Testing DistoX Device for Measuring in the Unfavourable Conditions

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Abstract

Indoor surveying is often more demanding than outdoor surveying. There are a few main reasons why: inability to use the GPS and often poor visibility, for example, in tunnel measurements. There are also situations where the indoor conditions are extremely difficult for surveying, like in caves. Speleologists use devices that are light weight and easy to handle. The aim of this study was to examine the accuracy of one device for surveying the cave. In this case, device DistoX was used. Tests were conducted in one part of the cave Veternica, which is located near the city of Zagreb and altogether has over 7 km of canals. Differences between the results obtained with DistoX and total stations are displayed. Based on these examinations the advantages and disadvantages of this kind of surveying are given.

Key words: Indoors surveying, unfavourable conditions, caves, DistoX

1 INTRODUCTION

Today, modern surveying instruments significantly simplify work to surveyors. Surveying in the outdoor has become very easy thanks to the application of Global Navigation Satellite Systems (GNSS) and modern surveying equipment. In some areas of geodesy these achievements are not easy to apply. For example, in tunnelling, the use of GNSS technology has been limited. But construction of tunnels is very important for people, and they are willing to provide high investments to make technology that could satisfy the requirements for accuracy of tunnel cutting. So, today we have gyro theodolite, 3D scanners and robotic laser measuring stations that make our work in the tunnels easier. However, on Earth we still have some extremely difficult conditions, where, in spite of all the technology, surveying represents a real challenge. Take caves for the example.

The caves are karst phenomena which hide many secrets. This is an area where you can find lots of information about Earth's history and especially the history of the human species, because people have used caves for a very long time as their shelter. Caves hide large amounts of fresh water, which will soon become a real treasure. Staying in caves helps people to heal from allergies because they do not contain any allergens. Moreover, in the caves there are some endemic and very rare animal species. For these reasons, but also of the mere desire to explore, some people dare to enter in those dark, humid and very inaccessible areas. They are cavers. These brave and noble people usually spend their free time to explore the mysterious underground world.

Caves represent very important research location of various karst science branches, e.g. biospeleology, paeleoclimatology, karst hydrogeology, speleogenesis, etc. For an accurate interpretation of the various specific research results it is often the most important to make a good topographic survey of the cave. Cavers perform their research mainly as a hobby. They are being paid very little or mostly they volunteer for that demanding job. Often their financing sources are very restricted and they are buying the equipment for topographical survey themselves. Their surveying equipment is essential to be small, lightweight, easy to handle and not too expensive.

For a topographic survey of caves, cavers around the world mainly use precise compass for measuring the azimuth and clinometer for measuring the vertical angles, while for measuring lengths, they are using tape or a distance meter laser. On the market there are devices that combine compass and clinometer in one. One of such devices that is very popular is the Suunto Tandem (Figure 1). Mapping data is usually done on the field, using a pen to sketch details on a graph paper which is coated and roughening prior to use. Later, these sketches are drawn again, but this time with more effort. As a result we obtain an analogue or digital display of the cave, which is generally suitable for most of the exploration. This equipment meets the above criteria, but resulting in the survey of the cave generally takes a long time.

Figure 1 Suunto Tandem - compass and clinometer'

Of course, the accuracy is not as that which is required to work engineering geodesy, but it is possible with this technology to work in areas where a very precise and often robust and expensive technology is not so appropriate.

Figure 2 DistoX “paperless caving” system (Paperless Cave Surveying, 2013)

In the last decade on the market we can find new products that enable automation of measurement and mapping of caves, and its price is not too expensive. Automatic storage of measured data allows us to measure with greater speed, and automatic transferring of digital data to PDA or PC reduces the possibility of errors during transcription and accelerates the mapping of caves. Name for such product is “paperless caving” system. One such product is DistoX, which we examined in this paper.

2 DISTOX “PAPERLESS CAVING” SYSTEM

The data collection part of “paperless caving” system consists of two devices, a measuring device and a PDA with a data management application. These two are linked together with a wireless Bluetooth connection. Each of them is useful by itself, but the full potential of the system is exploited only if they are used in combination. The measuring device acquires all relevant data, distance, declination, and inclination simultaneously. The compass and clinometer are both 3-axis systems that allow accurate measurements in any direction independent of the device orientation. The PDA application is used to manage and store measured data and to add missing information like the connectivity of the survey shots. It displays the data numerically and graphically and allows to add sketches directly on the PDA screen (Heeb, 2008).

