ROLE OF UNUSUAL BEHAVIOR OF ANIMALS IN CONTRIBUTION TO EARTHQUAKE PREDICTION FOR LESS DEVELOPED COUNTRIES

Adnan Zafar
Department of Information and Technology
Malaysia University of Science and Technology,
47301 Petaling Jaya, Malaysia
Email: adnanzafar@live.com

ABSTRACT

Earth-a beautiful planet, a planet of life which holds many mysteries underneath its soil, also known as a "Goldilocks planet". Besides being beautiful, this Goldilock faces menace as every second passes. Amongst the list of threats which Earth faces, Earthquake is the fiercest and catastrophic. Whenever it befalls, it leaves an unforgettable mark on this Goldilock and on the lifeform resided in it. The earthquake, before transpiring in the form of a strong and devastating primary wave, it releases a less devastating secondary wave, as a warning of its befalling. Many developed countries have crafted multiple state of art tools for earthquake's prediction and to some extent are successful in their own means, whereas, the less developed countries due to lack of resources faces the debris and unable to recover from it for ages. There are multiple indications that arises before earthquake's ensuing, which when taken into account carefully helps in Earthquake prediction, they are known as precursors. There are multiple precursors that can be used in earthquake prediction, but amongst them the unusual animal behavior is a cheap and reliable solution for less developed countries. Domestic and wild animals have a tendency to react upon the early release of the secondary wave, thus their reaction in terms of unusual behavior acts as a baseline for earthquake prediction. This paper discusses about the implementation of earthquake prediction system based on unusual behaviors of domestic animals. The system works on the data fetched from different data hubs which stores and processes the unusual behaviors of animals. These data hubs are located in those areas of the city which are at a higher risk of earthquakes. The data from the various data hubs are fed into the system, processed, and alerts are generated and disseminated to the community at large. The geographical region covered in this research is the greater Karachi area of Pakistan where many residents own pets and have the caged animals properly monitored by their caretakers.

Keywords: Earthquake, Sensory Mechanism of Domestic Animals (SMoDA), Crowd Sourcing Natural Disasters, Animal Behavior (AnB), Smart Phone (SMT).

Introduction

Earth- a planet full of mysteries and obscurities. The only planet with a life form having so many secrets hidden underneath its soil. Earth came into existence for about 4.6 billion years ago, formed with the rocky core with substantial elements ramming and binding together(Tylor Redd, 2017). Due to its nifty environment and its capability to allow diverse life forms live in it is it named as "Goldilocks planet", as told in the story of "Goldilocks and the Three Bears," a little girl named as Goldilocks liked everything just the way she wanted, that is everything should be perfect. Her porridge couldn't be too hot or too cold. And her bed couldn't be too hard or too soft. Due to this reason Earth is named as Goldilock, as, everything on Earth is just perfect for any life form to survive. The environment here is warm, but not too warm. And it has water, but not too much water, plenty enough for any life form to survive (MSFC, 2015).

Every beautiful thing has to pay the price and same is with this Goldilocks planet. Earth faces numerous menace as time passes; some are internal and some are external. The external threat mainly involves Meteors, excessive Ultraviolet light and lessening of O-Zone layer. Since the threat is natural, thus no life form present in it has the power to overcome it. Besides, these external threats, Earth is vulnerable from inside as well. There are two types of internal threats which when occurs, put this Goldilock in a great jeopardy.

1- Threat generated by the life forms
2- Catastrophes caused by the nature

Disasters caused by earth's life forms is a threat to their kind, as well as to the earth on a middling level, these threats includes biological influences, recession, toxins etc. (Personal, Archive, Khan, & Khan, 2008) whereas, the disaster caused by nature is more fiercer and devastating and has the capability to change the face of this Goldilock and it does whenever it befalls. Natural disaster entails, avalanche, volcanic eruption, earthquake, tsunami and thunder. From the list of natural disasters, Earthquake is considered to be the utmost sterner and distressing. The reason why it is considered to be the fiercest, is because it has the capability to transform into any other natural disaster. For e.g., if it befalls in ocean, it leads to Tsunami, if it befalls in a mountain region, it leads to avalanche and when it befalls in a volcanic region, it leads to a volcanic eruption. The Earth has a rocky core, which is based on plates, these plates are known as tectonic plates. Earthquake mainly occurs when these tectonics got fractured and start sliding on one another. As soon as the plates start sliding on each other, a wave is generated, this is a less devastating wave which acts as a signal for the upcoming disaster, and is known as Secondary wave. Times later a more

disturbing and devastating Primary wave is generated which wipes out everything which comes in its way ("pubs.usgs.gov/gip/earthq1/how.html", 2013). The illustration of the occurrence of Earthquake is illustrated in the figure 1 (a & b) below:

