ARM based 3-axis seismic data acquisition system using Accelerometer sensor and Graphical User Interface

Rajashri P. Patil[1], Vijay D. Chaudhari[2], Dr. Kantilal P. Rane[3]

[1]PG Scholar, Department of E&TC, GF's Godavari College of Engineering, Jalgaon (MH), India

rajashripp@gmail.com, Contact no.9552233900

Abstract— Seismology is the scientific study of earthquakes & the propagation of seismic waves through the earth. The large improvement has been seen in seismology from around hundreds of years. The seismic data plays an important role in the seismic data acquisition. The recorded seismic data is used by seismologists for analysis purpose. This analysis includes mapping of Earth's interior, locating an earthquake properly, and measuring magnitude of an earthquake. The more efficient systems are used now a day to locate the earthquakes as large improvements has been done in this field. In older days analog systems are used for data acquisition. The analog systems record seismic signals in a permanent way. These systems are large in size, costly and are incompatible with computer. Due to these drawbacks these analog systems are replaced by digital systems so that data can be recorded digitally. In this paper, a recent development in seismic data acquisition has been focused. A cost-effective, small size seismic data acquisition system is implemented successfully based on ARM. The system consists of an Accelerometer sensor for sensing seismic signal along 3-axis corresponding to accelerations and can save the respective data in the memory which can be used for further analysis. The software routines written in MATLAB give graphical representation of seismic data along X, Y, and Z axis. An ARM processor compares the input signal with reference signal which is already set into the ARM processor. If the value of input signal exceeds reference signal then an alarm about possibility of an earthquake rang in PC.

Keywords— Seismic Data Acquisition, Earthquake, ARM, Accelerometer, ADC, MATLAB, Graphical User Interface (GUI)

INTRODUCTION

An earthquake is a natural disaster which can cause damage and loss of lives. It is the result of a sudden release of energy in the Earth's crust that creates seismic waves. During earthquake, degree of the damage caused is depends on the magnitude that indicates the amount of energy released from Earth's crust [1]. The magnitude of earthquake which is less than 5 is measured using local magnitude scale called as Richter magnitude scale. However earthquakes having magnitude greater than 5 are reported for world. The Richter Scale is used to measure magnitude of the earthquake by observing the amplitude on a seismogram. The Richter Scale is used because it is capable to measure decreased wave amplitude as the distance from the epicenter is increased. Richter's scale is also a logarithmic scale [12]. In recent years, a standard magnitude scale is used which represents energy released at the time of earthquake more precisely including large magnitude events. The earthquakes can be measured using a recording device such as seismometers in the form of seismograph. Seismometers are sensors that sense and record the seismic waves. The seismic waves are captured by using Seismometer, Hydrophone (in water), Geophone, or Accelerometer. A seismogram is written by seismograph in a response to vibrations produced by earthquake, or explosion. The seismograms are recorded for finding the location and magnitude of the earthquakes. In older days, seismograms were recorded on the paper in a permanent manner while now seismograms are recorded in a digital format [14]. In seismological experiments, each component of acceleration that is along x, y, and z axes is important, however in seismological calculations only one component has been taken into account. The surface waves, primary waves (p-waves) and secondary waves (s-waves) are among the important types of seismic waves which are consider mainly in earthquake detection. P-waves arrive first at seismograph stations as they travel faster than other waves. P-waves are longitudinal and are also called as compression waves. S-waves arrive after p-waves at seismograph station therefore called as secondary waves and are transverse in nature. S-waves are also called as shear waves. The surface waves are most disastrous waves because of their long duration and large amplitude. The surface waves travel along Earth's surface. Figure 1 shows structure of p-wave and s-wave [15].

The seismic data is useful in detection of earthquakes and in studying effects of the earthquake. The same seismic methods can be used for exploration of oil and natural gas. The seismic methods are based upon seismic wave measurement. This measurement can be done when any seismic source start generating seismic waves. The collection and recording of continuous seismic signals and use it for further analysis is known as seismic data acquisition. The analysis of these recorded signals to eliminate noise and create map of
the subsurface is called seismic data processing.

