Automatic Earth Tides Observation System in Astrogeodetic Observatory in Józefosław

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SUMMARY

During this project the main goal was to develop and establish a complex solution that would allow us to automatically collect data from the LaCoste&Romberg model D gravity meter. We needed suitable software that processes, visualizes and stores data streams from an analog-to-digital converter connected directly to the meter. Furthermore, to remotely control the system and perform maintenance, we decided to use a stepper motor and a webcam that constantly displays the meter with its nearest neighbourhood.

The main part of the developed system is the software – a freeware program 'Auto L&R' written using Borland Delphi 7.0 Personal compiler. It mainly performs data capturing and storage but also draws graphs showing current survey status and allows the user to control and change basic parameters of the gravity meter. To avoid systematic time errors during the survey, a program that repeatedly updates the system clock is being used. Remote control over the system via network connection is achieved by an accompanying program WinVNC.

The hardware part of the system contains the gravity meter, the Advantech PCL-818L analog-to-digital PC card converter, Sanyo-Denki stepper motor with its steering device and Creative WebCam Live! camera.

The system developed during this project allows the user to constantly observe gravity changes in time. It also helps to control the survey correctness and, if the survey results appear to be incorrect, to change the input settings.

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1. INTRODUCTION

The main goal of this project was to develop a complex system that would allow us to automatically collect survey data from LaCoste&Romberg model D gravity meter in Astrogeodetic Observatory in Józefosław. We assumed that suitable software that processes, visualizes and stores data streams from an analog-to-digital converter connected directly to the meter would fulfill our goal. Additionally, to remotely control the device, we decided to use a stepper motor with a camera that would show us the preview of the meter.

Such a system should allow the user to conduct observation of temporal gravitational variability along with basic control of the results and ability to correct the input settings.

2. BRINGING UP THE SYSTEM

2.1 Data collection

We used Borland Delphi 7.0 Personal programmers' environment to compile the software for collecting and visualizing gravimetric observations.

The Advantech PCL-818L analog-to-digital PC card is responsible for transforming the signal from the meter to the computer. Of course to work properly, such a card needs to be programmed, and that is where drivers and sample programs provided by the producer became very helpful. In its final version the program AutoL&R provides the ability to choose any PC card converter installed on the computer, its input channel (PCL-818L has 16 channels), voltage input range, observations frequency and the buffer size. All these settings are accessible right after the program starts (fig. 1).

Fig. 1. Settings screen in AutoL&R 'A/D Card Settings' section.

The next challenging task was to preserve equal time intervals between data reads from the gravity meter. A standard Delphi component – Timer – was too limited because it doesn't have the ability to be controlled from outside the operating system. In this case we had to use an additional program – NetDate – which updates the system clock in defined time intervals.

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The up-to-date system clock is being checked by the Timer component to enable equal observation intervals.

Although AutoL&R is prepared to work with various observation frequencies and buffer sizes it works best with 5Hz frequency and buffer that stores 10 last reads. With these settings the 10-reads series is being repeated 15 times per minute in the following schema

$$\ldots \rightarrow 10 \text{ reads (2sec.)} \rightarrow 2\text{sec. break} \rightarrow \ldots$$

The break mentioned above allows the program to save the data stored in the buffer, empty it and visualize another portion of collected data.

The observations are stored in two files: daily and annual. They are collected for each minute as a moving average of 5-minutes time series.

The Settings section of AutoL&R also allows the user to input geodetic coordinates (φ, λ, H) that are used to calculate the theoretic Earth Tides correction. Also the values of the voltmeter's constant and micrometer's counter can be typed there. They are being used to recalculate the values collected in Volts to m/s^2.