Figure 1: a) Tectonic plates in contact with each other. b) Tectonic plates rubbing each other, causing Earthquake to occur
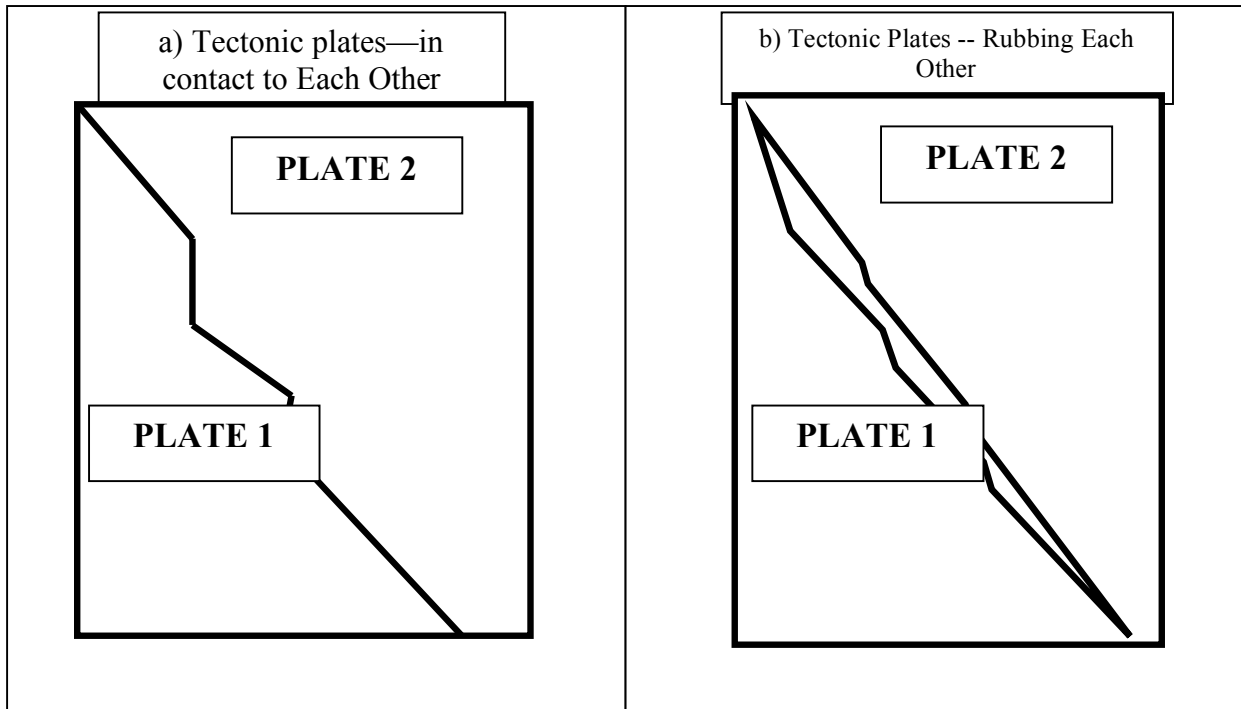
The intensity with which an Earthquake ensues can be measured and evaluated by a tool known as Richter scale. The amplitude (height) of the largest wave at a specific distance from the Earthquake can be measured by the help of Richter Magnitude. While it is correct to say that for each increase in 1 in the Richter Magnitude, there is a tenfold increase in amplitude of the wave (Stephen A.Nelson, 2013).

Predicting the Earthquake is a tough task, many high-tech tools are being developed and are continue to be developing for its prediction by the developed countries. Whereas, less developed countries also try to get in the race of predicting the Earthquake, but none proved to be successful yet, due to lack of resources and technology. Although the tools are based on latest technology and proves to be helpful in predicting the Earthquake, besides the available tools, there are other indications as well which arose before the Earthquake and focusing on which proves to be beneficial for less developed countries for predicting the Earthquake, they are known as precursors. The precursors are considerably a cheaper solution than using the expensive and delicate tools.