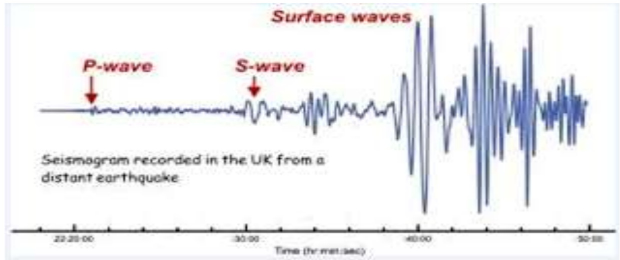

Figure 10: p-wave and s-wave from seismograph

LITERATURE REVIEW

According to survey we know that seismic data acquisition is very important factor in detection of the earthquake before arrival of it. Seismic waves are used for seismic data acquisition. Seismic waves are elastic waves that can travel through solid or liquid material. These waves are studied by seismologists to determine the location of the earthquake and measure size of sources. In previous days Seismometers are used at seismological stations for data acquisition. Conventional Seismometers use chart or drum recorder to record seismic signals. The diagram of drum recorder is as shown in Fig.2. These signals were recorded permanently. The Seismometers are costly, large in size, hard for maintenance and are not compatible with computer [1].

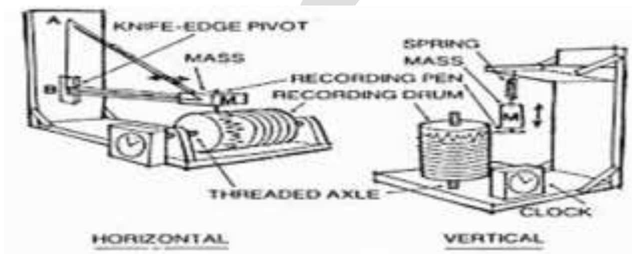

Figure 11: Drum recorder

In oil exploration, the area of exploration is large and the number of channels, sampling rate used for data acquisition are less. This decreases the efficiency of oil exploration. A multi-channel seismic data acquisition system was developed to improve the efficiency of oil exploration by means of increasing number of channels. This system is based on the wireless sensor network. The utilization of many channels at same time decreases production cost as well as efficiency also the data acquisition is improved [2]. There are many types of accelerometer sensors available in the market. The accelerometers can be used for tilt measurement, vibration or shock analysis, and to detect motion. The accelerometers available include both dual axis as well as 3-axis accelerometer sensors. The dual axis accelerometer is capable to measure dynamic and static accelerations. This dual axis accelerometer sensor can be simultaneously used as vibration or shock analysis as well as for tilt measurement. The 3-axis accelerometer sensor senses vibration, shock and gravity. This accelerometer measures accelerations along x, y, and z axes. The selection of MEMS accelerometer sensor which is to be used depends upon the requirement of the system and on the parameter which is to be measured. Micro Electro Mechanical System (MEMS) accelerometer acquires both low and high-frequency data as their frequency response is linear. MEMS accelerometer is a low cost, small size 3-axis acceleration sensor that gives acceleration value of X, Y, and Z axis. In 2008, Agoston Katalin developed microcontroller based system for vibration analysis. This system was constructed using dual axis accelerometer ADXL202 sensor and ATtiny2313 microcontroller. The system can be used for seismic monitoring, vehicle security system, inertial navigation, motion sensing. The system was based on LabWindows /CVI which gives data representation and analysis. An angle of tilt and acceleration measurement was represented corresponding to X and Y axis [3]. An inexpensive seismic network that is Quake-Catcher Network (QCN) was constructed by using distributed computing techniques and MEMS accelerometers. The QCN combine MEMS technology with computing and allows volunteers to collect seismic data and compute results. The QCN gives better earthquake recognition and helps in study of earthquakes [4]. Geophones are light in weight and require no electrical power for its operation. They are able to detect extremely small ground displacements. In older systems cables are used to carry seismic signals from geophones to recorders. In these seismic systems the number of cables and plugs used were large this causes number of troubles. In cordless seismic data acquisition system, geophones are replaced by a wireless network. The new system is based on an ARM and GSM/GPS module. This system avoids problems caused by use of geophone as well as reduces cost and manpower. Here, seismic data which is recorded was uploaded on FTP server and then converted to SEG-Y file using internet. On downloading files uploaded on FTP server, SEG-Y file was created and recorded seismic signal was represented graphically [5].In 2010.Li Ming, Yuan Zi, Jiang Chunlan developed a multi-channel data acquisition system based on data acquisition card, seismic sensor and an amplifying circuit. This system requires 8 sensors along with 8 amplifying circuits, 8-channel data acquisition board, a computer and data acquisition software. The 8-channel data was stored using spreadsheet and two waveforms are selected from 8 channels. The selected waveforms were displayed using virtual oscilloscope [6]. In recent years the use of embedded computers along with software platform in seismology has been increasing. This helps in performance improvement and offers reduced system cost. The seismic data acquisition system based on

