CHITTAGONG UNIVERSITY OF ENGINEERING AND TECHNOLOGY (CUET)
DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
CHITTAGONG-4349.

(Project proposal)

Application for the approval of B. Sc. Engg. Thesis/Project (Computer Science & Engineering)

Date: 18.01.2017

1. **Name of the student** : Rezaul Islam
   Roll No. : 1204088
   Session : 2016-2017

2. **Present Address** : Room No: B-203, Bangabandhu Hall,
   Chittagong University of Engineering and Technology (CUET)

3. **Name of the Supervisor** : Dr. Asaduzzaman
   Designation : Professor
   Department of Computer Science and Engineering (CSE)
   Chittagong University of Engineering and Technology

4. **Name of the Department:** Computer Science and Engineering
   Programme : B. Sc. Engineering

5. **Date of First Enrolment in the Program** : March 06,2013

6. **Tentative Title** : A Smartphone Application for Detecting and Ranging the Ground Vibration.

7. Introduction:

Ground vibrations can arise from many different sources in a modern society, for instance traffic, machines, hammering, explosions, earthquakes and construction work. Ground vibration inevitably influences its surroundings. It may affect buildings, streets, in-ground pipes and more, as well as disturb special equipment and people. Traffic vibrations are typically caused by large, heavy vehicles, like buses, driving over irregularities in the road surface. Explosions can be caused by cataclysmic nature inspired events like volcanic eruptions, or manmade ones like bomb blasts, electrical explosions and fireworks. Construction work today is frequently located in urban areas, adjacent to existing structures and humans. In Bangladesh, construction work are available all over the country. Construction-induced vibrations include vibrations from activities such as blasting, excavation, demolition, compaction and driving of piles and sheet piles. Today it is believed that vibrations from pile driving are the most common sources of construction vibrations [1].

It goes without saying that in order to quantify a problem, or potential problem, it is first necessary to measure it. There are basically three reasons why there may be a requirement to measure ground vibration:

a. To ensure that levels of vibration do not cause damage to property.
b. To prevent annoyance to people by maintaining the lowest possible levels.
c. To demonstrate compliance with conditions.

Usually ground vibration detect and monitoring by seismometer. Seismometers are instruments that measure motions of the ground, including those of Seismic waves generated by earthquakes, volcanic eruptions and other seismic sources. Records of seismic waves allow seismologists to map the interior of the earth, locate, and measure the size of these different sources. But, seismometer is costly and require experienced person to monitoring vibration by seismometer [2].

On the other hand, the sensors used in modern day smartphones are manufactured using MEMS technology (Micro-Electro-Mechanical-Systems) making them miniaturized and powerful. The modern-day smartphone is equipped with low-power three-axis linear accelerometer which measures acceleration (in meters per second2) in Linear, Transversal and Vertical directions. The maximum sampling rate that a smartphone accelerometer could give is currently 200 samples per second. However it varies over various phone platforms, 100 samples per second is observed to be consistent sampling rate which is guaranteed in almost all the smartphones across the platforms [3]. That's why I will make a smartphone application using sensor for detect and ranging ground vibration.

Processing of sensor readings from smartphones for analyzing vibration events can be challenging. Following are some challenges to build my application:

Availability of Real Data-Sets: It is even more challenging to have the environment controlled enough to be able to place smartphones in and around the vicinity of a vibration event, and simultaneously obtain high quality ground truth data for subsequent analysis of vibration events.

Stability of the Smartphone: Smartphone accelerometers being highly sensitive, generate noise (even when the phone is static) that needs filtering.

Retaining only Vibration Related Data in Smartphones to Save the Storage: While the energy consumed during sensing activities in modern smartphones is quite minimal (less than 200mJ per second), the issue of continuously collected sensory readings overloading the storage in the smartphone can become problematic.

Lack of Practical Models to Range Vibration Sources: The challenge in obtaining ground truth data during vibration, has meant that there is very little body of work in attempting to range vibration sources.

Designing a Smartphone App for Ranging and Estimating Intensity of Vibrations: After demonstrating the feasibility of leveraging smartphone sensors to estimate the range and intensity of vibration, the issue of designing smartphone apps becomes a practical one. However, this aspect is quite challenging from numerous fronts including energy and storage efficiency.

