

Collaborative Tsunami Detection System with Data Assimilation Using Lab-VIEW

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Abstract—The objective of tsunami modelling is to develop model for faster and more reliable forecasts of tsunamis propagating through the ocean and striking coastal communities. This current attempt is to provide assistance to the Tsunami Warning Centers (TWC) in the form of forecast modelling software specifically designed to support the Tsunami Warning Center's forecasting operations. Tsunami may be primarily caused due to the quake in the sea bed or due to the landslides. There are many tsunami detecting systems present around the globe. The set up consists of the ultrasonic sensor at the sea bed and a buoy which are communicated through the satellite system and then the warning station. Whenever the ultrasonic sensor detects a change in the height of the wave on the sea bed, it transmits its output to the buoy and then it is reached to the warning station via the satellite communication.

These warning systems are efficient and many times have issued warning alert hours prior to the tsunami attack on the sea coasts. But an important factor to the tsunami development is the wavelength change drastically as the pressure from the bottom of the sea bed pushes the large amount of water upwards and then the huge volume of water propagates through the length of the shore and due to slant structure of the coast, the wave increases indefinitely hits the shore causing devastation. Many times, these alerts which might cause due to cumulative outputs may not result in tsunami. Recent days there were incidents where the alert issued caused panic around and the tsunami did not occur. The alerts were considered false. After through survey and research, a set up that can focus on the major factor, i.e. wavelength change and strengthen the information to the warning system was anticipated.

Index Terms— Ultrasonic Sensor, Tsunami Warning Centers, Lab-VIEW.

1. INTRODUCTION

1.1 Tsunami

A tsunami is a series of ocean waves generated by sudden displacements in the sea floor, landslides, or volcanic activity. In the deep ocean, the tsunami wave may only be a few inches high. The tsunami wave may come gently ashore or may increase in height to become a fast moving wall of turbulent water several meters high. Although a tsunami cannot be prevented, the impact of a tsunami can be mitigated through community preparedness, timely warnings, and effective response. From the area where the tsunami originates, waves travel outward in all directions. Once the wave approaches the shore, it builds in height. The topography of the coastline and the ocean floor will influence the size of the wave. There may be more than one wave and the succeeding one may be larger than the one before. That is why a small tsunami at one beach can be a giant wave a few miles away.

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Tsunami is a set of ocean waves caused by any large, abrupt disturbance of the sea-surface. If the disturbance is close to the coastline, local tsunamis can demolish coastal communities within

minutes. A very large disturbance can cause local devastation AND export tsunami destruction thousands of miles away. Predicting when and where the next tsunami will strike is currently impossible. Once the tsunami is generated, forecasting tsunami arrival and impact is possible through modelling and measurement technologies



Figure 1: Sea horizon under no tsunami conditions and the Tsunami effecting the coastal areas

1.2. Forecasting Impacts

Recently developed real-time, deep ocean tsunami detectors will provide the data necessary to make tsunami forecasts. The November 17, 2003, Rat Is. tsunami in Alaska provided the most comprehensive test for the forecast methodology. The Mw 7.8 earthquake on the shelf near Rat Islands, Alaska, generated a tsunami that was detected by three tsunameters located along the Aleutian Trench—the first tsunami detection by the newly developed real-time tsunameter system. These real-time data combined with the model database were then used to produce the real-time model tsunami forecast. For the first time, tsunami model predictions were obtained during the tsunami propagation, before the waves had reached many coastlines. The initial offshore forecast was obtained immediately after preliminary earthquake parameters (location and magnitude $M_s = 7.5$) became available from the West Coast/Alaska TWC (about 15-20 minutes after the earthquake). The model estimates provided expected tsunami time series at

tsunameter locations. When the closest tsunameter recorded the first tsunami wave, about 80 minutes after the tsunami, the model predictions were compared with the deep-ocean data and the updated forecast was adjusted immediately. These offshore model scenarios were then used as input for the high-resolution inundation model for Hilo Bay. The model computed tsunami dynamics on several nested grids, with the highest spatial resolution of 30 meters inside the Hilo Bay. None of the tsunamis produced inundation at Hilo, but all of them recorded nearly half a meter (peak-to-trough) signal at Hilo gage. Model forecast predictions for this tide gage are compared with observed data. The comparison demonstrates that amplitudes, arrival time and periods of several first waves of the tsunami wave train were correctly forecasted. More tests are required to ensure that the inundation forecast will work for every likely-to-occur tsunami. When implemented, such forecast will be obtained even faster and would provide enough lead time for potential evacuation or warning cancellation for Hawaii and the U.S. West Coast.

