Ulyxes: an open source project for automation in engineering surveying

Ulyxes is an open source project to drive robotic total stations as well as other sensors, collect their measurements in database and finally publish the results for authorized users on the web. On special requests the results are also presented with web based maps in the background. This project is like an instant coffee: three in one (coffee, sugar and milk). The coffee and the strongest part is the research and coding. The sugar is the application of the program in industrial environment and the milk on the top is the educational usage. The software development started in 2008 connected to a monitoring task in the Hungarian Nuclear Power Plant. Since then the development has been extended from total stations to different positioning capable sensors. In 2012 the development of a new Python based object oriented framework started. The code is based on the results of some other open source projects, Python, PySerial, GNUGama, SQLite, OpenCV, etc. After connecting to the international Geo4All network in 2014, Ulyxes became a project of our Geo4All Lab. The project has its own home page (http://www.agt.bme.hu/ulyxes) and the source code is available on the GitHub portal (https://github.com/zsiki/ulyxes). The code is maintained by the colleagues at the Department of Geodesy and Surveying at the Budapest University of Technology, volunteers from all over the World are welcome. BSc and MSc students are also involved in the development and testing. More theses were connected to this project in the recent five years. In the curriculum of an MSc subject called Surveying Automation, Ulyxes is used to demonstrate automatized tasks in engineering surveying. The system has been applied for several projects during the last 10+ years. Typical applications are the load tests of bridges and other engineering structures and on the other hand Ulyxes can be used to monitor the movements of buildings in the nearby of constructional works, like metro stations, underground garage and other buildings as well. Raspberry Pi small, single board computers are used with Raspbian operating system during on-site works.

The source code is divided into three parts. The first one is the Ulyxes API which is the core of the system. The second one, Ulyxes Apps is a collection of applications based upon the API. Some of them were developed by our students. The third part is the server side scripts to publish observation results through the Internet. Moreover it is also planned to implement SOS standard using IstSOS. Our Geo4All Lab maintains another open source software, called GeoEasy to process observation data in engineering and land surveying. A closer cooperation is also planned between our two open source projects. In this paper the most important features of Ulyxes will be presented with examples, an actual monitoring project in Budapest and test loads of bridges and overpasses.

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Ulyxes: an open source project for automation in engineering surveying

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ABSTRACT

Ulyxes is an open source project (http://www.agt.bme.hu/ulyxes/) to drive robotic total stations as well as other sensors, collect their measurements in database and finally publish the results for authorized users on the web. On special requests the results are also presented with web based maps in the background. This project is like an instant coffee: three in one (coffee, sugar and milk). The coffee and the strongest part is the research and coding. The sugar is the application of the program in industrial environment and the milk on the top is the educational usage.
The software development started in 2008 connected to a monitoring task in the Hungarian Nuclear Power Plant. Since then the development has been extended from total stations to different positioning capable sensors. In 2012 the development of a new Python based object oriented framework started. The code is based on the results of some other open source projects, Python, PySerial, GNUGama, SQLite, OpenCV, etc. After connecting to the international Geo4All network in 2014, Ulyxes became a project of our Geo4All Lab (http://www.agt.bme.hu/osgeolab /index.php?page=start&lang=en).
The project has its own home page (http://www.agt.bme.hu/ulyxes) and the source code is available on the GitHub portal (https://github.com/zsiki/ulyxes). The code is maintained by the colleagues at the Department of Geodesy and Surveying at the Budapest University of Technology, volunteers from all over the World are welcome. BSc and MSc students are also involved in the development and testing. More diploma works were connected to this project in the recent five years. In the curricula an MSc subject called Surveying Automation, Ulyxes is used to demonstrate automatized tasks in engineering surveying. The system has been applied for several projects during the last 10+ years. Typical applications are the load tests of bridges and other engineering structures and on the other hand Ulyxes can be used to monitor the movements of buildings in the nearby of constructional works, like metro stations, underground garage and other buildings as well. Raspberry Pi Grimmett (2014) small, single board computers are used with Raspbian operating system during on-site works.
The source code is divided into three parts. The first one is the Ulyxes API which is the core of the system. The second one, Ulyxes Apps is a collection of applications based upon the API. Some of them were developed by our students. The third part is the server side scripts to publish observation results through the Internet. This part is unfortunately the weakest one of the project. Most of the new developments should be carried on here. Moreover it is also planned to implement SOS standard using IstSOS. Our Geo4All Lab maintains another open source software, called GeoEasy (https://github.com/zsiki/GeoEasy) to process observation data in engineering and land surveying. A closer cooperation is also planned between our two open source projects.
In this paper the most important features of Ulyxes will be presented with examples, an actual monitoring project in Budapest and test loads of bridges and overpasses.

