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Earthquake Prediction using SVM based Time Predictable Technique

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Abstract- As with so many natural phenomena, earthquakes are the product of what scientists call "complex systems," or systems which are more than the sum of their parts. Not just speaking proverbially, but in truest ever sense, precise prediction of earthquakes has long been a question of Life & Death for the scared inhabitants of earthquake-prone areas and so is for the forecasters and scientists ranging from Nostradamus to Dr. Vladimir Kellis-Borok since last a few centuries. Though the experts still don't know many of the details of the physical processes involved and how to predict these events, several prediction and chaos theories have been put forth with varying degrees of successes. In spite of the inherent complexities involved in such a complex system, the research is still on and on. The time- predictable model of earthquake prediction is based on the theory that earthquakes in fault zones are caused by the constant build-up and release of strain in the Earth's crust. This model has become a standard tool for hazard prediction in many earthquake-prone regions and, therefore, it is not surprising that the scientists in the United States and other Pacific Rim countries, such as Japan and New Zealand, routinely use this technique for long-range hazard assessments when adequate data are available.

Keywords—*Earthquakes;time-predictablemodel;forecasters.*

I. INTRODUCTION

When humans wondered in early centuries why the Earth occasionally trembles, and yearned to predict these frightening disturbances for thousands of years, Ancient cultural explanations of earthquakes were often along the lines of the mythical Japanese Namazu: A giant catfish with the islands of Japan on his backside. A demigod, or daimyojin, holds a heavy stone over his head to keep him from moving. Once in a while the daimyojin is diverted so Namazu moves and the Earth trembles.

Earthquakes are more deadly than any other form of weather hazard [1] . They have killed 2.7 million people during the period of 1900 to 1976 [2]. In comparison 1.8 million people were killed by all natural disasters combined together, excluding earthquakes. Numerous forecasts and scientists earthquake predictions, ranging from Nostradamus [3] to Dr. Vladimir Kellis-Borok [4,5,6,7], have been made since last a few centuries. Several prediction and chaos theories of earthquake predictions have been put forth with varying degrees of successes over the years including but not restricted to seismicity patterns, crustal movements, elastic rebound [8], ground water level in wells [1,2,9], earthquake clouds , changes in ion concentration in the ionosphere , various types of electromagnetic indicators including infrared and radio waves, radon and hydrogen emissions, telluric currents, and even unusual animal behavior [1,2]. The mystery of earthquake occurrence frequently sparks people without scientific training into claiming that they have found the solution to the earthquake prediction problem. Discredited, incredible theories of predicting earthquakes include weather conditions and atypical clouds, and the phases of the moon. These pseudoscientific theories and predictions ignore the requirement of rigorously formulating the hypothesis and to test it statistically. Self-appointed prediction experts often resort to the technique of making vague statements, which they claim were right predictions, subsequent to an earthquake has happened somewhere. Rudolf Falb's "lunisolar flood theory " is a typical example from the late 19th century. And, therefore, it is necessary to define what exactly an earthquake prediction is. According to the Seismological Society of America, for a statement to be accepted as a valid earthquake prediction, it has to contain the expected magnitude with error limits, the well define area of the epicenter, the range of dates, also the probability of this to come true. The data from which the prediction was derived must be verifiable and the analysis of these data must be reproducible. Long term predictions (years to decades) are more likely to be achieved than medium term predictions (months to years), and short tenure predictions (hours to days) are in general unlikely to be achievable, at present.

If a plausible mechanism linking the observations with the predicted earthquake is not offered, the credibility of the prediction is moderated, but it may not essentially be rejected. Evaluations of evident successes must include a statistical estimate of the probability that the prediction came true by chance, which is frequently the case by means of predictions by amateurs. Whether a guess is scientific or amateurish is not based on who makes the prediction, except based on how the prediction is prepared and tested. Predictions can be formulated either by defining the limits of the parameters probabilistically or by firm values within the rigorous bounds.

II. THE THEORY OF ELASTIC REBOUND

The theory builds on the older concepts of continental drift, developed during the first decades of the 20th century (one of the most famous advocates was Alfred Wegener), and was accepted by the majority of the geo-scientific community when the concepts of seafloor spreading were developed in the late 1950s and early 1960s. Probabilistic estimates of earthquake hazard use various models for the temporal distribution of earthquakes, including the 'time-predictable' recurrence model formulated by the Japanese geophysicists K. Shimazaki and T. Nakata in 1980 , which incorporates the concept of elastic rebound described as early as 1910 by H. F. Reid [8].