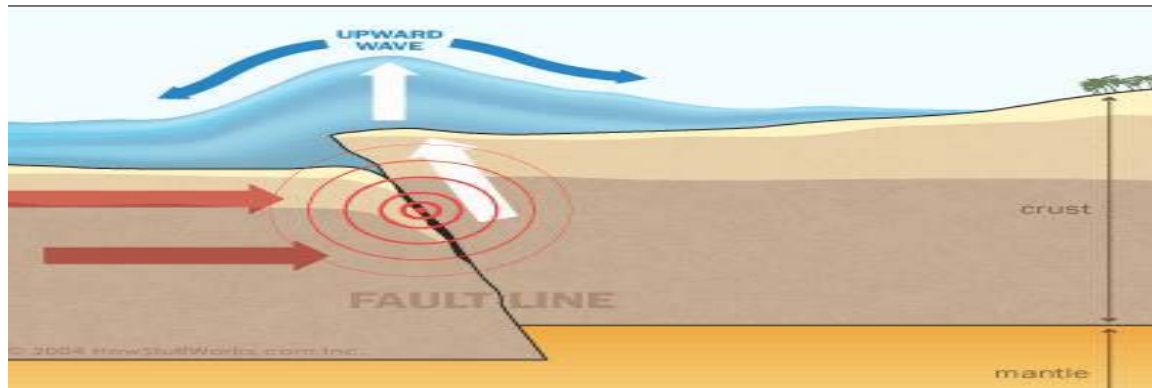


Figure 2: Animation figure for the Tsunami generation

1.3.Reduction of Impacts

The recent development of real-time deep ocean tsunami detectors and tsunami inundation models has given coastal communities the tools they need to reduce the impact of future tsunamis. If these tools are used in conjunction with a continuing educational program at the community level, at least 25% of the tsunami related deaths might be averted. By contrasting the casualties from the 1993 Sea of Japan tsunami with that of the 1998 Papua New Guinea tsunami, we can conclude that these tools work. For the Aonae, Japan case about 15% of the population at risk died from a tsunami that struck within 10 minutes of the earthquake because the population was educated about tsunamis, evacuation plans had been developed, and a warning was issued. For the Warapa, Papua New Guinea case about 40% of the at risk population died from a tsunami that arrived within 15 minutes of the earthquake because the population was not educated, no evacuation plan was available, and no warning system existed.

2. PREVIOUS WORK

Operational ocean observatory known as CYCOFOS (Cyprus Coastal Ocean Forecasting and Observing System), with a network of tsunami detection sensors was developed. The expanded network will serve as the prototype Tsunami Warning and Early Response system of Cyprus . Currently, the state of the art in tsunami detection is achieved with bottom pressure recorders (BPRs). One alternate approach utilizes GPS to measure vertical displacements of a buoy moored near

shore in conjunction with fixed differential beacons on shore [1]. Twitter demonstrated [2] its value as a viable substitute to traditional communication channels during the recent disasters. Data are collected from e-government websites of agencies involved in disaster preparedness and response. This research concludes that the Twitter-based warning system demonstrated its value as a viable complement to Indonesia's InaTEWS -- a comprehensive disaster information management system for governments -- by informing the public and creating public value through its communication speed, reach and information quality.

Earthquakes generate Rayleigh waves which travel along the surface of the earth about 20 times faster than the potentially destructive tsunami and reach distant points several hours before the tsunami. The Rayleigh wave excites an upward-propagating acoustic wave which, because of the exponential decrease in air density with height, increases to a large amplitude at ionospheric heights and produces ionization density changes in the ionosphere proportional to the amplitude and form of the wave. By analyzing the ionospheric record and tracing the Rayleigh wave back to the earthquake's epicenter, the characteristics of the earthquake can be determined [3]. Tsunami Early Warning System (TEWS) is built for minimizing impact of tsunami disaster [4]. The generic system consists of two components: the first is sensor network for tsunami detection and the second is interconnected communication infrastructure for evacuation notification. In this paper, additional sensor based on computer vision

technology is proposed for observing ocean and wave condition. This technology, combined with other sensors technology, will increase the effectiveness of the TEWS. To avoid accidents such as Tsunami, safe maritime applications [5] are

needed to determine the overhead clearance of vessels and wave height in real time using precise positioning technology. It also evaluates a software platform for precise positioning using measurements acquired in a test bed.