INTRODUCTION TO ULYXES

Ulyxes is an open source project (http://www.agt.bme.hu/ulyxes/) to drive robotic total stations as well as other sensors, collect their measurements in database and finally publish the results for authorized users on the web. On special requests the results are also presented with web based maps in the background.

This project is like an instant coffee: three in one (coffee, sugar and milk). The coffee (the strongest part) is the research and coding. The sugar is the application of the program in industrial environment and the milk on the top is the educational usage.

The software development started in 2008 connected to a monitoring task in the Hungarian Nuclear Power Plant. Since then the development has been extended from total stations to different positioning capable sensors (Hillar, 2016). In 2012 the development of a new Python based object oriented framework started. The code is based on the results of some other open source projects, Python, PySerial, GNUGama, SQLite, OpenCV, etc. After connecting to the international Geo4All network in 2014, Ulyxes became a project of our Geo4All Lab (http://www.agt.bme.hu/osgeolab /index.php?page=start&lang=en).

The project has its own home page (http://www.agt.bme.hu/ulyxes) and the source code is available on the GitHub portal (https://github.com/zsiki/ulyxes). The code is maintained by the colleagues at the Department of Geodesy and Surveying at the Budapest University of Technology and Economics, volunteers from all over the World are welcome.

METHODS

The source code is divided into three parts. The first one is the Ulyxes API which is the core object library of the system. This is useful only for programmers. The second one, Ulyxes Applications is a collection of useful standalone applications based upon the API. Some of them were developed by our students. The third part is the server and client side scripts to publish observation results through the Internet. There is a sample web application on the Ulyxes home page to demonstrate the publication of the coordinate data stored in relational database. The backend is a PostgreSQL/PostGIS database, the middleware is written in PHP, on the client side JavaScript functions are running based on jQuery and jQueryUI. AJAX technology is used to connect the middleware to the client side. Data are sent from the server to the clients in JSON format.

The API is a collection of Python classes, on the top there are the sensor classes, each sensor class contains a communication interface, a measure unit and an optional writer instance (Figure 1). The task of the communication interface is to send commands to the physical sensor and to receive the answer. Different interface classes can be plugged into a sensor object, e.g. serial communication or i2c. The measure unit is responsible to build the sensor specific native command and to parse and interpret the answer from the sensor (Figure 2).

The Ulyxes Applications demonstrate the usage of the API. Most of them are useful for end users. The most complex application is called RobotPlus, it realizes the on-site part of a monitoring system based on robotic total stations. It integrates four other Ulyxes applications/classes (FileGen, BlindOrientation, Robot and FreeStation) and an external open source application, called GNU Gama (Cepek, 2002). The monitoring process is driven by a JSON configuration file where several parameters can be set. The RobotPlus application is started as a cron job and the configuration file is loaded before each observation circle. It makes easy to change the configuration on a running system. The application can handle control points and monitoring points. The control points are supposed not moving and are used to check the stability of the station position. The monitoring points are on the structures to check. Points are marked by prisms.

