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A Seminar Report On

EARTHQUAKE PREDICTION

AND

MOBILE TECHNOLOGY

(3rd year VI Semester Computer)
For the partial fulfillment of internal assessment of the subject:
Seminar

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Under the Guidance of

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CERTIFICATE

This is to certify that Students of third year of the course Computer Engineering as a part of seminar work prescribed by the Mumbai University for the subject
Seminar

And the following students associated with the topic

EARTHQUAKE PREDICTION AND MOBILE TECHNOLOGY

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"It is not possible to prepare a project report without the assistance & encouragement of other people. This one is certainly no exception."

On the very outset of this report, we would like to extend our sincere & heartfelt obligation towards all the personages who have helped us in this endeavour. Without their active guidance, help, cooperation & encouragement, we would not have made headway in the project.

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Introduction:

Earthquake warning system

An **earthquake warning system** is a system of accelerometers, communication, computers, and alarms that is devised for regional notification of a substantial earthquake while it is in progress. This is not the same as earthquake prediction, which is currently incapable of producing decisive event warnings.

Time lag and wave projection

An earthquake is caused by the release of stored elastic strain energy during rapid sliding along a fault. The sliding will start at some location and progress away from this hypocenter in each direction along the fault surface. The speed of the progression of this fault tear is slower than and distinct from the speed of the resultant pressure and shearwaves, with the pressure wave traveling faster than the shear wave. The pressure wave will generate an abrupt shock while the shear waves can generate a periodic motion (at about one cycle per second) that is the most destructive in its effect upon structures, particularly buildings that have a similar resonant period, typically buildings around eight floors in height. These waves will be strongest at the ends of the slippage, and may project destructive waves well beyond the fault failure. The intensity of such remote effects are highly dependent upon local soils conditions within the region and these effects are considered in constructing a computer model of the region that determines appropriate responses to specific events.

Transit safety

Such systems are currently implemented to determine appropriate real-time response to an event in determining train operator response for urban rail systems such as BART (Bay Area Rapid Transit). The appropriate response will be highly dependent upon the warning time, the local right–of–way conditions, and the current speed of the train.

Deployment

As of 2013, Japan is the only country with a comprehensive nation-wide earthquake early warning system. Other countries and regions have limited deployment of earthquake warning systems, including Taiwan, Mexico (installed to issue alerts to Mexico City primarily), limited regions of Romania (Basarab bridge in Bucharest) and parts of the United States. The earliest automated earthquake pre-detection systems were installed in the 1990s, for instances in California the Calistoga fire station's system which can automatically trigger a city-wide siren to alert the entire area's residents.[1] While many of these efforts are governmental, several private companies also manufacturer earthquake early warning systems to protect infrastructure such as elevators, gas lines and fire stations.

Japan's Earthquake Early Warning system was put to practical use in 2006. Its scheme to warn the general public was installed on October 1, 2007.[2][3] It was modeled partly on the Urgent Earthquake Detection and Alarm System (UrEDAS) of Japan Railways, which was designed to enable automatic braking of bullet trains.

Chapter 2: Monitoring Instruments

2.1 Creepmeters

A creepmeter measures fault slip by recording the displacement between 2 piers or monuments located on opposite sides of the fault. Typically, an invar wire is anchored to one pier and is stretched across the fault. Its displacement relative to the second pier is measured electronically and checked periodically with a mechanical measurement. Using the angle of the wire from the strike of the fault, the change in distance between the two piers is directly proportionally to fault slip.

Because the piers are anchored to about 2 meters depth, they are subject to the influence of seasonal (winter) rainfall. Many of the creepmeters show an annual cycle due to the wetting and drying of the near-surface materials within the fault zone. In addition, creep is influenced by large rainfall events and nearby earthquakes.

2.2 Magnetometers

Magnetometers measure changes in local magnetic fields resulting from a combination of mean crustal stress change, fluid flow associated with earthquakes, fault slip, and a number of processes related to volcanic activity. To isolate these local magnetic fields, the magnetic data must be corrected for normal geomagnetic field variations, magnetic storms and other disturbances including those generated by cultural activity. Ultra-precise, absolute instruments with a precision of 0.2 nanotesla are used. Higher frequency disturbances are monitored using fluxgate or coil magnetometers. The monitoring sensors are carefully located in regions where the local magnetic field gradient is less than 1 nanotesla/meter to avoid spurious signals being generated during ground movement generated by earthquake shaking and volcanic eruptions. Because proton magnetometer measurements are absolute, data from any particular year can be compared with that from yesterday or 20 years ago or longer. Thus, long term changes related to plate movements can be isolated in the data. Rapid correction for most non-tectonic disturbances can be achieved by simple differences between data from two nearby magnetometers.

Pore Pressure Monitors

These instruments record fluid pressure changes in deep boreholes that may be driven by fault activity. Measurements can be made to better than 0.1 millibar.

2.3 Strainmeters

Strainmeters for continuous crustal strain monitoring are highly sensitive instruments with precision of less than 1 part per billion (i.e. less than 1 inch in 16,000 miles). They are usually installed in boreholes where surface noise is greatly reduced. These instruments monitor the change in crustal strain near active faults and volcanoes associated with fault slip, earthquakes, and volcanic activity. Currently, numerous instruments have been installed by the USGS along the San Andreas fault, in the Long Valley Caldera, and by other institutions near active faults and volcanoes in the US, Japan, China, Iceland, Italy, and Taiwan.

The *Sacks-Evertson dilational borehole strainmeter* consists of a stainless-steel cylinder with an annulus filled with silicone oil. Changes in volumetric strain in the ground are detected by small movements of the walls of the borehole and are measured relative to the borehole diameter. This is translated into displacement and voltage by an expansion bellows attached to a linear voltage displacement transducer. The instrument is cemented into the ground at a depth of about 200 meters.The *Sacks-Evertson tensor strainmeter* is similar in principle but the annulus is divided into three independent segments, 120 degrees apart. Strain is determinied in these three directions.

Borehole tensor strain is also measured with a *GTSM strainmeter* built by GTSM Technologies in Queensland, Australia. These instruments measure strain in three directions, 120 degrees apart (a fourth redundant component is also included) with a differential capacitance displacement transducer.

For near-surface strainmeters, we measure linear strain by detecting the relative movement of deep anchor points about 10 meters apart and about 2 meters deep in three directions 120 degrees apart with differential capacitance displacement transducers.

Networks of dilational and tensor strainmeters were initially installed in San Juan Bautista, Parkfield, Southern California and Long Valley in the early 1980's. These networks were later supplemented as increased hazard was identified in Parkfield in the mid-1980, Long Valley in 1989, and the San Francisco Bay area in the late 1990's. A network of six dilational strainmeters and two tensor strainmeters was initially installed along the Hayward fault in the San Francisco Bay area in 1992 with an additional five DTM tensor strainmeters added through the Bay Area in 2001. Near-surface strainmeters have operated in the Presidio of San Francisco since 1972.

The figure shows a borehole strainmeter being installed to a depth of about 200 meters near the Hayward fault, San Francisco Bay, California. A commercial drill rig is used to drill and case 6" to 8" diamater holes and to core the bottom of these holes until a section of about 10 feet of unfractured rock is obtained. The strainmeter is then installed into a bath of expansive grout within the cored section of the hole. After the grout has set, the instrument detects deformation of the rock. This deformation is converted to ground strain through calibrations obtained from comparing the measured earth tide with the predicted tides in the solid earth corrected for ocean tide loading.

2.4Tiltmeters

Tiltmeters are highly sensitive instruments used to measure ground tilt (rotation) near faults and volcanoes caused by fault slip and volcanic uplift. The precision to which tilt can be measured is less than 1 part per billion (i.e. less than 1 inch in 16,000 miles). For crustal monitoring applications, these instruments are mostly installed in boreholes to avoid spurious ground tilts produced by differential thermal expansion in near-surface materials, rainfall and pumping effects.

Tilt detections systems vary depending on the particular instrument design types used. These design types include simple pendulums (boreholes), liquid level systems (vaults or observatories) or the position of a bubble under concave quartz (similar to a carpenter's level deep borehole tiltmeters. This type of detection system was used in five of the seven tiltmeters installed in the San Francisco Bay area from 1992 to 2001.

The figure shows borehole strainmeters and tiltmeters being installed at a depth of about 200 meters near the Hayward fault, San Francisco Bay, California. A water-well drill rig is usually used to drill and case these boreholes and to core the bottom of these holes. Tiltmeters are usually cemented well within the casing to avoid tilting from movement on localized cracks and fractures.

