Horizontal comparator for the system calibration of digital levels — realization at the Faculty of civil engineering, CTU Prague and in the laboratory of the Department of survey and mapping Malaysia (JUPEM) in Kuala Lumpur

Zdeněk Vyskočil and Zdeněk Lukeš

Department of Geomatics,
Czech Technical University in Prague
Thákurova 7, 166 29 Prague 6, Czech Republic
zdevyskoc@centrum.cz
zdenek.lukes@fsv.cvut.cz

Keywords: digital level, geodesy, leveling staff calibration, metrology, surveying

Abstract

Metrological procedures require a leveling staff calibration for an estimation of a true staff scale. The calibration process is usually realized on laboratory comparators. Two automatic comparators for digital level calibration were built by the staff of Department of Geomatics. This article brings some information about properties of developed systems and about a control software for the comparators.

1. Introduction

In the year 2009 the horizontal comparator was modernized in the metrological laboratory in Kuala Lumpur in the frame of cooperation between Department of Advanced Geodesy (now Department of Geomatics) at the Czech Technical University (CTU) and Department of Surveying and Mapping Malaysia (JUPEM). New arrangements allow automatic calibration of digital levels. The model solution for this innovation was rebuilding of the comparator in laboratory of CTU Prague where the functional prototype of this system was designed in the way of rebuilding of older calibration bench.

This kind of calibration facility used for system calibration of digital levels can be found in geodetic or metrological laboratories in the world in two varieties. The technology of system calibration of digital levels is generally known and several universities and institutes are using comparators to process calibration.

Comparator for system calibration

Items of this type serve generally to leveling staff calibration or for calibration of digital levels [1]. Calibration means here the true length of staff meter estimation. Calibration can be realized as optical aiming at graduation respectively at bar code edges and comparison with length value measured by a laser interferometer. The second variant is using of digital level height reading. Staff interval is read by the digital level and compared with the value realized by interferometer. Figure 1 shows the system scheme.

The first method gives a higher precision of staff scale detection, but this method is time demanding and it is very difficult to capture a possible irregularity of the staff scale. In opposite to it, the second method can be easily automatized thanks to the availability of digital levels remote control and an automatic reading. Next advantage of this system is the recent determination of reading precision of level (but without influence of compensator function ability). This process of calibration is associating staff calibration and currently instrument testing and in literature it is called "system calibration".

During the system calibration process level height reading is changed through staff shifting and this change is compared with a length variance measured by the interferometer. It provides a height deviation as output, which can be processed by linear regression and provides staff scale.

Comparator for system calibration allows change of position toward the line of sight of the level, which is stably emplaced on a pillar. Comparators are mostly vertical, allowing measurement at the vertical staff, which is shifted in vertical direction. The second variety is horizontal comparator (see the scheme below). The staff lies horizontally on a chariot. Vertical picture of a bar code is displayed in the mirror tilted by 45 deg to levels line of sight and to staff normal. The advantage of the first variant is that it allows installing level in every distance. The disadvantage is constructional, a large vertical space is needed for an installation (twice length of the staff). In the case of horizontal comparator, real disadvantage is a limited distance of level and the staff given by mirror dimensions.

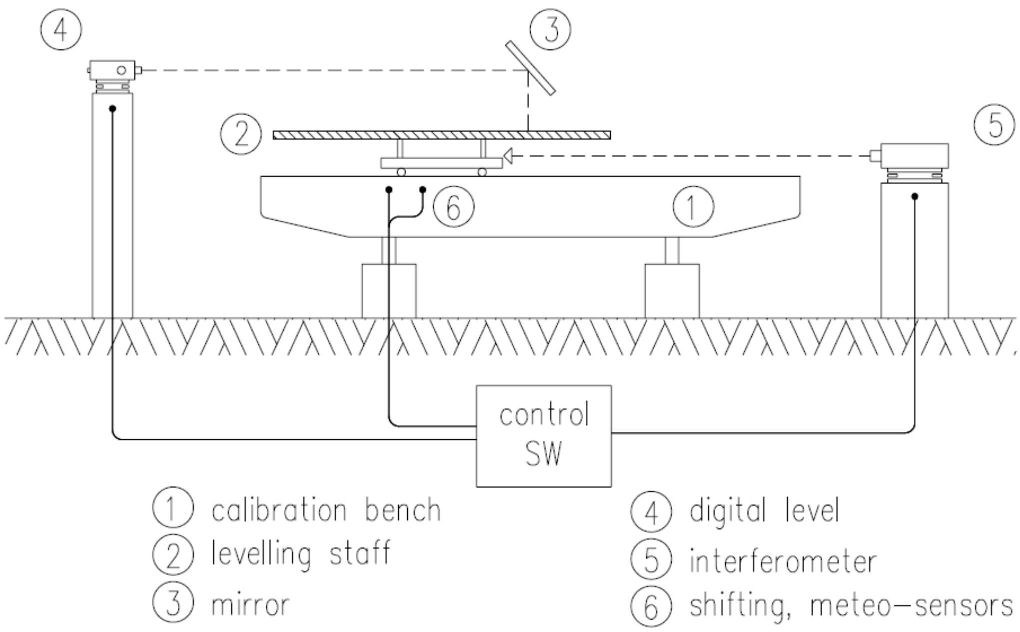

Figure 1: Scheme of horizontal comparator for system calibration

2. Comparator at the Department of Geomatics

Submission

The old comparator Carl Zeiss Jena was used as a fundament of the automatic comparator, see Fig.2. It was originally assigned for the precise machine measurement and is consisting of a precise straight traverse bench. This comparator was so far used just for an optical calibration of level staffs and other length scales.

