Instrumentation and Control of Rock Mechanics Laboratory Equipment by Means of Self-Developed Low-Cost Devices

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Abstract. Control and monitoring of laboratory tests in the field of rock mechanics are usually expensive due to a wide variety of applications, normally carried out with very specific equipment (UCS and triaxial testing, tilt-test, permeability…). This fact may represent an issue for laboratories located in developing countries, but also for companies or educational institutions with limited budgets. Aiming at overcoming these difficulties and to open new possibilities in laboratory testing methods, the authors of this publication recently developed some sensors and applications based on open-source hardware and small-board computers (SBC). In this paper, we present main aspects on the implementation of a Python-based script allowing the communication through a Single Board Computer (SBC) via RS-232 protocol, with a standard frequency inverter Siemens G110, currently controlling the tilting rate of a tilt-test machine. In addition, the instrumentation of this device to be able to measure the temperature, humidity and vibrations is briefly described, as well as a shutdown system to stop the machine when the sliding of the rock specimen starts. These applications allow improving the possibilities not only of new devices but also of those out-of-date apparatuses that might be still useful in laboratories. This extended abstract aims at open new possibilities on the rock mechanics laboratories.

Keywords: Raspberry pi, Arduino, tilt test, strain gauge.

1 Introduction

Sensors used in geotechnics are, in most cases, very expensive, a fact that can be a problem for some laboratories, especially for those with budget constrains like in small companies or educational centers. The development of simple and inexpensive sensors may be a great opportunity for researchers, and it may allow improving testing methods in both laboratory and in-situ rock mechanics.

Since the beginning of the 21st century, different companies and research groups have started projects for developing open-source hardware, initially for educational purposes. Today, some of these projects had created numerous devices that allow people without much knowledge in electronics to design and build complex electronic devices. The most widespread platforms are Arduino and Raspberry Pi, both with an active community of users who share and discuss their projects on the internet.

The capabilities of commercial sensors are almost impossible to reproduce in 'hand-made' sensors. Nevertheless, the requirements are much lower in most projects. The low cost of these kind of sensors, together with their somewhat quick and easy manufacturing, make them ideal for research purposes.

In this article, the preliminary control of a laboratory tilt-test machine (tilting platform) based on a Raspberry Pi microprocessor and Python programming is presented besides some useful applications involving low-cost sensors.

2 Materials and methods

The tilt test is commonly used in rock mechanics laboratories and rock engineering projects as a straightforward, sufficiently reliable and affordable technique for estimating the basic friction angle of planar rock surfaces (Alejano et al. 2018). These tests are carried out with tilting tables in which the tilting mechanism can be hand-operated, through induction motors or by pneumatic cylinders (Alejano et al. 2017). Considering the evolution of electronics and software and, particularly, the so-called high-level programming (e.g. Python language), it seemed appropriate to try to improve, by taking advantage of these technologies, the performance of tests with the tilting platform available at the rock mechanics laboratory in the University of Vigo (Spain). An improvement of two relevant tasks when carrying out tilt tests is proposed in this work. First, the control of the frequency inverter of the machine through a Raspberry Pi (model 3b) connected to a frequency inverter Siemens Sinamics G110, to be able to start, stop and pre-select the tilting rate of the platform. The communication is made by sending and receiving telegrams from the master (in this case, the Raspberry Pi-3b) and the slave (frequency inverter Siemens Sinamics G110). By following guidelines presented by Siemens (1994), a Python script was developed. Additionally, the tracking of vibrations and tilting angle by means of an inexpensive (less than 4€) but sufficiently accurate Inertial Measurement Unit (IMU) model MPU-6050 and temperature and humidity by a sensor DTH-11 type. An Infra Red (IR) break beam sensor is implemented to stop the machine at the beginning of the sliding of the top specimen. These features are described by Fig. 1.

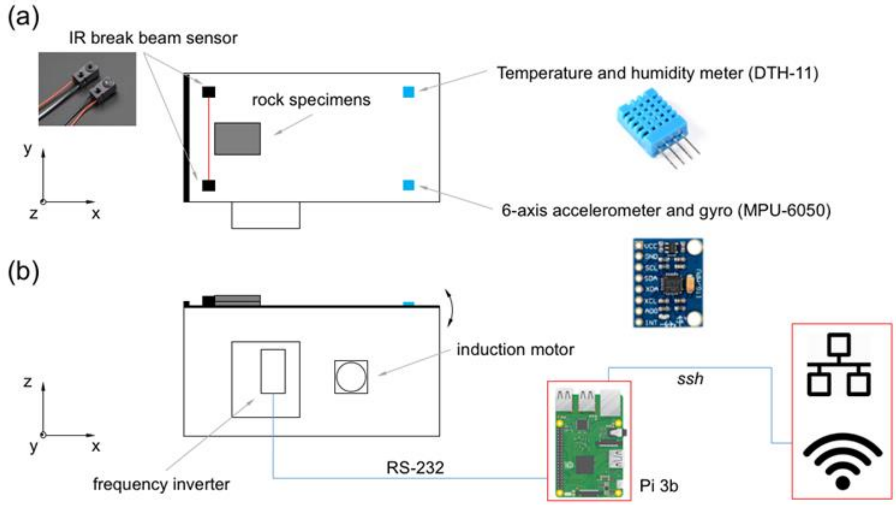

Fig. 1. Top (a) and front (b) view of a scheme of the tilting table , schematic wiring of the Raspberry Pi 3b and frequency inverter and sensors used.

Prioritizing the use of low-cost technologies such as those described in this paper, it was first necessary, prior to read data from any sensor, to be capable of controlling the frequency inverter and, therefore, the start, stop and velocity of the motor through the operating system (Raspberry Pi-3b). For this purpose, a detailed assessment of the operating interface in digital mode of the Siemens Sinamics G110 frequency inverter has been required. This interface is known as Universal Serial Interface Protocol (USS® protocol), and consists of an access technique according to the master-slave principle for communications via a serial bus. The tilting machine is now designed to be completely remote-controlled from a UNIX or LINUX-based environment from a PC connected to the internet and values obtained from sensors can be all read during the development of the whole test. Currently, a program is being developed to perform tests while recording temperature, humidity, angle of inclination and vibrations throughout the entire test and to automatically create a spreadsheet file with all tracked data.

3 Conclusions

Open-source hardware and software could be a very useful tool for research centers and universities, mainly those with low budgets, such as small research groups or those located in developing countries. The creation of an online platform where rock mechanics practitioners could share its open source designs may be very rewarding, following the philosophy of Arduino and Raspberry Pi platforms, where the members of the community could help each other and contribute to the spreading of these tools.

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