Electronic seismograph for measuring and detecting telluric movements with low cost portable wifi wireless communication

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***Abstract*—This work presents the development and implementation of a seismograph prototype with Wi-Fi communication to a client for the monitoring of seismic events through a web page. The prototype is divided into two stages, Hardware and Software. The Hardware represents the seismographic station, which has several interconnected electronic modules in order to detect seismic signals, including a GPS module for its geographical location, an SD-Card reader for data storage, an accelerometer for movement detection and an ESP32 card for code execution of the error threshold detection algorithm. For the detection of seismic events through thresholds, thanks to the characteristics of the card, Wi-Fi communication is carried out with a Web server, to which the alert message of a registered seismic event will be sent, then the data corresponding to the detected signal is sent to an output file for recording and storage. The web server has been called System Software, this will be in charge of displaying the parameters of the seismic event detected by the station, for further processing through calculations to obtain approximate values of the Mercalli scale intensity and depth, to finally show through a page web the location on a map of the station (s). To achieve the server characteristics, programming languages such as HTML and c ++ were used. Finally, a seismographic station is installed in a stable place (flat terrain test) for their respective tests.**

***Index Terms*—HTML, c ++, Wi-Fi, Seismograph and Wireless Communication, Accelerometer, Mercalli Scale, Lowcost.**

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I. INTRODUCCIÓN

THE technology applied to sensors and sensor platforms has evolved at a strong and rapid pace in recent years, which translates into higher performance, lower power consumption, better connectivity, greater accessibility and reduced costs. These innovations provide scientific communities and experimenters with promising prospects, such as the deployment of large sensor networks for real-time monitoring of seismic activity with high spatial resolution.

Every year there are about 20 earthquakes of magnitude 7 or higher cite mpubrazil. These types of seismic events are potentially destructive and can cause various structural damage, economic and human losses. To carry out effective risk prevention and management work, geophysics must be equipped with appropriate software and hardware tools. Seismic studies comprise not only risk management, geophysical studies of the earth, but vibration monitoring has also become a very useful scientific approach to address safety and structural maintenance. Among these devices, the MEMS accelerometer combines great performance with low costs, characteristics that have made it one of the most popular devices when it comes to this task.

The seismometer is a sensor that is used to measure the vibration on the ground surface so that it can record earthquake signals and it has a high sensitivity to ground vibrations including noise. Sensitivity to noise can cause unstable recording, even component damage, requiring calibration. Seismometers consist of several types depending on their response, one of which is a short period seismometer [15].

Considering the practicality of design and construction of a system that allows obtaining variation of accelerations, this article proposes the development of a system that allows recognizing seismic activity at low cost and easy implementation. Specifically designed to be built with accessible resources and for learning purposes. This will make possible the Mercalli scale intensity detection and can be compared with an accelerographic proposal.

This article is organized as follows: Section 2 describes the state-of-the-art description of seismology, then advances in research that propose the perception of telluric movements are shown. Section 3 describes the proposed design and its characteristics. Section 4 shows the design criteria considered. Section 5 presents the construction process of the accelerograph system. Finally, section 6 presents the construction results.

II. STATE OF ART

In Peru, it is possible to find geology, geochemical and geophysical studies carried out for the design of a seismograph or for the detection of telluric manifestations, which are detailed below:

In [5], there is the accelerographic network of the College of Engineers of Peru, National Council, where it has been

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implemented since 2014. Currently in 2021, it has 79 accelerographs. These equipments send the information of the digitized seismic records to a server, to be monitored in real time. It is observed that a precise location is found and they are built in a box that are made to record the seismic acceleration, speed and ground displacement and intensity. spectral.

Also, there is the Satellite Seismic Network for early warning of Tsunamis in charge of the Geophysical Institute of Peru (REDSSAT - IGP), which is an integrated system of seismometers with satellite transmission. And its objective is to constantly monitor seismic activity that may affect the national territory, so that rapid and effective alerts can be given to the possible occurrence of tsunamis [14]. At the time of installation, an adequate geometry should be considered, with stations installed in geological environments suitable for recording seismic data, such as rocky basement, competent soil.