8. Background and Present State of the Problem:

This dissertation work shares similarity with the below discussed systems in the aspect of working with the accelerometer sensors in smartphones to detect ground vibrations, however the focus was on monitoring the earthquakes producing ground vibrations and on sharing the data across the network. My work differs from them in the sense of analyzing ground vibration arising from pilling and construction project by the smartphones using continuously sensed accelerometer.

In reference [4], Community Sense and Response (CSR) system proposed by Faulkner,leverages accelerometer sensors in smartphones and consumer electronics for monitoring earthquakes. The authors have built a seismic network for the smartphone users to contribute a significant amount of event data to a centralized server. To demonstrate the effectiveness of the system, the authors have used real data-sets collected from 3000 low-cost accelerometers distributed freely in the Los Angeles area, where minor earthquakes are a common phenomenon. The CSR system demonstrated that around 50 phones should be enough to detect a nearby magnitude 5 or larger earthquake event with high success rate. The algorithmic challenges of designing, building and evaluating a scalable network for real-time awareness of earthquakes were also presented.

In reference [5], The iShake project designed by Jack, at the University of California, Berkeley resulted in the design of a mobile client back-end server architecture that uses sensor-equipped mobile devices to measure vibrations from earthquakes. iShake provides the general public with a service to contribute a significant amount of data towards earthquake research by automating the data collection and reporting mechanisms via the iShake mobile application. To demonstrate the feasibility, a test procedure called Shake-table was devised to verify the quality of the accelerometer recordings in the context of earthquake sensing.

In reference [6], accelerometer readings from numerous smartphones were collected over a continuous period of time in Berkeley (CA) area, during which time multiple earthquakes affected the area of monitoring. Subsequently human activities were also been recorded using these smartphones and using a classifier algorithm based on neural networks, accelerometer readings associated with earthquakes were distinguished from that associated with activities of human users with very high accuracy.

9. Aims with Specific Objectives and Possible Outcomes:

The proposal work will be carried out with view to achieve the following objectives:

i. To detect ground vibration arising from pilling and construction project.
ii. To evaluate the range of vibration.
iii. To evaluate the intensity of vibration.

10. Outline of Methodology/Experimental Design:

The schematic representation of proposed system is illustrated in Figure 1.

