and digital leveller at the same time. The measurements are carried out by moving the graded coded staff in the vertical comparator every 25 mm and writing the readings of the laser interferometer and digital leveller. The amendments of scale for each staff are determined by adding the changes of interval row.

The comparator of staffs calibration consists of a slider, where the calibrating staff is installed and controlled, laser interferometer (standard measure) with reflecting prism, tightly fixed *CCD* (digital) photo camera, moved to the staff grades shifted along it by steps, drive which is used for the

staff with mirror to move along the edge of the staff, the block of results storage and processing.

The discussed devices are complex, expensive and large because it is necessary to move the staff into the same height as its length by steps. The comparators should always have a stepper drive to move the grades of the staff into the focus zone of camera capture (optic). Besides, a very expensive and complex device is used – laser interferometer. All this makes the comparator construction very complex and expensive. Economically it is expensive and requires much work as well as high qualified specialists.

2. Description of levelling staff's scales in digital format

To improve the quality of digital images and to submit the proper video information for automatic processing in the appropriate format the methods of images processing are applied. These methods replace the characteristics of digital photographs and the principle of computer vision (seeing) helps to identify points in digital images.

The processes of digital images processing consist of the following main stages:

- extraction, that is the creation of a high quality (bright contrast, brightness, expression) photograph when taking photos by digital cameras;
- saving and compression, that is the rearrangement of large digital images by reducing the computer memory it occupies. Effective compression of images, retention and placement is one of the most important tasks of images' processing;
- improvement of radiometric properties, that is the development of colour distribution of photographic images;
- smoothing – the removal of random image „rubbish" or „noises", the highlighting of image edges;
- segmentation – decomposition of images by defining the boundaries of segments;
- visualization.

The digital photograph is a continuous image. This image is converted to digital by splitting the continuous function. The conversion of continuous image into discrete is called digitization. It is obtained by creating matrix *NxM* from N rows and M columns and evaluating the intensity of colours. The colour saturation of each image is expressed by the number of pixel bits.

The matrix of digital image is expressed as follows:

$$g(x, y) = \begin{matrix} g(1,1) & g(1,2) & g(1,3) & \dots & g(1, M) \\ g(2,1) & g(2,2) & g(2,3) & \dots & g(2, M) \\ \dots & \dots & \dots & & \dots \\ g(N,1) & g(N,2) & g(N,3) & \dots & g(N, M) \end{matrix} \quad (2.1)$$

here $g\ (N,M)$ is the intensity of colours; M – number of digital image columns; N – number of rows; x,y – coordinates of digital image (pixels) (x – column, y – row).

The geometric resolution of digital image shows the size of digital image i.e. number of pixels, which depends on the size of pixels.

In order to evaluate the accuracy of coded staffs‘ calibration and find the accuracy of levelling staff’s coded scales, using the specially created computer program PIKSELIS, the investigations have been carried out, during which a part of digital coded levelling staffs‘ images have been converted into digital information. Program PIKSELIS has been created using MATLAB software packet. The resulting program allows to save the obtained variant of numeral matrix in a personal computer in TXT format or to submit all the information graphically writing the value of each pixel.