3. HARDWARE IMPLEMENTATION

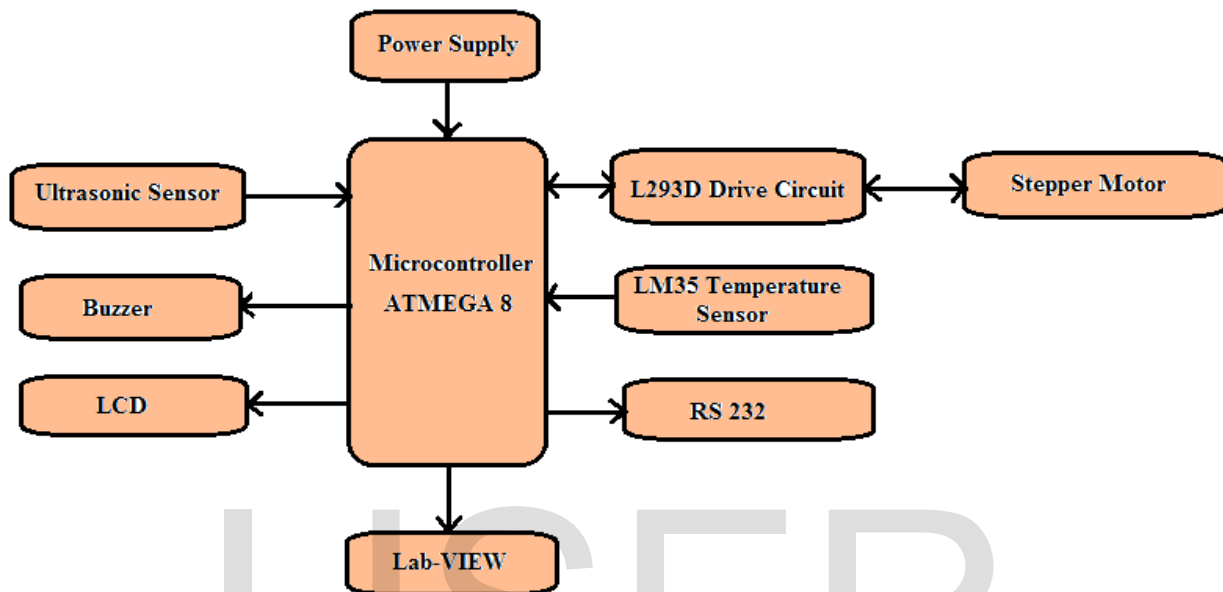


Figure 3 : Block Diagram of the Tsunami Warning System.

This paper proposes a collaborative tsunami detection system that performs continuous scan of the water horizon on the sea or ocean body. The scanning is carried out by the ultrasonic sensor that focuses on the level of the horizon. The position of the ultrasonic is a function of the steps of a stepper motor. Depending on the program in the controller, the warning is given on the LCD display and a buzzer is accompanied for the obstacle detection in the path of the ultrasonic. This set up comprises of the embedded network of the device. The project covers the data assimilation of each set up with the other similar devices which are in remote distance. For this purpose, a Lab-VIEW environment is used. In the lab-view, the distance and temperature of the ocean surface water is displayed and any changes beyond the desired levels can be detected in the lab-view and data is processed. The interfacing is done using RS-232.

The warning is given as in accordance with the micro controller when the level of the

water increases beyond the desired levels. The micro controller has given a cut off range of 30cms for the ultrasonic sensor. Whenever the obstacles occur in the cut off, then the warning displays OBSTACLE and again starts scan position from 0 with respect to the stepper motor. In the lab-view, the data assimilation is carried out whenever the alert is displayed on the ZONE1, the other ZONES acquire the data and display the alert status and location on them. To display the warning, Boolean functions are used on the front panel. All the functions are placed in the WHILE loop. A STOP button stops the function of the serial communication.