Finally, different areas are currently being monitored with the aforementioned institutions. Likewise, the Geological Mining and Metallurgical Institute (INGEMMET), through its Volcanological Observatory (OVI), monitors the Ubinas volcano in real time through a network of multiparametric sensors. These equipments have the ability to measure volcanic gas flows, ground deformation, ground vibrations (earthquakes), products emitted by the volcano and surface activity such as gas emissions from the crater cite igemmet. The instrumentation is installed around the Ubinas volcano and the recorded information is transmitted in real time to the OVI facilities, in the city of Arequipa.

Some research scopes seek records with low-cost systems taking advantage of the progress of microelectromechanical systems (MEMS) [4]; develop a low-cost detection system to record accelerations that allows the collection of strong movement data at ground level during earthquakes, as well as monitoring of structures. It can also be considered peculiarities, Ringler D. cite dolowcost with the proposal for the use of RS-4D that includes a vertical component geophone, a three component accelerometer, a digitizer and a near-time mini-SEED data transmission real.

Some works that propose the use of microcontrollers is in [12], which shows the operation of the implementation of a seismograph system that is being carried out on a Raspberry model 3B + development board together with a mpu6050 gyroscope accelerometer module. The information recorded by the MPU6050 module will be analyzed and stored in a graph database. Each vibration felt by the accelerometer-gyroscope module will send an SMS alert to the mobile phone through an IFTTT service. The notification will contain the type of earthquake produced according to its magnitude (minor, mild, moderate, strong) as well as its classification in various degrees on the Richter scale and the time of its production.

A work that seeks to find microseismic records with low SNR is in [7]. Where, the STA / LTA algorithm is presented as a challenge application in the microseismic field. Due to the complexity of the mining environment, the microseismic records collected by different channels vary and generally have a low signal-to-noise ratio (SNR). Therefore, the automatic location algorithm is required to be robust and accurate. This importance of threshold recognition for the detection of seismic events is to process the signals, in reference to this, in the article referenced in citep staLta the STA / LTA algorithm code is used. Reliable and accurate detection of P-wave arrivals is summarized as a key step in determining seismic parameters. In this article, an innovative and automatic algorithm was developed to detect the arrival of the P wave based on the theory of the fractal dimension and the relationship between the short-term and long-term average fractal dimension, called the STA / LTA fractal dimension algorithm.

III. Low cost seismograph

For our own requirements proposed in the problem and justification of our work; for Arequipa we require our own design of a low-cost and accessible seismograph to be portable.

According to a bibliographic review, we see the construction of this accessible using accelerometer as is done in the accelerographic network of the College of Engineers of Peru [5]. More with a variation of instrumentation, in this case referring to [12], where MPU6050 is used with good results in capturing movements. Then, for signal processing, we see that it is necessary to use a threshold algorithm for motion event detection, as it has a low noise ratio; which is a summary for reliable and accurate detection of P-wave arrivals as a key step in determining seismic parameters.

The algorithm is such that a detection alert is triggered event if the preset threshold is exceeded. Once the threshold is exceeded, the station sends the message about the phenomenon, in such a way that it starts with the record of the last samples detected.

The signals of a seismic movement after being processed and observed in response to acceleration, have 3 prominent forms of impulses as noise; These are known as P, S, and surface waves.

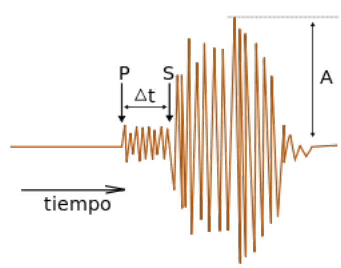

Fig. 1: Characterization of S and P waves seismic movement.

There are several scales of magnitude, although probably the best known among people is the Richter scale and Mercalli scale. Depending on the seismic network and distance, one or more can be used. Due to the different terrain structure and station position at one location, a large magnitude variation can occur between these different stations, demonstrating that magnitude measurement is not an exact discipline. Each scale of magnitude or intensity has a range of application and they are suitable for different conditions that are standardized.

According to the seismic waves read, then it can be considered Mercalli scale of measurement. Where, from the sampled graph, a description of the phenomenon will be given according to the Mercalli table and a description of the event in sensations can also be obtained.

The simplest way to calculate the local magnitude is by using Magnitude Mc (sometimes called magnitude of duration). It is an approximation of local magnitude that relates the length of the coda (duration of the event) with the size of the earthquake [11]. Is defined as:

$$M = \log A + 3\log(8 * \triangle_t) - 2.92$$

With regard to this, we obtain in magnitude if the movement is simple or dangerous. And it is possible to apply a local reference system.