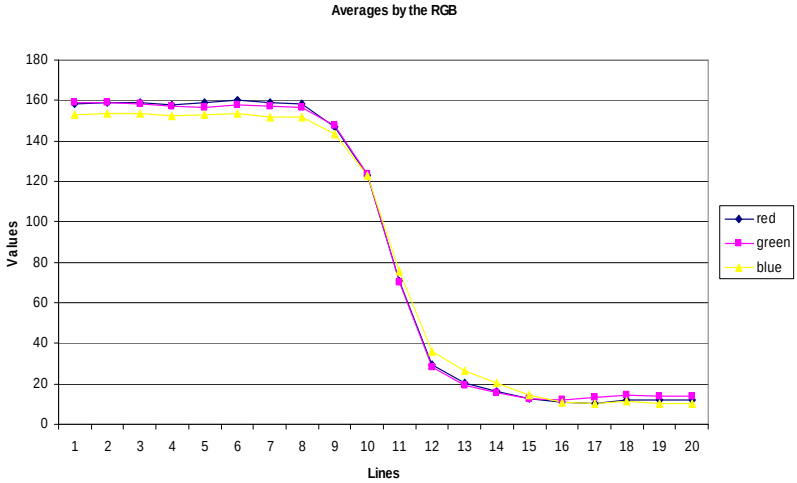

Fig. 1. The first piece of coded scale pixel values in *RGB* components

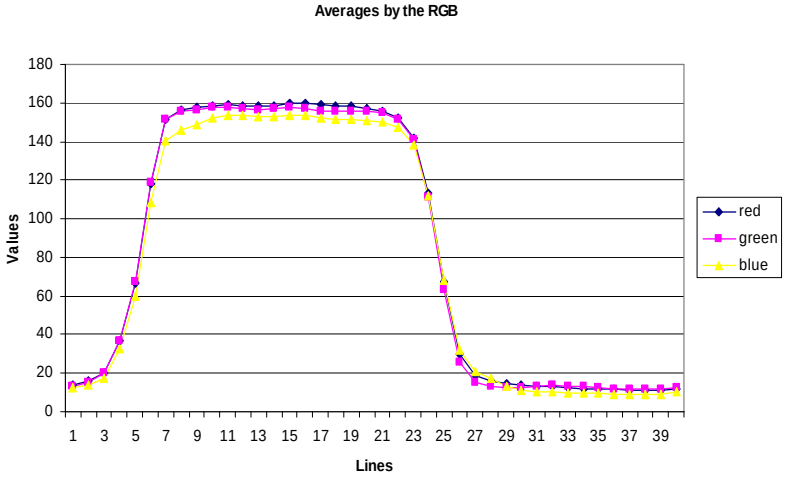

Fig. 2. The second piece of coded scale pixel values in *RGB* components

It was experimented with measuring the fragments of digital photographs of coded levelling staff's scales in the following formats: JPEG, BMP 16 bits, BMP 256 bits, BMP 24 bits, BMP MONOCHROME, TIFF and GIFF. Moreover, the experiments of red, green and blue colours components have been carried out (called RGB colours). The results show that the changing of components does not have influence of the final results (Fig. 1 and Fig. 2).

In Fig. 1 and Fig. 2 we see that the colors vary from one another, and it demonstrates the effectiveness of the program created. The study was conducted in the levelling staff's areas, where the scale of coded tag changes from dark to bright. In numeral matrices of coded scales the darker colours are expressed in smaller numbers meanwhile the lighter colours are expressed in larger numbers (interval from 0 to 256). The computer program provides these values in accordance with the colours of digital photo pixels (Fig. 3).

Having used the results of numeral matrices we can set the thickness of each coded scale grade, which will be necessary for further staff's calibration.

Therefore, we can set the boundary between black and white edges of coded scale's grades or see the mechanical damages of the coded scale.

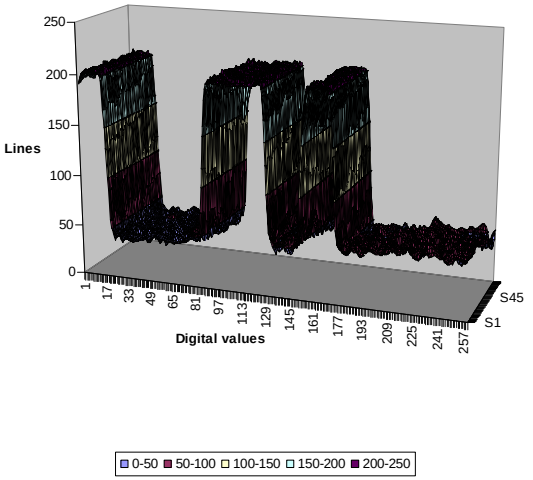

Fig. 3. Coded scales and average values of each pixel graph

BMP 256 bits format was the most suitable for the determination of coded scale's edges and performance of the investigations because the boundaries of coded scale's edges between black and white grades were the clearest and there was the least distortion in digital photographs.

