LOW COST EXPERIMENTAL DEVICES FOR EDUCATIONAL SEISMIC NETWORKS

George Hloupis, Ilias Stavrakas, Konstantinos Moutzouris and Dimos Triantis
Department of Electronics, Technological Educational Institute of Athens, Agiou Spyridonos, Egaleo, Athens, Greece

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Abstract: The current paper deals with the use of open source, low cost solutions for the development of educational seismic networks. The contribution of the current research is the minimization of sensors' and accompanying hardware costs through newly implemented devices as well as their coupling to custom and public available software. Our effort is to deploy plug-n-play devices with initial cost under 10€ in their basic versions that can be easily operated by school teachers without the need of complicated instructions. Two solutions based on different microprocessors (with the accompanying software) along with preliminary guides for inquiring students into seismology are presented.

1 INTRODUCTION

The subset of Information and Communication Technologies (ICT) that used to design and implement interactive physical systems by means of corresponding software and hardware that can sense and respond to the analogue world is called "physical computing" (Sullivan, 2004) which is a subset of regular computing. Supported by the extensive use of powerful microcontroller units (MCUs) the idea of using physical computing in students' experiments and projects can provide the learning schemes that are based on the use of motivation when a student is faced with stimuli.

The societal problems caused by natural hazards have stimulated the interest of many students (Brudzinski, 2011). Towards to this direction it should be teachers' goal to convert that interest into problem solving skills. A representative example is the earthquake, where the threat is ever present, but a lot of questions raised regarding how and why earthquakes happen.

Helping students understand the properties of seismic waves is fundamental to teaching about earthquakes. An obvious approach is the visualization through animations on seismic waves (Braile, 2005; Jones, 2005; Ammon, 2007). Unfortunately, visualization approaches in educational seismology present lack of hands-on experimentation due to complexity of required instruments. To overcome the above limitations efforts of providing hardware and software in schools resulted in several studies oriented to a dominant educational approach that focus to: a) present earthquake science and earthquake impacts in an attractive and exciting way and b) provide teachers and students with seismic sensors and software as well as educational modules. Implementations of the last approach led to several projects around the world in the forms of seismic school networks: QCN at USA (Cohran, 2009), Eduseis at Italy (Cantore, 2003), EduSimso at France (http://www.edusismo.org/index.asp), School Seismology at UK (http://www.bgs.ac.uk/schoolseismology/), DIAS SIS at Ireland (http://www.iris.edu/hq/sis).

All the above named projects based on the use of a simplified seismic station. Traditionally, a seismic station requires a sensor to record the ground motion (seismometer), a computer to save the data, a GPS for accurate timing and location, telemetry or radio equipment to send the data back to a data collection center and a power supply unit. While these stations provide continuous, accurate, reliable data, currently costs (in the order of tens thousands €) prohibit installation of this type of seismic stations over a large number of schools. Solutions that provided today cost from tens to thousand euros in their basic versions (SEP 061: 510€, AS-1: 350€, EIA S102: 1100€, Guralp PEPP : 2000€, MotionNode Accel: 100€, O-NAVI B: 80€, JoyWarrior24F: 50€).

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In this paper, we describe our proposal for a seismological experimental device which presents possibly the lowest initial cost for everyone wants to involve in educational seismology. Without compromising in sensitive system's functions (sensor performance, adaptability with several software, expandability) we present an experimental device which costs 10€. Focus our efforts to the use of powerful MCUs and the elimination of external electronic components as well as on the construction of rigid and adaptive firmware we are able to provide an educational seismology experimental device with possible the lowest cost available. In addition to the basic version of the proposed device we proved a series of expansion capabilities in order to transform the experimental device to an autonomous networked ground motion monitoring system.

2 DESIGN APPROACH

The overall system configuration is represented in this section along with brief explanation of each block's major characteristics.

