THE FEASIBILITY OF APPLYING AUTOMATIC TARGET RECOGNITION IN TRIGONOMETRIC LEVELLING

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INTRODUCTION

Tacheometers equipped with automatic target recognition are more and more readily used in geodesy, especially where it is necessary to examine periodically and constantly the position of checkpoints on monitored objects. Besides this type of application there are other tasks where the ATR system may contribute to greater accuracy and infallibility of scrutiny. Such an unusual application can be synchronic trigonometric levelling where the applied system enables to eliminate an observer's errors and considerably limit the atmospheric influence on measurement results. The ability to continue observations over a long period of time allows us to average the affect of atmospheric refraction, while automatic measurement gives us a chance to carry out measurements at night when the stability of atmospheric conditions is high and the influence of differential refraction in mutual measurements is close to zero.

The present paper presents a general concept of an automatic measurement system making use of ATR, as well as initial results of measurements carried out on a tested span at Józefosław and some selected spans of a geodynamic testing ground in the Pieniny Mountains.

ATR CONTROLLED MEASUREMENT

Automatic Target Recognition used to automate measurements is a system enabling precise telescope guidance onto the target after some prior rough pointing by an observer. The ATR sensor emits an invisible beam which is bounced off any standard prism (no special active prisms are required) and received by an in-built CCD camera in the telescope. The maximum of a received signal is defined against the camera centre. Horizontal and vertical displacements are next used for automated positioning of the cross hairs of a telescope onto the prism. To shorten the aiming time, the cross hairs are directed onto the prism with an accuracy of $\pm 50^{cc}$ only, in relation to the real prism centre. The final "targeting accuracy" is analytically obtained by introducing into horizontal and vertical cross read-outs a correction resulting from the distance and value of an image displacement of the "signal maximum" in relation to the centre of the CCD matrix.

An average error of automatic targeting with a standard prism is estimated at about $\pm 3^{cc}$ (at a distance of 500m, the accuracy with which the prism centre is defined is $\pm 2^{cc}$) whereas the targeting time ranges from 3 to 4 s. So the targeting accuracy is comparable to that of manual control in a classical instrument. The ATR system enables observations in any atmospheric conditions, also at night, which is especially important for eliminating the influence of refraction.

The measurements presented in this paper were controlled and data gathered by means of a computer and a GeoCOM system, with which Leica TPS 1200 instruments are equipped. GeoCOM is an interface which connects the client (the instrument user, PC applications) with the server (TCP1200 instrument) by means of commands written in the ASCII code. The link can be direct - by means of a cable (instrument – port RS232 or USB) or a Bluetooth interface. “Demands” are sent in to be later “answered” by the instrument. The client has access to, practically, every instrument function. By means of GeoCOM one introduce parameters and constants to the instrument, control measurements (angle, distance, ATR), control servomotors, acquire observation results, etc.

EXPERIMENTS ON THE TEST SPAN AT JÓZEFOSŁAW

The first test to define height differences by automatic trigonometric levelling was carried out in the Astronomic Observatory of the Warsaw University of Technology at Józefosław near Warsaw at the beginning of June 2006. In a 12-hour session nearly 800 mutually synchronic observations of the zenithal distance were made, as well as those of 35 oblique lengths on a span of 430 m.

Two motorized Leica instruments (TCRP 1202 and 1203) were used in the experiment, each placed at a distance of 8 m from benchmarks. Topcon prisms were used as a target of the ATR system, placed directly on the instruments. As previously planned in the observation schedule, measurement control, data storage and processing were fully automated with a specially designed piece of software. Only the span closure on benchmarks was carried out by manual pointing at staffs. The diagram of the whole measurement system is presented in Fig.1.