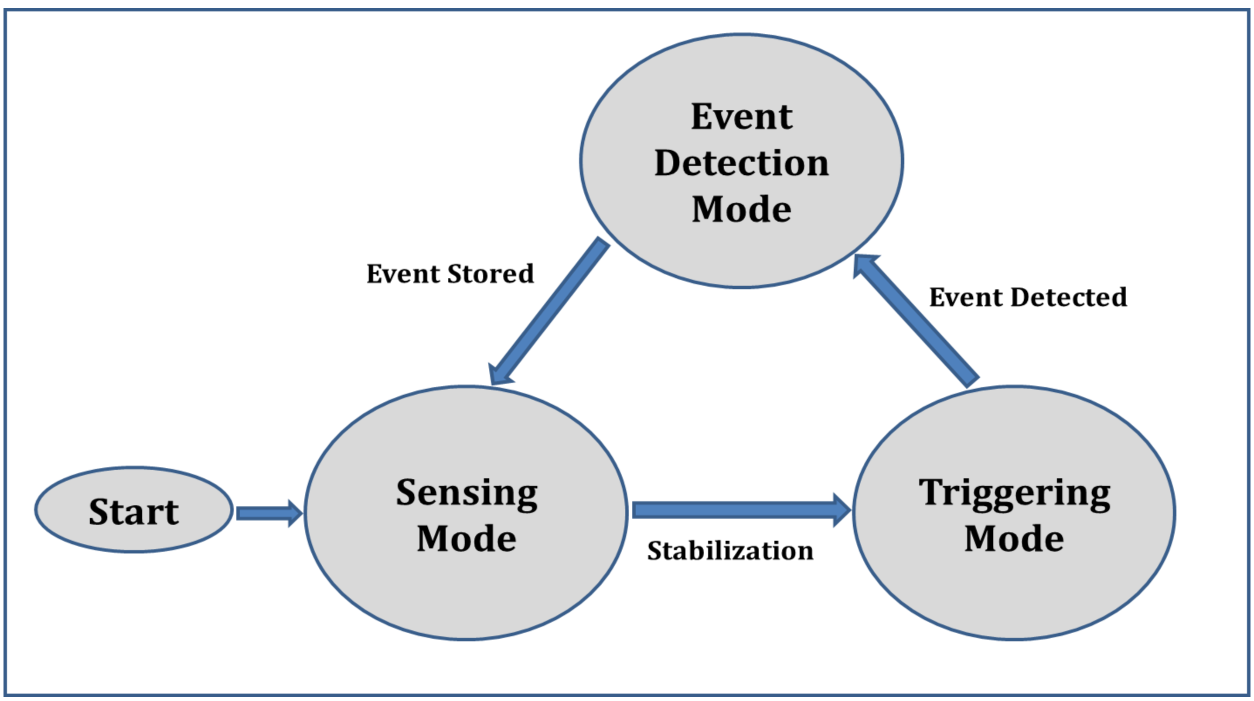

Figure-1: Schematic representation of proposed system

There are three phases of operation: Sensing, Triggering and Event Recording. In the Sensing phase, the smartphone will execute tasks related to sensing of ground vibrations, with the core challenge being ensuring the stability of the phone from ambient noise, prior to data processing.

Sensing Phase: As soon as the smartphone starts monitoring, it has to be checked for the stability since the design specifically detects the vibrations from the stationary device. In this mode the stability of the device is made sure to move on to the next state and stability (s_d) of the system is determined by the change of acceleration from the last known sample to the present sample. Since the smartphone accelerometer is a tri-axial sensor that gives acceleration in longitudinal, transversal and vertical (x, y and z respectively) directions, the stability is determined for the resultant of acceleration in all the 3 directions.

$$\mathrm{S}_{\mathrm{d}=}(\mathrm{a}_{\mathrm{t}}^{\mathrm{x}} - \mathrm{a}_{\mathrm{t}-1}^{\mathrm{x}})^2 + (\mathrm{a}_{\mathrm{t}}^{\mathrm{y}} - \mathrm{a}_{\mathrm{t}-1}^{\mathrm{y}})^2 + (\mathrm{a}_{\mathrm{t}}^{\mathrm{z}} - \mathrm{a}_{\mathrm{t}-1}^{\mathrm{z}})^2$$

Where,

t: time of arrival of current sample,

t - 1: time of arrival of previous sample,

a_{t}= ($\mathrm{a}_{\mathrm{t}}^{\mathrm{x}}$; $\mathrm{a}_{\mathrm{t}}^{\mathrm{y}}$; $\mathrm{a}_{\mathrm{t}}^{\mathrm{z}}$): acceleration vector at time t.

Ideally $S_{d=}$ 0, if the device is absolutely stable, which happens when $\mathrm{a}_{\mathrm{t}}^{\mathrm{x}}= \mathrm{a}_{\mathrm{t}-1}^{\mathrm{x}}$, $\mathrm{a}_{\mathrm{t}}^{\mathrm{y}}= \mathrm{a}_{\mathrm{t}-1}^{\mathrm{y}}$ and $\mathrm{a}_{\mathrm{t}}^{\mathrm{z}}= \mathrm{a}_{\mathrm{t}-1}^{\mathrm{z}}$.

Triggering Phase: In this phase the device is confirmed to be stable. This is phase in which the smartphone detects the actual triggering of an vibration if it meets the criteria for the vibration. The method processes each incoming signal in multiple steps. When an accelerometer sample is received, each component of the measurement vector x, y and z are processed separately. In the first step, the samples x, y, z are corrected as (x - $\bar{x}$), (y - $\bar{y}$), (z - $\bar{z}$) respectively, using the correction factors evaluated in the sensing phase to measure the absolute change in acceleration. Then, the next step is processing these acceleration values to detect the triggering of ground vibration.