To calculate the magnitude of the Richter scale and to know the location of the epicenter for this work, it is feasible through the construction of 3 of these systems that, when obtaining sensed information, are defined in a single epicenter point and allow calculation of moment in seismic movement.

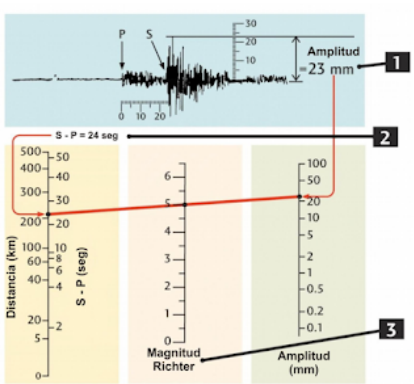

Fig. 2: Richter seismogram

Applicable to events of amplitude less than 6-7, distance less than 1500 km and frequency band of 1-20 Hz. [12], in this reference there are calculations and interpretations according to the parameters described.

Finally, this work proposes detection of seismic movement with accelerometer sensations in X, Y and Z axes, phenomenon recognition and analysis of the waves that are generated to obtain location data, date time and Mercalli scale intensity.

Mercalli escale	Sismic Aceleration(g)	Sismic Velocity (cm/s)	Earthquake perception	Potencial for harm
I	<0.0017	<0.1	No apreciable	Ninguno
II-III	0.0017 - 0.014	0.1-1.1	Muy leve	Ninguno
IV	0.014 - 0.039	1.1-3.4	Leve	Ninguno
V	0.039-0.092	3.4-8.1	Moderado	Muy leve
VI	0.092-0.18	8.1-16	Fuerte	Leve
VII	0.18-0.34	16-31	Muy fuerte	Moderado
VIII	0.34-0.65	31-60	Severo	Moderado a fuerte
IX	0.65-1.24	60-116	Violento	Fuerte
X+	>1.24	>116	Extremo	Muy fuerte

TABLE I: Mercalli scale parameters

A. *Operation Approach*

Typical rural and isolated installation locations, as well as competitive dynamic ranges and signal-to-noise ratios must be considered for real-time signal processing or post-processing, combined with very low response time settings and on-demand, activated data transfers, allowing seamless integration with existing and future earthquake monitoring and early warning systems [10].

The operation is based on the records of vibration, shock or movement detected by the integrated sensor, electrical signals will be sent to a microcontroller constantly, which through programming generates a signal where the high and low frequencies that have been observed are observed. detected to finally record the information.

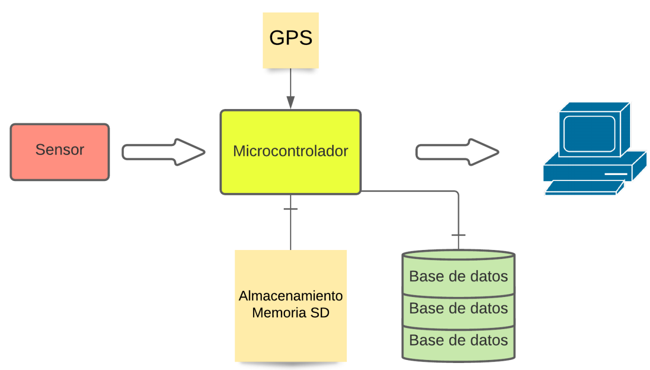

Fig. 3: Operation diagram

IV. Design Criteria

In this section, the development of the proposal is carried out in synthesis through quantitative methodology according to the proposal with choice of design feasibilities such as programming (C ++ and HTML), sensors (IMU, GPS) and, as a result action seismic detection processing calculation parameter.

The following figure summarizes the operation of the system.

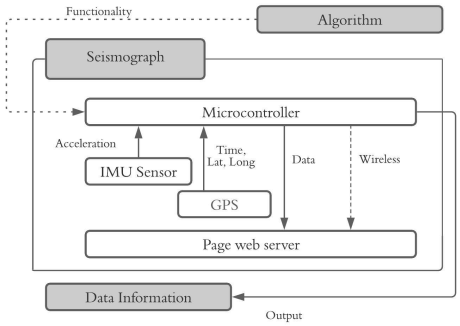

Fig. 4: System functional diagram (Own source)

Considering the portability of the seismograph, it will have a small size (a box of $18cm$ x $15cm$ x $8cm$), all the components are inside the box built with mock-up cardboard so that it cannot harm the seismograph sensitivity.