PREDICTING THE UNPREDICTIBLE

Many developed countries have crafted multiple state of art tools and techniques for Earthquake's prediction and to some extent they seemed to be successful in their own means. But though these fancy crafted tools play a vital role in the prediction of Earthquake for developed countries, they come up with a heavy price and special skills, for its operation. Since less developed countries are already struggling with their socio-economic issues, they are unable to buy or craft such tools and thus stays behind in the race for predicting Earthquake and faces the debris which befalls on them. These countries although cannot craft or buy a tool, but they surely can able to predict Earthquake by the help of Precursor Analysis.

Precursors are a special type of warning signals which appear before the Earthquake ensues. There are multiple precursors which appear, including: Humidity changes, Ground tilting, electric currents, ion discharge, unusual behavior of animals and Magnetic field radiations (Kirschvink, 2000). For a cheaper and reliable solution for predicting Earthquakes, less developed countries can focus on a precursor i.e. unusual animal behavior. It has been proved that animals have a tendency to react unusually before any danger is about to befall. There are about 58 different animal species from the animal kingdom whose behavior changes as soon as any disaster, mainly Earthquake is about to ensue (Harnett, 2012). These animals are categorized in to two main categories, domestic and wild animals.

A big majority of this world is a pet lover, almost everyone owns a pet either a person living in a developed country or a person living in a less developed country, research has shown that if animals observed carefully they can be a viable asset for any

country in predicting Earthquake. The sensory mechanism of animals is far more advanced and complex than humans. Different animals have different senses, it varies from species to species. Reptiles have a different mechanism for sensing and prediction, whereas birds use their own mechanism for predicting Earthquake, same goes with any other species which are in the list for Earthquake prediction.

a) Domestic Vs Wild Animals for Earthquake prediction

Animals are divided into two major categories: domestic and wild, though Wild animals are more subtle and quick in taking precautionary measures, whenever they encounter any impending danger, but using them for an earthquake prediction is a hassle itself, because they cannot be tamed that easy, they move places frequently and their fierce nature is not friendly for humans at all. None the less, the domestic animals are not lacking from anything in terms of sensing the befalling Earthquake.

Domestic animals are habitually reported to become aggressive, agitated or restless and sometimes get enough panicked that they break free of tethers. Whereas, the reports on wild animals showed that they leave an area and move somewhere else. According to Tributsch, in the book "on animal behaviour and earthquakes" discussed that, wild animals are reported to show unusual movements, whereas domestic animals mainly show restlessness, aggression and attempts to escape. This could be interpreted as animals moving away from aversive stimuli to other areas, and those prevented from doing so, start to panic or attempt to escape (Tributsch, 1982).

The reason why animals are considered to be one of the reliable precursor is that they have a very complex and smart sensory mechanism, which continuously helps them predicting any debris. Due to its complexity, this mechanism helps them to pick up any other precursor as well that arose in the environment before the Earthquake befalls (Wattananikorn, Kanaree, Wiboolsake, 1998). Most likely the animals react on gases which are emitted out due to the fracturing of rocks or sometimes it is the magnetism in the air or the high concentration of positive air ions (Grant, Halliday, Balderer, Leuenberger, Newcomer, Cyr, Ferund, 2011).

Table 1 below shows the distinguished behavior of domestic and wild animals which arose before the ensuing of Earthquake.

Table 1: Unusual behaviour of Wild vs. domestic/captive animals prior to Earthquake

Domestic Animals	Wild Animals
Horses: • **Escaped/ lost** • **Breaking out of halter or tether** • **Vocalizing excessively** • **Impossible to ride or refuse to walk** • **Stamping, kicking or rolling on the ground**	Rats and/ or weasels: • Run around town • Appear in packs • Fleeing the city or town • Leave houses and granaries or other buildings
Dogs: • **Barking or howling excessively** • **Escaped/ lost** • **Fearfully, agitated or restless**	Birds: • Take to the air en masse • Vocalizing excessively • Giant flock seen • Leave usual habitat • Behave fearfully or agitated
Domestic Birds (Hens/ Chicken/ Geese): • **Behave fearfully or agitated** • **Excessively noisy** • **Escape/ lost** • **Break out of enclosure or try to escape** • **Refuse to enter coops** • **Cockerels crow all night long**	Reptiles and amphibians: • Snakes leave their burrows in winter/ crawl on snowy ground • Turtles jump out of water • Snakes seen in large numbers • Lizards come out of their burrows • Amphibians leave their breeding site
Cattle/ sheep • **Escape from enclosure/ lost** • **Try to break out** • **Become aggressive, bite each other** • **Vocalizing excessively** • **Refuse to enter stalls** • **Behave fearfully or agitated, restless** **Zoo animals** • **Behave fearfully, excited or restless** • **Refuse to enter pens or enclosures** • **Try to breakout of enclosure** • **Escape/ lost**	Invertebrates: • Ants leave holes • Many octopuses in shallow water or acting strangely • Lobster and squid caught at surface • Sea snake swim up river • Swarms of millipedes are seen • Large number of flying ants are seen • Plankton comes to the surface • Large crab migrations/ crabs crawl to the shore • Large number of sea urchins appear • Large number of earthworms leave the soil • Sea cucumber disappear • Swarm of bees leave the area