Event Recording Phase: The final phase of the operation of the method is the Event Recording Phase. This phase is executed when the phone detects the triggering of the ground vibration, and its subsequent de-triggering. When that happens, the accelerometer samples are recorded on to the phone along with the pre-event memory as an Event (E). Note that all readings are recorded until the de-triggering condition is met. The phone then returns to the sensing phase and the cycle repeats.

After took data from android app I use the model for estimating the distance and intensity of ground vibration. Subsequently, the model is validated and results are presented. For ease of reading, I point out that the parameters I want to estimate are the distance (d) and intensity (i) of ground vibration, and these two are called world-states. The inputs I have are the raw measurements from the smartphone accelerometers in lateral (x), longitudinal (y), and vertical (z) directions.

I will implemented the application as a two module architecture, as shown in Figure 2 and Figure 3. The functionality of first module is to detect the triggering of the ground vibration and handover the detected event to the second module which estimates the distance and intensity of the vibration. The detailed functionality is described in the following:

Functionality of Module-1: This module is to sense and retain only ground vibration. I will used time-window values, threshold constants determined in my prior work. While the app runs continuously in the background, the smartphone senses and processes the acceleration samples in two moving time windows of different sizes. The sample S_a consists of accelerometer readings available in x, y, z directions. The readings in sample S_a are added to two moving time windows, namely a `short-time-queue' (STQ) of size 0:1 second and `long-time-queue' (LTQ) of size 10 seconds (simultaneously for all the 3 directions). Further, averages are calculated in the moving time windows, and their ratio is computed as:

short-time-queue-average/long-time- queue -average (STA/LTA)

This ratio is compared against the trigger-threshold TRth. If the ratio founds to exceed the threshold in all 3 directions, then the algorithm triggers the detection of ground vibration and starts recording the vibration event as `E'. The event is recorded until the ratio value falls below the de-trigger threshold DTRth in all 3 directions.

