SOFTWARE DEVELOPMENT FOR GEODETIC TOTAL STATIONS IN MATLAB®

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Abstract

Geodetic total stations are electronic measuring devices for determination of spatial position of points. Thanks to development of automation, good exploitation have not only in mapping works and cadaster, but in structural monitoring and industrial measurements, also. Robotics of total stations able good possibilities for dynamic measurements of moving objects. Total stations have integrated software applications for basic and commonly used works in geodesy and industry. Robotic total stations allow development of another software for management of specific measuring processes.

The paper is focused on development of software applications for automation of dynamic geodetic measurements for indoor navigation and for industrial and structural monitoring use. We use standard programming protocol Leica GeoCOM, which includes instructions for automation of measurement processes by Leica Geosystems total stations. Software development is provided in MATLAB®.

Presented software is used for determination the trajectory of a moving object by dynamic measurements of robotic total station Leica TS30. Software can determine spatial position of moving object in real time with maximum frequency up to 10 Hz. Accuracy of the spatial position determination by dynamic measurements is at the level of 1 mm. Communication of the total station and a control computer is realized by RS232 and TCP-IP interface. Software has integrated graphic user interface for intuitive control.

1 Introduction

Possibilities of MATLAB® functionalities in programming of measuring devices are extremely wide. MATLAB® offers a wide range of tools for user software designing focused on device management with wide support of communication interfaces. Possibilities of programming are restricted only by range of manufacturer's user software support for machine control.

Measurement devices of Leica Geosystems have integrated relatively wide support for development common software solutions for measurement control and data analysis. Different types of measurement technologies have developed communication protocols for programming of user software solutions. Therefore, geodetic measurement devices can be used for automation of processes in area of spatial position determination.

The paper is focused on development of software solution for management of dynamic measurements by total stations Leica TS30. This solution can be used for many different types of applications in area of engineering surveying. The software application is developed in MATLAB®.

2 Total stations

Total stations are geodetic measuring devices for measurement horizontal angles, vertical angles and measurement of distances. Based on these variables we can determine spatial position of total station and measured points in the surrounding referenced to specified reference local coordinate system. Total stations are based on construction of theodolites. The difference stays in automation of measurement of variables [1].

Application areas of total stations are very wide. They can be used in many areas where we need to determine spatial position of objects with high precision:

- indoor and outdoor navigation,
- geodesy and cadaster,
- staking out the structures (civil engineering),
- deformation monitoring of structures,
- precise measurement the geometry of products in mechanical engineering, etc.

Angle measurements are the most important areas of total station use. They able to measure horizontal and vertical angles with high accuracy. The high accuracy of total station is at the level of 0.5“. Measurement principle is based on optical-electronic sensing using special coded goniometers which are integrated in devices.

Other important measuring parameter is distance. Distance measurement is based on electronic principle. Generally are used two methods - phase or impulsive distance measurement. Phase distance measurements are based on phase difference measurements of transmitted and reflected signal. The measuring signal is distributed in microwave or infrared frequency band. Impulsive distance measurement is based on principle of time correlation measurement of difference in transmitting and receiving of reflected signal. Measurement can be realized on points stabilized by special prism reflectors or object cannot be signalized (non-prism or any contact measurement).

Based on measured angles and distances we can calculate spatial position of points by trigonometric formulas. Spatial position of points we can determine by spatial coordinates in common reference cartesian coordinate system.

Recently, automation in measurement technologies allows to partially or fully automate the measurement process by total stations. Supported communication protocols developed by manufacturers of total stations able the development of common user software.

3 Total station Leica TS30

Total station Leica TS30 is the flagship of Leica Geosystems AG in area of precise geodetic measurement technologies (Fig. 1) [2]. Area of use is focused on precise measurements in engineering surveying, industrial surveying and structural health monitoring of engineering structures where the millimeter or sub-millimeter accuracy is required. Station has integrated different technologies which able fully automation of measurement process.

Figure 1: Total station Leica TS30 [2]

Station is fully automated what means automated turning to defined direction and automated tracking of defined moving object signalized by special prism reflector. Target tracking can be measured on the frequency level up to 10 Hz. Table 1 describes main parameters of total station accuracy.

TABLE 1: SELECTED ACCURACY PARAMETRES OF TOTAL STATION LEICA TS30 [2]

Angle measurements	0.5”
Accuracy of Automated Target Recognition	1”
Distance measurement	
Precise mode	0.6 mm + 1 ppm
Standard mode	1 mm + 1 ppm
Tracking/SynchroTrack mode	3 mm + 1 ppm

Measurement of horizontal and vertical angles is realized using glass code goniometers and four sensors for sensing of an angle value. Sensor consists of source of light (LED diode), system of prisms for light beam aligning and line sensor for sensing of light signal. The code is placed on glass goniometers shaped by concentric circles. LED diode transmits light signal pass through code glass and are sensed by line sensor. Information about intensity of light signal is transformed to angle value. Angle can be measuring on the frequency level up to 5 kHz what increases the reliability in angle determination [3].