The monitoring process has the following sequence of operations:

- load JSON configuration,
- get meteorological data for EDM corrections,
- load coordinates of the points (both control and monitoring points and the station),
- generate direction (bearing and zenith angle) and distance to the points from the station,
- orient the station (preliminary orientation is made),
- make observations for the control points,
- calculate free station from the observation with blunder detection using GNU Gama,
- set station coordinates and orientation,
- make observations for the monitoring points,

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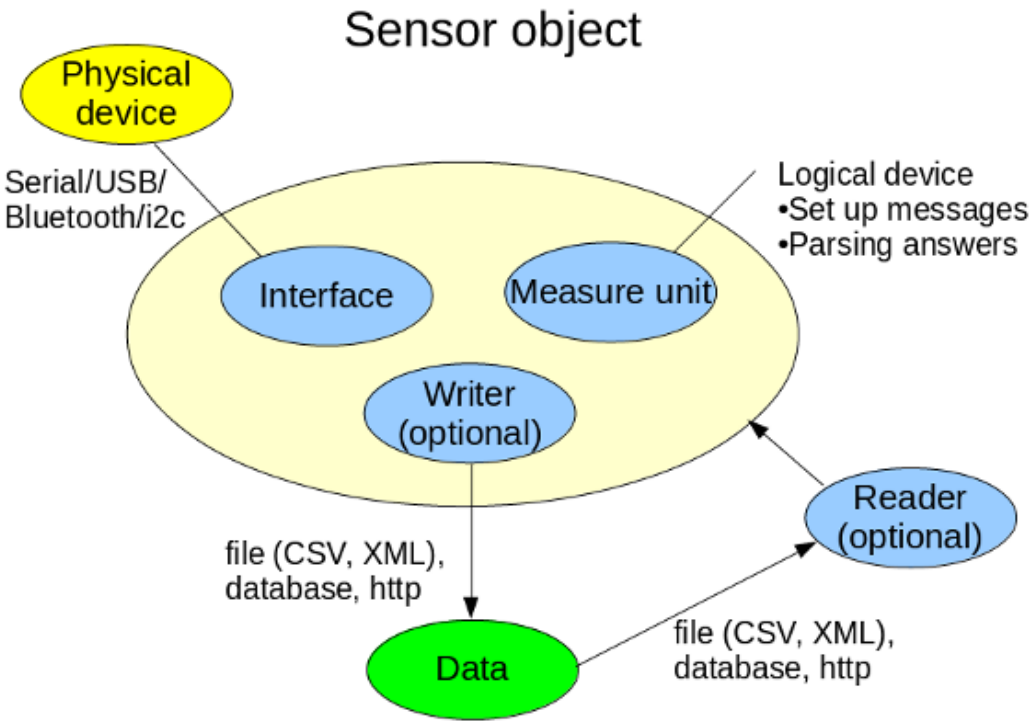

Figure 1. Logical components of an Ulyxes sensor object

- save observations/coordinates.

During the process a log file is written, the log level (DEBUG, INFO, WARNING, ERROR) can be set in the configuration.

RESULTS

The system has been applied to several projects during the last 10+ years. Typical applications are the load tests of bridges and other engineering structures(Berberan et al., 2007) and on the other hand Ulyxes can be used to monitor the movements of buildings in the nearby of constructional works, like metro stations, underground garage and other buildings as well. A monitoring process was made more than ten months long during the building of an underground garage in Budapest. Two Leica TCA 1800 instruments were set up with Raspberry Pi 3 computers (Raspbian operating system) and mobile internet (Figure 3). The observations were made in every two hour from 2017 September to 2018. Our department worked in a consortium with Hungeod Ltd.

Meteorological sensors were not installed on the field, instead the API of openweathermap.org was used to get temperature, air pressure and humidity for Budapest. As the measured distances were below 100 meters the small differences between the real and the openweathermap.org data cause few tenth of millimeters differences in the meteorological corrections of the distances.

The collected data were stored in an SQLite database on the Raspberry Pi, separately for the two stations and were uploaded to the common central database through the mobile Internet connection. Besides the coordinates, angle and distance observations, the meteorological data and some other information are stored in the database, e.g. the mean error of the free station calculations and maximal inclination angle of the standing axis of the instrument. Charts are generated from the data in the database (Figure 4).