Different animals have different sensory organs which helps them to communicate each other, as soon as they sense any impending danger. Animals alarm about the danger by changing their behaviors, but unfortunately it is unkempt by humans (Hussain & Asif, 2012).

From the vast list of animals, the animals which are considered and discussed in this research paper are cats and dogs, as they are the most kept pet animals and have a higher tendency in showing an unusual behavior, when it comes to sensing the Earthquake.

Amongst the list of multiple domestic animals which when observed for unusual behavior, 236 of 1,259 dog owners and 115 of 703 cat owners observed UABs in their pets, with restless behavior being the most bulging change in both species. Most of the unusual behavior of animals occurred almost one day before the Earthquake. The unusual animal behaviors showed a direct relationship with the epicentral distance (Buskirk, Frohlich, Latham, 1981). Cats and Dogs showed a drastic change in their behavior during the last 24 hours, as they were observed closely, before the Kobe Earthquake (Wadatsumi, 1995). These behaviors included "being panicked", "barking loudly", or "biting owners" in dogs, and "hiding", "meowing pathetically", "being restless", "climbing a high tree", or "disappearing" in cats (Ikeya, 2004). The hearing range in dogs is 67 to 44,000 Hz and 55 to 79,000 Hz in cats, whereas, humans have 13 to 17,000 Hz (Heffner, 1998). Thus, dogs and cats can hear ultrasounds that humans cannot. The smelling sense in dogs and cats are very high as well. It is known as Olfactory, olfactory cells in dogs and cats are much higher than humans (Shier, Butler, Lewis, 2004). The olfactory bulb contains approximately 280 million cells in dogs, 67 million in cats, and 5 to 20 million in humans (Hart, 1977) & (Beadle, 1977). Humans can detect odor foci from $10{-}4.5$ molar (M) to $10{-}5.0$ M. inquisitively, dogs can detect a concentration of $10{-}17$ M (Halász, 1990) & (Passe, Walker, 1985). With these superior senses, dogs and cats show a greater sensitivity to small changes in smell and/or sound in their environment than humans.

ARCHETYPAL IMPLEMENTATION FOR EARTHQUAKE PREDICTION

ROLE OF SMARTPHONES
Technology is evolving exponentially. There was a time when it was considered as an oasis in the desert, but now it became an integral part of life. There are so many great inventions which has been devised till now and amongst those, one of the invention is mobile phones. Smart phone is a current trend in mobile phone technology and smart phones play a vital t role in today's time, as it possesses characteristics of having multiple features at the same time, it comes in handy when any catastrophe transpires. They are considered to be the transceivers, as they acquire and disseminate knowledge at the same time. Initially before the advent of smartphones, the sources of information broadcasting include: Televisions, radio or by letter/ telegram. But now, by its development, distances have been reduced, knowledge can be conveyed with a blink of an eye. Use of smart phones are increasing day by day, now almost every person has a smart phone. As per the statistics, the number of smartphone users around the world has increased to 2.03 billion and the number of users are expected to reach around 6 billion in 2020 ("emarketer.com/Article/Smartphone-Users-Worldwide-Will-Total-175-Billion-2014/1010536", 2016). The smart phone users in Pakistan are increasing exponentially as well, there were 14.6 million users as of July 2015, and it is expected to reach a figure of 40 million by the end of December, 2016 ("tribune.com.pk/story/953333/telecom-sector-pakistan-to-have-40-million-smartphones-by-end-of-2016", 2016).