Hydrologic precursors to earthquakes:

Abstracts

This review summarizes reports of anomalous flow rates or pressures of groundwater, oil, or gas that have been interpreted as earthquake precursors. Both increases and decreases of pressure and flow rate have been observed, at distances up to several hundred kilometers from the earthquake epicenter, with precursor times ranging from less than one day to more than one year. Although information that might rule out nontectonic causes does not appear in many published accounts of hydrologic anomalies, several recent studies have critically evaluated the possible influences of barometric pressure, rainfall, and groundwater or oil exploitation. Anomalies preceding the 1976 Tangshan, China, and the 1978 Izu-Oshima-Kinkai, Japan, earthquakes are especially well-documented and worthy of further examination.

Among hydrologic precursors, pressure head changes in confined subsurface reservoirs are those most amenable to quantitative interpretation in terms of crustal strain. The response of pressure head to earth tides determines coefficients of proportionality between pressure head and crustal strain. The same coefficients of proportionality should govern the fluid pressure response to any crustal strain field in which fluid flow in the reservoir is unimportant. Water level changes in response to independently recorded tectonic events, such as earthquakes and aseismic fault creep, provide evidence that a calibration based on response to earth tides may be applied to crustal strains of tectonic origin.

Several models of earthquake generation predict accelerating stable slip on part of the future rupture plane. If precursory slip has moment less than or equal to that of the impending earthquake, then the coseismic volume strain is an upper bound for precursory volume strain. Although crustal strain can be only crudely estimated from most reported pressure head anomalies, the sizes of many anomalies within 150 kilometers of earthquake epicenters appear consistent with this upper bound. In contrast, water level anomalies at greater epicentral distances appear to be larger than this bound by several orders of magnitude.

Earthquake precursors

Earthquake predictions are based mainly on the observation of precursory phenomena. However, the physical mechanism of earthquakes and precursors is at present poorly understood, because the factors and conditions governing them are so complicated. Methods of prediction based merely on precursory phenomena are therefore purely empirical and involve many practical difficulties.

A seismic precursor is a phenomenon which takes place sufficiently prior to the occurrence of an earthquake. These precursors are of various kind, such as ground deformation, changes in sea-level, in tilt and strain and in earth tidal strain, foreshocks, anomalous seismicity, change in b-value, in microseismicity, in earthquake source mechanism, hypocentral migration, crustal movements, changes in seismic wave velocities, in the geomagnetic field, in telluric currents, in resistivity, in radon content, in groundwater level, in oil flow, and so on. These phenomena provide the basis for prediction of the three main parameters of an earthquake: place and time of occurrence and magnitude of the seismic event.

The most important problem with all these precursors is to distinguish signals from noise. A single precursor may not be helpful; the prediction program strategy must involve an integral approach including several precursors.

Moreover, in order to evaluate precursory phenomena properly and to be able to use them confidently for predictive purposes, one has to understand the physical processes that give rise to them. Physical models of precursory phenomena are classified in two broad categories: those based on fault constitutive relations, which predict fault slip behavior but no change in properties in material surrounding the fault, and those based on bulk rock constitutive relations, which predict physical property changes in a volume surrounding the fault. Nucleation and lithospheric loading models are the most prominent of the first type and the dilatancy model is of the second type. During the past two decades efforts have been made to measure anomalous emanations of geo-gases in earthquake-prone regions of the world, in particular helium, radon, hydrogen, carbon dioxide. Among them radon has been the most preferred as earthquake precursor, because it is easily detectable.

Earthquake precursors can be divided into two major categories, physical and tectonic. I define physical precursor to be a direct or indirect indication of initiation or progression of an irreversible rupture-generating physical process within the preparation zone of a forthcoming earthquake. Tectonic precursor is defined as a manifestation of tectonic movement which takes place outside the preparation zone of an impending earthquake as a link in a chain of particular local tectonism in each individual area preceding the earthquake.

Most intermediate-term, short-term and immediate precursors of various disciplines within the source regions of main shocks are considered physical ones. Some precursory crustal deformations around the source regions are, however, possibly tectonic precursors, because they may be caused by episodic plate motions or resultant block movements in the neighboring regions of the fault segments that will break. A possible example of this phenomena is the anomalous crustal uplift in the Izu Peninsula, Japan, before the 1978 Izu-Oshima earthquake of M_s 6.8. Some precursory changes in seismicity patterns in wide areas surrounding source regions also seem to be tectonic precursors, because they were probably caused by the particular tectonic setting of each region. A typical example is a so-called doughnut pattern before the 1923 Kanto, Japan, earthquake of M_s 8.2.

Although most studies on earthquake precursors so far seem to regard implicitly all precursory phenomena observed as physical ones, the two categories should be distinguished carefully when statistical analysis or physical modeling is carried out based on reported precursory phenomena. In active plate boundary zones, where a practical strategy for earthquake prediction may well be different from that in intraplate regions, tectonic precursors can be powerful additional tools for intermediate-term earthquake prediction.

Only a few earthquake precursor signal generation related processes are being discussed here.

B - 1 Phenomena such as the piezoelectric effect cause different types of electromagnetic energy field fluctuations to be generated in fault zones in the days, weeks, months, and years before earthquakes occur.

B - 2 Geomagnetic storm energy (which often has its origins in solar storms) can interact with fault zones and in the process contribute to or amplify certain fault zone activity related electromagnetic energy field fluctuations.

B - 3 Solar storm activity is associated with events taking place in and around the sun. Interactions between solar storms and the Earth's geomagnetic field and earthquake fault zones are affected by the nature of the solar storm and also the orientation of the sun's magnetic field lines relative to those of the Earth. About every 7 days the sun magnetic field lines orientation can shift from being in the same direction as those of the Earth to being in the opposite direction.

B - 4 Earthquake fault zone activity related electromagnetic energy fields can be focused in specific directions by a variety of phenomena. As a result before an earthquake a sensor located a certain distance on one side of the fault zone might be detecting strong energy field fluctuations while another one an equal distance away on the fault zone's other side might not detect anything. This is one of the important reasons that some energy field detectors give the appearance of not producing consistent results.

B - 5 The geomagnetic storm - earthquake fault zone interactions take place most often during the days and weeks just before an earthquake occurs when the fault zone’s rock layer's physical, chemical, and electrical properties change as it gets close to fracturing. But they can also take place months and perhaps years before the earthquake occurs.

B - 6 Phenomena such as lighting strikes and I believe geomagnetic storms can cause low frequency radio waves to be generated. I expect that events taking place within fault zones can also cause them to be generated.

Those radio waves can travel around the world with relatively little loss in signal strength. Air is a reasonably good conductor for them. Water is better. And metal is best.

As they interact with fault zones and/or when they are generated as the result of fault zone activities, information regarding fault zone events can be superimposed on them and then be carried by them around the world.

B - 7 Some fault zone event related electromagnetic energy field fluctuations range in time from 0.25 seconds to perhaps 30 seconds in duration. Others may persist for hours, days, and even weeks.

B - 8 Because the times when those energy field fluctuations occur can be controlled by forces or phenomena related to the gravitational pulls of the sun and the moon and also forces or phenomena related to geomagnetic storms etc., the fluctuations can occur at high strain level times etc. in the same time cycles which control earthquake occurrence times. Or they can occur at somewhat random looking times which may be days, weeks, or months apart.

B - 9 Other earthquake precursors possibly related to electromagnetic energy field fluctuations have been reported over the years. They would include Earthquake Lights which are a type of temporary, local luminescence, glowing balls of light which may be suspended in the air, and static noise on radio, television, and telephone transmissions.

B - 10 Interactions taking place between earthquake fault zones located even great distances apart can result in signals being generated which are stronger than they might otherwise be. For a hypothetical example, an approaching 8.0 magnitude earthquake in one fault zone might cause a signal associated with a 4.0 magnitude earthquake which is about to occur in another, distant fault zone to be amplified to a point where it appears to be for a 6.0 magnitude earthquake.

