Building a performance protocol of a low cost seismograph.

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ABSTRACT

The aim of this work is to design and test a performance protocol for a proposed low cost seismograph, which was developed for local to regional seismicity and micro seismicity monitoring. Most earthquakes are due to tectonic plates movements, and as a result the zones of intense seismic activity are essentially identical to the edges of these plates. Greece is characterized by intense seismic activity (the seismicity of a place is determined by the frequency of earthquakes and their magnitudes), because it lies on the verge of contact and collision of the Eurasian plate with the African one. According to statistics, Greece ranks first in terms of seismicity in the Mediterranean and Europe.

For this reason, since the Greek region is a living earthquake production laboratory, the need to record them is imperative. Our aim is to propose recording systems with cost ranging from 1000 euros, much cheaper than the cost of a classic seismograph which ranges from 15,000 euros and up. Reducing the development cost gives the opportunity of a dense seismic network development. The proposed low-cost system was installed in an area of high seismic activity (Lefkada Island – Village Evgiros) and the recordings are transmitted to the database continuously from the day of its installation up today. Thus an amount of data for more than 280 days have been stored to our database. Collocated with a high resolution 24 bits digitizer equipped with a broad band seismometer give us the opportunity to compare the recordings.

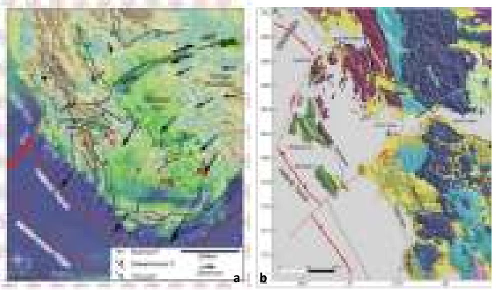

Figure 1. (a) Main tectonic elements of the Hellenides and the Aegean Sea – The Hellenic trench. (b) External geologic units of the Hellenides in western Greece. (E. Vassilakis et. all, 2011)

Figure 2. The study area at southeast of Lefkada island (red mark: Evgiros village - Coordinates: 39°43'11.14"N, 19°42'37.03"E)

INTRODUCTION & METHODOLOGY

The system was designed and developed with an emphasis on the following features:

- Low construction cost (hardware), based on a single microcontroller board (Arduino Uno R3) and a microprocessor board (Raspberry Pi 3 B+).
- Sensors: a) Ceramic Accelerometer with cutoff frequency fc=0.15H z and b) moving coil geophone with cutoff frequency fc=4.5Hz. The signals from the two sensors are amplified independently, while an active second order low-pass anti-alias filter and an 8th order active low-pass anti-alias filter have been used.
- Open Source Software.
- Sampling frequency: 345 Hz
- Locally data storage (in the internal memory of the system) as well as remote data transfer through internet connection to the Ionian University database every (5) five minutes.
- Timestamp (DD / MM / YYYY HH: mm: ssssss)
- Ideal for local seismicity recording.
- Energy autonomous design for use with the PPC 220Volt network but also with the use of PV panels and batteries.
- Ease of transport and installation.
- Remote access and remote device control via known remote access software (such as teamviewer, anydesk etc.), giving the capability of operating system changes, sensor calibration, code problems fixing etc., remotely.

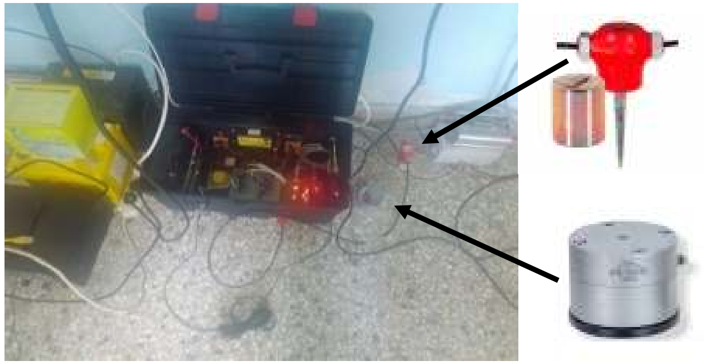

Figure 3. View of the installed low cost seismometer (black case) along with the broad band seismometer in the area of Evgiros (Lefkada island). In addition are shown: a) Velocity sensor used (Geophone GS11D – 4.5 Hz) and b) acceleration sensor used (Accelerometer KB12VD).