During Earthquake, smart phones plays a vital role, as they became a useful tool for knowledge sharing and awareness.

IMPLEMENTATION OF DATA HUBS FOR PREDICTING EARTHQUAKE

A less developed country can also be in the race of predicting the Earthquake, if they start focusing on this reliable and cheap precursor i.e. Unusual Animal Behavior. The archetypal includes data hubs. Data hub is a place where the data from domestic animals i.e. cats and dogs, is received and processed. The data is continuously monitored and analyzed. The datahubs are deployed in various areas of the city, having a sole purpose for predicting the Earthquake. For increasing the activeness of the system, they are formed on the fault lines.

Pakistan, a less developed country, due to its geographical location, considered to be an Earthquake prone country. The Uniform Building (UBC) Code, 1997 has placed Peshawar (a city in Pakistan) in the most austere earthquake zone i.e. Zone-4, along with the other cities which have frequent Earthquakes with greater magnitudes. These include: California, Alaska, Japan, Chile, Taiwan and Turkey. Besides Peshawar, there are two more major cities of Pakistan which has been placed by UBC in Earthquake zone 4, they are Karachi and Islamabad (Ali, Khan, 2004)

Karachi is a heavily inhabited city, having a population of approximately 20 million people. With this kind of population, it cannot endure the risk of an Earthquake. If an Earthquake with a magnitude greater than 6 hits this city, it will be ruined. "If there is an earthquake in Karachi like there are in Japan, this city will be trodden. Roads structures will be destroyed, the billboards will fall down, the buildings would collapse and ambulances will not be able to reach survivors," says Roland de Souza, an engineer and a human rights activist who is part of the NGO SHEHRI. The buildings of offices, houses etc. are quite old, even the newly developed buildings do not have a structure to avoid Earthquakes. If there is a case of an Earthquake, there will be no spurt. To avoid the loss, there must be a prediction system implemented for awareness and precautionary measures ("dawn.com/news/509742/karachi-study-identifies-most-vulnerable-quake-zones-in- pakistan", 2009).

ARCHETYPAL IMPLEMENTATION USING CROWDSOURCING

Crowd sourcing plays an important role in the information broadcasting. It is like fire in the jungle and spread within seconds' form one place to another. Crowdsourcing is used to create and increase collective knowledge, community building, collective creativity and innovation, crowdfunding, and civic engagement. Powered by widespread and increasing access to the Internet, mobile phones, and related communication technologies, the use of crowdsourcing for policy advocacy, e-government, and e-democracy has grown exponentially during the past decade (Bott & Young, 2012).

The archetypal include data hubs, which feeds on crowdsourcing. People having cats and dogs as their pets are registered from different areas of the city. The system accepts their registration based on few simple questions. Once registered, they become the part of crowdsourcing community and started participating in the knowledge sharing of unusual behavior of their animals.

The System works on three phases:
1) Acquire the information
2) Evaluate the information and
3) Respond to the community

Initially the animals remain calm and data received by the data hubs through the community of pet owners is low as shown in figure 2. Whereas, as soon as, the owners started experiencing any unusual behavior of animals, they started uploading the responses of their animals using their smart phones, on the system and soon after the data received from any area exceeds the threshold, an alert is engendered and strewn to the registered community of that area to take precautionary measures as shown in figure 3.