ARM-Linux is one of the systems which are based on the hardware and software platform. This system is based on ARM9 and embedded Linux that uses high-resolution ADC. In this system a device driver that interacts with Direct Memory Access (DMA) is developed. This feature helps processor to read large amount of data from ADC. This reduces processor workload up to 25% [7]. In recent years, the use of GPS technology is increased and is helpful in examination of accelerations and motions. The disadvantage of high-rate GPS is that it gives uncertain output at high frequencies because of instrumental noise. In 2013, a new system is proposed which gives measurements from a GPS as well as a MEMS accelerometer. The sensors are low-priced as compared to Global Navigation Satellite Systems. This combined system is capable of recording ground displacements along with acceleration changes which is important factor in earthquake detection [8]. It is essential to keep record of environmental factors such as pressure, vibration, acceleration, and temperature for any device's Prognostics and Health management. These factors are helpful in estimation of process failure. The system based on MEMS sensors, ARM and FLASH is used to keep record of all these parameters. The data collected by MEMS sensors is stored in a memory and via wireless module transmitted to computer. This system offers advantage of reduced size and power consumption [9]. To analyze proper working of machines, engines, in earthquake detection, or in many scientific researches vibration measurement and its visual presentation is of important concern. A system based on accelerometer, PIC microcontroller and C# .NET was constructed which measure vibrations as well as the output can be shown graphically on the computer. This low cost system gives stable and good response in correspondence to vibration analysis up to 5 KHz frequency [10]. An earthquake alarm system using ATmega328p, ADXL335 and XBee S2 is a low cost system which can be used at home as a consumer product to save their lives. This system also consumes less power and can be used in sleep mode too [11].

SEISMIC DATA ACQUISITION SYSTEM

In recent years significant improvement and wide-spread use of digital embedded computers in seismology have been increased. This includes embedded computers consisting of a powerful microprocessor unit (MPU), a high-resolution analog to digital converter (ADC) and storage memory. However, these commercial devices are costly and restricted to modification or upgrade as well as not compatible with the computer. The use of open-source software with common hardware platform has been increasing because of advantages like open platform, improved performance, and lower cost. The seismic signals have very large dynamic range and wide bandwidth; hence ADC resolution is a key factor of designing a digital acquisition system. Here, a cost-effective seismic acquisition system based on ARM, without compromising its performance is developed. Figure 3 indicates the block diagram of the system. The first block is an accelerometer sensor which converts nonelectrical signal into electrical quantity which is in the range of (0-1.76V).Here; we are using an accelerometer sensor ADXL 335 to measure accelerations. It is a 3-axis small, thin, low power accelerometer with signal conditioned voltage outputs. When any seismic like activity happens vibrations are generated at that time accelerometer sensor senses seismic data along X, Y, and Z axis corresponding to accelerations. After sensing the vibrations the sensor converts the vibrations in to some voltage levels then an accelerometer transfers the signal to the low pass filter which is inbuilt in an accelerometer. LPF is used to reduce the high frequency component from the received signal means it reduces the distortions present in the signal. The LPF output is then passed to the ADC of an ARM 7 microprocessor. ADC converts the analog signal in to the digital form. Then the signal is given to ARM processor.