The article describes the invention patent LT 5559 B „Calibration device of levelling staffs scales tags accuracy". Invention patent application was filed on the basis of dissertation studies. The proposed invention consists in levelling staff's tags calibration and reference measurements of the staffs tags using their digital images, entered into a computer screen or on a memory unit.

A new method of photometric calibration of levelling staffs scales tags has been created, based on the processing variants of digital images.

3. Photometric calibration of levelling staffs scales tags

In order to evaluate the accuracy of coded staffs calibration and find the accuracy of levelling staffs coded scales using the specially created computer program, the investigations have been carried out, during which a part of digital coded levelling staffs' images have been converted into digital information.

Figure 4 shows the fragment of numeral matrix which has been obtained using the specially created computer program.

Fig. 4. Digital image presentation of the identity of the pixel

In numeral matrices of coded scales the darker colours of pixels are expressed in smaller numbers, meanwhile the lighter colours are expressed in larger numbers. The computer program provides these values in accordance with the colours of digital photo pixels. Therefore, we can set the boundary between black and white edges of coded scales grades or see the mechanical damages of the coded scale.

Having used the results of numeral matrices we can set the thickness of each coded scale grade, which will be necessary for further staff's calibration. The thickness of coded scales grades has been obtained using AutoCad software by loading the results of coded scales numeral matrices into its working window. In order to evaluate the accuracy of the performed investigations, the thicknesses of the same coded scales grades have been measured with a microscope UIM- 21, No. 640072 for control.

Having used the created computer program, the investigation of accuracy determination of coded scales' grades edges has been carried out.

In order to evaluate the accuracy of performed investigations, the thicknesses of the same coded scale's grades have been measured with microscope UIM-21 for control. Figure 5 shows that the smallest difference

between two types of measurement is about 2 μm, whereas the biggest difference does not exceed 6 μm.

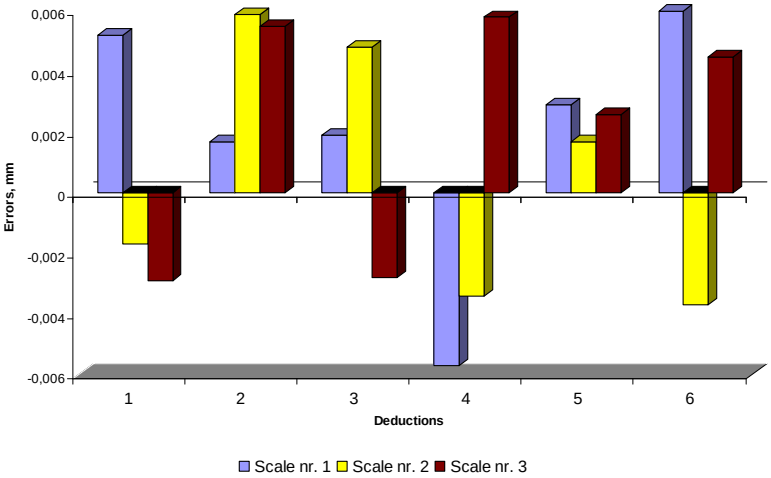

Fig. 5. The errors measured with UIM and AutoCAD software

The initial studies have shown that the analysis of digital image is highly dependent on the lighting when taking photo, the light reflectance rate of staffs surface and the cleanliness of that surface, distance from the camera to the staff as well as the contrast of coded grades.