TYPES OF WAVES:

P WAVES

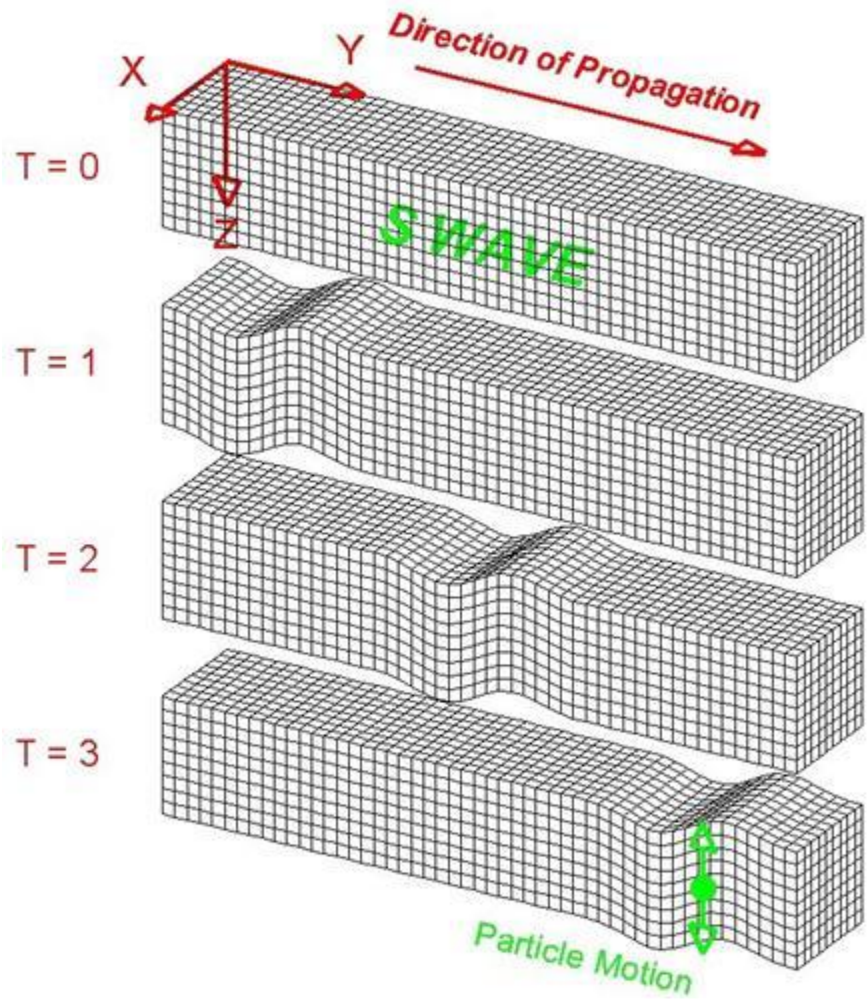
The first kind of body wave is the **P wave** or **primary wave**. This is the fastest kind of seismic wave, and, consequently, the first to 'arrive' at a seismic station. They typically travel at speeds between ~1 and ~14 km/sec. The slower values corresponds to a P-wave traveling in water, the higher number represents the P-wave speed near the base of Earth's mantle.

The P wave can move through solid rock and fluids, like water or the liquid layers of the earth. It pushes and pulls the rock it moves through just like sound waves push and pull the air. Have you ever heard a big clap of thunder and heard the windows rattle at the same time? The windows rattle because the sound waves were pushing and pulling on the window glass much like P waves push and pull on rock. Sometimes animals can hear the P waves of an earthquake. Dogs, for instance, commonly begin barking hysterically just before an earthquake 'hits' (or more specifically, before the surface waves arrive). Usually people can only feel the bump and rattle of these waves.

P waves are also known as **compressional waves**, because of the pushing and pulling they do. Subjected to a P wave, particles move in the same direction that the the wave is moving in, which is the direction that the energy is traveling in, and is sometimes called the 'direction of wave propagation'.

S WAVES

The second type of body wave is the **S wave** or **secondary wave**, which is the second wave you feel in an earthquake. An S wave is slower than a P wave and can only move through solid rock, not through any liquid medium. It is this property of S waves that led seismologists to conclude that the Earth's **outer core** is a liquid. S waves move rock particles up and down, or side-to-side--perpendicular to the direction that the wave is traveling in (the direction of wave propagation)

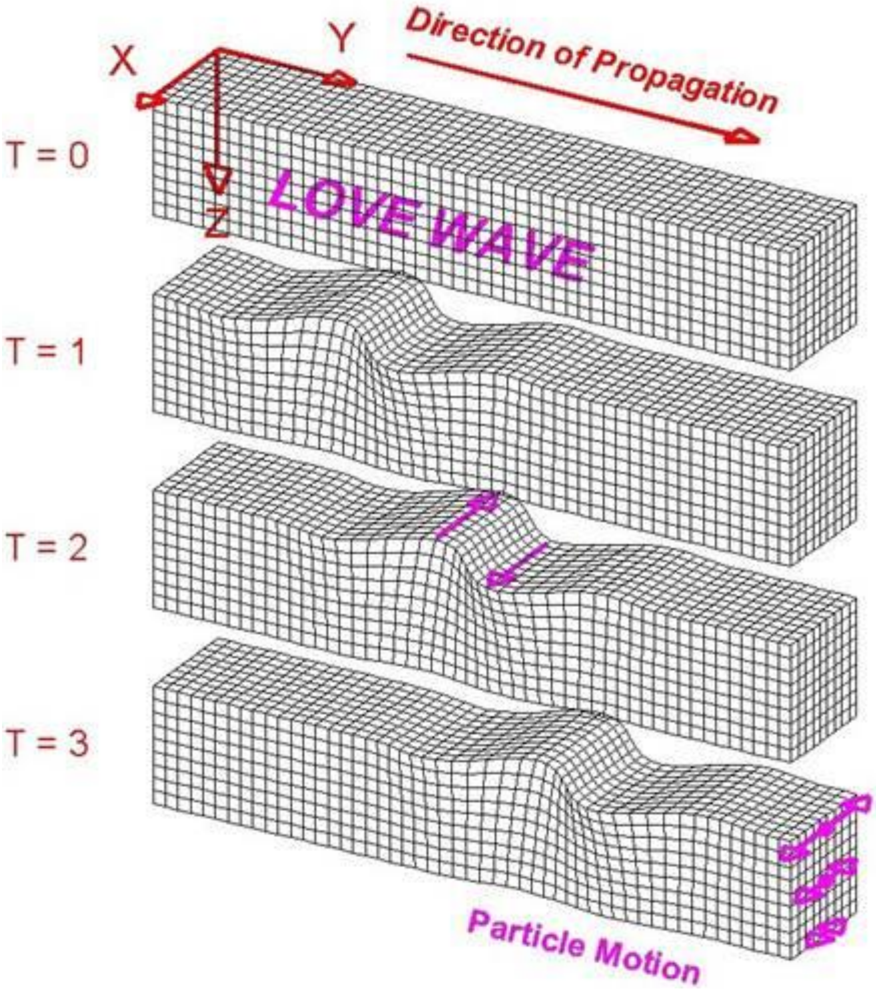


SURFACE WAVES

Travelling only through the crust, **surface waves** are of a lower frequency than body waves, and are easily distinguished on a seismogram as a result. Though they arrive after body waves, it is surface waves that are almost enitrely responsible for the damage and destruction associated with earthquakes. This damage and the strength of the surface waves are reduced in deeper earthquakes.

LOVE WAVES

The first kind of surface wave is called a **Love wave**, named after A.E.H. Love, a British mathematician who worked out the mathematical model for this kind of wave in 1911. It's the fastest surface wave and moves the ground from side-to-side. Confined to the surface of the crust, Love waves produce entirely horizontal motion.



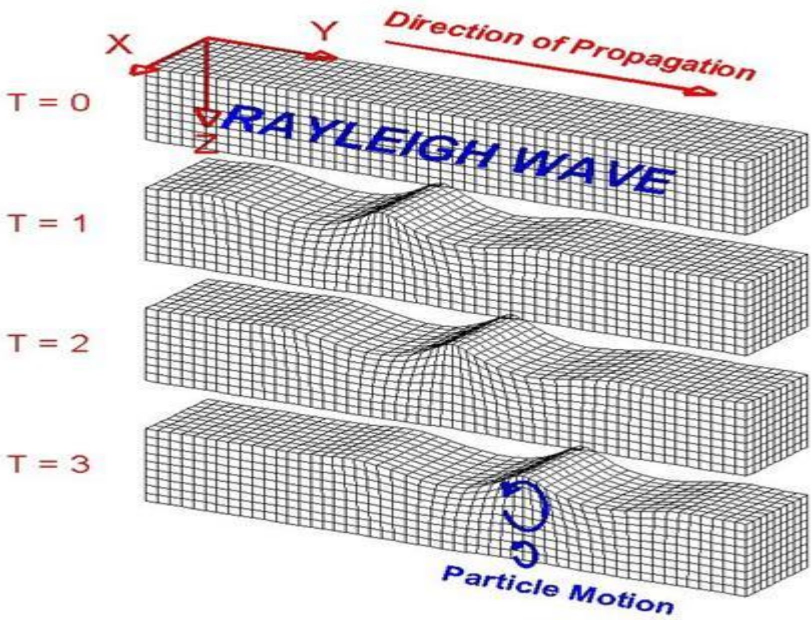
Love waves are transverse waves that vibrate the ground in the horizontal direction perpendicular to the direction that the waves are traveling. They are formed by the interaction of S waves with Earth's surface and shallow structure and are dispersive waves. The speed at which a dispersive wave travels depends on the wave's period. In general, earthquakes generate Love waves over a range of periods from 1000 to a fraction of a second, and each period travels at a different velocity but the typical range of velocities is between 2 and 6 km/second.