Mercalli intensity scale measurement response is used, which, by location, is proposed to be able to sense and measure a result up to no greater than 10 degrees in Mercalli intensity.

It requires a 9V power supply. In this construction a 9v battery will be used. The system will be able to measure sensations of movement thanks to the MPU6050 that integrates its Digital Movement Processor (DMP). Where it will be possible to have the measurements of the movement in 3 dimensions that will be sent to the ESP32 microcontroller by I2C communication. To filter the generated signal, the filtering algorithm is implemented, which will limit a measurement threshold. Finally with the GPS, the information is joined and the Mercalli intensity measurement is sent to a computer and to an SD memory for storage (8GB capacity).

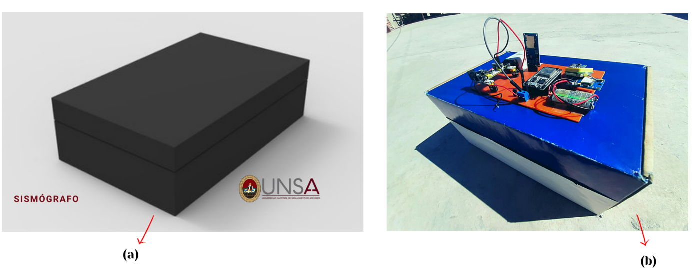

Fig. 5: Seismograph physical implementation representation

	Description	Correspondence
1	Tamaño	Box 20x15x8 cm
2	Wifi incorporado	ESP32 Wifi 802.11 n (2.4 GHz), hasta 150 Mbps
3	Almacenamiento de datos	Memoria SD Card 8Gb
4	Voltaje de operación	9V. DC
5	Convertidor	MEMS. Acelerómetro
6	Frecuencia de muestreo	10HZ-1000HZ a configurar
7	Medición	Hasta 6 a 7 grados escala Richter
8	Procesamiento	Procesador Digital de Movimiento (DMP) del MPU6050
9	Condiciones de Operacion	Aprox. Temp = 0 - 50°C.
		Humedad: por debajo del 95% de HR

TABLE II: Low cost seismograph prototype characteristics

A. Lowcost

The main criteria of the design of the system are the use of low-cost and widely available materials, especially in developing countries. This would facilitate the development of educational principles such as seismography to more students with low budgets.

The list of materials used for construction, including their costs, are shown in the following table.

	Component	cant.	price x unit	price '$S/$'
1	Módulo GPS Ublox Neo-6m V2 con memoria Eeprom.	1	92.00	92.00
2	Módulo MPU6050.	1	13.50	13.50
3	Modulo Lector De Memoria Micro SD	1	7.00	7.00
4	Cable conexión Mini-USB	1	2.50	2.50
5	Carton maqueta pliego	1	2.50	2.5
6	Bateria Pila Toshiba 9v	1	4.50	4.50
7	Módulo de interfaz Micro USB MB102 DC 7 12V	1	6.00	6.00
8	Placa Desarrollo ESP32 Ble Wifi Bluetooth 38 Pines	1	38.00	38.00
9	Computador PC	1	–	–
10	Taladro, alicate, cables, protoboard, multimetro, tablero, etc	–	–	–
-	—	- –	—	$<$ 160.00

TABLE III: Summary of components to use

B. Portable

The need for device portability arises from the trend of wireless communication technologies. That, as a good use, it is possible to transmit and obtain data from a remote place.

C. They don't need complex tools

Although it is possible to acquire a seismograph as a product in the market, they are not always available and if you are looking to put together a design, the requirements are not always available in all locations. That is why this system does not require the use of sophisticated tools for its construction.

D. OpenSource

To promote the wide use of this prototype, the information necessary for its replication is released under an open-source license.

V. Construction and Implementation

A. Schematic diagram

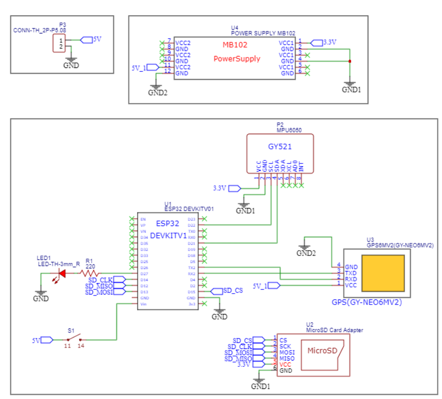

Fig. 6: Schematic diagram designed on EasyEDA platform

B. Threshold Algorithm

The implemented algorithm is described in figure 7. In such a way that it starts with the sensation of the magnitude of the acceleration. With this, when passing a threshold (specified value) it generates a record stored in a one-dimensional array of size 'n'.