I have analyzed the data on calibration from 1998 to 2004. The data has shown that the accuracy of calibration in Finnish Institute of Geodesy is about 1–2 μm. From 2003 to 2004 the changes of calibration amendments for the reading of 3000 mm do not exceed +10 μm, meanwhile from 1998 to 2004 calibration +36 μm. The accuracy of photometric calibration with digital camera with 8 millions pixel resolution there are ± 6 μm. The permissible manufacturing errors of invariant coded staffs is less than ±7 μm; the accuracy of photometric calibration is ± 6 μm. The results of photometric calibration meet the manufacturers requirements for coded levelling staffs accuracy.

Having performed mathematical statistical calculations, using a series of data on coded scales numeral matrix, in accordance with the obtained dispersions and the values of correlation rates, we can accurately determine the boundary of coded scales grades between black and white edges of coded scales grades or see the mechanical damages of the coded scale.

General conclusions

1. There has been compiled a new method of photometric calibration of levelling staffs scales tags based on the methodology of processing of the variants of digital images. The method allows to determine the positioning of edges of the levelling staff's scales tags with the accuracy of 6 μm. In accordance with the ISO 12858–1 standard requirements the tolerances of the errors for the positioning of the edges of levelling staff's scales tags has been allowed up to 20 μm. Thus, it is stated that the compiled calibration method is recommended to be implemented practically for the assessment of the quality of the levelling meters.
2. The application of the worked out method of calibration is considered to be considerably cheaper as well as the instrumentation applied for the calibration is simplified when compared to the interferometer comparators currently used for the routine calibration.
3. When applying the proposed methodology of calibration, generally the calibration instruments include a digital camera with the high resolution capacity (not lower than 8 million pixels), a personal computer and the software have been compiled to process the derived findings and to describe in a digital form the photographic images taken by the levelling staffs scale.
4. Having compared the photometric calibration results obtained for the positioning of the edges of the levelling staff's scales tags to the results of the pilot measurements produced by means of the optic microscope it is possible to state that the accuracy of the suggested method of calibration (6 μm) corresponds to the requirements for accuracy (7 μm) submitted by the manufacturers of the levelling staff's scales.

List of Published Works on the Topic of the Dissertation

In the reviewed scientific journals

1. Aksamitauskas, Č.; Rekus, D, Čirba, S. 2010. Investigation error source measuring deformations of engineering structures by geodetic methods, *The Baltic Journal of Road and Bridge Engineering* 5(4): 185–190. ISSN 1822-7275 (ISI Web of Science).
2. Aksamitauskas, Č.; Rekus, D. 2009. Investigation of levelling staff's coded scales accuracy under their digital photos, *Geodesy and Cartography* 4(35): 140–143 (in Lithuanian). ISSN 1392-1541 (Compendex).

3. Giniotis, V.; Rekus, D.; Aksamitauskas, Č. 2007. Accuracy calibration of the bars of levelling meters, *Geodesy and Cartography* 4(33): 102–105. ISSN 1392-1541 (Compendex).

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1. Aksamitauskas, Č.; Rekus, D.; Wasilewski, A. 2007. Impact of digital level Wild NA3003 error investigations on construction engineering measurements, in *Proceedings of the 9th international conference Modern Building Materials, Structures and Techniques held on May 16–18, 2007 Vilnius, Lithuania*. Vilnius: Technika, 1–5. ISBN 978-99-5528-131-3 *(Thomson ISI Proceedings).*
2. Giniotis, V.; Rekus, D.; Aksamitauskas, C. 2008. Calibration of coded levelling staffs, in *Proceedings of the 7th International conference "Environmental engineering": selected papers, Vol. 3, May 22–23, 2008 Vilnius, Lithuania*. Vilnius: Technika, 1310–1313. ISBN 978-9955-28-265-5 *(Thomson ISI Proceedings).*
3. Rekus, D.; Aksamitauskas, Č.; Giniotis, V. 2008. Application of digital automatic levels and impact of their accuracy on construction measurements, in *The 25th International Symposium on Automation and Robotics in Construction (ISARC 2008): selected papers, June 26–29, 2008 Vilnius, Lithuania*. Vilnius: Technika, 625–631. ISBN 978-9955-28-329-4 *(Thomson ISI Proceedings).*
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7. Rekus, D.; Aksamitauskas, V. Č. 2008. Influence of digital levels errors on construction measurements, in *Conference of Students, Masters Degree*