Motorization is based on piezoelectric principle where electric energy is transformed to motion. Motion units of horizontal and vertical moving parts are based on firmly placed two diametric piezoelectric ceramic members and rotating ceramic circle. Diametric placed ceramic members are alternately polarized and rotate ceramic circle in defined direction. Motion units are based on piezoelectric principle and able to achieve high speed of rotation and acceleration of rotational members at the low level of power consumption [3].

Automated targeting of a total station is realized by function ATR (Automated Target Recognition), which identifies prism reflector by image sensor. Identification is realized by CMOS sensor. View of center of prism is represented by rectangular coordinates of CMOS sensor and these values are transformed to angle deviation for defined turning of total station [3].

Based on position of prism center on CMOS sensor is determined horizontal and vertical deviation from optical axis of telescope. These deviations are used for turning of telescope to center of prism. Process is realized iteratively up to minimum deviation at the level 50”, when the software calculate final angle value. Searching of prism is realized by function PowerSearch which works by laser beam [3].

4 Communication protocol for Leica TS30 control

Programming user applications for measurement control can be realized using communication protocol Leica GeoCOM what is licensed and multiplatform protocol for development of software for Leica TPS 1200 total stations. The basic principle is based on Remote Procedure Call (RPC) protocol, which was developed by SUN Microsystems.

Communication protocol is based on data exchange between two participants:

- client (external device),
- server (total station).

The medium of communication is a serial communication line. The client sends a request to the server and server evaluate the request and sends a reply back to the client. Protocol is designed for synchronous communication. That means, a request and reply pair cannot be interrupted by another request and reply pair (Fig. 2).

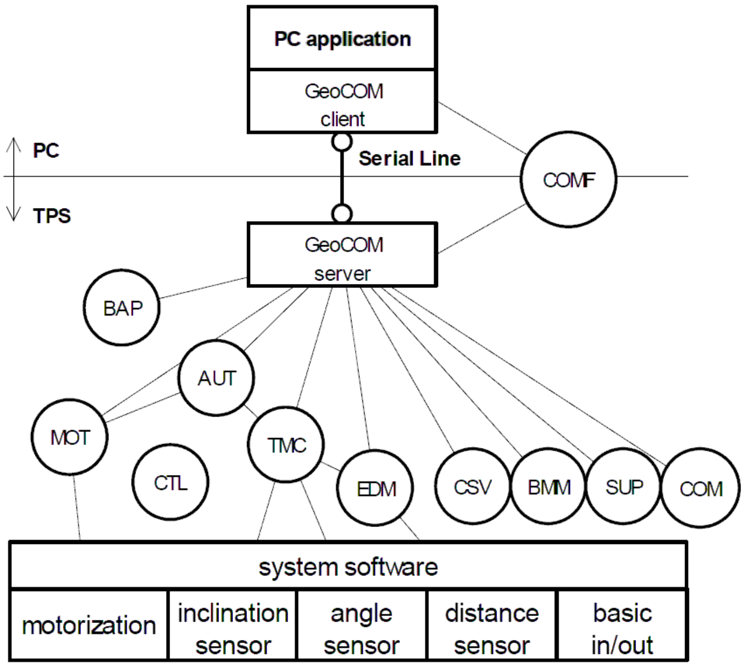

Figure 2: Client/Server application [4]

Protocol contains several subsystems of functions for client/server communication:

- automatisation and motorization functions for using functions for automatisation of measurement by total station,
- basic functions for measurements,
- basic input and output functions,
- communication settings,
- functions for getting and setting parameters of total station,
- functions for distance measurements,
- data transfer functions,
- calculation functions to processing of basic measurements.

Leica GeoCOM protocol supports programming in several language platforms:

- C/C++ language,
- Visual Basic,
- ASCII protocol.

Each programming language has defined standard procedures which can be integrated in developing software. For development of software in MATLAB® is optimal solution using ASCII protocol. Package of procedures contains defined text commands of request and reply values [4].

5 Software for dynamic measurements by total station Leica TS30

Software products for measurement control using total stations have several disadvantages. The most important disadvantage is absence of functions for dynamic measurements by total stations. Range of functions integrated in application allows use for different purposes:

- determination of trajectory of moving objects,
- navigation of objects in indoor and outdoor environment,
- dynamic deformation monitoring of the engineering structures [5].