Following the great 1906 San Francisco earthquake, Harry Fielding Reid studied the displacement of the ground surface around the San Andreas Fault [8]. From his observations he concluded that the earthquake must have been the result of the elastic rebound of previously stored elastic strain energy in the rocks on either side of the fault. The elastic rebound theory is an explanation for how energy is spread during earthquakes. As plates on differing sides of a fault are subjected to force and move, they accumulate energy and slowly deform until their internal strength is go beyond. At that time, a sudden movement occurs along the liability, releasing the accumulated energy, and the rocks snap reverse to their original unreformed shape. In geology, the elastic rebound theory was the first theory to satisfactorily clarify earthquakes. Formerly it was thought that ruptures of the surface were the result of strong ground shaking rather than the converse suggested by this theory.

In an inter seismic period, the Earth's plates move relative to each other except at most plate boundaries where they are locked. The far field plate motions cause the rocks in the region of the locked fault to accrue elastic deformation. The deformation builds at the rate of a few centimeters per year, more than a time period of a lot of years. When the accumulated strain is great enough to overcome the strength of the rocks, an earthquake occurs. for the duration of the earthquake, the portions of the rock around the mistake that were locked 'spring-back' to original position, relieving the displacement in a few seconds that the plates moved over the entire inter-seismic period. The time of strain accumulation could be months to hundreds of years, while the time of _spring-back‘ action is in seconds. Like an elastic band, the more the rocks are strained the more elastic energy is stored and the greater potential for an event. The stored energy is unconfined during the rupture partly as heat, partly in damaging the rock, also partly as elastic waves. Modern measurements by means of GPS largely support Reid‘s theory as the basis of seismic movement, though actual events are frequently more complicated.

III. THE TIME –PREDICTABLE MODEL OF EARTHQUAKE PREDICTION

The Time-Predictable Model of Earthquake Prediction states that an earthquake occurs when the fault recovers the stress relieved in the most recent earthquake. In other words, earthquakes in fault zones are caused by the constant build-up and release of strain in the Earth's crust. Unlike time-independent models (for example, Poisson probability), the time-predictable model is thought to encompass some of the physics behind the earthquake cycle, in that earthquake probability increases with time. This model has become a standard tool for hazard prediction in many earthquake-prone regions and, therefore, it is not surprising that the scientists in the United States and other Pacific Rim countries, such as Japan and New Zealand, routinely use this technique for long-range hazard assessments when adequate data are available. For example, the U.S. Geological Survey (USGS) relied on the time-predictable model and two other models in its widely publicized 1999 report projecting a 70-percent probability of a large quake striking the San Francisco Bay Area by 2030.

According to this model, when an earthquake occurs on the fault, a certain amount of accumulated strain is released. Following the quake, strain builds up again because of the continuous grinding of the tectonic plates. If the size of the most recent earthquake and the rate of strain accumulation afterward is known, one should be able to forecast the time that the next event will happen simply by dividing the strain released by the strain-accumulation rate. Arising from the Elastic Rebound Theory, geophysical precursors preceding an earthquake may be divided into five stages, each stage manifesting a typical set of changes in the earth as follows [1]:

Stage I: As the two sides of a fault move, flexible strain slowly builds up in the rocks, and the rock particles turn into compressed together.

Stage II: It is the stage of dilatancy and development of cracks. The rocks are currently packed as tightly as possible, and the lone way the rocks can change shape is to expand and occupy a larger volume. This raise in volume is called dilatancy. The volume raise is caused by the formation of micro cracks. As micro cracks form, the water that normally fills the pores and cracks in the rocks is forced out, very much like stepping on damp beach sand. Air now fills the pores and cracks in the rocks. During this process, the rocks turn into stronger and can store more elastic strain. This procedure can be detected on the surface by uplift and tilting of the ground.

Stage III: During this stage, water is forced back into the pores and cracks in the rocks by the surrounding water pressures, much similar to when water fills the foot print in the sand. As the water returns, the dilatants rock loses its improved strength. The rocks are already strained beyond their usual capacity, and the rate at which the rocks fall in strength determines the instant of failure. The inflow of water also prevents auxiliary generation of micro cracks; thus, the rocks stop increasing. In addition, the water in the rocks provides lubrication for the eventual release of the built-up strain.

Stage IV: Eventually, the rocks can no longer resist the strain; the fault suddenly ruptures, releasing the elastic energy stored in the rocks in the form of heat and seismic waves. It is these waves that comprise an earthquake.

Stage V: It is the manifested by the sudden drop in stress followed by aftershocks. The majority of the elastic strain energy is released by the principal earthquake; though, additional smaller ruptures occur producing aftershocks. The aftershocks free the remaining strain energy, and ultimately the strain in the region decreases and stable conditions return. knowledge .