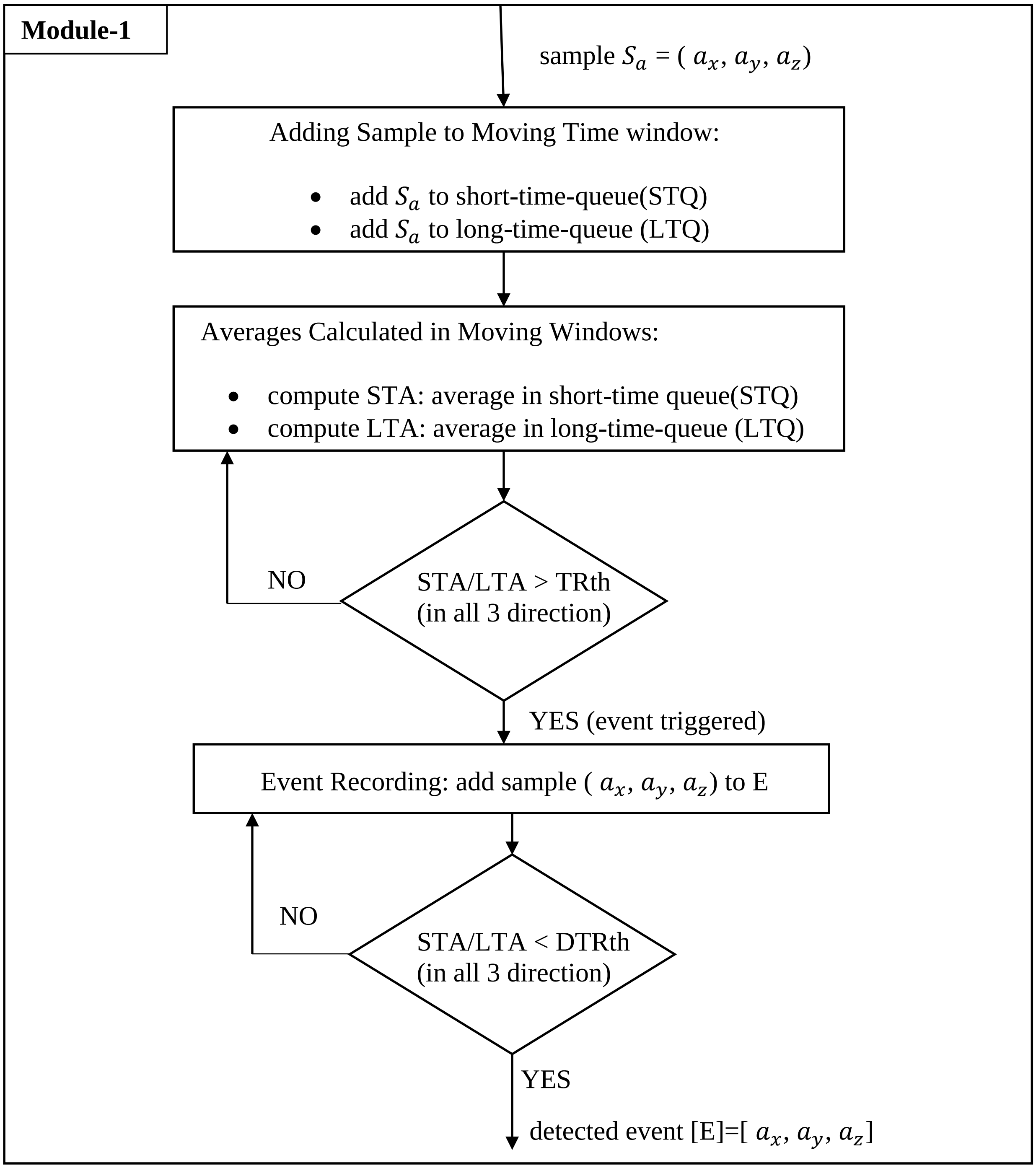

Figure 2: Module-1 Architecture

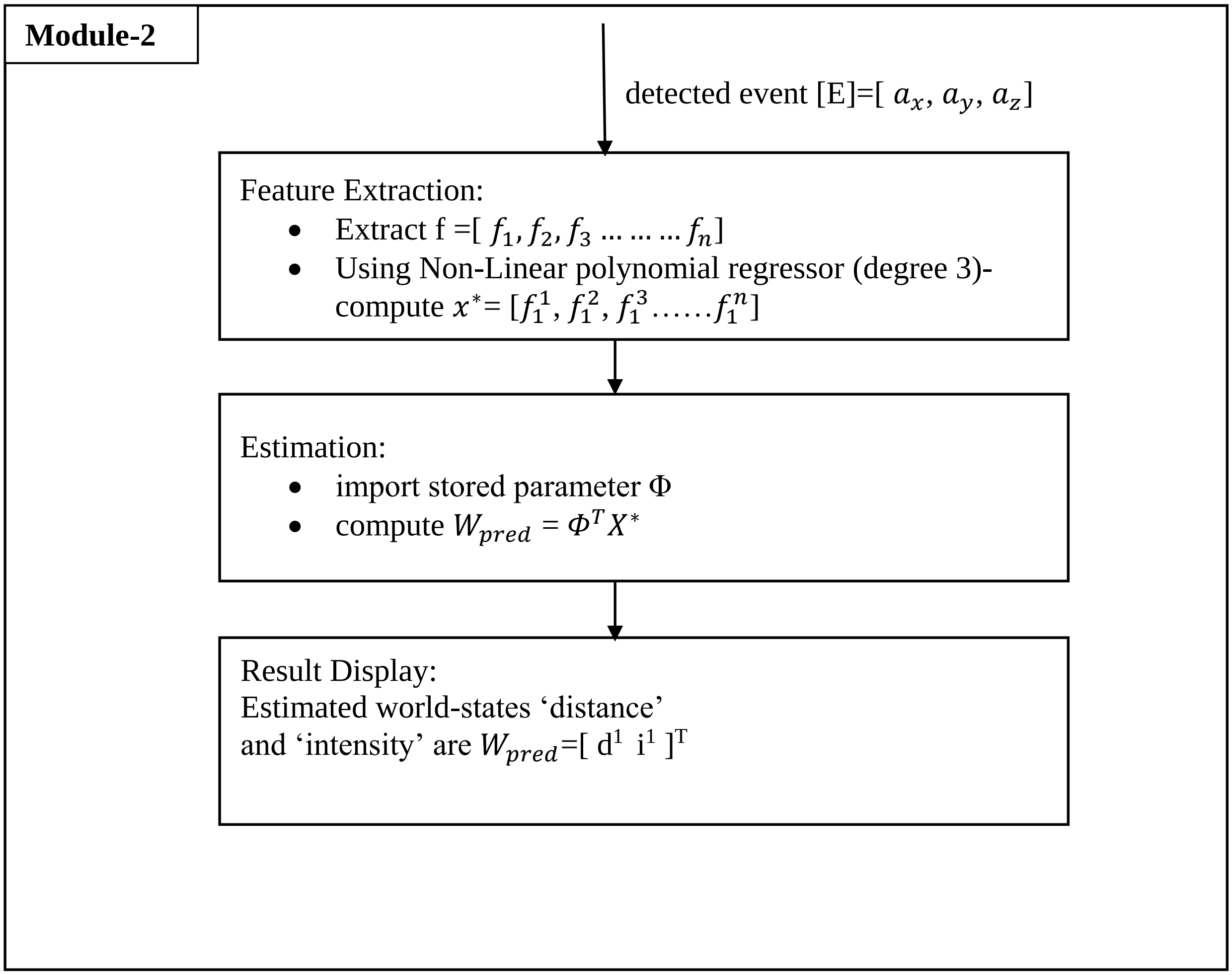

Figure 3: Module-2 Architecture

Functionality of Module-2: This module is an implementation of the model proposed in the current work for ranging and estimating intensity of ground vibration detected. As soon as the module receives the event [E] = [a_x, a_y, a_z] from the previous module, the feature-vector f=[$f_1, f_2, f_3 \ldots \ldots \ldots f_n$], is extracted for the event. The feature vector is then fed to a nonlinear polynomial regressor of degree-3, which results in a test vector X^* = [f_1^1, f_1^2, $f_1^3 \ldots\ldots f_1^n$$]^T$. The next step is estimation, where world parameters distance and intensity.

11. Application Area:

1. Detecting and ranging the ground vibration arise from piling and construction project.
2. Ranging the explosive event.
3. Ranging the vibration arise from instance traffic, machines and hammering,

12. Resources Required Completing the Work:

1. **Hardware:**
   i. Personal Computer
   ii. Android Phone
2. **Operating System:**
   i. Android 4.4 or above
   ii. Windows 8
   iii. Windows 10

3. **Platform:**
   i. Android
   ii. Java

13 References:

[1] F. Deckner, "Ground vibrations due to pile and sheet pile driving – influencing factors, predictions and measurements" at *NCC Engineering and the Division of Soil and Rock Mechanics,* September 2009.

[2] A. Maslin, "Monitoring Ground Vibration arising from Piling and Civil Engineering Projects", May 2004 (Revised May 2015).

[3] S. C. Thandu, S. Chellappany, Z. Yin, “Ranging Explosion Events Using Smartphones” at *2015 IEEE 11th International Conference on Wireless and Mobile Computing, Networking and Communication (WiMob).*

[4] M. Faulkner, R. Clayton, T. Heaton, K. M. Chandy, M. Kohler, J. Bunn, R. Guy, A. Liu, M. Olson, M. Cheng, and A. Krause “Community sense and response systems: Your phone as quake detector” *Commun*. ACM, 57(7):66-75, July 2014.

[5] J. Reilly, S. Dashti, M. Ervasti, J. D. Bray, Steven D. Glaser, and A. M. Bayen “Mobile phones as seismologic sensors: Automating data extraction for the ishake system” IEEE T. *Automation Science and Engineering*, 10(2):242:251, 2013.

[6] Q. Kong and R.M. Allen. “Using smartphones to detect earthquakes” In AGU *Fall Meeting Abstracts*, volume 1, page 04, 2012.

14. CSE Undergraduate Studies (CUGS) Committee reference:

Meeting No.: **Resolution No.:** **Date:**

15. Number of Under-Graduate Student(s) working with the Supervisor at Present: 12

Signature of the student

Signature of the supervisor

Signature of the Head of the Department