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A PROTOTYPE SYSTEM FOR MONITORING THE DEFORMATION AND STABILITY OF DIFFERENT TYPE OF CRITICAL CONSTRUCTIONS

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Abstract

In this paper, we present a system prototype for monitoring the deformation and stability of different types of critical constructions. This system can be applied in order to achieve a higher level of risk management and safer working conditions. The system can have a wide application, for example it can be used as a real-time system for detecting deformations of mining construction or other types of critical construction areas. The main component of this system contains a Laser distance measurement module and single-board computers (SBCs) Raspberry Pi. This system can be integrated as a module in an already pre-existing monitoring system or as a stand-alone system. Here the basic functionality of the system platform and what can be done to improve monitoring process will be presented.

Key words: *Laser distance module, Raspberry Pi, equipment, toolset.*

INTRODUCTION

Computer science and information technologies can find many applications in mining, civil engineering, etc. The critical constructions or mining sites can have significant benefits from these technologies and they can help automate work, thereby improving the efficiency of many working processes. One example is real time monitoring of the deformations of sensitive mining constructions or various types of critical construction points or areas. This system can help to improve staff safety and also to prevent accidents.

With the help of modern computer technologies, monitoring data can gather, store and process. Based on this data mathematical models of construction stability and some predictions models concerning the constructions can be done. The stability of these constructions is essential for all mining or any construction operations and hence the safety of workers.

The stability of the mining structures provides the safety of the miners. Different mining operations and processes underground affect the mining structure in many ways. There are different methods for monitoring of construction structures [1,2] but none of them gives total guarantees and occasionally there is need for some additional security adjustments. The purpose of this paper is to present a real-time system for detecting deformations of mining constructions. It does not exclude the possibility of use in any other areas where there is need for specific monitoring of sensitive critical construction points. Mining shafts and tunnels are critical mining constructions and they unite all mining sites as a whole. Tunnels are an important and critical component of the mine integrity and stability.

Our monitoring objects can be mining shafts and tunnels and the monitoring equipment is placed on the predefined concrete place. These places are selected by prior observation and can represent some critical points. The correct choice of these monitoring points is very significant. Proper monitoring points can provide more accurate data, and by this more precise models, predictions and a more reliable and accurate warning system.

MATERIAL AND METHODS

Components equipment and toolset

This system practically can be used as a stand-alone or to be integrated as a module in a pre-existing monitoring system. System integration will depend on the needs, infrastructure, robustness, and the environment. To be able to work properly, this system needs to have compatible components equipment and an appropriate software toolset.

The monitoring equipment consists of two main hardware components - Laser distance measurement module (Fig. 1) and Raspberry Pi 3 (Fig. 4). External environment influences as temperature and humidity may adversely affect equipment components and they should be protected. One way of protection is putting the laser module component in a special hermetically sealed box with a transparent side with insignificant refracting index.

The Laser measurement module properties are described in Table 1. They are designed for users to easily connect the Laser measurement module to a PC or an MCU through RS232 communication (UART - Universal Asynchronous Receiver-Transmitter, TTL - Transistor–Transistor Logic). The connection properties for connecting to the PC (Raspberry Pi) serial communication (TTL) 19.2K baud rate, parity bit: no parity, data bits: 8, stop bit and no flow control. All commands are single ASCII character code in upper case, capital letters "O" to turn on the laser, capital letters "C" to close the laser, capital letters "D" for measuring distance, capital letters "S" to view the module temperature and power supply. Measurement command also activates the notification sound. Attention should be paid to the conditions in which measurements are made. Too much ambient light, as well as an unbalanced diffusion coefficient, negatively affect the measurements. Poor measurement conditions have an adverse effect and cause greater error (±3 mm, Table 1). There is a different external and internal condition that can cause laser module malfunction. This malfunction will generate some Error codes. Typical malfunction that can result in error codes are low voltage, internal error, module temperature is too low or too high, out of measure range, hardware fault etc.

Figure 1. Laser distance measurement module.

Table 1. Description of the Laser distance measurement module.

Component equipment	**Laser module**
Product Model:	B605B
Accuracy:	± 3 mm
Measuring Unit:	meter/inch/feet
Measuring Range (without Reflection):	0.03-150 m
Measuring Time:	0.1~3 seconds
Laser Class:	Class II
Laser Type:	635nm, < 1mW
Size:	72 ∗ 40 ∗ 18 mm
Weight:	About 38g
Voltage:	DC2.5±3V
Operating Temperature:	0-40 ºC
Storage Temperature:	-25±60 ºC

The auxiliary component which provides interface between laser module and the Raspberry Pi is USB to UART TTL Connector Module (CH340) Serial Converter (Fig. 2). Laser module pin *Rx* is connected to USB *Tx* pin, module pin *Tx* is connected to USB *Rx* pin, module *GND* pin is connected to USB *GND* pin and module DC is connected USB *VCC* pin. It is important to mention that the interconnection laser module power supply is not stable. DC-DC Step-up Power Module Adjustable (MP1584EN, Fig. 3) is added to insure stable power supply. The power module adjustable performs voltage regulation and stabilization. When the laser module receives the activation measurement command abrupt voltage withdrawal occurs which results in a malfunction and connection loss. The power module prevents this from happening.