Love waves are transverse and restricted to horizontal movement - they are recorded only on seismometers that measure the horizontal ground motion.

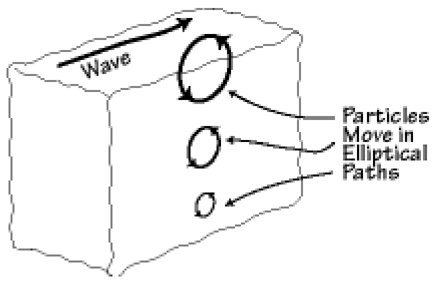
Another important characteristic of Love waves is that the amplitude of ground vibration caused by a Love wave decreases with depth - they're surface waves. Like the velocity the rate of amplitude decrease with depth also depends on the period.

RAYLEIGH WAVES

The other kind of surface wave is the **Rayleigh wave**, named for John William Strutt, Lord Rayleigh, who mathematically predicted the existence of this kind of wave in 1885. A Rayleigh wave rolls along the ground just like a wave rolls across a lake or an ocean. Because it rolls, it moves the ground up and down, and side-to-side in the same direction that the wave is moving. Most of the shaking felt from an earthquake is due to the Rayleigh wave, which can be much larger than the other waves.



Rayleigh waves are the slowest of all the seismic wave types and in some ways the most complicated. Like Love waves they are dispersive so the particular speed at which they travel depends on the wave period and the near-surface geologic structure, and they also decrease in amplitude with depth. Typical speeds for Rayleigh waves are on the order of 1 to 5 km/s.



Rayleigh waves are similar to water waves in the ocean (before they "break" at the surf line). As a Rayleigh wave passes, a particle moves in an elliptical trajectory that is counterclockwise (if the wave is traveling to your right). The amplitude of Rayleigh-wave shaking decreases with depth.

Using P and S-waves To Locate Earthquakes

We can use the fact that P and S waves travel at different speeds to locate earthquakes. Assume a seismometer are is far enough from the earthquake that the waves travel roughly horizontally, which is about 50 to 500 km for shallow earthquakes. When an earthquake occurs the P and S waves travel outward from the region of the fault that ruptured and the P waves arrive at the seismometer first, followed by the S-wave. Once the S-wave arrives we can measure the time interval between the onset of P-wave and the onset of S-wave shaking.

The travel time of the P wave is

distance from earthquake / (P-wave speed)

The travel time of the S wave is

distance from earthquake / (S-wave speed)

The difference in the arrival times of the waves is

distance from earthquake / (S-wave speed) - distance from earthquake / (P-wave speed)

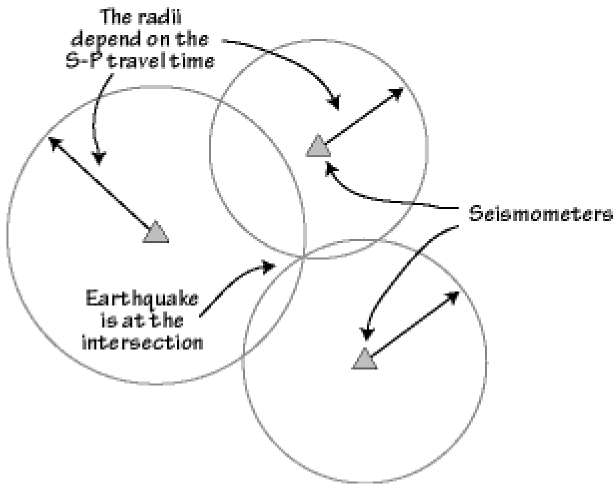
which equals

distance from earthquake * (1/ (S-wave speed) - 1 / (P-wave speed))

We can measure that difference from a seismogram and if we also know the speed that the waves travel, we could calculate the distance by equating the measured time difference and the expression. For the distance range 50 to 500 km, the S-waves travel about 3.45 km/s and the P-waves around 8 km/s. The value in parentheses is then equal to about (1/3.45 - 1/8) or about 1/8. Thus the simple rule of thumb for earthquakes in this distance range is the distance is about eight times the arrival time of S-wave less the arrival time of the P-wave.

That means that we can estimate the distance an earthquake is from a seismometer. The earthquake can be in any direction, but must be the estimated distance away. Geometrically that means that the earthquake must be located on a circle surrounding the seismometer, and the radius of the circle is about eight times the observed wave travel-time difference (in kilometers).

If we have two other seismometers which recorded the same earthquake, we could make a similar measurement and construct a circle of possible locations for each seismometer. Since the earthquake location since it must lie on each circle centered on a seismometer, if we plot three or more circles on a map we could find that the three circles will intersect at a single location - the earthquake's epicenter.



Using the "S minus P arrival time" to locate an earthquake. You need at least three stations and some idea of the P and S velocities between the earthquake and the seismometers.

In practice we use better estimates of the speed than our simple rule of thumb and solve the problem using algebra instead of geometry. We also can include the earthquake depth and the time that earthquake rupture initiated (called the "origin time") into the problem.

Unusual Animal Behavior before Earthquakes:

Unusual animal behavior before major earthquakes has been reported through the ages [1,38]. Apparently, during the build-up of stresses deep in the Earth crust to dangerously high levels, many animals are able to perceive cues from the environment, which cause them to react abnormally. Animals both on land and in water are reportedly affected. Evidence for unusual animal behavior has been widely reported in the past as a warning sign of impending major earthquake activity, though such reports have widely been called anecdotal [24,39]. Since earthquakes are rare events, reports of unusual animal behavior are—by their very nature—in almost all cases anecdotal [24,39].
Attempts to validate the unusual animal behavior in laboratory experiments have been largely inconclusive [25,40]. However, as pointed out in a recent review of the 1975 Haicheng earthquake in China [41]: ―Among the animals, the most difficult to ignore are the snakes coming out hibernation dens when the average temperature was much below freezing. There were nearly 100 snake sightings within one month prior to the earthquake [42]… such suicidal behavior is extremely difficult to explain‖.

A recent example of unusual animal behavior has been given by Grant and Halliday, who reported that the activity of common toads at a breeding site in a small lake about 75 km north of L'Aquila, Italy, declined dramatically five days before the M6.3 L'Aquila earthquake on April 6, 2009 [43]. The apparent abandonment of the breeding site and interruption of spawning is highly unusual in these amphibians, which exhibit an explosive breeding behavior. Once the breeding activity has commenced, the toads normally do not leave the site for 3–7 weeks until spawning is completed [44]. Although the breeding site was some distance from the epicentre, it has been shown that there was a major extension of earthquake related phenomena to the north of the epicentre, including earthquake lights and electric anomalies [45]. A similar effect seemed to have occurred before the great 1873 earthquake in central Italy as reported by Serpieri, who observed unusual snake behavior in his laboratory upon application of electric currents [46]. Int. J. Environ. Res. Public Health **2011**, 8 **1946**