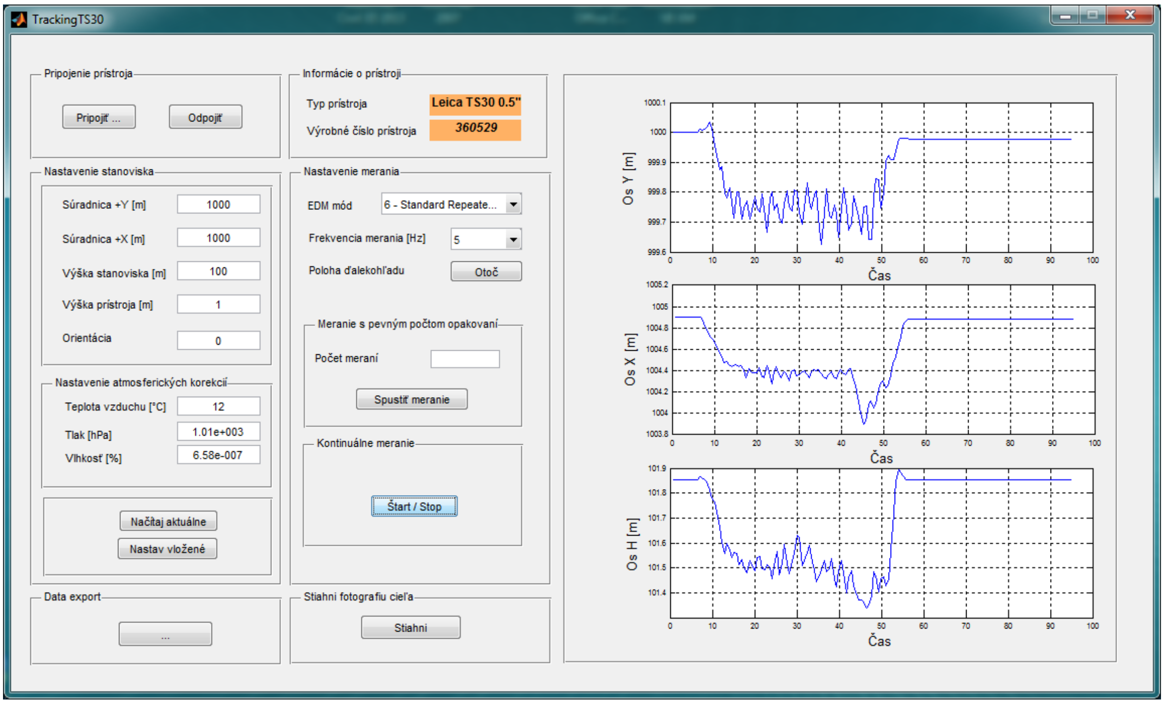

Figure 3: Graphic User Interface of software

Software application was developed in MATLAB® and has built graphic user interface. Application communicates with total station Leica TS30 using RS232 and TCP-IP interface. These interfaces allow to connect a total station remotely or locally according to requirements of user. Communication parameters is necessary to set before connection by editing of settings (COM port or IP address).

After connection the device we can see in part "Information about device" („Informácie o prístroji") general information about device (type and serial number of device). Setting the station parameters and coordinate system is realized in section "Setting the station" („Nastavenie stanoviska"). In this part we can load current station parameters setting in device memory or we can set them manually and write to device. There can be set spatial (3D) coordinates (X, Y and Z) of station, station height and angles orientation. In the part "Setting the atmospheric corrections" ("Nastavenie atmosférických korekcií") we can set weather parameters (air temperature, air pressure and relative air humidity) for correction of measured distances.

In part "Measurement settings" („Nastavenie merania") is possible to define mode of distance measurement. Default setting is Tracking mode of measurement which can measure angles and distances continuously on moving object. Frequency of measurements can be set by the tool "Measurement frequency" („Frekvencia merania"). Maximum frequency for dynamic measurement can be set at the level of 10 Hz. In real application the frequency has variable behavior from 3 Hz to 10 Hz. Measurements can be realized by two modes. The first one is measurement with defined finite number of measurements where the measurement process is stopped after realized number measurements. In other mode we can realize continuous measurement when we start and finish the measurement manually.

Software visualize measured spatial position of moving object in real time. Measured data can be exported to defined data formats. Default export data format is using for dynamic analysis of deformation using software Lomb, which was developed at the Department of Surveying (Slovak University of Technology in Bratislava) [5] and [6].

6 Conclusions and future work

Software solution was integrated into the system for indoor navigation developed at the Department of Surveying. The main role of total station in combination with this software is verification of quality of spatial position determination by using technologies.

Other application is integration to automated measurement system for structural health monitoring of Bridge of Slovak National Uprising in Bratislava. Software continuously realize the dynamic monitoring of selected points ate the bridge. Measurement control is managed from the master server installed at the Department of Surveying.

MATLAB® is optimal system for development the applications for control of total stations. The reason is relatively simple user interface, wide range of implemented preprogrammed functions and support of communication interfaces.

For the future work is planned extension of software for integration of other functions Leica GeoCOM protocol, extension of functions for powerful data visualization of spatial trajectory of moving objects and development of other solutions for different types of measurements in the area of engineering surveying, surveying in industry and navigation in indoor environment.

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