2.2 Visualizing observations

Based on the collected data our program illustrates the observations with 2-D plots updated at the end of each series. The first plot shows an average of each 4-sec series (thin red line) and also the 5-min moving average (thick green line) – fig. 2.
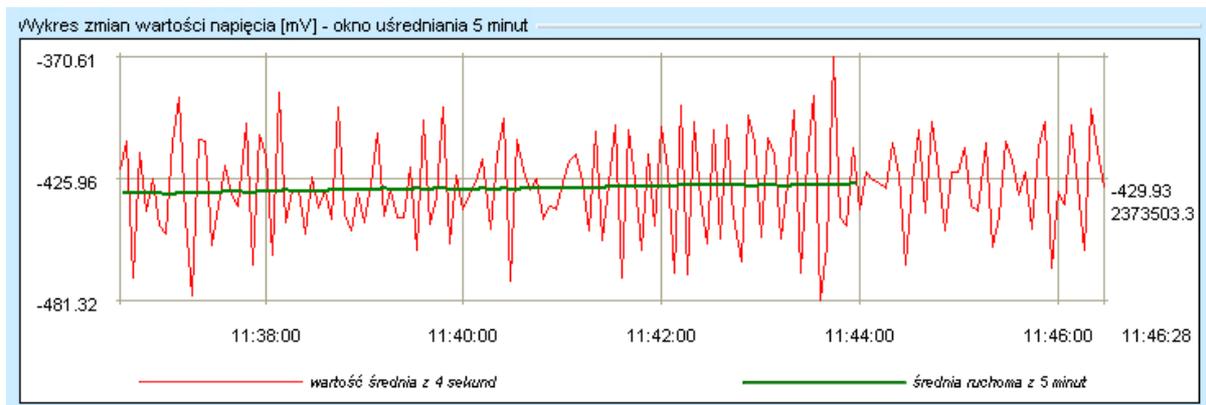

Fig. 2. Gravimetric observations from last 10 minutes.

The second plot that shows last 2 days of observations enables the real-time control of correctness of the collected data. Here the average data are illustrated as above, and the theoretic tidal correction – with thin violet line (fig. 3).
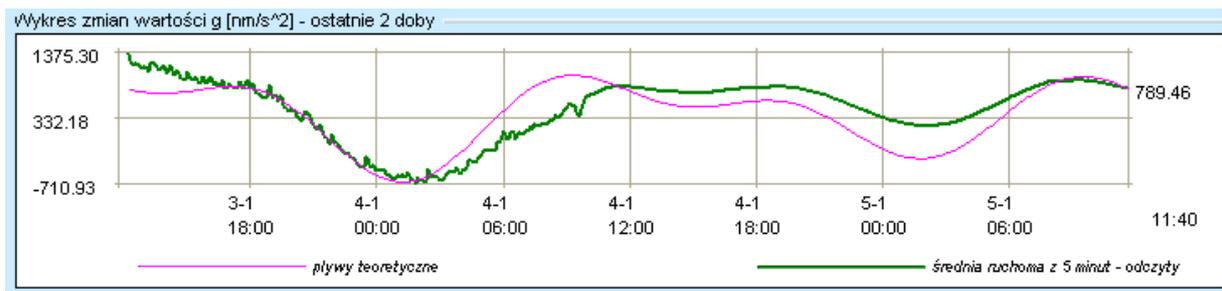
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Fig. 3. Gravimetric observation from 2-days period.

2.3 Remote control of the meter

To eliminate costly and long-lasting trips to the meter in order to manually control its parameters, the developed system should enable remote control of the measuring device. The responsible module consists of:

- Creative WebCam Live! camera,
- Sanyo-Denki TYPE 103-590-0211 stepper motor (0.9 °/step),
- hardware driver based on ULN2803 darlington array,
- light source for the camera,
- steering and power cables and ports,
- LPT port software driver.

The camera is used to show the actual view of the meter's counters and other settings. The obtained screen resolution (640x480) and the ability to focus the camera properly close to the presented object (even 10cm), makes it sufficient enough to fulfill this task.