The crucial modification lies in the change of a configuration of reading apparatus and the staff. During the optical calibration, the staff is fixed and a microscope (or another reading item) is moving on the traverse bench and its shift is controlled by an interferometer. In the system calibration improvement there is a reading item (digital level) stabile fixed and the staff is moved on the bench. This is necessary because of the distance fixing between the staff and the level that means keeping of a bar code image focusing. Renovation of the comparator is implemented in the way that all new devices can be easily removed and it is possible to use the current comparator in a primary configuration. The position of the bench in laboratory allows measurement with the level in the distance interval from 2.5m to 6m in the case of positioning of the instrument in the next room and thanks to a through view in the wall.

Realization

The bench is six meters long what is the efficient length for the purpose of calibration. Comparator is positioned plumb to the wall in the distance of about 0.3 m from the bench edge to the wall. This is a limiting calibration interval, which is now just 2.5 m. This year it is planned to enlarge the space around the comparator and to extend the calibration interval in the length of the staff. The mirror is fixed in the centre of the comparator, it hangs on the solid console, which is constructed from rectangle hard aluminum profiles 100 x 30 x 3 [mm]. The mirror holder allows to set a station around three coordinate axes and also precise petting its tilt 45 degree to horizontal line of a sight of the level and to the normal of the horizontal positioned staff.

The staff is positioned on the holder and shored up by three screws which allow to set up the horizontation. Shifting of the staff is realized by the step motor which drives a ball screw in 10:1 gear. The ball screw is 4500 mm long and it has 40 mm diameter. The gearing and step dividing of the step motor allows precise positioning with the resolution about 10 μm but on the other side limits a maximal velocity of shifting.

The laser interferometer Renishaw ML10 Gold is used as a length standard for this comparator. This instrument is connected to PC via USB interface. Standard error of determined staff interval is given by the manufacturer as 1 ppm.

The system is controlled by the original program developed in the Department of Geomatics and it is described in the last paragraph. The staff calibration in the interval of 2 m takes at this facility about 30 minutes in the step of calibration 20 mm. The interval and the step of calibration is configurable at will.

3. Realization for JUPEM

Submission

The submitter of the action, JUPEM, required a creation of modern system for automatic

Figure 2: Comparator in laboratory of the Department of Geomatics.

system calibration of digital levels. It was negotiated with the submitter that the automatic system will be built on the current platform of horizontal comparator. It was realized in metrological laboratory in 80's by an expert group from Japanese GSI, see Fig. 3.

Realization

The comparator consists of a huge steel bench from H-profile of dimension 600 x 400 x 15 mm, the bench is 6 m long. In precise milled cuttings on the upper side of the bench there are two rails fixed of linear shifting. The chariot with adjustable staff holder is moving on the rails. In the middle of the comparator bench there is a suspension console. In the origin modification there was a light holder and a reading microscope at the console. The microscope was removed by a digital camera and the holder was modified for the mirror positioning and fixing. The camera is here for the calibration of optical (regularly graduated level staff). As in the case of Institute of Geomatics comparator, here is the interferometer (on the solid pillar) and level on the opposite sites of the bench. For the level position there is a steel pillar situated 4 m from the middle of the comparator.

After the negotiation with the submitter it was decided to build up automation items in the same way as they were done in the case of the horizontal comparator in the Institute of Geomatics (CTU Prague) laboratory. Montage of the components (except for some details) was accomplished as it's described in the paragraph "The comparator at the Institute of Geomatics – Realization".

The brand new laser interferometer LMS from Limtek Blansko/Czech Republic was bought for JUPEM laboratory. The instrument fills required parameters: open communication protocol, Ethernet communication interface, delivery of just required components. Costs for the instrument are on the same level as asked competitors Renishaw and Agilent. Atmosphere control sensors connected via wi-fi to the control unit of interferometer are optional accessories of the instrument.

Figure 3: Comparator in Laboratory of JUPEM.

For the staff shifting the well-tried step motor Microcon is used. Is is operated by (via serial port easily programmable) control unit. The vendor also supplies compatible right angle worm-gears, the smallest rate 10:1 was used.

In consideration of preparation heftiness there were all mechanical parts of innovation prepared in advance in the Czech Republic and sent to JUPEM. The fitting of components, the montage and the adjustment took nine workdays. In regard of robust material used for the body of the comparator (steel) and new items (hard –aluminum) are all parts connected with screws in coils or with nuts.