As soon as the wave event is recorded, the data is sent to detect a maximum value amplitude. This last value will describe the maximum sensation in the telluric movement, and by means of the Mercalli scale an output value regulated by values of table 1 is recorded. This functionality is carried out in a repetitive loop cycle, in such a way that each time If a movement is registered, it has an output value and at the same time, it is always being verified that the threshold is exceeded to detect its amplitude.

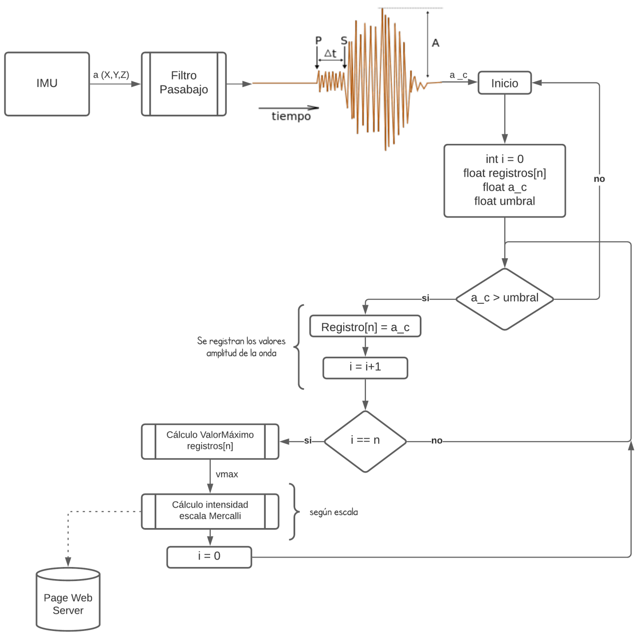

Fig. 7: System functional diagram (Own source)

C. Building

The attributes of the connection canvas for the PCB are thick $0.7mm$. On this occasion, the Cooper Area on the PCB was not considered because there is not much power in the circuit and, for convenience, connections were made that allow us to easily connect our modules for the seismograph.

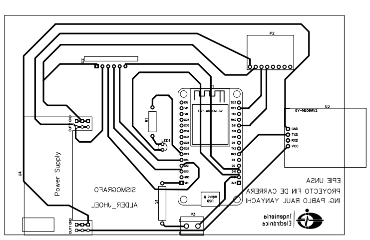

Fig. 8: PCB to scale 60% top layer (Reverse for printing)

Below is the integration of the components of the system that before is performed review of connectivity between tracks, connections, and communication for station stabilization (complete system).

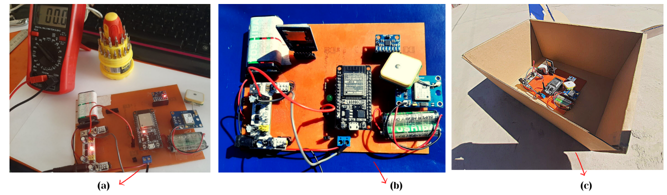

Fig. 9: Physical implementation

VI. Results

The detection of movements generating variations in acceleration in a movement are recorded in figure 10. Where, accelerations in X, Y, Z and the magnitude a_c are shown.

The final result of sending data is shown on the server web page (figure 12), which presents the sensed values in real time. Considering each acceleration value, real location, time and date, and finally the Mercalli intensity registered in the last event.

An api was added that allows us to visualize the location where we are through a Map in real time.

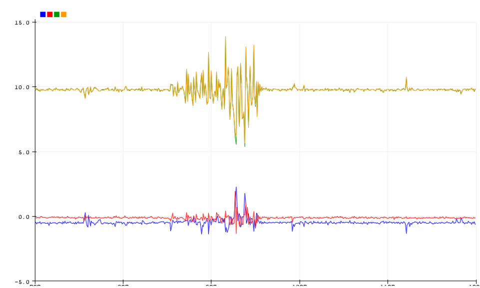

Fig. 10: Visualization of accelerographic parameters in (m / s)