For the static part of test loads of bridges and overpasses Ulyxes is used in a similar way as in building monitoring (Lienhart, 2017), but the period is much shorter. In this case the advantages of the automation are the shorter observation time and the faster on site result generalization using few SQL scripts. In case of dynamic test loads the observed movement lasts few seconds, therefore Ulyxes

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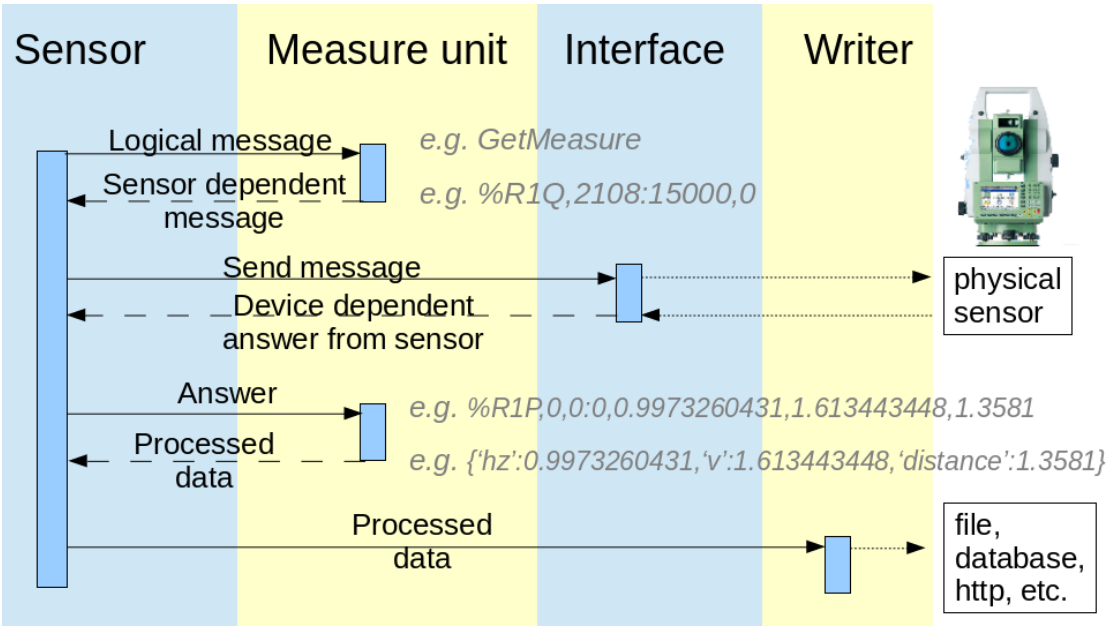

Figure 2. UML sequence diagram of command processing

supported digital cameras are preferred (e.g. Raspberry Pi Camera Module), usually attached to the telescope of an instrument to increase resolution.

Another interesting application of Ulyxes is to collect data for indoor navigation. The Wi-Fi fingerprint method needs a map of the strengths of the signals of the wireless access points. By the combination of two Ulyxes applications (MeasureToPrism and WifiCollector) the signal strengths and positions can be collected. A robotic total station, driven by MeasureToPrism application, follows a 360 degree prism and measures the distance as often as possible (1-2 seconds in fast distance measurement mode), while a Raspberry Pi 3, running the WifiCollector application, is moved along the prism and collects the Wi-Fi data. It is a one man measuring system, no operator is necessary at the robotic total station. The instrument is locked on the prism at the beginning. The MeasureToPrism application stores point coordinates with a timestamp, the WifiCollector stores SSID, address, signal quality, signal strength and timestamp. The two data sets are connected by the observation timestamps, so clocks have to be synchronised before the observations. The positions are interpolated to each second, if the observations are rarer and the signal strengths are aggregated to seconds as these data can be collected more often than one second, depending on the available Wi-Fi access points.