Software

The original program working in Linux OS was developed for the calibration system, see Fig.4. This software connects staff shifting control (by force of step motor), laser interferometer measurement and digital level measurement. In the time of development of the program there were available communication protocol just from manufacturers Leica and Trimble, so it was so far possible to work with these instruments: Wild NA2000/NA3003, Leica DNA03/10, Trimble Zeiss DiNi11/12/12D.

In the program there is possible to accomplish single measurement – staff shifting to required position, staff reading, interferometer and athmospheric sensors measurements. The program above all allows execution of full automatic calibration after setting of input parameters. These are interval of calibration (interval of staff reading), step of calibration and number of measurement repeating. The computed staff scale and the calibration protocol are outputs. Measured data, deviations and an actual system scale are displayed during the measurement in the table.

Individual calibrations are organized into projects (corresponding to pair instrument – staff) and subordinate relations (sessions). This cascading allows easy comparing of results by repeated calibrations.

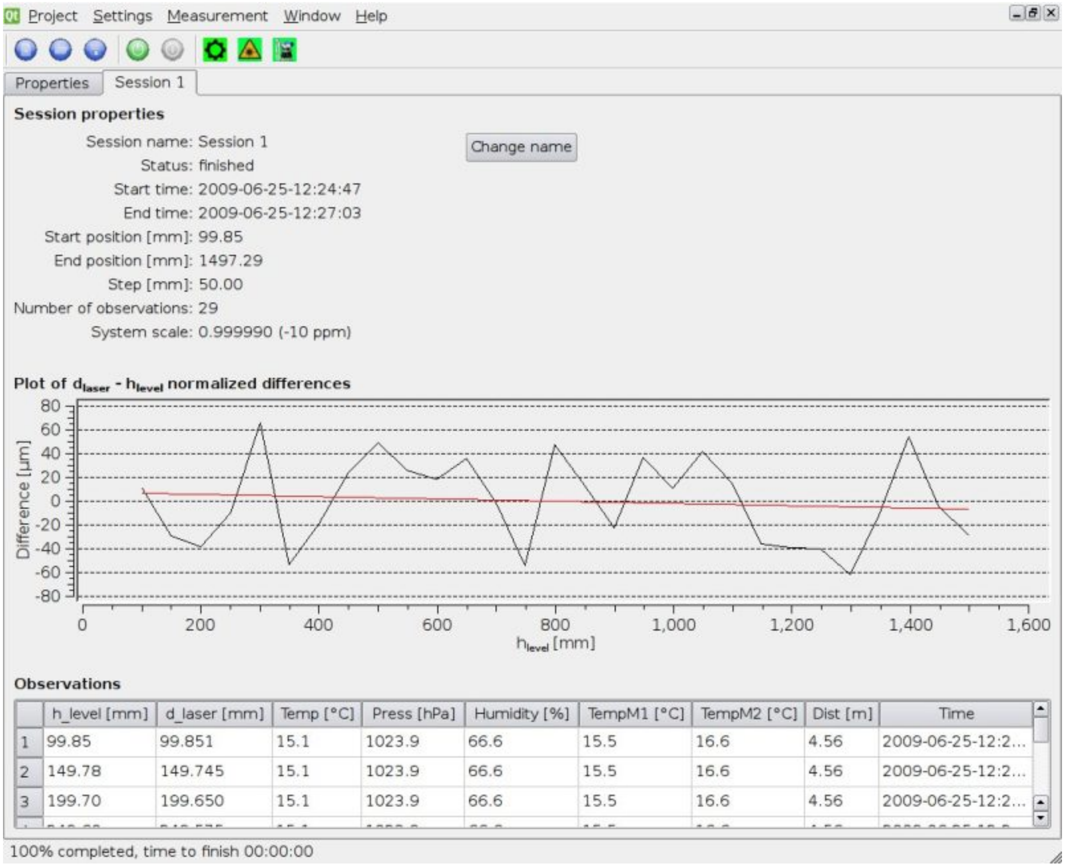

Figure 4: Window of control program.

4. Conclusion

Both introduced systems are, in the sense of design, similar. In the time of usage (six years) of the comparator in JUPEM there occurred no defect (term of guarantee was negotiated to one year), employees of the office were theoretically and practically trained and they manage the work with comparator without any problems.

In the article, there was noticed that this year there are planned some constructive modifications of the laboratory of the Institute of Geomatics. These changes allow calibration of leveling staffs in their whole length. Our next goal is to complete the calibration basement of possibility of separate (full automatic as well) calibration of scale by aiming at staff graduation (bar code edges) with a digital microscope. The final goal is the separate calibration of the staff and the level.

At the same time, there is 24 meters long horizontal comparator for electronic distance meters (EDM) calibration developed in the same laboratory. Automatic system of EDM will be described in some next paper.

References

[1] Helmut Woschitz and Fritz K. Brunner. "Development of a Vertical Comparator for System Calibration of Digital Levels". In: *Österreichsiche Zeitung für Vermessung und Geoinformation* 91 (Apr. 2003), pp. 68–76.