Students, Doctoral Students „Civil Engineering and Architecture“ Kaunas, 47–57. ISBN 978-9955-25-605-2.
8. Rekus, D.; Aksamitauskas, V. Č. 2009. Investigation of levelling staff's coded scales accuracy. *Collection of articles „Measurement Engineering and GIS “ Mastaičiai,* 36–40. ISBN 978-9955-27-133-81.

Patent

Giniotis, V.; Rekus, D.; Petroškevičius, P.; Skeivalas, J.; Aksamitauskas, Č.; Bručas, D. 2009. *Calibration device of levelling staff's grades positioning accuracy*. Lithuanian patent LT 5559 B.

About the author

Donatas Rekus acquired the bachelor's qualification degree in measurement engineering in Vilnius Gediminas Technical University in 2003, and in 2005 he acquired master's qualification degree in measurement engineering. From 2006 to 2010 is a doctoral student at Vilnius Gediminas Technical University. The author participated in two internships abroad:

- Internship of Leonardo da Vinci program: „Training of geographic information specialists and formation of professional improvement strategy for the development of information society“. Amsterdam, Holland, 2007.
- Internship in Federal University of Technology in Zurich (Switzerland) (2007).

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NIVELIAVIMO MATUOKLIŲ SKALIŲ FOTOMETRINIS KALIBRAVIMAS

Problemos formulavimas

Tobulėjant šiuolaikinei geodezinei matavimų technikai, skaitmeniniuose nivelyruose įmontuotas mikroprocesorius pagal pasirinktą programą fiksuoja niveliavimo matuoklių atskaitas ir veiksmų seką, tokiu būdu 100% eliminuodamas darbus atliekančio matuotojo asmenines paklaidas. Tačiau atsiranda kitų paklaidų šaltinių, kuriuos būtina ištirti papildomai. Tai gali būti kodinių matuoklių skalių žymų paklaidos. Jos gali būti gamyklinės ir susijusios su matuoklių eksploatavimo sąlygomis. Dirbant lauko sąlygomis jas veikia drėgmė, staigūs temperatūros pokyčiai, intensyvi saulės radiacija, mechaniniai smūgiai bei apkrovos. Dėl šių priežasčių niveliavimo matuoklės turi būti periodiškai kalibruojamos.

Šiuo metu naudojami niveliacijos matuoklių kalibravimo interferometriniai įrenginiai sudėtingi, brangūs, didelių matmenų, ilgai trunkantis kalibravimo procesas.

Darbo aktualumas

Niveliavimo rezultatai gaunami su neišvengiamomis paklaidomis, kurios gali priklausyti nuo naudojamų prietaisų, nuo aplinkos poveikio arba niveliuotojo. Siekiant gauti patikimus matavimų rezultatus prietaisus reikia kalibruoti. Niveliavimo matuoklių kalibravimo tobulinimui reikalingi nauji kalibravimo būdai, lanksčiomis skaitmeninėmis technologijomis pagrįsta kalibravimo įranga, nesudėtinga kalibravimo darbų technologija. Tai užtikrintų savalaikę niveliavimo matuoklių kokybės kontrolę, leistų kontroliuoti ir eliminuoti sistemingąsias niveliavimo paklaidas, priklausančias nuo matuoklių skalių padalų netikslumų.

Tyrimų objektas

Niveliavimo matuoklių skalių žymų padėties tikslumo nustatymas.

Darbo tikslas

Sukurti naują niveliavimo matuoklių kalibravimo būdą, supaprastinti kalibravimo įrangą ir kalibravimo procesą.