Server and client side scripts

This is the part of the project that still needs improvement. There is a simple AJAX based web application written in JavaScript and PHP, data are stored in PostgreSQL/PostGIS database. A PHP script is responsible for answering HTTP GET/POST requests, the responses are sent in JSON format, which is a native format for JavaScript and ES6. We have just started to upgrade our scripts to support different databases and not only to display elevation change trends but horizontal ones, too.

Educational usage

The aim of the educational usage is to introduce open source software development and some automation case studies to the students. BSc and MSc students are also involved in the use cases, development and testing. More theses were connected to this project in the recent five years. In the curriculum of an MSc subject called Surveying Automation, Ulyxes is used to demonstrate automatized tasks in engineering surveying. Some sample applications were developed by students (HorizontalSection, Section, MeasureMatrix), which are also available on GitHub.

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Figure 3. Instrument on site

FUTURE OF THE PROJECT

The redesign of the server and client side scripts is in progress. We hope those will be ready by the time of the OGRS 2018. Moreover it is also planned to implement SOS standard using IstSOS. Our Geo4All Lab maintains another open source software, called GeoEasy (https://github.com/zsiki/GeoEasy) to process observation data in engineering and land surveying. A closer cooperation is also planned between our two open source projects.

ACKNOWLEDGMENTS

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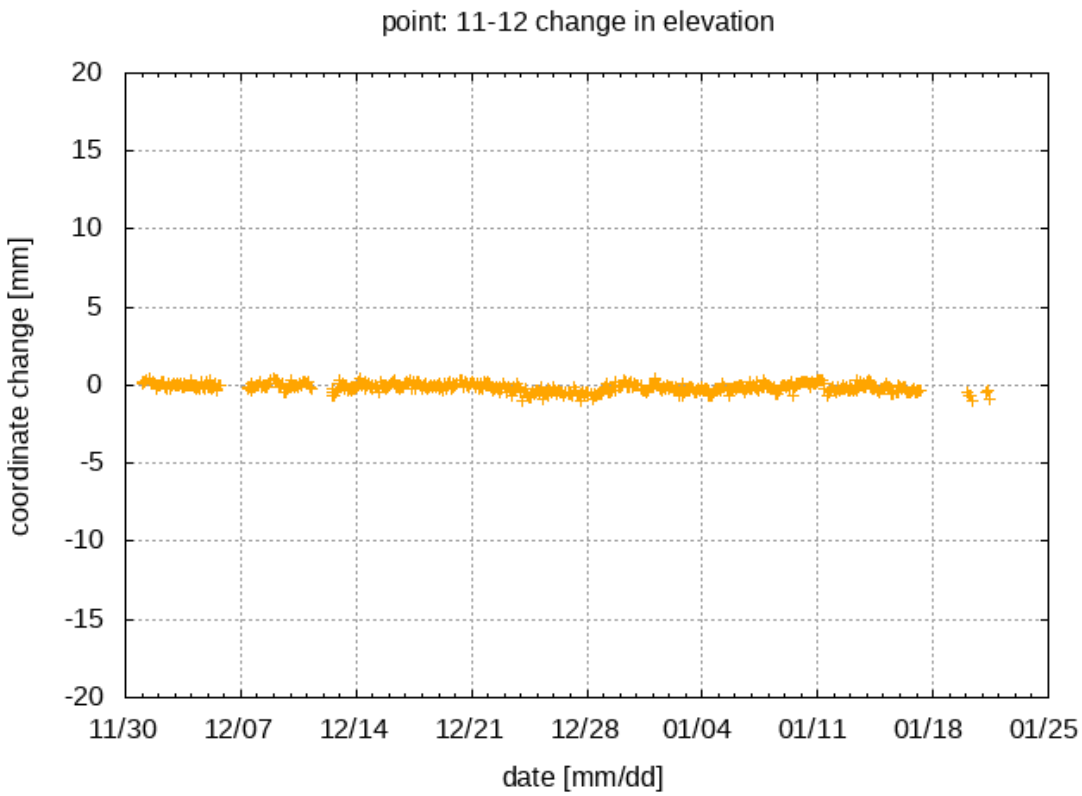

Figure 4. Change of elevation chart

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