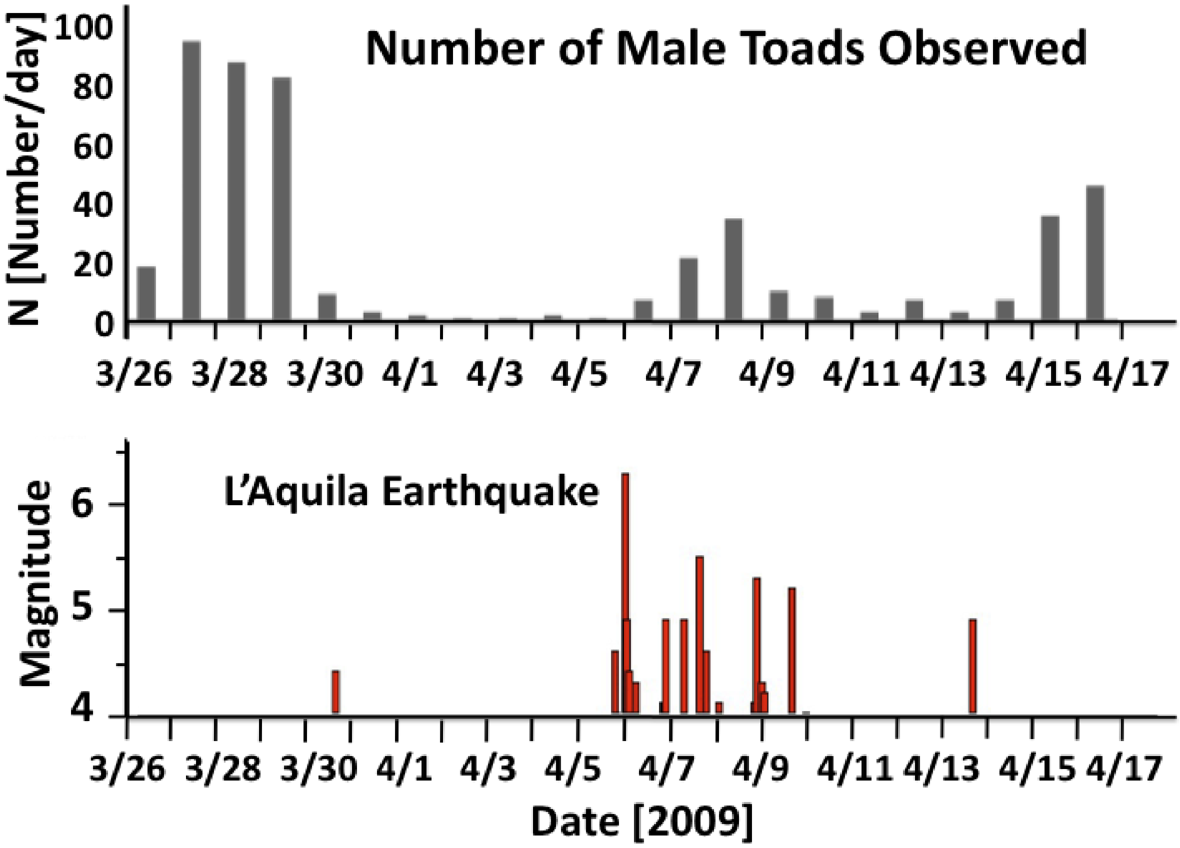
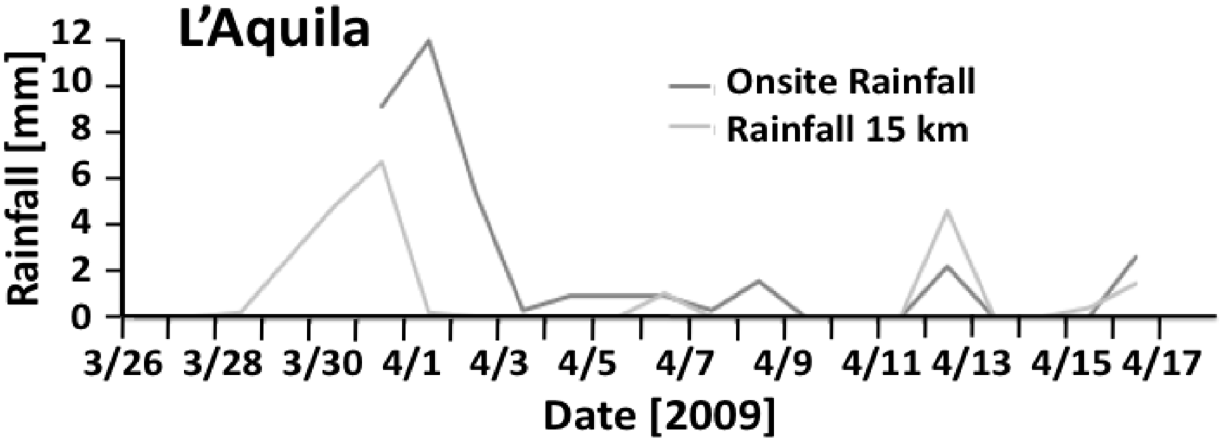


Figure shows the rainfall recorded both locally at the site and at a weather station about 15 km away from the lake. Since the period of highest rainfall between March 30 and April 04 coincides with the apparent disappearance of the toads from their breeding site, lack of precipitation can definitely not be the cause of the unusual toad behavior.

Figure 10. Rainfall records for the lake site and at a weather station at a distance of 15 km.



The rainfall measurements at the breeding site and contemporary field observations indicate that the ground was highly saturated in the week prior to the earthquake. Under normal circumstances such conditions would be advantageous to toads, which are prone to desiccation because of their permeableskins and always prefer humid or damp environments. The disappearance of the toads from the breeding site is all the more unusual, as they would be expected to be more active during rainy periods [47].
The time period during which the toads left the lake coincided with other suspected pre-earthquake indicators such as disturbances in the ionosphere. These disturbances consist of changes in the transmission characteristics of radiowaves along direct great circle paths between two stations. The changes arise between sunset and sunrise, e.g., during the dark hours, when the ionosphere above the region of interest, in this case central Italy, moves out of and back into the influence of the ionizing solar radiation, respectively. Processes that occur at the Earth surface before major earthquakes have an influence on the concentration profile of free electrons in the ionospheric plasma [48,49]. Electrons contribute primarily to the mirror-like reflection of radiowaves, which allows them to be transmitted over long distances. Therefore a change in the vertical distribution of electrons in the ionosphere causes a distinct shift in the so-called terminator times, e.g., in the transmission characteristics around sunset and sunrise [50,51].

Figure 11 shows an example of such ionospheric disturbances as they expressed themselves in the difference between the amplitudes (dAmplitudes) of radio signals emitted from two stations in Italy, ICV at 20.27 kHz in Sardinia and ITS at 45 kHz in Sicily, and received at the MOS station in Moscow, Russia. On their path to MOS in Moscow, Russia, the ICV and ITS signals pass over the ionospheric region that lies within the sphere of influence of the L'Aquila earthquake [20]. By referencing the signals along the path ICV-MOS and ITS-MOS to signals received in Moscow from radio stations in England and Iceland, it can be shown that the ionosphere above central Italy was perturbed several days before the L'Aquila event, giving rise to anomalous negative intensities (dAmplitude) as marked by dotted circles.

Detecting Earthquakes and other Rare Events from Community-based Sensors:

Can one use cell phones for earthquake early warning? Detecting rare, disruptive events using community-held sensors is a promising opportunity, but also presents difficult challenges. Rare events are often difficult or impossible to model and characterize a priori, yet we wish to maximize detection performance. Further, heterogeneous, community-operated sensors may differ widely in quality and communication constraints.
In this paper, we present a principled approach towards detecting rare events that learns sensor-specific decision thresholds online, in a distributed way. It maximizes anomaly detection performance at a fusion center, under constraints on the false alarm rate and number of messages per sensor. We then present an implementation of our approach in the Community Seismic Network (CSN), a community sensing system with the goal of rapidly detecting earthquakes using cell phone accelerometers, consumer USB devices and cloudcomputing based sensor fusion. We experimentally evaluate our approach based on a pilot deployment of the CSN system. Our results, including data from shake table experiments, indicate the effectiveness of our approach in distinguishing seismic motion from accelerations due to normal daily manipulation. They also provide evidence of the feasibility of earthquake early warning using a dense network of cell phones.