The block diagram gives the over view of the mechanism of the Tsunami Warning system. The embedded set up of the paper has been made standby using the display and buzzer system on board. The data assimilation is carried out by the Lab-VIEW environment. The RS-232 serial port acts as the interface between the micro controller and the Lab-VIEW. The stepper motor and the

ultrasonic sensor work in conjugation and the program for their functioning is dumped in the micro controller. The stepper motor works on 12V dc supply. Whereas, the onboard supply is only 5V which is regulated by the power supply circuitry. Therefore current amplification is needed in the working of the stepper motor. And for this reason, drive circuit for the stepper motor L293D is used. The set-up also consists of a temperature sensor

LM35 that can measure the temperature around the surroundings. A power supply of 220V is given which is stepped down to 12V using an adapter.

The software for the implementation was developed in the Proteus and has been dumped in the controller using the dumping software. The output for the circuit has been testing in the simulation software and verified before using the actual hardware.

3.1 Ultrasonic Sensor

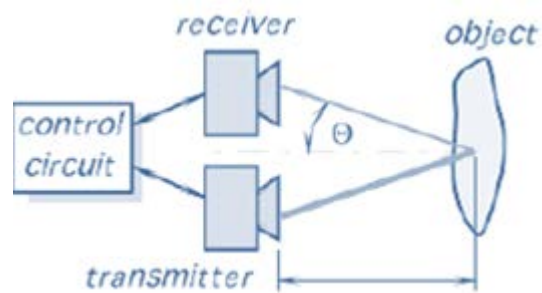
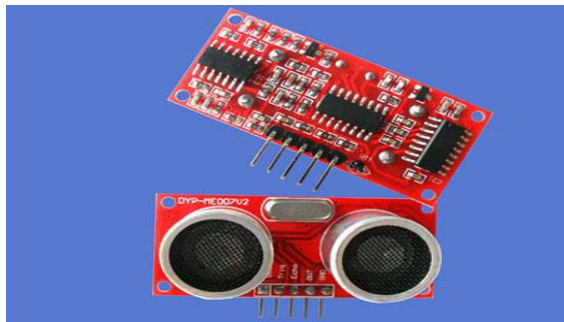


Figure 4: Ultrasonic sensor (DYP-ME007V2) and Principle of Ultrasonic Sensor

DYP-ME007 V2 ultrasonic ranging module is a high performance, cost-effective non-contact distance measurement module, and with temperature compensation; are calculated by distance by 340 m / sec to calculate; measuring range of 0.02 ~ 5.00m, accuracy 1cm, measured with the measured object without direct contact.

pulse width and can be calculated by the formula above. If no obstacle is detected, the output pin will give a 65ms high level signal.

$$\text{Ultrasonic Calculation: } L = (vt \cos \Theta) / 2 \quad \text{---(1)}$$

3.2 Stepper Motor

A short ultrasonic pulse is transmitted at the time 0, reflected by an object. The sensor receives this signal and converts it to an electric signal. The next pulse can be transmitted when the echo is faded away. This time period is called cycle period. If a 10µs width trigger pulse is sent to the signal pin, the Ultrasonic module will output eight 40kHz ultrasonic signal and detect the echo back. The measured distance is proportional to the echo

Stepper motors work on the principle of electromagnetism. It is a brushless, synchronous motor which divides a full rotation into a number of steps. Unlike a brushless DC motor which rotates continuously when a fixed DC voltage is applied to it, a step motor rotates in discrete step angles. The stepper motor can be controlled with or without feedback. There is a soft iron or magnetic rotor shaft surrounded by the electromagnetic stators. The rotor and stator have poles which may be teathed or not depending upon the type of stepper.



Figure 5: Stepper Motor.

3.3 Temperature Sensor (LM35)

LM35 is a precision IC temperature sensor with its output proportional to the temperature (in °C). The sensor circuitry is sealed and therefore it is not subjected to oxidation and other processes. With LM35, temperature can be measured more accurately than with a thermistor. It also possess low self heating and does not cause more than 0.1 °C temperature rise in still air. The operating temperature range is from -55°C to 150°C. The output voltage varies by 10mV in response to every °C rise/fall in ambient temperature, *i.e.*, its scale factor is 0.01V/ °C.