Darbo uždaviniai

Darbo tikslui pasiekti reikia spręsti šiuos uždavinius:

1. Atlikti mokslinės literatūros apie interferometrinių horizontaliųjų ir vertikaliųjų komparatorių konstrukciją, veikimo principo analizę.
2. Išanalizuoti ir teoriškai pagrįsti skaitmeninius niveliacijos matuoklių vaizdų apdorojimo būdus.
3. Sukurti fotometrinio niveliavimo matuoklių skalių žymų kalibravimo būdą pagrįstą niveliavimo matuoklių skalių vaizdų aprašymu skaitmenine forma.
4. Atlikti fotometrinio niveliavimo matuoklių skalių padėties nustatymo būdo patikimumo įvertinimą, kontrolinius matavimus atliekant optiniu mikroskopu.
5. Atlikti palyginamąją fotometrinio niveliavimo matuoklių skalių žymų padėties tikslumo nustatymo analizę su kalibravimo rezultatais gautais sertifikuotose geodezijos kalibravimo laboratorijose bei niveliavimo matuoklių gamintojų duomenimis.

Tyrimų metodika

Darbe naudoti teoriniai ir eksperimentiniai tyrimai, taikant skaitmeninių vaizdų apdorojimo ir analizės principus, atliekant palyginamuosius niveliavimo matuoklių žymų padėties matavimus bei taikant matematinę statistinę analizę niveliavimo matuoklių skaitmeninių vaizdų vertėms palyginti.

Darbo mokslinis naujumas

Tyrimų metu buvo gauti šie nauji rezultatai:

1. Sukurtas fotometrinis niveliavimo matuoklių skalių žymų padėties kalibravimo būdas, pagrįstas bendru etaloninės ir kalibruojamos matuoklių skalių žymų briaunų skaitmeninių fotovaizdų koreliacine analize.
2. Disertacijos tyrimų pagrindu gautas išradimo patentas.
3. Sukurta metodika leidžianti niveliacijos matuoklių skalių žymų padėties skaitmeninių nuotraukų pikselių reikšmėms suteikti skaitines vertes.
4. Fotometrinio niveliavimo matuoklių žymų padėties kalibravimo būdo tikslumo analizės rezultatai, kurie pagrindžia fotometrinio niveliavimo matuoklių skalių žymų briaunų padėties nustatymo būdo praktinio taikymo galimybes.

Darbo rezultatų praktinė reikšmė

Taikant parengtą fotometrinį niveliavimo matuoklių kalibravimo būdą yra žymiai supaprastinamas niveliavimo matuoklių kalibravimo procesas, jis tampa pigesnis, užimantis mažiau laiko ir darbo sąnaudų, lyginant su kitais šiuo metu taikomais kalibravimo būdais.

Ginamieji teiginiai

1. Naujas fotometrinis niveliavimo matuoklių skalių žymų padėties kalibravimo būdas, pagrįstas bendru etaloninės ir kalibruojamos matuoklių skalių žymų briaunų skaitmeninių fotovaizdų koreliacine analize.
2. Sukurta metodika leidžianti niveliacijos matuoklių skalių žymų padėties skaitmeninių nuotraukų pikselių reikšmėms suteikti skaitines vertes.
3. Sukurto naujo niveliacijos matuoklių kalibravimo būdo praktinio taikymo galimybių pagrindimas, remiantis atliktų eksperimentų tikslumo matavimų rezultatų analize.

Darbo apimtis

Darbo apimtis 109 puslapiai, tekste panaudotos 26 formulės, 38 paveikslai ir 8 lentelės. Rašant disertaciją naudotasi 101 literatūros šaltiniu.

Disertaciją sudaro įvadas, trys skyriai, rezultatų apibendrinimas, naudotos literatūros ir autoriaus publikacijų disertacijos tema sąrašai, du priedai.