While the camera shows the view of the micrometer, stepper motor enables the user to rotate it as much as needed. A stepper motor is an electro-mechanical device that converts discrete electric signals to rotation proportional to the number of them. One of the most important advantages of a stepper motor is that no systematical errors are included in rotation. This means that rotation error is not proportional to the rotation itself. Another important thing is that when you know the initial position of the rotor, you only have to count the input electric signals in order to determine the new position. The most important disadvantage of stepper motors is their ability to vibrate significantly, especially during low-speed turns. The motor used in this project is unipolar (fig. 4) which made it much easier to build the hardware driver which controls the device. Also its resolution (0.9 °/step) combined with half-step (interleaved) driving enables the user to position LaCoste&Romberg's micrometer with high enough precision (1/800 of the full turn).
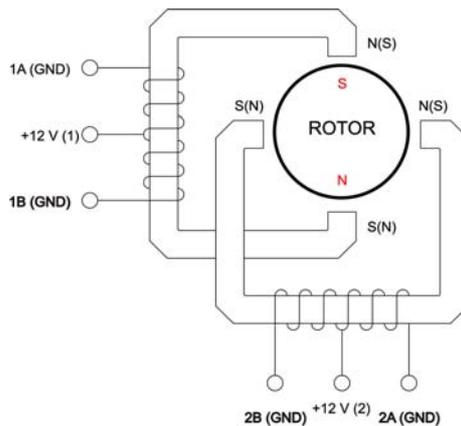
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Fig. 4. Unipolar stepper motor schema.

One can manipulate the motor using standard TTL signals interpreted by the LPT port of the PC. The port itself provides sufficient voltage for some stepper motors but without the hardware driver such as ULN2803 it would be dangerous to the PC to conduct such an intense current through LPT. That is why the additional +12V DC line is provided.

Using the Settings screen in AutoL&R one can access the Meter Preview section where user remotely controls the stepper motor and reads the actual value of micrometer (fig. 5). A special Delphi component was used to control the camera and change the video stream settings. Each time the user tries to access the Preview screen a 12Cd diode is being switched on (switched off on exit). In this module there are two ways to control the stepper motor:
-   coarse, with three possible turning speeds,
-   precise, which requires earlier calibration and allows the micrometer to rotate to any chosen position.
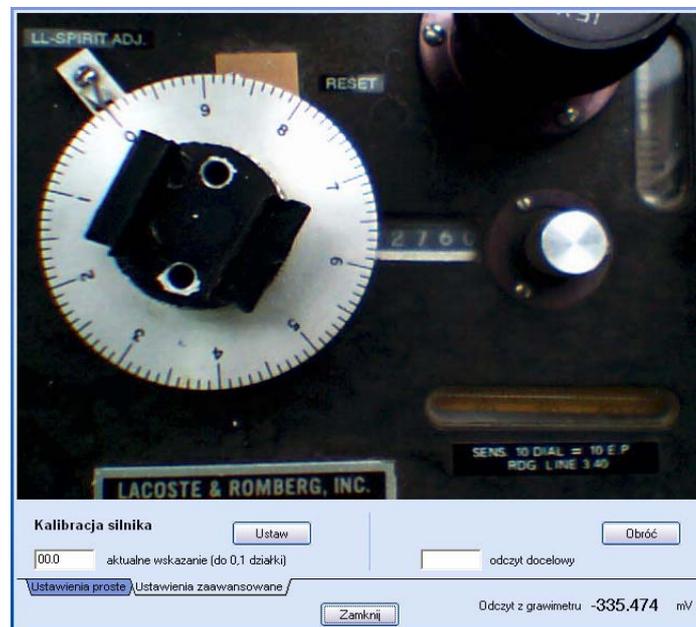

Fig. 5. Meter Preview module in AutoL&R

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The ability to fully remotely control the data collection process via Internet is possible due to use of WinVNC application.

3. CONCLUSION

Almost a year-long work on this project led to development of the complete Earth tides observation system in Astrogeodetic Observatory in Józefosław. It should significantly minimize the amount of time and money needed to conduct long-lasting gravity surveys, partially eliminating the need to directly control the survey process.

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