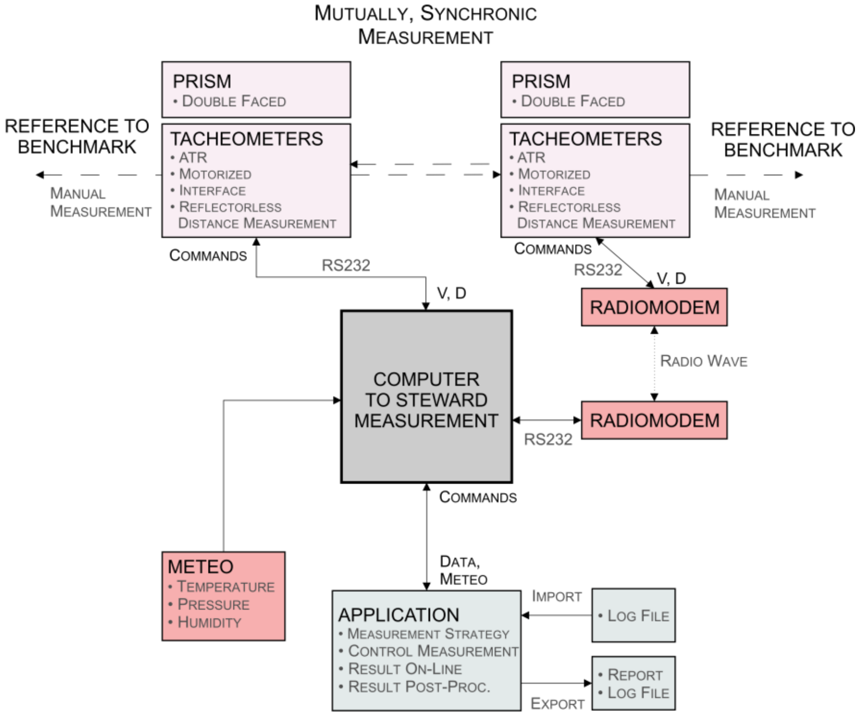


Fig. 1. Measurement system.

The value of observed zenithal lengths on both ends of the tested span was most greatly affected by horizontal atmospheric refraction. Fig. 2 shows the values of mutually synchronic measurements of the vertical angle with instruments A and B. Targeting and measuring accuracy throughout the observation remained at the ±3-5^{cc} level. A much greater change in the zenithal length was caused by atmospheric refraction. Its influence resulted in a change of the observed angles amounting to nearly 70^{cc} throughout the measurement. Analyzing the diagrams of the observed zenithal length, one can note its dramatic increase at c. 10 pm. It was caused by a disturbed refraction value at sunset. It is worth noting the stability of observation after 12 midnight, when the accuracy and certainty of defining the zenithal length value increased with the stability of atmospheric conditions.

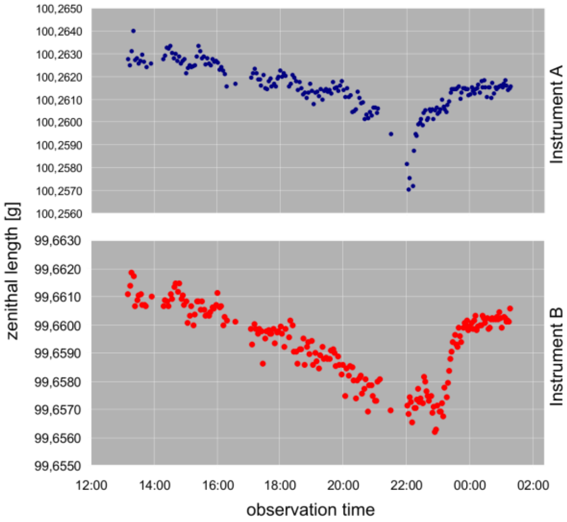


Fig. 2. Mutually, synchronic measurements of the vertical angle, instruments A and B.

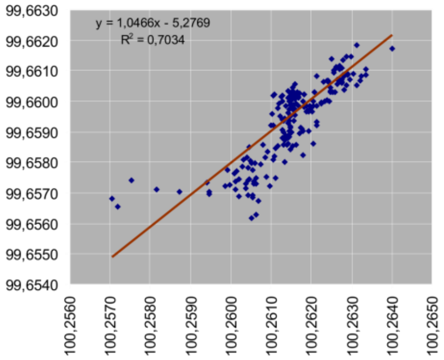


Fig. 3. Correlation mutually observations V, span A-B.

On the diagrams of measured zenithal lengths (Fig.2) one can notice high coherence of observations made from both measured span ends. It is confirmed by the diagram showing the correlation of these observations (Fig.3). The diagram in question presents the zenithal length measured with one instrument as the length function measured with the other. The mutual correlation coefficient was 0.95, which points to high compatibility of mutual observations. The mean values of mutual measurements are presented in Fig.4. It can be noted that atmospheric refraction has not been entirely eliminated. The theoretical value of height difference therein was determined by means of precise geometric levelling.

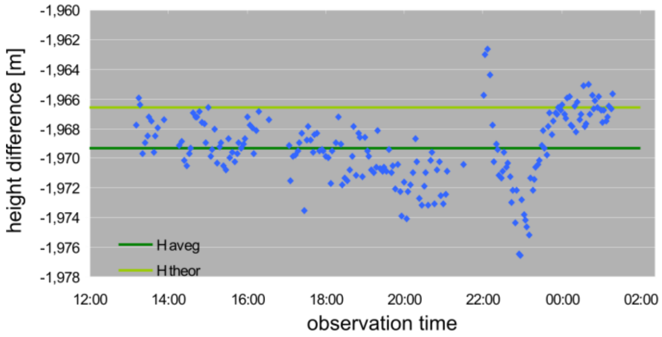


Fig. 4. Mean values of mutual measurements, span A-B.