Figure 2: Community either uploading a positive data or no data to the System
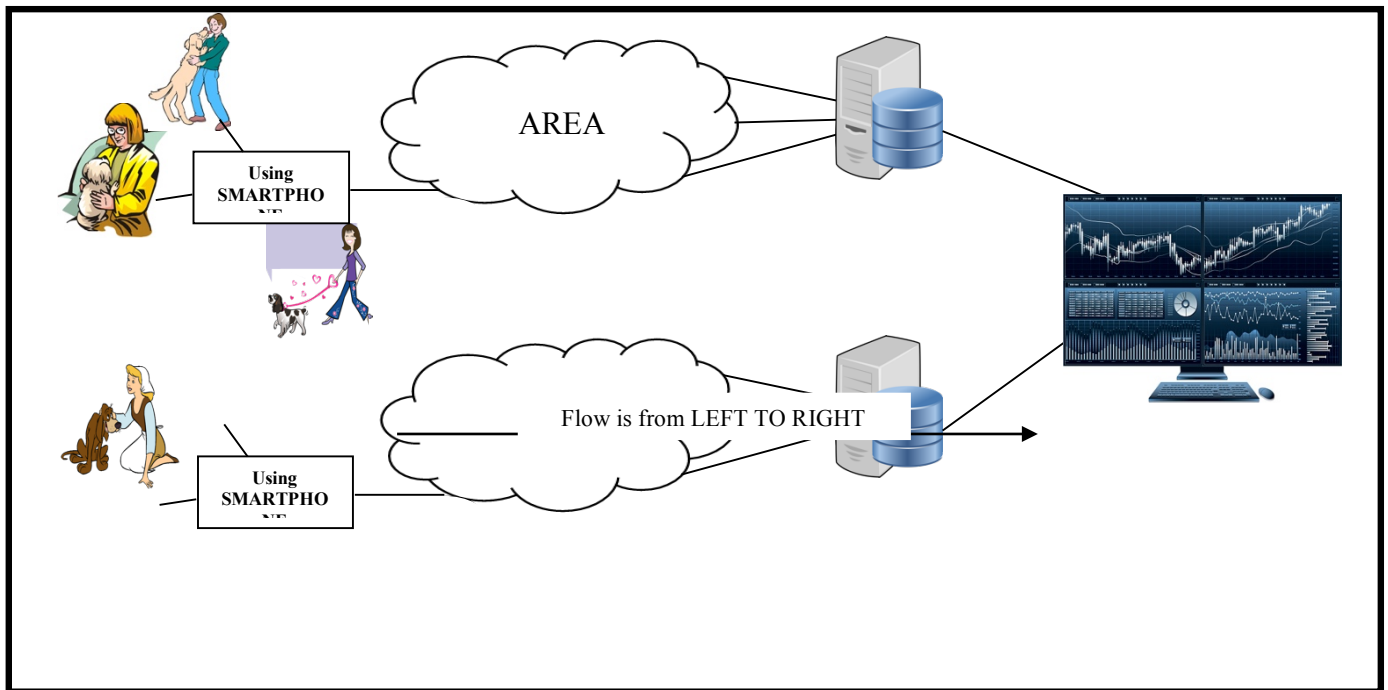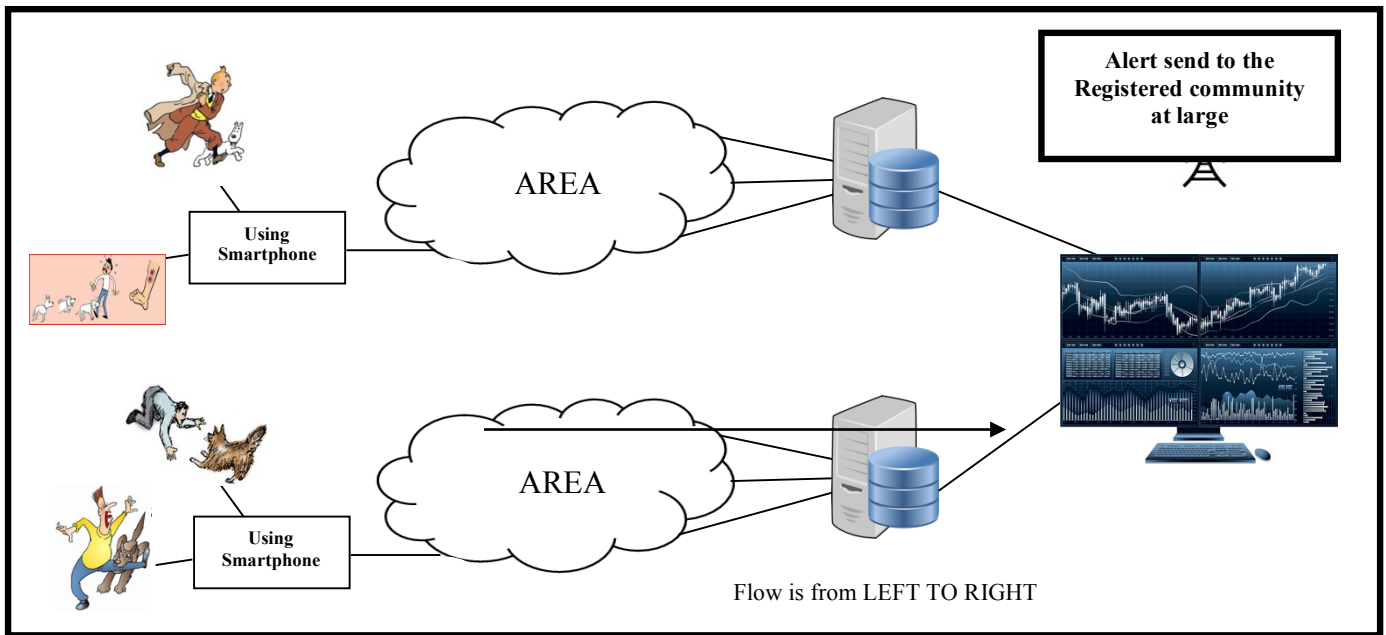