DistoX is an upgrade board mounted in Leica Disto A3 or Stabila LE50. The DistoX consists of three magnetic field sensors and three accelerometers. They allow to determine the precise orientation of the device in space and the direction relative to the earth magnetic field. Due to manufacturing tolerances and external influences, such a system inevitably reveals certain errors. Among them, they are:

- Offset and gain errors of the sensors.
- Sensors mounted under incorrect angles.
- Angular errors between the sensors and the Laser beam.
- Influences of metal parts (in particular the battery) on the magnetic field.

Fortunately all these errors can be eliminated relatively easily by a bunch of calibration measurements and the corrections calculated from them. Use the 14 directions given by the middle of the 6 faces and the 8 vertices of a cube as seen from its centre. Measure each direction with four evenly spread roll angles, giving a total of 56 measurements (Fig. 3) (Heeb, 2010).

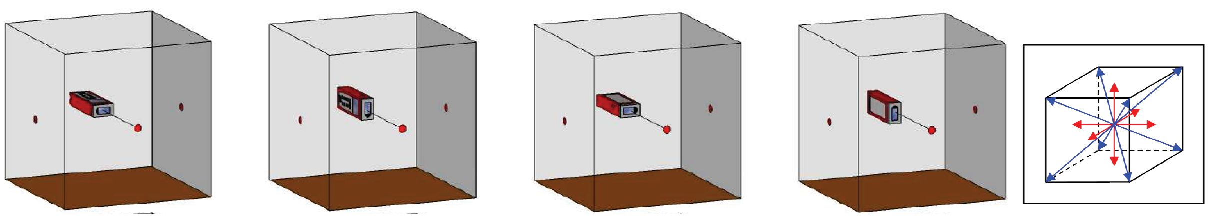

Figure 3 Four evenly spread roll angles in 14 directions suitable for calibration (Heeb, 2010) and (Heeb, 2014)

It is important that an undisturbed magnetic environment is present to do the calibration measurements. It is practically impossible to do a precise calibration in a house or near buildings. Even metal screws in a wooden construction have an influence! The best environment is either a cave or a forest (Heeb, 2014).

3 COMPARISON OF MEASURED VALUES OBTAINED FROM THREE DIFFERENT SURVEY DEVICES IN THE CAVE VETERNICA

Veternica is the 6th longest cave in Croatia with cave channel length totalling 7128 m (http://www.speleologija.hr/popis/index.html, 2014), and is easily accessible from Zagreb, the largest city in Croatia. As a result, there is a great public interest in this cave. The first 380 m of the cave length are open for tourists.

Many studies have been conducted in the cave. One of the recent researches was aimed at gaining detailed information about the history of the cave that could then be incorporated into tourist guides and shared with visitors, such as the nature and timing of major palaeoenvironmental changes associated with an abrupt water level lowering in the karst drainage system of Veternica cave. This information was primarily gathered through an in-depth study of the cave flowstone and shelfstone deposits and their radiometric dating using the U-Th method (Lacković, 2011). Defining of precise height position of the deposits was of crucial importance for the interpretation of the obtained results.

For this purpose, a large number of traverse points were stabilized in the cave. Traversing was done in March 2009 by using “Suunto” compass and clinometer. In 2011, Speleological section of “PDS Velebit” has purchased DistoX "paperless caving" system. To test the accuracy of this equipment, and also to check the results obtained by traversing in the year 2009, we decided to develop a precise traverse using the same points that were used for traversing in 2009 with precise total station Topcon GTS-105N.

The problem was that some of the traverse points were destroyed, so we skipped that points or we set the new ones. Developing a precise traverse was carried out by using total station Topcon 105N with a specified accuracy of measurement of angles 5". The same points have been observed by using the devices DistoX. Declared accuracy of angular measurements for devices DistoX is below 0.5°, if the calibration is performed well. Accuracy of angular measurements for “Suunto” compass and clinometer, which are derived measurements from 2009, is also below 0.5°. Declared length measurement accuracy for all three devices is equal and that is within 3 mm.