FIELD TESTS ON A GEODYNAMIC TESTING GROUND

In September 2006, measurements were made of two spans of the geodynamic altimetric network of the Pieniny mountain range: ZAP – K15 and CYP–K11 (Fig.5). Observations were made with two: Leica TCRP 1203 tacheometers. The tacheometers and prisms were placed side by side near the end benchmarks (about 7 m) so that measurements made with both instruments could be considered synchronic and mutual. The zenithal length was measured every 10 minutes in a series of 6 observations (KL-KP-KP-KL-KL-KP) and registered in the instrument memory. Observations on both spans were carried out at night. On span ZAP-K15 there were, in total, 210 observations made during 5 hours (from 6 pm to 11 pm), on span CYP-K11 - 400 observations for over 12 hours (between 8 pm and 8.30 am).

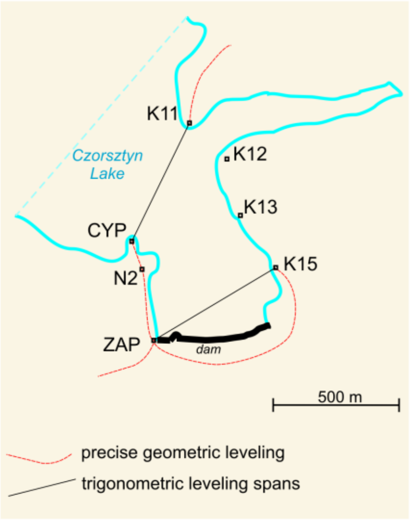


Fig. 5. Geodynamic altimetric network, Pieniny mountain.

Analyzing the measurements results from span CYP-K11, one can notice a relatively small refraction change of angles in relation to the measurements from Józefosław – of only about $\pm 25^{cc}$ throughout the whole experiment (fig.7). However, short-time measurement compatibility for station CYP increased. It could have been caused by specific station conditions: a completely open area close to the reservoir. So situated a station can be especially prone to accidental and momentary disturbances caused by atmospheric refraction.

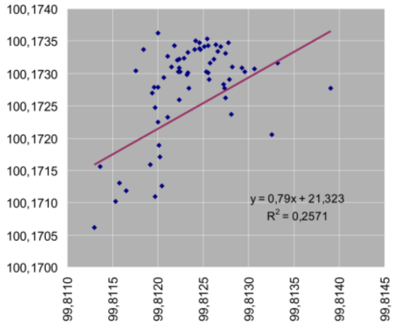


Fig. 6. Correlation mutually observations V, span CYP-K11.

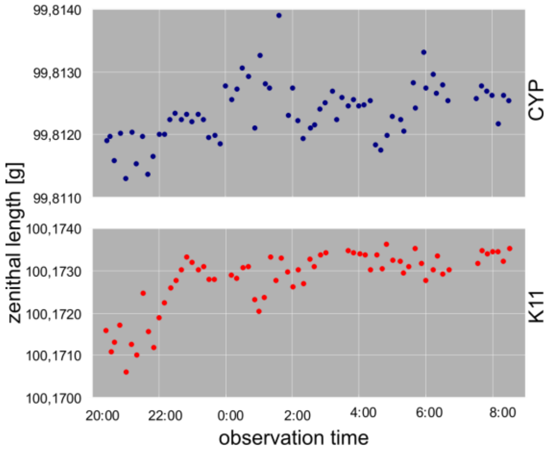


Fig. 7. Mutually, synchronic measurements of the vertical angle, span CYP-K11.

The correlation of mutual synchronic measurements of the zenithal length is at the 0.79 level (Fig.6). Small correlation coefficient and big dispersion of a mean height difference throughout the experiment - of c.11 mm (Fig.8) show that synchronic measurements did not eliminate entirely atmospheric refraction and the influence of fragmentary refraction is considerable.

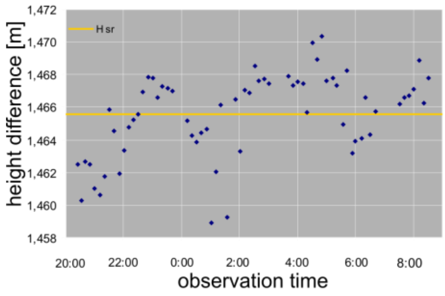


Fig. 8. Mean values of mutual measurements, span CYP-K11.