Privately owned commercial devices equipped with sensors are emerging as a powerful resource for sensor networks. Community sensing projects are using smart phones to monitor traffic and detect accidents [13, 17, 15]; monitor and improve population health [5], and map pollution [18, 29]. Detecting rare, disruptive events, such as earthquakes, using community-held sensors is a particularly promising opportunity [4], but also presents difficult challenges. Rare events are often difficult or impossible to model and characterize a priori, yet we wish to maximize detection performance. Further, heterogeneous, community-operated sensors may differ widely in quality and communication constraints, due to variability in hardware and software platforms, as well as differing in environmental conditions.
In this paper, we present a principled approach towards detecting rare events from community-based sensors. Due to the unavailability

of data characterizing the rare events, our approach is based on anomaly detection; sensors learn models of normal sensor data (e.g., acceleration patterns experienced by smartphones under typical manipulation). Each sensor then independently detects unusual observations (which are considered unlikely with respect to the model), and notifies a fusion center. The fusion center then decides whether a rare event has occurred or not, based on the received messages. Our approach is grounded in the theory of decentralized detection, and we characterize its performance accordingly.
In particular, we show how sensors can learn decision rules that allow us to control system-level false positive rates and bound the amount of required communication in a principled manner while simultaneously maximizing the detection performance.
As our second main contribution, we present an implementation of our approach in the Community Seismic Network (CSN). The goal of our community sensing system is to detect seismic motion using accelerometers in smartphones and other consumer devices (Figure 1(c)), and issue real-time early-warning of seismic hazards (see Figure 1(a)). The duration of the warning is the time between a person or device receiving the alert and the onset of significant shaking (see Figure 1(b)); this duration depends on the distance between the location of initial shaking and the location of the receiving device, and on delays within the network and fusion center. Warnings of up to tens of seconds are possible [1], and even warnings of a few seconds help in stopping elevators, slowing trains, and closing gas valves. Since false alarms can have high costs, it is important to limit the false positive rate of the system.
Using community-based sensors for earthquake early warning is particularly challenging due to the large variety of sensor types, sensor locations, and ambient noise characteristics. For example, a sensor near a construction site will have different behavior than a sensor in a quiet zone. Moreover, sensor behavior may change over time; for example, construction may start in some places and stop in others. With thousands of sensors, one cannot expect to know the precise characteristics of each sensor at each point in time;

COMMUNITY SEISMIC NETWORKS

The big brother to the Community Seismic Network project is the California Integrated Seismic Network's Earthquake Early Warning System.

"The network of seismometers is really a computer network," says the director of Caltech's Earthquake Engineering Research Laboratory, Tom Heaton.

"We basically monitor all of the shaking that happens at roughly about 400 stations in the western United States, and we have access to that information within about a second of when the shaking occurs at the station."

When a quake is detected members of the network are alerted.

"We've been writing software that does the kind of analysis a human being would do if they had time to do it," he says.

"The one that I work on is called the virtual seismologist, we're trying to teach a computer to be like a seismologist, but unlike a seismologist, computers can stay awake all the time and they don't get bored."

The early warning system has already been proven to work. At Caltech they're working on ways to send alerts to smart devices, which inevitably includes a smartphone app.

Sim city: The early warning system was used during an earthquake drill held in Los Angeles in March

"The app gets notification that an earthquake has occurred .... it can project when the shaking will get to the phone and how big it will be. And then the phone can start to countdown and say, shaking in 10, 9, 8,… and even give some idea - strong shaking or weak shaking depending on what we anticipate."

One of the big hold-ups is financing. The project has received funding from the US Geological Survey (USGS) and more recently the Gordon and Betty Moore Foundation, while waiting to find out whether a bill currently in front of the state legislature will implement the system.

Proof that this type of technology works can be found in Japan.

The country has an effective early warning system administered by the Japan Meteorological Agency. Thanks to apps like Yurekuru Call, earthquake alerts can be pushed to smartphones, while the iPhone 5 can do it automatically.

No matter how sophisticated these systems are, there's only so much a warning can do.

In March 2011, the north-east of Japan experienced the most powerful earthquake to hit the country, a magnitude of 9.0. This was followed by a tsunami that inundated the Pacific coast.

In Japan it is called the Great East Japan Earthquake. It is thought that close to 20,000 people were killed.

Carp streamers - or koinoburi - are hung outside Japanese homes with sons on

Children's Day on 5 May. But this school of 370 blue carp mourn the children who died in Higashimatsushima, Miyagi prefecture

The early warning system certainly saved lives. But the scale of the disaster was just too big. And the tsunami alert, which takes longer to compute and generate, gave some only 15 minutes to get to higher ground.

The American Red Cross has launched a suite of apps created by UK-based developers 3 Sided Cube for use in natural disasters, one of which is for earthquakes.

It uses the USGS feed giving information on quakes as they happen, and sends alerts to people who have set the app to watch certain areas. It then sends them to a page with more information.

The American Red Cross app gives details of shelters

"[We] developed this app to give instant access to information on what to do before, during and after earthquakes with preparedness information developed by trusted Red Cross experts," says the American Red Cross's Matt Goldfeder.

"The app also includes preparedness information for events that may happen after earthquakes, such as fires and tsunamis."

An "I'm safe" button lets you send an alert to family, friends and social networks, where you can also share information. It includes a toolkit that has a torch setting, strobe light and an alarm.

"A recent Red Cross survey shows that nearly one-fifth of Americans say they've received some kind of emergency information from an app they've downloaded. It's important that people can access this information right on their mobile device," says Mr Goldfeder.

Other apps that claim to help in the aftermath include Earthquake Buddy, which will send an alert to four contacts if a phone detects an earthquake, with your GPS co-ordinates attached. For Californians, MyFault shows areas likely to be subject to landslide or liquifaction.

And apps like QuakeFeed and QuakeWatch let you track earthquakes around the world as they happen.

Technology might not be able to save the world. But it might be able give you and your loved ones the edge when it comes to surviving the worst of natural disasters.

Accelerometer

An accelerometer is an electromechanical device that will measure acceleration forces or it is a device that measures proper acceleration. These forces may be static, like the constant force of gravity pulling at your feet, or they could be dynamic - caused by moving or vibrating the accelerometer. It is a sensor that measures acceleration relative to a free-falling frame of reference. They can measure the magnitude and direction of the acceleration, and can be used to sense the orientation of the device.

For example, an accelerometer at rest on the surface of the earth will measure an acceleration $g = 9.81\ m/s^2$ straight upwards, due to its weight. By contrast, accelerometers in free fall or at rest in outer space will measure zero. Another term for the type of acceleration that accelerometers can measure is g-force acceleration.

What are accelerometers useful for?

By measuring the amount of static acceleration due to gravity, you can find out the angle the device is tilted at with respect to the earth. By sensing the amount of dynamic acceleration, you can analyze the way the device is moving. At first, measuring tilt and acceleration doesn't seem all that exciting. However, engineers have come up with many ways to make really useful products with them.

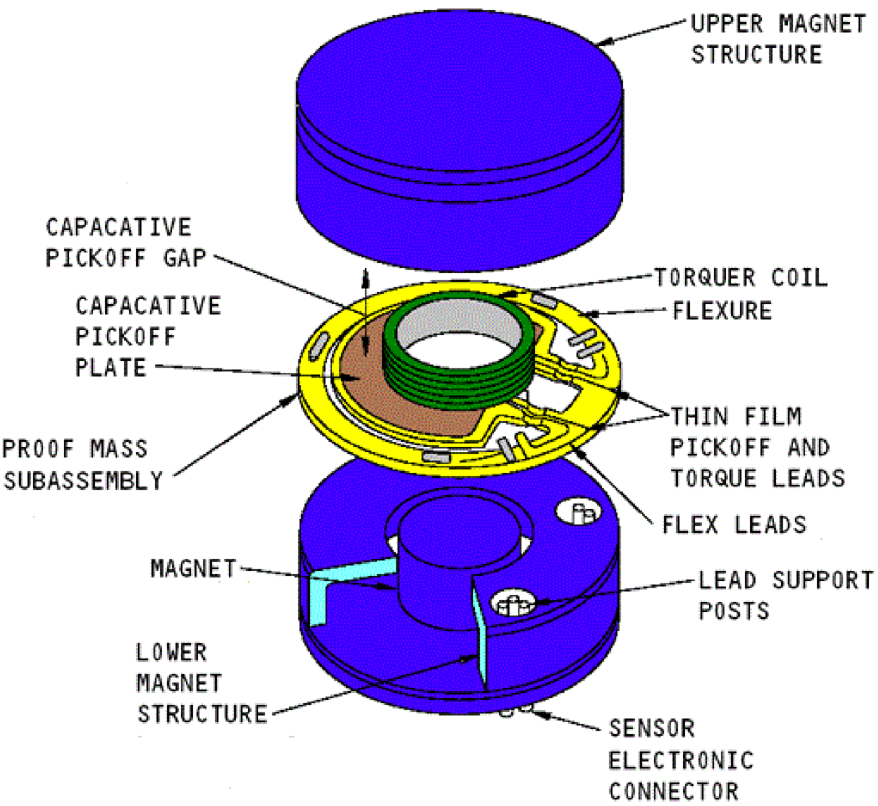
An accelerometer can help analyze problems in a car engine using vibration testing, or you could even use one to make a musical instrument.