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Connecting to <CR><LF>
ROS_Wireless<CR><LF>
..........<CR><LF>
WiFi connected<CR><LF>
IP address is : <CR><LF>
192.168.1.7<CR><LF>
Server started<CR><LF>
<CR><LF>
GPS GY-GPS6MV2 Leantec<CR><LF>
 ---Buscando senal--- <CR><LF>
<CR><LF>
-0.33,0.21,9.76,9.77,1.00<CR><LF>
-1.19,0.16,10.33,10.40,1.06<CR><LF>
-0.07,0.26,10.10,10.10,1.03<CR><LF>
-0.41,-0.13,9.28,9.29,0.95<CR><LF>
-0.19,-0.24,8.62,8.62,0.88<CR><LF>
-0.28,-0.18,7.85,7.86,0.80<CR><LF>
-0.11,0.19,9.64,9.65,0.99<CR><LF>
-1.35,0.55,12.23,12.31,1.26<CR><LF>
Se reconocio umbral limite<CR><LF>
0<CR><LF>
1.26<CR><LF>
1.26<CR><LF>
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0.00<CR><LF>
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Fig. 11: Visualización de parámetros numéricos

In this visualization it is a simulation of movement. Where the acceleration parameters that are normally being obtained are shown as information, and until a threshold is passed, then the number is recorded in an initially empty array, and then to perform the processing and recognition of Magnitude Intensity, such as in figure 12, a Mercalli intensity scale result.

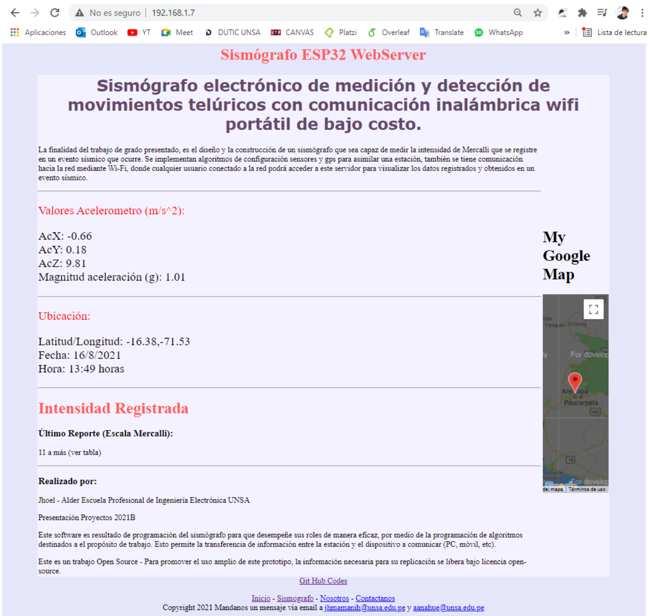

Fig. 12: Capture of web server page addressed to PC

This last figure. shows the page where any user connected to the network can enter through an IPv4 address. The server is ESP32 and each user who connects to the page will be a client, this is how this work is described.

VII. Conclusions and Recommendations

- The electronic prototype equipped with the devices of instrumentation necessary for the detection of seismic events, which are made up of of an accelerometer to determine significant telluric movements, a module GPS for location and time, a WIFI module for internet connection and a module SDCard for data backup. The prototype uses the minimum energy that can be conditioned for a longer duration, considering a jack cable input to add a type of battery supported between 9-12V for its operation but also has a battery backup to avoid the suspension of operation in the future in the event of any failure electrical. Thanks to the design developed with Wifi, there is stable connectivity with the server, allowing it to provide a degree of local reliability.

- Within the seismic monitoring system an algorithm was designed for discrimination of false earthquakes (sensor uncertainties), the same that checks that a threshold is exceeded in such a way that a data recording is activated during a seismic event, allowing the algorithm determine the intensity on the Mercalli scale, providing instant information in the range seconds range, and it can also be like an alarm before the secondary wave that is the cause of destructive situations arrives, this stage would behave as an early warning that is could connect with the relevant control agencies.

- This work has a local data feel, which allows studies of building stiffness or study of places in soils such as characteristics of compactness for thick soils, or consistency for thin soils. This is also the way to check the behavior of seismic waves traveling through soft soils, which vary by the principle of energy conservation. Possibly the topography and geometry of the deposits will constitute relevant factors for future study.

- Finally, in order to obtain a record of the epicenter of the seismic event and thus obtain the Richter scale, it is proposed in an advance to consider the construction of 3 systems that can sense different movements that when intersecting an epicenter point will be obtained, allowing us to find and find the relationship between moment and energy with scale. Richter degrees.