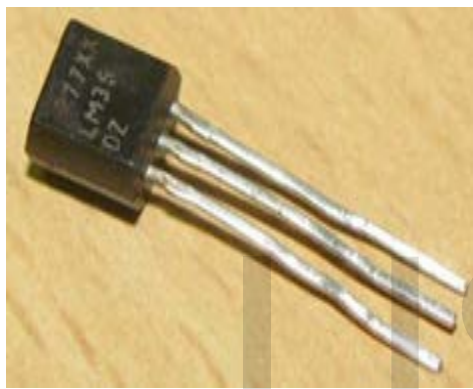


Figure 6: Temperature sensor LM35

3.4 Stepper Motor Drive Circuit

L293D is a dual *H-bridge* motor driver integrated circuit (IC). Motor drivers act as current amplifiers since they take a low-current control signal and provide a higher-current signal. This higher current signal is used to drive the motors. L293D contains two inbuilt H-bridge driver circuits. In its common mode of operation, two DC motors can be driven simultaneously, both in forward and reverse direction. The motor operations of two motors can be controlled by input logic at pins 2 & 7 and 10 & 15. Input logic 00 or 11 will stop the corresponding motor. Logic 01 and 10 will rotate it in clockwise and anticlockwise directions, respectively.

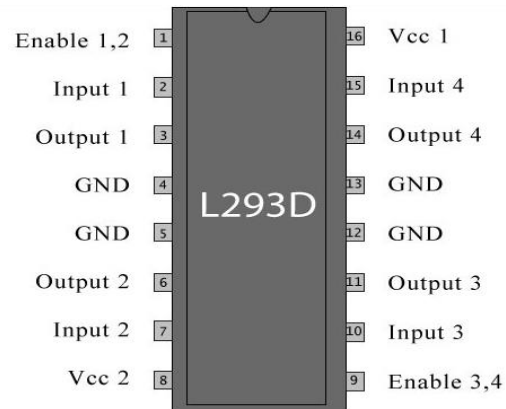


Figure 7: Pin Diagram of L293D

3.5 Microcontroller programmer/burner

It is a hardware device accompanied with software which is used to transfer the machine language code to the microcontroller/EEPROM from the PC. The compiler converts the code written in languages like assembly, C, java etc to machine language code and stores it in a hex file. A **microcontroller programmer** acts as an interface between the PC and the target controller. The API/software of the programmer reads data from the hex file stored on the PC and feeds it into the controller's memory. The target controller on which the program needs to be burned is placed on the programmer using a ZIP socket. The software transfers the data from the PC to the hardware using serial, parallel or USB port.

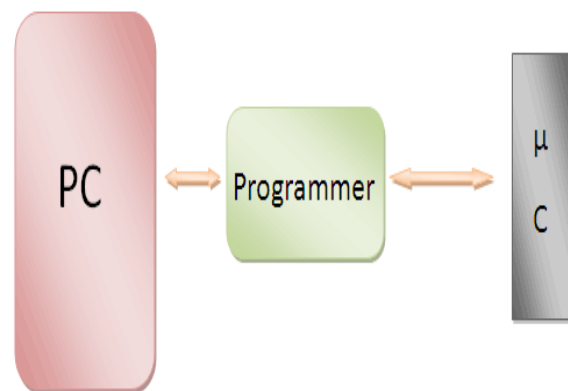


Figure 8: Microcontroller programmer/burner

IV. SOFTWARE IMPLEMENTATION

The lab view implementation of the detection of tsunami using ultrasonic sensor is carried out by coding the virtual instrument on the lab view window, both at front panel and block diagram. The window contains the indicators (here gauge and thermometer) for the distance and temperature measurement respectively. The distance from the ultrasonic is transmitted to the lab view through the serial interface unit RS-232 from the micro-controller via VISA. The warning is given as in accordance with the micro controller when the level of the water increases beyond the desired levels. The micro controller has given a cut off range of 30cms for the ultrasonic sensor. Whenever the obstacles occur in the cut off, then

the warning displays OBSTACLE and again starts scan position from 0 with respect to the stepper motor.

In the lab-view, the data assimilation is carried out whenever the alert is displayed on the ZONE 1, the other ZONES acquire the data and display the alert status and location on them. To display the warning, Boolean functions are use on the front panel. All the functions are placed in the WHILE loop. A STOP button stops the function of the serial communication. The Fig 9 below shows the front panel for the virtual instrument of the project. The case denotes OFF condition.