In the computing world, IBM and Apple have recently started using accelerometers in their laptops to protect hard drives from damage. If you accidentally drop the laptop, the accelerometer detects the sudden freefall, and switches the hard drive off so the heads don't crash on the platters. In a similar fashion, high g accelerometers are the industry standard way of detecting car crashes and deploying airbags at just the right time.

How do accelerometers work?

There are many different ways to make an accelerometer! Some accelerometers use the piezoelectric effect - they contain microscopic crystal structures that get stressed by accelerative forces, which causes a voltage to be generated. Another way to do it is by sensing changes in capacitance. If you have two microstructures next to each other, they have a certain capacitance between them. If an accelerative force moves one of the structures, then the capacitance will change. Add some circuitry to convert from capacitance to voltage, and you will get an accelerometer. There are even more methods, including use of the piezoresistive effect, hot air bubbles, and light.

Accelerometer in mobile devices



Accelerometers have multiple applications in industry and science.. Accelerometers are used to detect and monitor vibration in rotating machinery. Accelerometers are used in tablet computers and digital cameras so that images on screens are always displayed upright.

Small sensors found in most smartphones and laptops are sensitive enough to detect the movement of moderate and large earthquakes,and could vastly expand the information gathered during seismic events in densely populated cities, new research suggests. Scientists have discovered that a tiny sensor that detects which way a handset is facing and orientates the screen accordingly can also pick up strong vibrations.

The smartphone chip was found to record accurate data on earthquakes greater than magnitude five when placed close to the epicentre, while smaller quakes were drowned out by the noise of the handset.
However improvements in technology are likely to bring about more sensitive sensors in the future which could have a dramatic impact on how rescue operations are conducted

The Micro Electro-Mechanical Systems (MEMS) accelerometer is a chip found in most smartphones and laptops which monitors the rate of acceleration of ground motion as well as vibration of cars, buildings and installations.

Given the widespread use of laptops and smartphones containing these devices, researchers at Italy's National Institute of Geophysics and Volcanology decided to test whether the sensors could adequately record earthquake movements.

"Theoretically, any device connected to the Internet with an internal MEMS accelerometer, such as a computer or mobile phone, can become a strong-motion seismic station, and that could be easily used to enormously increase the number of observation points when an earthquake occurs," said study co-author Antonino D'Alessandro.

To test the effectiveness of the MEMS technology, the team attached a MEMS accelerometer -- the same model found in the iPhone 4 and 5 -- to a device used in conventional seismic surveys, and placed both on a vibrating table, that was oscillating at a known rate. They then compared the readings, to determine if the MEMS chip produced the same readings as the conventional technology.

The researchers found the chip did indeed collect data comparable to that of the standard device. This suggests the MEMS chip could gather data during moderate and large earthquakes (those with a magnitude of 5 or greater), as long as the device was near the epicenter of the movement. The team details their findings today (Sept. 29) in the journal Bulletin of the Seismological Society of America.

"The number of victims following a strong earthquake depends mainly on the intensity of shaking, and the speed of rescue operations," said study co-author Antonino D'Alessandro. "A real-time urban seismic network can drastically reduce casualties in urban areas immediately following a strong earthquake, by quickly distributing information about the distribution and intensity of ground shaking."

The chip did not accurately detect small movements, suggesting it would not be useful in small earthquakes, but the researchers noted that MEMS technology is advancing, and might soon be able to deal with subtler movements.

Researchers at Stanford University in California have also recently explored ways to use MEMS technology in seismic networks, and have even begun creating an international network of volunteer internet users called the Quake-Catcher Network.

While such networks are valuable, they may not be possible to create well in poor or remote cities, where fewer residents have Internet access, D'Alessandro noted. As an alternative, the team suggested manufacturers could develop MEMS devices for the sole purpose of collecting seismic data, and distribute them to emergency management teams in earthquake-prone cities. The teams could then deploy the devices to locations as they see fit.

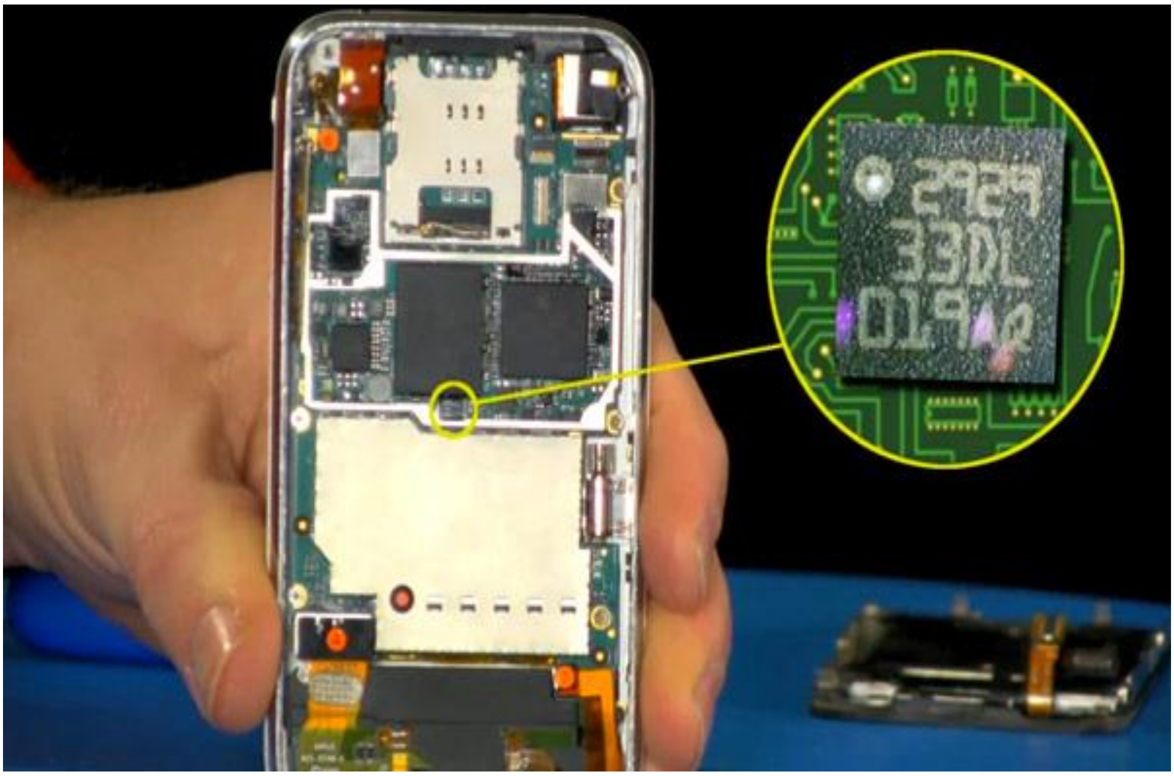
The research group is now testing a new MEMS accelerometer model that they say is 100 times more sensitive than the one currently used in iPhones, which may be sensitive enough to accurately record small-scale earthquakes.

They tested a version of the chip found in some iPhones, the LIS331DLH MEMS accelerometer, and compared it to the earthquake sensor EpiSensor EST force balance accelerometer.

The pair found that the iPhone chip had "excellent frequency and phase response" while only picking up earthquakes of greater than magnitude five on the Richter scale. The smartphones also had to be close to the centre of the quake.

The authors concluded that given these sensors are in "common use in mobile phones" and are likely to improve in the future they could be used in rescue operations.

Minutes after a major earthquake GPS location data from the phones could be sent into a central command point, detailing where the worst tremors were felt and helping determine where emergency services should be sent.
Antonino D'Alessandro said: "The number of victims following a strong earthquake depends mainly on the intensity of shaking, and the speed of rescue operations.
"A real-time urban seismic network can drastically reduce casualties in urban areas immediately following a strong earthquake, by quickly distributing information about the distribution and intensity of ground shaking."
The researchers believe that technological improvements will mean earthquakes less than magnitude five will soon be detected by smartphone chips.



QUAKEFINDER

The largest efforts to provide early warning of earthquakes rely on quick detection of the faster, but not very destructive, P-waves as they travel through the ground. Since P-waves arrive slightly before the more damaging S-waves, it is possible to send out an earthquake alert seconds before shaking can be felt.