The minimum hardware and software requirements that our prototypes must cover are:

- Cost under estimated threshold value (here under 10€) for basic version;
- Ready to operate procedures (along with plug-n-play specifications) ;
- Open Design (use of open source software and hardware)

2.1 Hardware Description

2.1.1 Sensor

In seismological data acquisition systems two main categories of sensors used for recording earthquakes: strong motion and weak motion. This separation is dictated by the fact that there is no unique type of sensor that can capture the broad range of amplitudes and frequencies of seismic waves. Low amplitude ground motion generated by small local earthquakes (or by significant earthquakes far away) can be captured reliable by weak motion sensors. Unfortunately weak motion sensors are useless for capturing ground motion from moderate to large local earthquakes since they saturate. In order to avoid this type of upper values clipping we used strong motion sensors. It is obvious that the main disadvantage of strong motion sensors is that they are not so sensitive to weak ground vibrations.

For the purposes of school experimental device we select strong motion sensors in the form of MEMS (Micro-Electro-Mechanical Systems) accelerometer. Commercial MEMS accelerometers today can offer characteristics that enable reliable earthquake capturing with local magnitude over 3.0. The sensor block consists of the acceleration sensor and its necessary passive components. Our selection was Bosch's BMA180 MEMS (Micro-Electro-Mechanical Systems) accelerometer which has the following major properties:

- Digital output which means that we avoid the use of external A/D converter.
- 14bit accuracy; thus 1.5mG resolution
- Several measuring ranges (from ±1g to ±16g)
- Multiple sampling rates (from 10Hz to 200Hz)
- Cost under 5€

A prototype of sensor block is depicted in Fig.1.

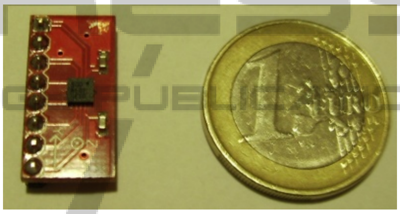

Figure 1: Sensor block with MEMS accelerometer.

2.1.2 Acquisition – Processing Block

The acquisition–processing block is responsible for:

- Gather the binary values from sensor's digital output
- Transform the values to readable format
- Feed the data to the communication port
- Control additional activities (such as feeding the data to Ethernet port, provide in situ calculations for earthquake alarms e.t.c)

The solution to the above is the use of modern, low cost MCUs. We concluded in two solutions: Texas Instruments MSP430 and AVR's ATMEGA328. We developed the proposed experimental device in two versions using each MCU. This rather controversial approach dictated by the different characteristics that each MCU presents. MSP430 is offered to the market as a complete development board (named "LaunchPad") for a price of 4.30$ (including all the necessary electronic components plus communication and power regulation unit) ready to host only the sensor. This was our initial solution which led us to an experimental device with total cost under 10€. Apart from the major characteristics which are comparable with AVR's ATMEGA328 its main disadvantage is the lack of maturity since it is a new product and the support by open source community is not very widespread.

To overcome the last limitation we slightly relaxed our cost limits in order to gain the better results on the subject of expansion simplicity. The selection of ATMEGA328 MCU provide us an extremely huge community support which expressed by the use of programming tools which are suitable for novice (Arduino, Fritzing, Minibloq e.t.c.) as well as a remarkable range of extensions. The main disadvantage is the higher price (2.6€/per 25 only for MCU) which leads to a complete product cost around 11€.

2.1.3 Communication – Power Block

In order to fulfil the “plug-n-play” requirement we adopt the use of USB connection for data transfer to host PC. In the case of MSP430, USB connection is offered as standard in the LaunchPad board whereas for ATMEGA328 we developed separately.

Since we focus on cost reduction we selected not to include independent power supply unit. Instead of this we used the power lines of USB connection for producing the 5V and 3.3V supply required for our circuits. The maximum current for each proposal was not exceeded 150mA whereas USB can provide 500mA maximum.

Complete prototypes are depicted in Fig.2 and Fig.3.

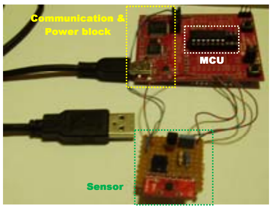

Figure 2: Prototype based on MSP430.