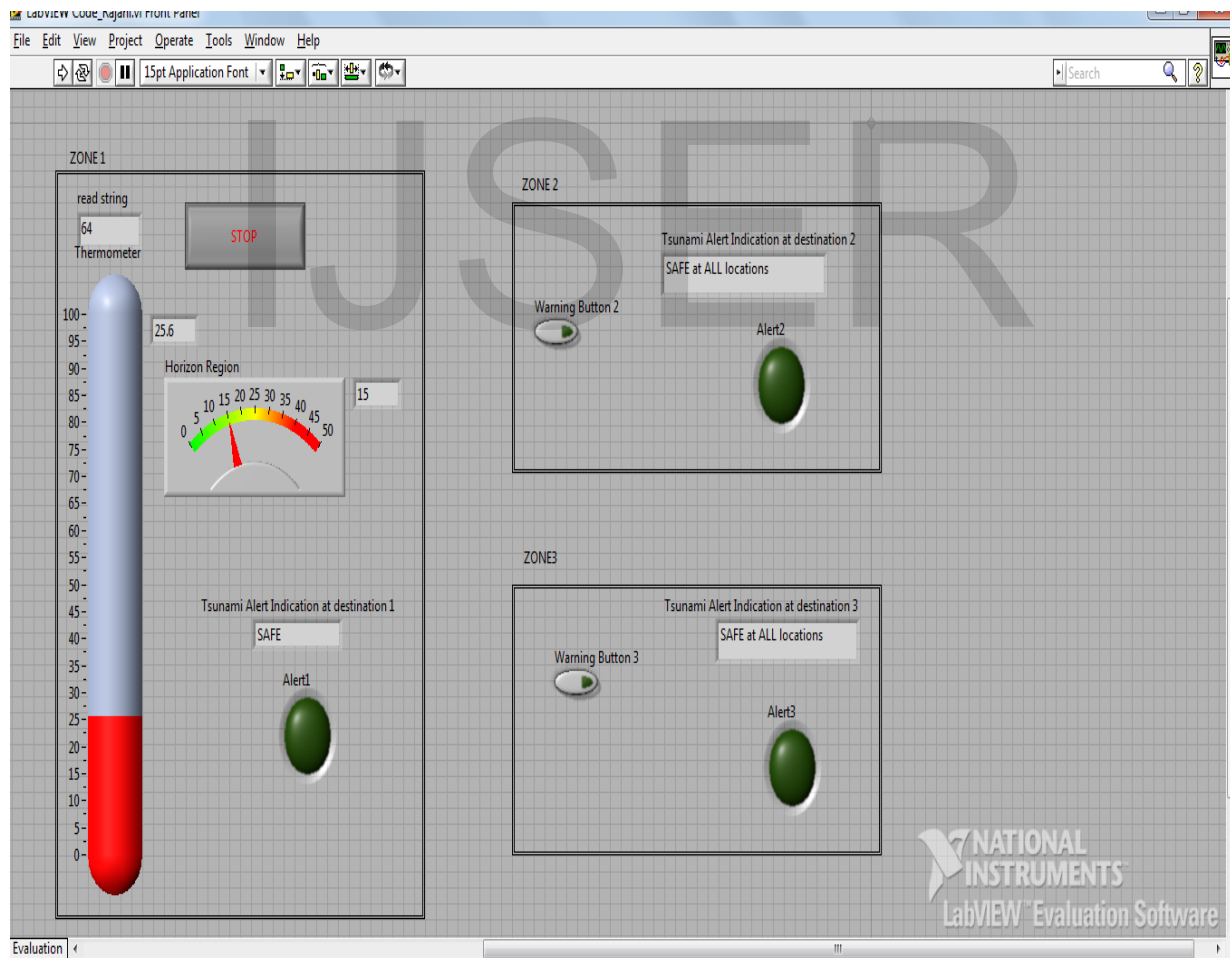


Figure 9: Lab-view front panel before the tsunami alert

The Fig 10 here shows the ON condition of the front panel. The warning alerts are display depending on the ultrasonic outputs.