From the declared angular accuracy for all three devices, it is evident that the accuracy of a total station is far greater than the other. For this reason it is considered as a measure faultlessly. The comparison is made on the traverse total length of 565.44 m. At this length, traverse from the 2009 had 40 points and traverses made in 2011 consisted of 38 points.

Figure 4 shows the altitude deviations, which were very important for this study. The results showed that the measurement performed using DistoX at the end of traverse deviate by 56 cm, and measurements performed using a compass and clinometer deviate for significant 206 cm.

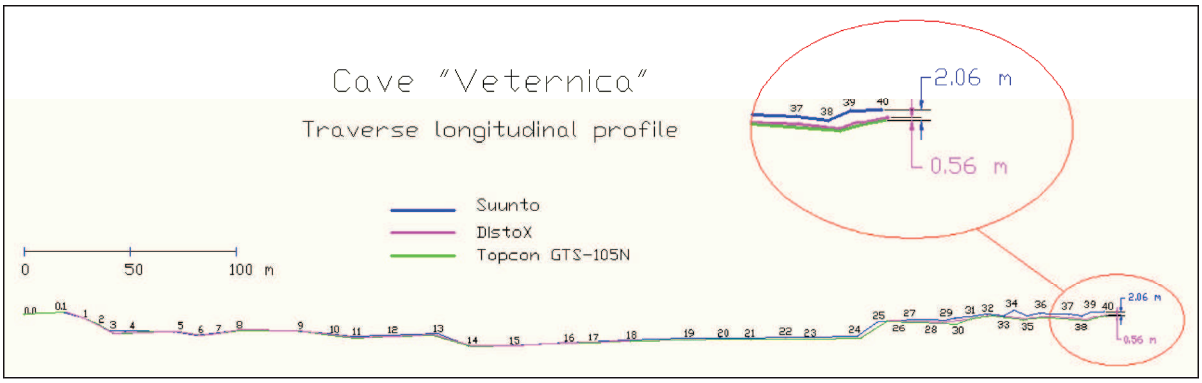

Figure 4 Altitude deviations

Figure 5 shows the traverse positional deviations.