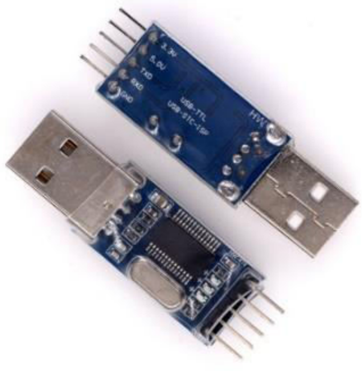


Figure 2. USB to UART TTL Connector Module (CH340) Serial Converter.

Figure 3. DC-DC Step-up Power Module Adjustable (MP1584EN).

Raspberry Pi 3 Model B Rev 1.2 is small SBCs developed by Raspberry Pi Foundation in association with Broadcom [3]. The original model became more popular than expected, selling outside its target market for uses such as robotics, IoT, Media Center etc. It is widely used in many areas because of its low cost, modularity, and open design. Hardware configuration, Operating system and the additional software used of Raspberry Pi for the development of this prototype monitoring system are described in Table 2.

Figure 4. Raspberry Pi 3 Model B Rev 1.2.

Table 2. Description of Raspberry Pi, hardware, and software.

Component equipment	**Raspberry Pi [4]**
Product Model:	Pi 3 Model B Rev 1.2
CPU:	Quad-Core ARM Cortex-A53, 1.2 GHz
Memory:	1GB LPDDR2
OS:	Raspbian GNU/Linux 10 (buster)
Kernel Version:	raspberrypi 5.10.11-v7+
Compiler:	gcc/g++ 8.3.0
IDE:	Code::Bloks 17.12
Graphing Utility:	Gnuplot 5.2
Remote Access:	TeamViewer 15.14.5 H

The application program is written in *C++* programming language, in *Code::Blocks~IDE* (Integrated Development Environment) [5]. Measurement data is stored and visualized on a daily basis with the help of *Gnuplot* [6]. In the next section more detail about interface and user interaction is given.

Software interface and user interaction

The basic interface is User-Friendly and the gathered measurement data is visualized for easy overview. Intention here is for users to have minimal interaction during the turn on and setting up of the measurement configuration of the prototype system.

Prototype application version 0.1 has a simple and easy to use command-line interface. The application program has a main directory that contains the executable file *LaserUSB_v0.1*, *Configuration* file and the *Results* subdirectory. The *LaserUSB_v0.1* runs the program, *Configuration* file contains predefined configuration parameters, and the subdirectory *Results* contains a subdirectory structure where the gathered data is stored. Configuration files have a couple of parameters, the first one is *USB port*, the second is *sampling* time (in seconds), the third one is *additional sampling* time (usually shorter) that takes effect in case when the current sample (measurement) compared with the first one is bigger than the predefined *border* (in *millimeters*) which is set as the fourth parameter. When the program is run, *Execute in Terminal* option needs to be chosen in order to have interaction and to see the program configuration parameters and settings (Fig. 5).

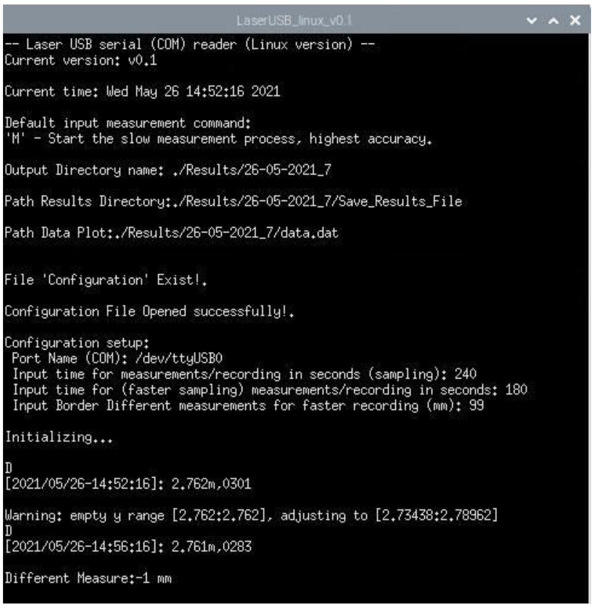


Figure 5. Command-Line interface from Laser program.