IV. STUDY CASTS DOUBT ON VALIDITY OF STANDARD ARTHQUAKE- PREDICTION MODEL

Whether accumulation of strains is necessarily a precursor to an earthquake is still unclear,‖ says Trudy Bell . Although the time-predictable model makes perfect sense on paper, following studies have raised serious questions about this fundamental technique for making long-range earthquake predictions:

STUDY I: James C. Savage [2], a USGS geophysicist at Menlo Park, is measuring strain accumulation in the San Andreas fault by terrestrial laser ranging. His group made measurements two weeks, one week, and one day before a magnitude 6.2 earthquake near Morgan Hill, California, on 24 th April, 1984. Just by happenstance, they made their measurements close to the earthquake‗s epicenter. But within the accuracy of the measurements, they saw no change in the rate of the strain accumulation before the quake. Although this results was discouraging, ―may be the earthquake was not large enough to see any anomaly,‖ concluded Savage.

STUDY II: When Stanford University geophysicists decided to put this model to the test using long-term data collected from an ideal setting, their obvious choice was Parkfield - a tiny town in Central California midway between San Francisco and Los Angeles. Perched along the San Andreas Fault, Parkfield became a heaven for geophysicists for the simple reason that it has been rocked by a magnitude 6 earthquake every 22 years on average since 1857. The last one struck in 1966, and geologists have been collecting earthquake data there ever since. Parkfield is a best place to test the model because we have measurements of surface ground motion during the 1966 earthquake and of the strain that's been accumulating ever since. It's also located in a fairly simple part of the San Andreas system because it's on the main strand of the fault and doesn't have other parallel faults running nearby.

When Murray and Segall [2] applied the time- predictable model to the Parkfield data, they came up with a forecast with 95 percent confidence that a magnitude 6 earthquake should have struck the San Andreas Fault in Central California have taken place between 1973 and 1987, but it didn't. In reality, 15 years have gone by. As the results were consulted with the Stanford

Statistics Department just to make sure that this was done as carefully and precisely as anybody can, the researchers are quite confident that there's no way to fudge out of this by saying there are uncertainties in the data or in the method. Can these observations be disregarded as an exceptional case? Could the time-predictable method work in other parts of the mistake, including the densely populated metropolitan areas of Northern and Southern California? The researchers have their doubts. At Parkfield, things are fairly simple, while at Bay Area or Los Angeles, there are a lot extra fault interactions there, so it's probably even with a reduction of likely to work in those places. The model's poor performance in a relatively simple tectonic setting does not bode well for its successful application to the many areas of the world characterized by complex fault interactions.

V. PREDICTING EARTHQUAKES

Today's scientists understand earthquakes a lot better than we did even 50 years in the past, but they still can't match the quake-predicting prowess of the common toad (*Bufo bufo*), which can detect seismic activity days in progress of a quake. A 2010 study published in Journal of Zoology found that 96 percent of male toads in a population abandoned their breeding site five days before the earthquake that struck L'Aquila, Italy, in 2009, about 46 miles (74 kilometers) left. Researchers aren't quite sure how the toads do this, but it's believed that they can notice subtle signs, such as the discharge of gases and charged particles, that may occur before a quake [source: Science Daily].Scientists can predict where major earthquakes are likely to occur, though, based on the movement of the plates in the Earth and the location of fault zones. They also can make common guesses about when earthquakes might occur in a definite area, by looking at the history of earthquakes in the region and detecting where pressure is building along fault lines. For instance, if a region has experienced four magnitude 7 or larger quakes during the past 200 years, scientists would work out the probability of another magnitude 7 quake occurring in the next 50 years at 50 percent. But these predictions might not turn out to be reliable since, when strain is released along one part of a fault system, it may in fact increase strain on another part [source: USGS]. As a result, the majority earthquake predictions are vague at best. Scientists have had more achievement predicting aftershocks, additional quakes subsequent an initial earthquake. These predictions are stand on extensive research of aftershock patterns. Seismologists can build a good guess of how an earthquake originating along one fault will cause additional earthquakes in connected faults.