The output of ADC is transmitted via wireless transmitter Xbee S1 module. On receiver side another wireless XBee S1 module is used which receives signal from transmitter. The Xbee S1 wireless module is based on 802.15.4 protocol 1mW with wire antenna and it allows communication between microcontrollers, computers, systems, etc. with a serial port. The received data is then transferred to computer and cab be saved using excel sheet which can be used later for analysis by seismologists at seismological station. PC will contain MATLAB code with GUI which will have routines for serial communication and graph plotting. It will show real time display of graph of received data verses time.ARM processor compares the input seismic signal and referenced signal which is already set in to the processor. If input signal is greater than the referenced signal then an alarm blows in computer about possibility of arrival of an earthquake.

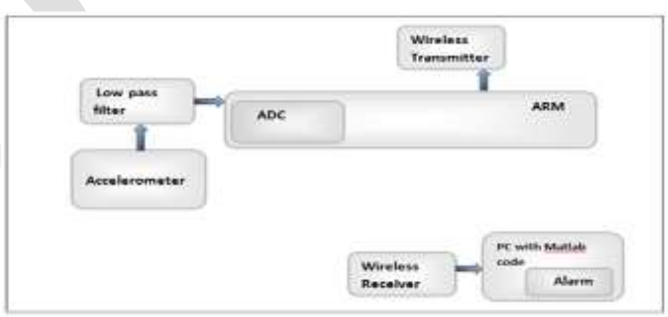

Figure 12: Block diagram of proposed seismic data acquisition system

RESULTS AND DISCUSSION

Figure 4 shows complete hardware seismic data acquisition system. The circuit operates on 5V power supply voltage. The experimental setup for data acquisition is as shown in Fig.5.An experimental setup consists of whole circuitry require for seismic data acquisition, PC and a wooden sheet of near about 7feet. The accelerometer sensor ADXL 335 is placed at one end of the sheet. When accelerometer sensor senses vibrations it produces corresponding analog output voltage. The voltage converted by ADC is transmitted using one wireless XBee module to another XBee module present at receiver side and finally transferred to PC.

Figure 4: Complete hardware system

Figure 5: Experimental setup

The GUI is as shown in Fig.6. There are three push buttons present in the GUI (1. Initialize serial port 2. Stop serial 3. Run). For the system to show graphical representation of collected seismic data, initialize serial port button is pressed due to which serial port is initialized as indicated in Fig.7.

Figure 6: Graphical user interface

Figure 7: Initialization of serial port

After pressing "Run" button on GUI, the graphical representation appears on the screen along X, Y, Z axes corresponding to voltage. For experiment, vibrations are given by steel hammer at different distances from accelerometer sensor. The experimental setup when vibrations are given at distance 1 foot from sensor is given in Fig.8 and the values obtained at X, Y and Z axis are as shown in Fig.9. Similarly, other readings are taken at distance 3 feet and 7 feet and readings are mentioned in Table 1.