The command-line interface (Fig. 5), beside configuration setup parameters contains additional information as default input version, program startup time, laser measurement command, storage results directory with data files etc. The purpose of this information is easier orientation and working with the program. The program can also startup without the *Configuration* file but in this case the user needs to interact through the command-line to setup configuration parameters.

Data visualization is shown in Fig. 6. *Gnuplot* requires specific customizations as load-path of results data file, needs to define data display according to the data file structure. Additional general customizations are title, x data time, time format, *x* range ["00:00:00":"23:59:59"], *x* label *Time*, *y* label *Distance (meter)*. The *y* range is auto adjust by the measurement data. For more additional customizations and settings see [6].

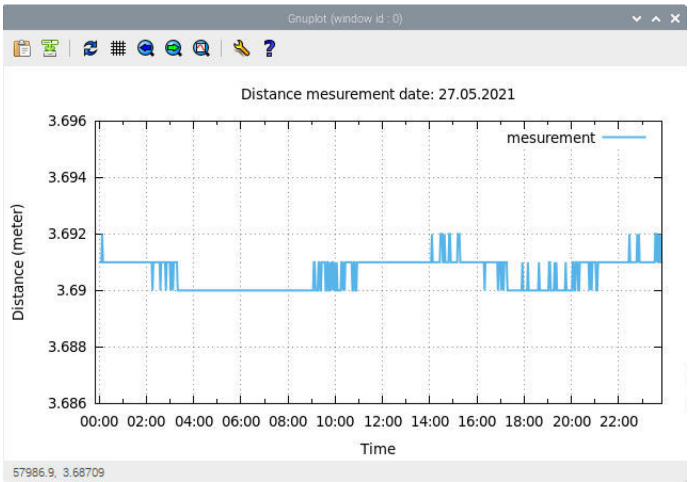


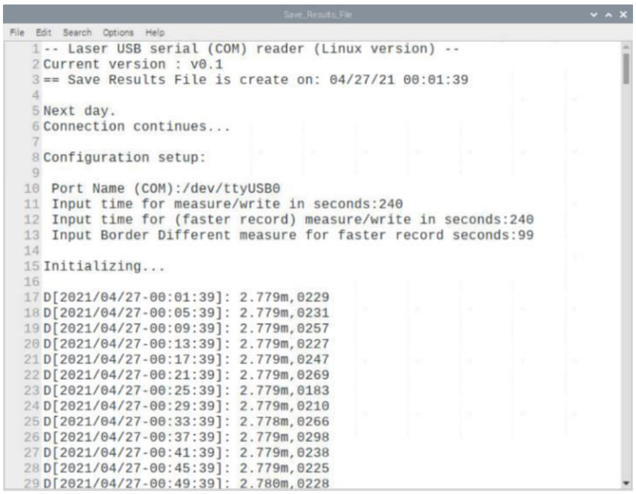
Figure 6. Data visualization plot (Gnuplot)

RESULTS AND DISCUSSION

Prototype testing and some preliminary results

This prototype system is in the testing phase. The testing phase includes software testing and functionality as well as testing if the laser module works properly and gives correct measurements. During the testing phase, the environment conditions were without unnecessary external influences as temperature, humidity, or other atmospheric deviation.

The basic testing contains static laser module positioning and activating. After turning on the prototype, storing the taken measurements starts immediately. The measurements results are stored in the text file in open form and simple structure (Fig. 7). Simple data structure of the file allows to visualize data (Fig. 6) by a simple script integrated into the program code. This *Gnuplot* script can be executed separately from the main application program. The testing time duration covers time periods from few hours till few days and a couple of weeks. During this testing time, the prototype system gives stable results with high accuracy within the error measurement border limit (±1 mm).



```
-- Laser USB serial (COM) reader (Linux version) --
Current version : v0.1
== Save Results File is create on: 04/27/21 00:01:39

Next day.
Connection continues...

Configuration setup:

 Port Name (COM):/dev/ttyUSB0
 Input time for measure/write in seconds:240
 Input time for (faster record) measure/write in seconds:240
 Input Border Different measure for faster record seconds:99

Initializing...

D[2021/04/27-00:01:39]: 2.779m,0229
D[2021/04/27-00:05:39]: 2.779m,0231
D[2021/04/27-00:09:39]: 2.779m,0257
D[2021/04/27-00:13:39]: 2.779m,0227
D[2021/04/27-00:17:39]: 2.779m,0247
D[2021/04/27-00:21:39]: 2.779m,0269
D[2021/04/27-00:25:39]: 2.779m,0183
D[2021/04/27-00:29:39]: 2.779m,0210
D[2021/04/27-00:33:39]: 2.778m,0266
D[2021/04/27-00:37:39]: 2.779m,0298
D[2021/04/27-00:41:39]: 2.779m,0238
D[2021/04/27-00:45:39]: 2.779m,0225
D[2021/04/27-00:49:39]: 2.780m,0228
```