For quakes within 20 miles, the waves are too close for any warning, but a quake 40 miles away, for example, could be preceded by an alert as much as 10 seconds in advance. USGS is working with several universities on an Earthquake Early Warning system which relies on this approach. Japan and Mexico have already deployed similar systems which automatically provide alerts when an earthquake is detected.

Clearly, a few seconds isn't enough time to evacuate a city or even get out of most buildings. It is helpful for powering down computers and transformers, opening firehouse doors, starting generators, and taking other quick precautions though, so long as appropriate systems are set up in advance. Aside from potentially finding a doorway or doing a "drop, cover and hold on" this type of alert unfortunately doesn't do much to reduce the human toll of a major earthquake.

That's where the idea of true earthquake prediction comes in. Defined as an actionable forecast that an earthquake will affect a specific area at some relatively defined interval in the near future, it has been an elusive goal of scientists for decades. Early efforts concentrated on measuring seismic activity and using geologic models to predict when a fault was finally going to give way. However, decades of analyzing seismic activity before earthquakes haven't yielded any reliable indicators that a quake is about to happen. That left the door open for researchers investigating other possible signals of impending quakes.

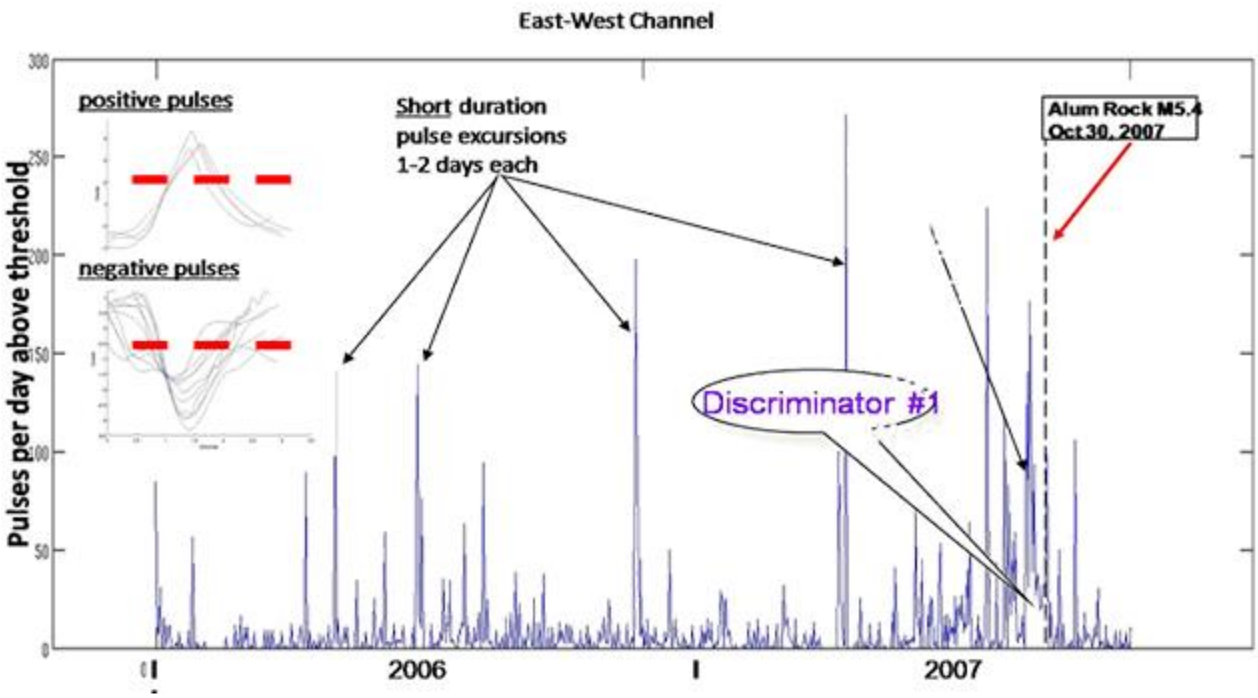
In 1989 a Navy-funded Stanford magnetometer looking for ultra-low frequency (ULF) signals recorded sizable electromagnetic (EM) activity prior to the nearby Loma Prieta earthquake. As a result, Bleier was inspired to redouble his informal efforts. After persevering on his own, ten years later Bleier began QuakeFinder — a formal effort to build a network of sensors that could record EM pulses and other possible precursors to earthquakes.

Its initial sensor units were fairly simple, but the current tenth generation model includes sensors for various frequencies of electrical and magnetic disturbances, as well as ionization, seismic and other sensors. One of the hardest parts of collecting this type of data is filtering out irrelevant information caused by nearby trains, trucks, electric cattle fences and even weather patterns. In addition to selecting isolated sites and burying the magnetometers, the data from the network of sensors and satellite data are combined to allow selecting out signals that might be related to potential earthquakes.

How QuakeFinder works

While traditional earthquake monitoring relies on seismographs, which measure physical movement in the ground, it turns out that sufficient stress on rocks causes them to emit magnetic pulses. The currents created can be massive, around 100,000 amps for a magnitude 6 quake, and over a million amps for one that is over 7. The ultra-low frequency component of those pulses is capable of traveling miles through the rock, making it feasible to measure with a network of monitoring stations.

While these short pulses occur on a regular basis — perhaps ten or so on a normal day — QuakeFinder sensors have recorded unusually high concentrations of them in the hours and days prior to earthquakes — well over 100 per day — even after filtering out spurious pulses from nearby lightning or other large electrical sources.



While it isn’t clear exactly which of several possible theories explain the magnetic pulses, their existence can be verified by stressing a large rock to the breaking point, like in the pictured experiment QuakeFinder conducted by stressing a seven ton boulder until it fractured. However, the large, dry, boulders used in experiments aren’t the same as the brine-soaked rock at earthquake depth. So there is plenty of room for speculation on how things are really working miles down where a typically quake gets its start.

QUAKEFEED

QuakeFeed has the most features of any free earthquake app. There are seven beautiful base maps provided by Esri, the worldwide leader in GIS. Choose from either the 1-day, 7-day or 30-day USGS data feeds. A variety of filter and sort options are provided. The app is location aware so you can find quakes that are closest to you. Push notifications are free for M6+ worldwide quakes.

Basic Features

- Choose from USGS 1-day, 7-day, or 30-day data feeds.
- Toggle between list and map views.
- Select from seven basemap options, plus plate lines.
- Push notifications free for M6+ quakes
- Upgrade to Custom Notifications available via In-App Purchase
- Drill down to details view.
  - Detail map zooms to quake location
  - Displays magnitude, time, lat/long, distance, depth
  - Link to additional quake details on USGS website
- Social media integration - share via Facebook, Twitter or Email.

Intuitive User Interface

- Map symbols are color-coded and sized by magnitude.
- Quake list is color-coded by magnitude.
- Sort list by date, magnitude, depth, or distance from current location.
- Specify units for distance (km or miles).
- All screens work in portrait or landscape mode.

Base Map Options

- Street Map
- Topographic Map
- Satellite Imagery
- Imagery with Labels
- Shaded Relief Map
- Physical Map
- Terrain Map
- Ocean Bathymetry

Future Scope of Earthquake prediction and Mobile Technology:

No 100% accurate way to predict an earthquake.

As more data is collected, predictions will get better.

From data mining, more patterns will be found increasing the accuracy of predictions.

However, with smartphone technology advancing every day, the we believe that Smartphone's will be able to detect earthquakes in the future.

Bibliography:

http://www.theverge.com/2012/12/7/3739082/earthquake-japan-twitter-alerts-disaster

http://www.extremetech.com/extreme/153197-quakefinder-earthquake-prediction-technology

http://www.bbc.com/news/business-23204346

http://en.wikipedia.org/wiki/Accelerometer

http://allshookup.org/quakes/wavetype.htm

http://eqseis.geosc.psu.edu/~cammon/HTML/Classes/IntroQuakes/Notes/waves_and_interior.html

http://www.rense.com/general61/use.htm

http://blogs.scientificamerican.com/history-of-geology/2011/12/12/can-animals-sense-earthquakes/

http://en.wikipedia.org/wiki/Earthquake_prediction

http://csn.caltech.edu/

http://earthquake.usgs.gov/research/earlywarning/nextsteps.php

http://qcn.stanford.edu/wp-content/uploads/2011/10/2009-Cochran_et_al_IEEE_QCN_smaller.pdf