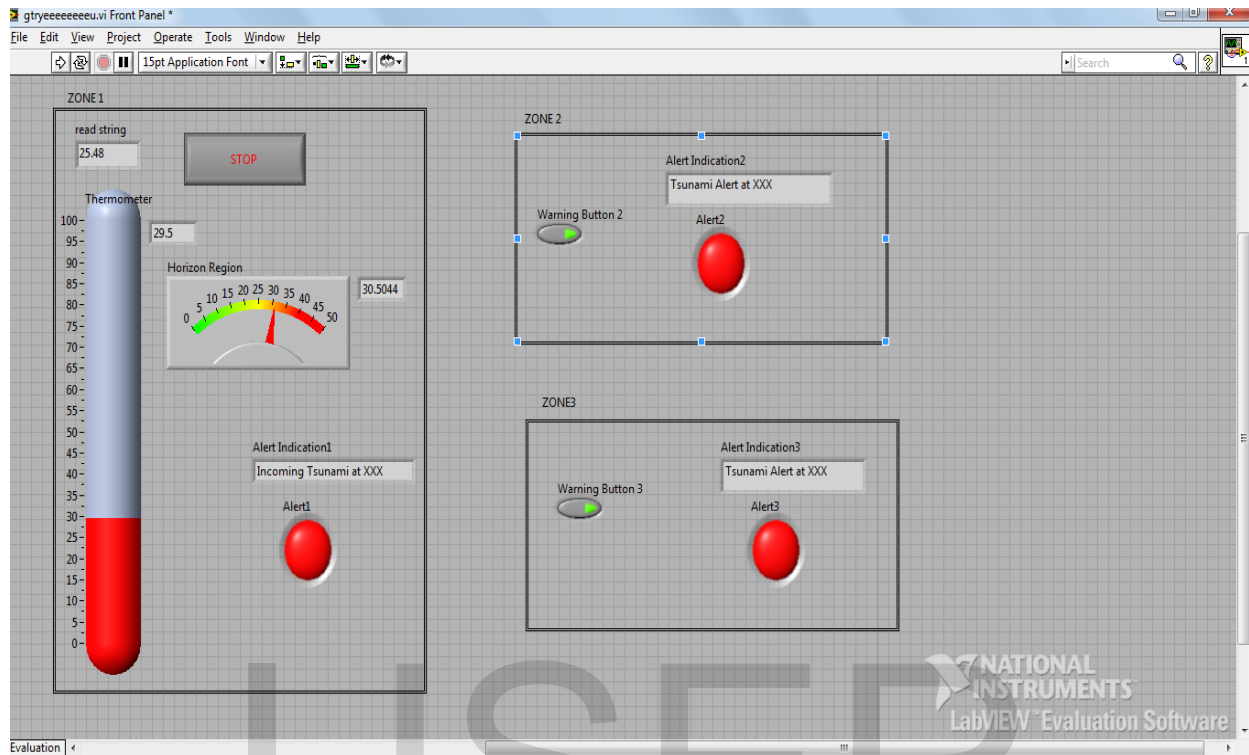


Figure 10: Front panel of Lab-view on tsunami alert

V. RESULTS AND CONCLUSION

The model for the collaborative tsunami detection is achieved with the data assimilation using the Lab-VIEW environment. The project has focused on the miniaturization of the real-time set up with a small range ultrasonic sensor and a micro controller of 8-bit. During the project, development from an idea into a hardware realization has brought about many improvements in shaping the project for more efficient output.

The objective of tsunami modelling is to develop model for faster and more reliable forecasts of tsunamis propagating through the ocean and striking coastal communities. This current attempt is to provide assistance to the Tsunami Warning Centers (TWC) in the form of forecast modelling software specifically designed to support the Tsunami Warning Center's forecasting operations. A tsunami is a series of ocean waves generated by sudden displacements in the sea floor, landslides, or volcanic activity.

Although a tsunami cannot be prevented, the impact of a tsunami can be mitigated through community preparedness, timely warnings, and effective response.

In conclusion of the report on the Collaborative Tsunami Detection System using Ultrasonic sensor, the paper was educational on various factors that cause tsunami and the various tsunami detection systems that are presently working on the cause. This paper demonstrated the scan and monitor capabilities which can strengthen the information acquired by other systems. The recent development of real-time deep ocean tsunami detectors and tsunami inundation models has given coastal communities the tools they need to reduce the impact of future tsunamis. If these tools are used in conjunction with a continuing educational program at the community level, at least 25% of the tsunami related deaths might be averted.

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Authors Profile



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