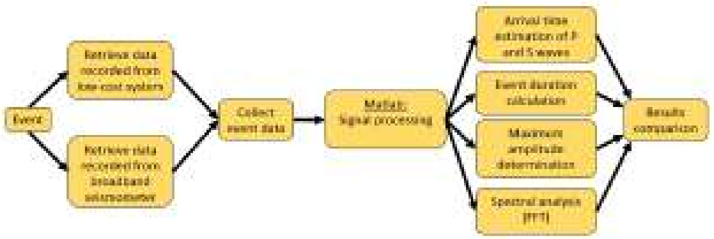

Figure 4: The workflow concerning the steps followed for each seismic event during this study.

RESULTS & CONCLUSIONS

To this end, a testing list of 3 local events is presented with different epicenters and magnitudes. For each event the recording signals have been analyzed in terms of a) power spectrum analysis, b) estimation of arrival times of both P and S waves, c) signal amplitudes and d) earthquake duration, as illustrated in figure 4. The choice of those specific measures was done in order to evaluate the performance of the low-cost seismograph in terms of certain seismic parameters such as magnitude, epicenter and source properties. Initial results in terms of the proposed protocol are also presented showing an adequate performance of the propose low cost seismograph.

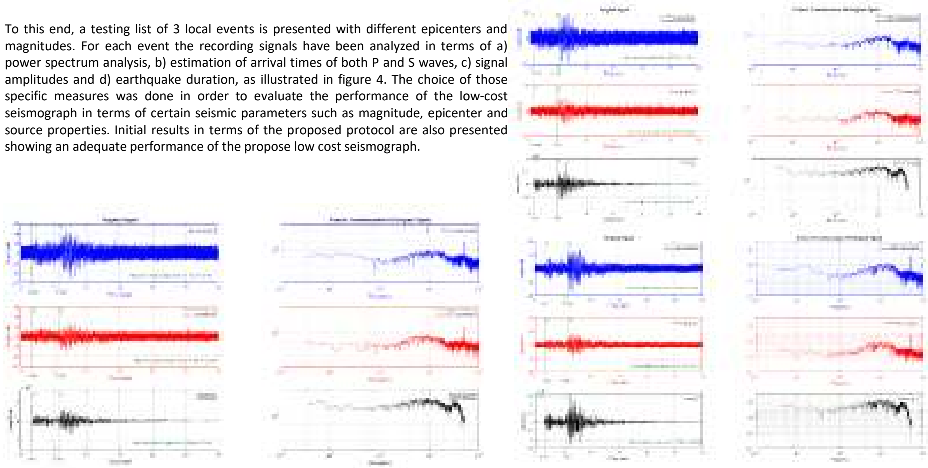

Figure 4. Real event data comparison between a conventional broad-band high resolution seismograph (black waveforms) and proposed low cost seismograph (blue waveforms represent accelerometer- retrieved records while red waveforms represent geophone - retrieved records). Both recording systems are located in the same place (Evgiros, Lefkada Island, Greece). After the signal is processed, the seismic waveforms were retrieved, where a selection of first arrival times was possible, as well as further processing with max amplitude estimation, event duration and spectral analysis (Fourier Transformation).

	Event 1 [illegible]			Event 2 [illegible]			Event 3 [illegible]		
	LC s (accelerometer)	LC s (geophone)	BB s	LC s (accelerometer)	LC s (geophone)	BB s	LC s (accelerometer)	LC s (geophone)	BB s
P-arrival time (seconds)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S-arrival time (seconds)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S-P	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Max Amplitude (positive)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Max Amplitude (negative)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Max Amplitude Range	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 1. Collective result representation of the 3 event analysis, with record comparison between low – cost seismometer (LC s) and high sensitivity broadband seismometer (BB s).

DISCUSSION & FUTURE WORK

- Incorporation of an Analog Mem's accelerometer and of a Digital Mem's accelerometer.
- Incorporate a GPS circuit for greater accuracy in the Time-stamp of the recording data.
- Upgrade current 10bit analog to digital converter (A/D) with a new one of 24bit resolution.

ACKNOWLEDGMENTS

This work was supported by the **«Telemachus – Innovative Seismic Risk Management Operational System of the Ionian Islands»** which is part of the Operational Program «Ionian Islands 2014-2020» and is co-financed by the European Regional Development Fund (ERDF) (National Strategic Reference Framework - NSRF 2014-20).

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