REFERENCES

[1] The science of earthquakes. what is seismology? http://www.seismo.unr.edu/Monitoring. Last accessed on 10/08/21.

[2] S. V. C. Alejandro. Sistema de alerta temprana de movimientos teñuricos en la universidad técnica del norte. Dissertação de pregrado, Facultad de Ingeniería de Ingeniería en Ciencias Aplicadas, Arequipa, 2020.

[3] R. Anthony, A. Ringler, D. Wilson, and E. Wolin. Do low-cost seismographs perform well enough for your network? an overview of laboratory tests and field observations of the osop raspberry shake 4d. *Seismological Research Letters*, 90, 11 2018. doi: 10.1785/0220180251.

[4] B. Haro and A. Elghazouli. Multi-purpose open-source and low-cost seismic sensing. seismo Revision 1, EEFIT Research Grant Scheme. Imperial College London, London, 2019.

[5] J. A. Hurtado, editor. *Redes acelerográficas en el Perú,*, Lima - Perú, 2020.

[6] IGEMMET. Reporte especial de actividad volcánica del ubinas. seismo Revision 1, http://ovi.ingemmet.gob.pe, Perú, 2021.

[7] Y. Jiang, P. Peng, L. Wang, and Z. He. Automated locating mining-induced microseismicity without arrival picking by weighted sta/lta traces stacking. *Sustainability*, 12 (9), 2020. ISSN 2071-1050. doi: 10.3390/su12093665. URL https://www.mdpi.com/2071-1050/12/9/3665.

[8] M. T. M. Análisis sobre la recurrencia de terremotos severos en ecuador. *Revista Prisma Tecnológico*, 1(1): 21–28, 2017.

[9] M. B. M. Manso and B. Caldeira. Design and Implementation of a Network Enabled High-Throughput MEMs-based Seismic Sensor. *Comunicações Geológicas*, 1(1): 5, 2 2017. ISSN 0873-948X. URL http://www.lneg.pt/iedt/unidades/16/paginas/26/30/209.

[10] J. A. Marta Moyano, Gabriela Iñigo. *Sismógrafo*. Instituto Nacional de Educación Tecnológica, - Buenos Aires: Ministerio de Educación, Ciencia y Tecnología de la Nación., 2006. ISBN 950-00-0536-0.

[11] M. Martinez. Seismic and vibration signal analysis and monitoring using labview. Dissertação de pregrado, School of Computing, Engineering and Physical Sciences, United Kingdom, 2016.

[12] G. Murariu, C. Vlad, D. Munteanu, G. D. Mocanu, S.-N. Iancu, V. C. Domnitanu, C. Ionescu, R.-A. Tudoran, and S. Epure. Personal seismograph system - a functional prototype. In *2019 6th International Symposium on Electrical and Electronics Engineering (ISEEE)*, pages 1–5, 2019. doi: 10.1109/ISEEE48094.2019.9136139.

[13] R. Ortiz. *Vulcanologia, instrumentación*. Cabildo de Lanzarote, Islas Canarias, 2010.

[14] C. J. M. Samanez. Evaluación de los niveles de ruido sísmico en la red sísmica satelital para la alerta temprana de tsunamis a cargo del instituto geofísico del perú. Dissertação de pregrado, Escuela Profesional de Ingeniería Geofísica, Arequipa, 2016.

[15] B. E. Udias A. Madariaga. Source mechanisms of earthquakes: Theory and practice. *University Printing House, Cambridge CB2 8BS, United Kingdom*, 2014.

[16] L. R. T. Velarde. Análisis de métodos geofísicos en la evaluación del volcán activo misti (región sur del perú). Dissertação de pregrado, Escuela Profesional de Ingeniería Geofísica, Arequipa, 2013.

[17] J. Zhang, Y. Tang, and H. Li. STA/LTA Fractal Dimension Algorithm of Detecting the P-Wave Arrival. *Bulletin of the Seismological Society of America*, 108(1):230–237, 11 2017. ISSN 0037-1106. doi: 10.1785/0120170099. URL https://doi.org/10.1785/0120170099.

[18] W. Z. H. Zin Mar Cho. Design and construction of earthquake detection and location reporting system on google map. *International Journal of Scientific Research and Engineering Development*, 2(3):3–8, 2019.