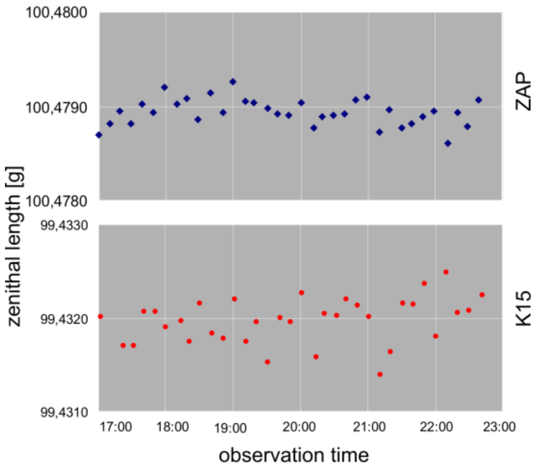


Fig. 9. Mutually, synchronic measurements of the vertical angle, span ZAP-K15.

In the case of span ZAP-K15 stable atmospheric conditions and short measurement time (until 11pm) resulted in the fact that the observed mutual zenithal length was devoid of any significant tendency caused by atmospheric refraction (Fig.9). In the case of the observed vertical angle, targeting and measuring accuracies oscillated around mean values.

No systematic influence of vertical atmospheric refraction on the observed vertical angle values makes the correlation of mutual observations virtually non-existent (Fig.10). Differences of height differences for span ZAP-K15 do not exceed ±5mm (Fig.11).

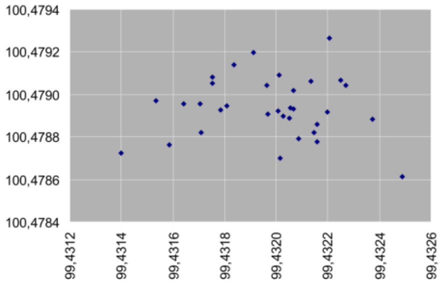


Fig.10. Correlation mutually observations V, span ZAP-K15.

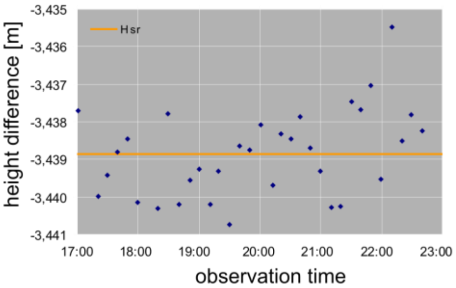
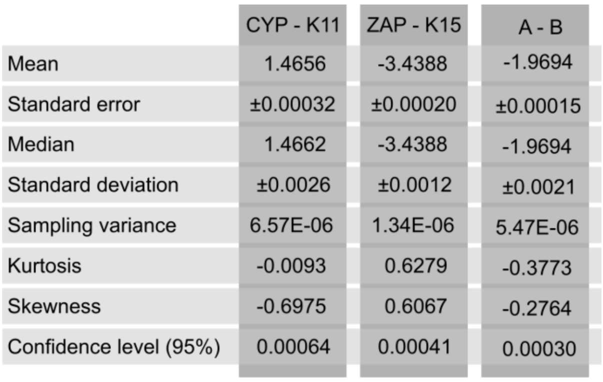


Fig. 11. Mean values of mutual measurements, span ZAP-K15.

SUMMARY

The obtained results of the field experiments fully confirmed the feasibility of applying ATR systems in trigonometric levelling. In the tested span experiment at Józefosław, the value difference of height differences obtained with precise geometric levelling and the mean value of all measurements differed by a mere 2.7 mm, and for midnight measurements – it did not exceed 1 mm. The measurements made in the Pieniny Range were also successful in the case of observation compatibility and limiting the impact of atmospheric refraction on measurement results. Unfortunately, the comparison of the obtained height differences with those of 5 years ago showed considerable discrepancies stemming from benchmark subsiding rather than technological accuracy of trigonometric levelling. To verify this thesis it is planned to repeat trigonometric measurements on the testing ground in the Pieniny and to carry out control measurements by means of precise geometric levelling.

Table 1. Statistical measures of height differences.



	CYP - K11	ZAP - K15	A - B
Mean	1.4656	-3.4388	-1.9694
Standard error	±0.00032	±0.00020	±0.00015
Median	1.4662	-3.4388	-1.9694
Standard deviation	±0.0026	±0.0012	±0.0021
Sampling variance	6.57E-06	1.34E-06	5.47E-06
Kurtosis	-0.0093	0.6279	-0.3773
Skewness	-0.6975	0.6067	-0.2764
Confidence level (95%)	0.00064	0.00041	0.00030

Summing up, one can note that the use of tacheometers along with ATR enables to automate measurements and related quasi-continuous observations. These traits enable moreover:

- to increase the number of observations, and what follows, increase accuracy and reliability of the zenithal length determined,
- to average measurements made over a long period, which enables to undermine the influence of atmospheric refraction on the value of height difference measured,
- to make observations in different atmospheric conditions, including nighttime when the atmosphere is stable,

- **to eliminate personal errors of the observer,**
- **to analyze conducted observations in real time.**

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