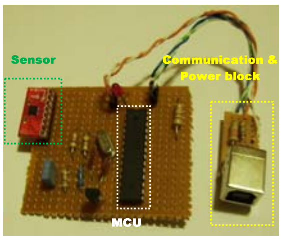

Figure 3: Prototype based on ATMEGA328.

2.2 Software Description

The required software for the experimental device belongs to three categories: firmware, accompanying software and data exchange.

The firmware is going to be stored in MCU’s non-volatile memory. It will be public available at http://research.teiath.gr/edu_tech_en/schoolseis at the first quarter of 2012. Programming each MCU is quite straightforward for both MCUs.

The accompanying software suite is a collection of public available software that fulfils three major requirements regarding captured data: storage, visualization and analysis. During system design special attention received for the subject of data format. The data streams that generated from the experimental device selected to follow three different formats that widely used in seismological signal processing: ASCII SAC, GSE binary and ASCII CSV. By using these formats we are able to use the vast majority of public available (and also commercial) software for seismological analysis as well as common data analysis products (MS-Excel, Visio, Matlab e.t.c).

Data exchange software module is responsible for the exchange and dissemination of each school results in order to deploy a seismological school network. It is scheduled to:

- Send the results from each school to a central database.
- Produce the necessary maps to display the results by means of Google Maps API.
- Disseminate each school’s results by using several web projections (Dynamic web pages, Twitter, Facebook, Pachube)

3 SYSTEM OPERATION AND EXPANDABILITY

The operation of the system is straightforward. Users initially plug in the experimental device in an available USB port. Before running the software for the first time, users must execute a preliminary script which is going to write the appropriate values to the configuration files (i.e which USB port is connected, synchronize PC clock with NTP, definition of geographic location by using IP geolocation services). The next step is to calibrate the sensor. Users will receive instructions of appropriate mounting and levelling of the sensor. Upon sensor’s start-up the firmware runs a series of calibration tests in order to ensure that the sensor is adequate installed (i.e X-Y components are in horizontal plane and Z is in vertical, the noise level is below a predefined threshold e.t.c). In opposite case, an informational message window pops-up. After the initial calibration users are ready to start the accompanying and the data exchange software.

Both proposed systems designed having always in mind future expansions and upgrades. We have successfully tested (and developed the corresponding firmware) a number of additional hardware modules that add flexibility to the whole system. Those are:

- Ethernet module which adds network feature.
- Secure Digital (SD) card module.
- GPS module.

4 DIDACTIC UNIT EXAMPLE

The proposed experimental device can be easily imported to an environmental oriented class course. Following an inquiry based approach students can experiment using their educational seismograph as proposed in Table 1 (Kafka et al, 2010).

Table 1: Structure of an inquiry based exercise.

Aspects of the scientific process	*Example Exercise Tasks*
Inquire	Install Seismograph
Explore	What signals captured by our seismograph
Investigate	What signals recorded by other seismographs around the world – Seismic waves
Apply	Detect local earthquakes
Learn	Estimate earthquake's epicentre, magnitude – Hazard correlation
Communicate	Exchange data and results with other schools

Apart from being a standalone experimental device, the proposed structure can be successfully used for active classroom activities. Under this approach students engaged to physically participate in learning activities. A proposal is to explore the nature and the properties of earthquakes. By letting the students to jump individually or by groups in specific distances from sensor, the teacher can present a set of inquiry questions such as the representative ones below:

- Is there a difference between a student's and a group of students' jump?
- What happened when student jumps near the sensor?
- Is there a difference between jumping over floor and over carpets that cover the floor?
- Can the students identify from the recordings when they start jumping?

5 CONCLUSIONS

The current study introduces a set of low cost educational seismological experimental devices with initial cost under 10€. It is oriented for standalone as well as networked operation implemented in this way the base of an educational seismic network. The complete design offered as open source hardware. Coupled with the proposed devices, a set of public available software tested and verified for concurrent operation. The proposed system can easily be adapted to curriculum including hands-on experiments providing in this way the core for various inquiry-based activities. Expansion of the proposed devices is possible by adding GPS, network capability and SD recording function leading to complete amateur seismological station.

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