Figure 8: Experimental setup for vibrations given at less than 1 foot

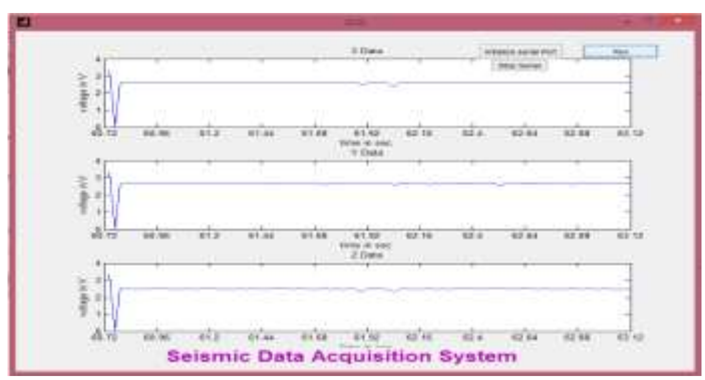

Figure 9: GUI for vibrations given at less than 1 foot

Figure 10 indicates the condition where input signal exceeds reference signal. Here, vibrations are given on wooden sheet by steel hammer with greater force as compared to vibrations given at different distances. At this situation, an alarm "An earthquake has been detected" rang in PC to inform us about arrival of an earthquake. As the sensitivity of ADXL335 is 270 mV/g to 330 mV/g, the minimum reference value selected here is 2.7V and maximum is 3.3V. The Table 1 shows outcome seismic data values obtained from experiment along X, Y, and Z axes for vibrations given at different distances from accelerometer sensor.

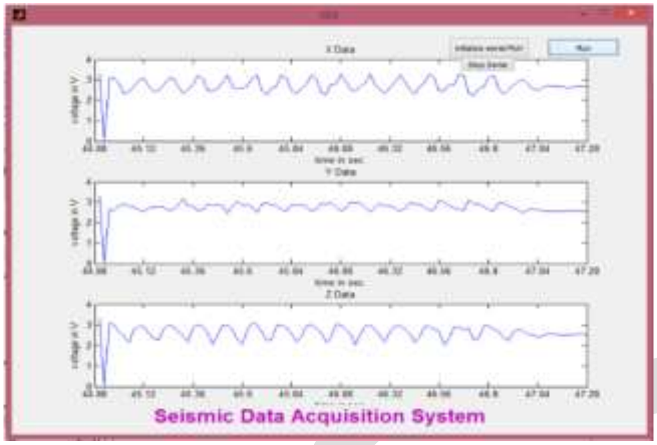

Figure 10: GUI when input signal exceeds reference signal

Table 1: Outcome seismic data values from experiment

Sr. No.	Distance From Sensor	X data	Y data	Z data	Critical Condition Indicator
1	Less than 1 foot	2.5	2.6	2.4	-
2	At 3 feet	2.5	2.6	2.5	-
3	At 7 feet	2.5	2.6	2.4	-
4	NA	3.1	3.1	3.1	Alarm in PC rang out indicates the possibility of an earthquake

From above table, it is observed that when the vibrations are given on a wooden sheet using steel hammer with same force at various distance from accelerometer sensor it is sensing data and produces the same output. This means that the accelerometer is capable of sensing data from larger distances too and gives same output as it gives at shorter distance. Also, from reading no.4 it was seen that when vibrations are given with greater force the seismic data exceeds reference value 2.7 and an alarm is generated at PC to inform about seismic like activity.

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CONCLUSION

Here, the seismic data acquisition system based on ARM7 is constructed successfully. The graphical representation along X, Y, Z axes can be seen using GUI effectively. To improve the sensitivity, high sensitivity sensor ADXL335 and high range wireless XBee series 1 module are selected. The accelerometer sensor senses the vibrations along three directions X, Y, and Z and produces corresponding output voltage within very short timing. The software routines written in MATLAB for GUI helps to represent the collected data graphically and this data is stored using excel sheet. The data stored in excel sheet can be used for further analysis by seismologists. If input signal is greater than reference signal then an alarm rang in PC to alert peoples about possibility of an earthquake. This system helps in significant reduction of cost, size and weight which help to improve its versatility and mobility as well as it is compatible with computer as compared to existing systems. As compared to already existing seismic data acquisition systems, this system is data acquisition system as well as an earthquake alarm system.

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