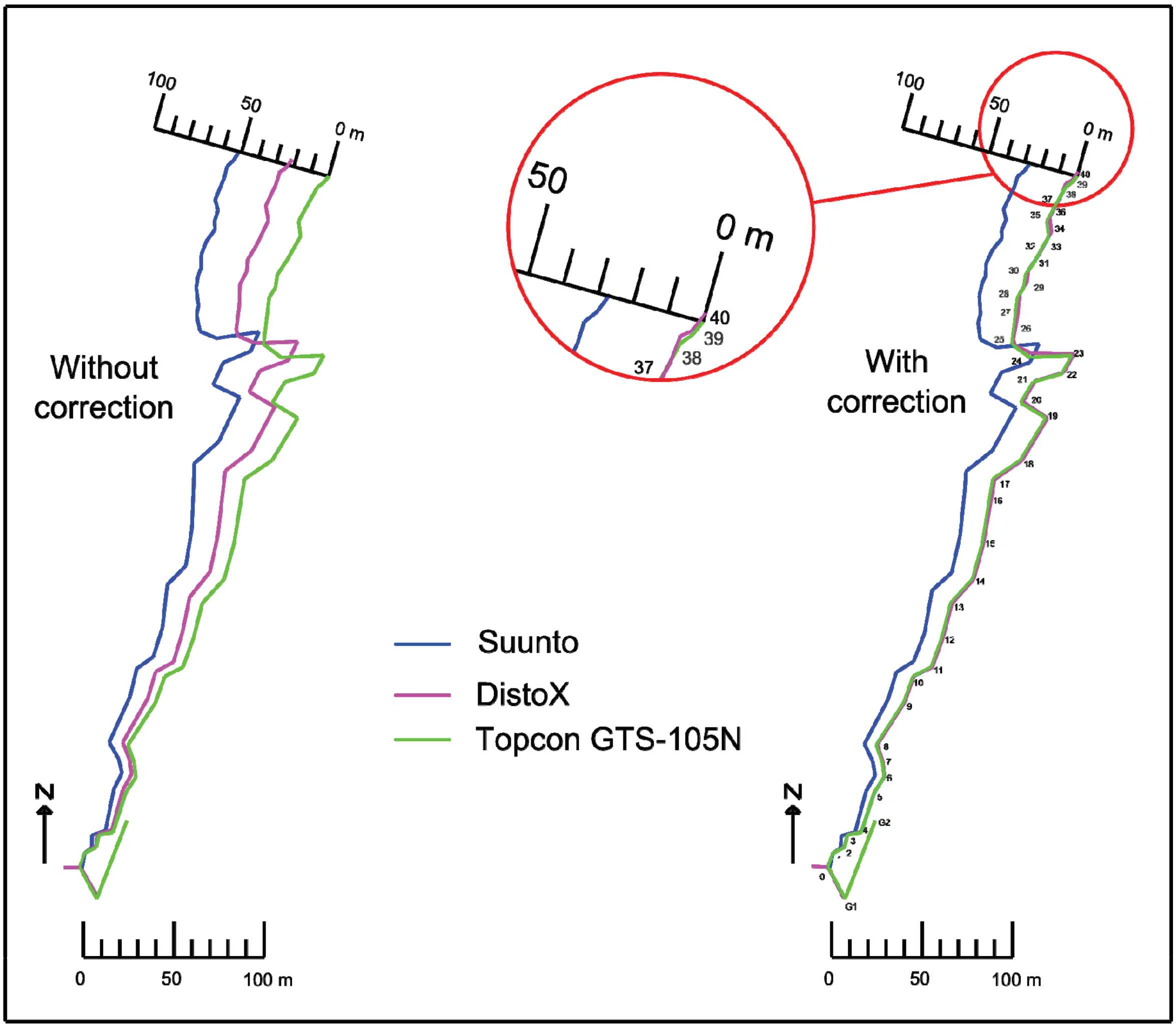

Figure 5 Positional deviations

When comparing positional results, it was necessary to take into account the correction of the measured values for the effect of the magnetic declination. It is very important to correct the measured azimuths influence of the magnetic declination, because ignoring them can have a significant impact on the accuracy of the final results.

The results show that the measurements obtained by using device DistoX achieved better results than when we used a compass and clinometer. Apart from the high accuracy, it is interesting that the price of this method is very economical. Surveying method by using total station demands precise centring and levelling the instrument, which is in many cases difficult to achieve (especially in deep pits). For a survey of this part of the cave using a total station, three people were working on the field for four days, from 8 am to 8 pm. When we were using DistoX device, same job was done in only one day (in five hours) by two people.

4 CONCLUSION

Based on the conducted measurements we can present the advantages and disadvantages of particular instruments and their applications in extremely demanding conditions such as caves. Good side of total station: extremely high accuracy, automated transmission and processing of data. On the other hand, the disadvantages are: high cost, time-consuming process of surveying, bulking (weight and dimensions of the equipment), and this measurement method prevents the survey in extremely difficult areas. Using total station is justified only if the requirements on accuracy are extremely high, and if it is possible regarding the conditions on the field.

Compass and clinometer advantage is that it is cost effective method, lightweight, can operate in harsh environments and requires no battery for operation. The disadvantage is that there is no automation, which extends the work on the field, makes post-processing of data long-term and increases the possibility of error. Effect of magnets on the measurement accuracy of the compass can result in measurement errors.

Benefits for DistoX are: moderate price, solid accuracy, small, lightweight, easy to handle, the overall measuring is faster because we only have one device to handle and it is not necessary to read and write results. Automatic data transfer also eliminates many sources of error. Disadvantage is that it also needs to take care of the fact that interfering objects have a detrimental effect on the determination of the azimuth, and that the batteries are necessary to operate the unit.

From all this we can conclude that the use of DistoX equipment represents a widely applicable cost effective solution regarding accuracy and efficiency of measurement in extremely unfavourable conditions, such as caves.

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