Įvadiniame skyriuje aptariama tiriamoji problema, darbo aktualumas, aprašomas tyrimų objektas, formuluojamas darbo tikslas bei uždaviniai, aprašoma tyrimų metodika, darbo mokslinis naujumas, darbo rezultatų praktinė reikšmė, ginamieji teiginiai. Įvado pabaigoje pristatomos disertacijos tema autoriaus paskelbtos publikacijos ir pranešimai konferencijose bei disertacijos struktūra.

Pirmame skyriuje analizuojami kodinių skalių duomenų apdorojimo metodai skaitmeniniuose nivelyruose, kodinių niveliavimo matuoklių kalibravimo vertikalūs bei horizontalūs komparatoriai.

Antrajame skyriuje pateikta kodinių niveliavimo matuoklių skalių analizė skaitmenine forma.

Trečiajame skyriuje analizuojamas fotometrinis kodinių niveliavimo matuoklių skalių kalibravimo būdas.

Bendros išvados

1. Sukurtas naujas fotometrinis niveliavimo matuoklių skalių žymų kalibravimo būdas paremtas skaitmeninių fotografinių vaizdų apdorojimo metodika, kurį taikant skalių žymų padėties briaunas galime nustatyti 6 μm tikslumu. Pagal ISO 12858–1 standartą matuoklių skalių žymų padėties paklaidų nuokrypos yra leidžiamos iki 20 μm. Todėl galime teigti, kad sukurtą kalibravimo būdą galime praktiškai taikyti niveliavimo matuoklių kokybei kontroliuoti.
2. Taikant sukurtą kalibravimo metodiką, reikalinga žymiai paprastesnė ir pigesnė kalibravimo įranga lyginant su šiuo metu matuoklių kalibravimui naudojamais įprastiniais interferometriniais komparatoriais.
3. Taikant siūlomą kalibravimo metodiką kalibravimo įrangą sudaro skaitmeninė aukštos skiriamosios gebos (ne mažesnė kaip 8 milijonų pikselių) fotokamera, kompiuteris ir sukurta kompiuterinė programa matuoklių skalių žymų fotografiniam vaizdui aprašyti skaitmenine forma bei gautai informacijai apdoroti.
4. Palyginus tuos pačius niveliavimo matuoklių skalių žymų kalibravimo fotometriniu būdu ir kontrolinius matavimus optiniu mikroskopu rezultatus, galime teigti, kad sukurto kalibravimo būdo tikslumas (6 μm) atitinka niveliavimo matuoklių gamintojų tikslumo reikalavimus (7 μm).

Trumpos žinios apie autorių

Donatas Rekus 2003 metais Vilniaus Gedimino technikos universitete įgijo matavimų inžinerijos bakalauro kvalifikacinį laipsnį, o 2005 m. matavimų inžinerijos mokslo magistro laipsnį. 2006–2010 metais – Vilniaus Gedimino technikos universiteto doktorantas.

Dalyvauta dviejuose stažuotėse užsienyje:

- Stažuotė pagal Leonardo da Vinci programą: „Geografinės informacijos specialistų mokymo ir profesinio tobulinimosi strategijos formavimas žinių visuomenės plėtrai“. Amsterdamas, Olandija, 2007.
- Stažuotė Ciuricho Federaliniame technologijos universitete (Šveicarijoje) 2007 m.

Padėkos

Autorius nuoširdžiai dėkoja darbo vadovui doc. dr. Vladislovui Česlovui Aksamitauskui už mokslinius patarimus bei pastabas rengiant disertaciją.

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Donatas Rekus

PHOTOMETRICAL CALIBRATION OF LEVELLING STAFFS SCALES

Summary of Doctoral Dissertation
Technological Sciences, Measurement Engineering (10T)

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Vilniaus Gedimino technikos universiteto
leidykla „Technika“,
Saulėtekio al. 11, 10223 Vilnius,
http://leidykla.vgtu.lt
Spausdino UAB „Ciklonas“,
J. Jasinskio g. 15, 01112 Vilnius