Another area of study is the relationship between magnetic and electrical charges in rock material also earthquakes. Some scientists have hypothesized that these electromagnetic fields change in a certain way just previous to an earthquake. Seismologists are also studying gas seepage and the tilting of the ground as warning signs of earthquakes. In 2009, for instance, a technician at Italy's National Institute for Nuclear Physics claimed that he was able to predict the L'Aquila earthquake by measuring the radon gas seeping from the Earth's crust. His findings stay controversial. So, if we can't predict earthquakes, what can we do to prepare for them? Earthquakes are disgracefully difficult, if not impossible, to predict. "You are dealing with a very difficult physical system that behaves very differently in various places," says David Schwartz, a geologist by means of the U.S. Geological Survey's San Francisco Bay Area Earthquake Hazards Project. Seismologist Andy Michael, by the agency's Western Earthquake Hazards Team, says some earthquakes might rupture without any early warning signs, rendering the science of earthquake guess futile. Nevertheless, researchers are trying to get better earthquake probability forecasts and working toward, possibly one day, prediction and prevention. Click the "Next" arrow above to learn about eight of their ideas.

A. *First Earthquake waves may provide early warning.*

Kazuhiro Nogi / AFP - Getty Images

Earthquakes send out two main kinds of waves - P and S- and key variation in how quickly they travel could buy people a few seconds to take action, such as crawling under a desk or shutting off a gas line. Some scientists trust the faster-moving Ps, or pressure, waves include information about the slower-moving but more damaging S's, or secondary, waves. Sensors set up to notice the P's can sound alarms warning of the S's to arrive. "The key here is observing an earthquake has happened and telling how big it is very quickly and, I believe, there is still some legitimate debate about how accurately one can achieve that," says seismologist Michael. Nevertheless, the USGS is keeping its eyes on top of a system deployed in Japan where a 6.8 magnitude earthquake in 2007 smashed this road leading to the world's largest nuclear power plant.

B. *Advertise | Ad Choices*

Crustal deformation considered for signs of pending quakes

UNAVCO / National Science Founda

Do the earth's crust deform prior to a foremost earthquake? "I would have to lay that underneath a hypothesis at this point," says Michael. "And I believe the proof, so far, is against it." But researchers are via satellites and GPS receivers in the hopes they'll notice a change in the earth's surface in the days, weeks, or months before a foremost earthquake.

Can Animal Predict Earthquakes?

August Cenname / Courtesy of Cal

Cal Orey, a California-based author and journalist shown here with her dog Simon, is one of many people who believe their pets pick up on some sort of cues that an earthquake is imminent and start to act strangely. Most seismologists who have looked into the issue, however, have found nothing tangible to support the notion. Schwartz says he's heard plenty of anecdotes, however, and can't 100 percent rule out the possibility. "If there is something there, we just don't know how to get our hands around it," he says.

C. Can earthquakes be safely triggered ?

Ng Han Guan / AP

Some of the scientists guess water stress from the reservoir behind the dam in the background of this image triggered the May 2008 magnitude 7.9 earthquakes in Sichuan Province, China. Dam reservoirs have triggered further, lesser earthquakes, including a 6.4 earthquake in India in 1967. As well, misuse fluids pumped into a well at the Rocky Mountain Arsenal in Colorado triggered a sequence of quakes in the 1960s. Given that humans have unintentionally triggered quakes, could they purposely trigger a quake, as well, perhaps in hopes of preventing a better quake from striking in the future? "There's a pretty elevated responsibility associated with fooling around similar to that," Schwartz says. Nor is anyone trying to do it, Michael adds.

SUMMARY AND CONCLUSION

Despite being a few negative observations, the basic concept behind this method is so scientific that its applicability cannot altogether be rejected. But the things are not as simple as they look. Speaking metaphorically, there may be lot many undercurrents crossing & crisscrossing each other in a complex pattern beneath the calm surface of an ocean. It just might be simple to measure the stress getting accumulated in a single fault, but how to account for the stresses being attributed by the parallel (or oblique) faults running nearby? Till all doubts are resolved, Use with Caution‘ is the message to all geophysicists about this model.

Recent Japan earthquake, 2011, and the subsequent gruesome-Chernobyl-nightmare in Fukuyama nuclear plant has undisputedly shown that the financial, infrastructural, nuclear, and climate crises are individually serious issues after a major earthquake, but in combination their impact could be catastrophic for the environment and global economy too. Authors fervently hope that the technological advances in earthquake science would make long-range forecasting a reality one day. Earthquakes are now a globally recognized as significant global threat and, as a consequence, debate over the need to understand our mother earth more has moved upto the top of the agenda amongst geologists, geophysicists, and government. Precise geodetic measurements are now possible with latest generation strains-meters and GPS. Agencies and geophysicists involved in all such studies and investigations has the responsibility for issuing meaningful forecasts with whatever information they have at their disposal, so that city planners and builders can use the best available knowledge for the benevolence of the environment and society as a whole.

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