Figure 7. File result structure

Poor measurement conditions can cause error measurement or return error codes. If the module returns an error code, this code (is not stored) initiates to repeat the distance measurement after *5* seconds, without waiting to finish the predefined (*sampling*) time period. The option for making a repetition measurement after an error code is a part of the program itself.

Discussion about the system operation and future work

Laser scanning technology is one special measurement method in geodesy and mining. It has been developed as a basic application for collection, interpretation, and analysis of data in surface and underground mines. The presented prototype strain measurement system can be used in mining with relative utilization. The development of innovative technologies, such as 3D laser scanning, opens new possibilities, particularly in the cases of large and difficult to place areas in mining. Terrestrial laser scanners provide fast, specific, detailed, and accurate three-dimensional data but are inherently very expensive and sensitive to the environmental conditions.

Precisely, the installation of several such systems in the observed mining area, which would work simultaneously, could create conditions for detecting geotechnical deformations on slopes of floors in surface exploitation, then in underground rooms and working heads in underground exploitation, etc.

The proposed system is relatively inexpensive and can be upgraded, both with real-time information and with the possibility of long-term data storage. The fast processing of the data and their presentation through Internet WEB portals and mobile applications provides the opportunity for wide availability and quick alerting to the responsible persons who monitor the geotechnical deformations in the mines. Any timely information about any emerging geotechnical deformation will mean an opportunity to react promptly and reduce further dangers for both employees and equipment and the mining process itself in general.

The case of the presented system uses only a scratch from the system potential functionality. The equipment itself gives sufficient space scalability and upgrades system opportunities. The system itself can be upgraded with additional components such as speakers, display, keyboard, step motors, battery power supply etc. The purpose of the added components is to provide more functionalities.

To be able to operate the presented prototype system basic infrastructure that contain power supply and computer network is needed. Depending on the environment, infrastructure and the additional components, there is need for some adjustments so that the system can properly operate. The system can be upgraded with a step motor and a rotation part to which the laser module would be placed. With this upgrade the rotation area with multiple points for create 3D scanning model can be observed.

The monitoring equipment can work independently for which a battery power supply is necessary, setting up *Configuration* file and setting up the laser program as a startup program. Independent working of the monitoring equipment means working outside of the computer network grid. If the system works independently, it has no impact on the pre-existing monitoring system. It is possible to mount speakers and to define some notification sounds, from predefined various cases.

CONCLUSION

In this paper, we proposed a prototype system for deformation monitoring of critical types of construction. With the help of this system the real-time monitoring of sensitive construction can be improved. One of the goals is to secure mining structures and by this to improve the safety of the miners.

Here one way to use the prototype monitoring system is presented. The platform and the equipment components insure possible upgrades and scalability. Some of these possibilities are mentioned in the discussion about future work. System improvements can be made according to requirements, hardware equipment and software upgrades.

From the computer science point of view, it can be said that the selected combination of hardware and software gives optimal system performance. System functioning is under the strong influence of environmental conditions. Future construction infrastructure The plays an important role which can give more system flexibility. We need to point out here that the hardware components equipment is not professional but it is next best for building a promising prototype.

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ПРОТОТИП СИСТЕМ ЗА СЛЕДЕЊЕ НА СТАБИЛНОСТ И ДЕФОРМАЦИИ НА РАЗЛИЧНИ ТИПОВИ НА КРИТИЧНИ КОНСТРУКЦИИ

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Резиме

Во трудот е претставен прототип за следење на деформацијата и стабилноста на различни типови на конструкции. Овој систем може да се примени со цел да се постигне повисоко ниво на управување со ризикот и побезбедни работни услови. Системот може да има голема примена, како на пример систем во реално време за откривање на деформации на рударски конструкции или други видови критични градежни области. Главната компонента на овој систем содржи ласерски модул за мерење на растојание и Развоен Микрокомпјутер Raspberry Pi. Овој систем може да се интегрира како модул во веќе постоечки систем за следење или како независен систем. Овде ќе бидат претставени основните функционалности на оваа платформа и што може да се направи за да се унапреди процесот на следење.

Клучни зборови: *ласерски модул за растојание, Raspberry Pi, опрема, комплет алатки.*