Figure 3: Community uploading the unusual behavior of their pet (dogs) using smart phone technology to the System, Alerts generated and disseminated to the registered community

AREA

Alert send to the Registered community at large

Using Smartphone

AREA

Using Smartphone

Flow is from LEFT TO RIGHT

Karachi is alienated into six districts: Karachi Central, Karachi East, Karachi West, Karachi South, Karachi Malir and Karachi Korangi ("pakimag.com/politics/karachi-divided-into-six-districts-with-korangi-new-one.html", 2013). Datahubs have been setup with in these districts for the prediction of Earthquake.

Every district has multiple areas and every area has a data hub. Data received by the hubs determines the criticality of the situation. The situation is observed and a panic alert is disseminated as soon as the received data hits the threshold, thus asking the community to take precautionary measures.

4 REASON FOR SELECTING THE MODEL

- Model is economically feasible and can easily implemented in both Urban and Rural
   Areas of any less developed country—Pakistan
- Accessibility of domestic animals
- Animals are subtler than humans

CONCLUSION

Earthquake is considered to be the mother of all disasters. It leaves an ever-lasting scar on the face of this planet and on the memories of the affected ones. For a, less developed country it is difficult to predict Earthquake with the help of high-tech tools and techniques. But with the knowledge of precursor analysis, they can also be in the race of Earthquake prediction. Though there are multiple precursors, but the most cheap and reliable one is unusual Animal Behavior. The animals which are considered in this research are domestic animals, as, almost everyone intrigued to have a pet. Animals have shown drastic change in their behavior before the Earthquake befalls, which has been studied for a long time.

The research focuses on the behavior of domestic animals i.e. cats and dogs, as they are easily available and accessible. The research works on the base principal of crowd sourcing, providing a solution for Earthquake prediction to less developed countries. An archetypal implementation is discussed in this paper which involves the placement of data hubs in various areas of Karachi, a large city of Pakistan in terms of population. The data hub works on receiving the information regarding the unusual behavior of animals, from the community. As soon as, the received information from a particular area becomes equal to, or greater than the threshold, an alert signal is generated and disseminated to that respective community, which are able to receive it on their smart phones. The archetypal plays an important role for predicting Earthquake for Pakistan a less developed country, as it involves in monitoring the unusual behavior of animals, which can easily be gathered via crowd sourcing through the community having domestic animals as their pets and helping the community to take precautionary measure before the debris befalls.

The research plays a vital role in the Earthquake prediction, as it focuses on that aspect of the domestic animals which are taken for granted by most of the countries and society. The research can act a fundamental pillar for those less developed countries who also wants to predict the Earthquake, but with only one hassle i.e. every country has to focus on their own domestic animals.

Those animals must be easily available, so that their behavior can be easily focused and a research can be carried out with an ease.

REFERENCES

MSFC, J. W. : (2015). What Is Earth? Tylor Redd, N. (2017). How Was Earth Formed? Retrieved January 24, 2017, from http://www.space.com/19175-how-was-earth-formed.htmlPersonal, M., Archive, R., Khan, H., & Khan, A. (2008). Mpra, (11052)

United States Geological Survey. (2013). The Severity of an Earthquake. Retrieved from http://pubs.usgs.gov/gip/earthq4/severitygip.html

Stephen A.Nelson. (2013). Earthquakes : Causes and Measurements, 1–16.

Kirschvink, J. L. (2000). Earthquake prediction by animals: Evolution and sensory perception. *Bulletin of the Seismological Society of America*, *90*(2), 312–323. http://doi.org/10.1785/0119980114

Harnett, C. (2012). To what extent can animals aid earthquake prediction? The 1975 Haicheng Earthquake.

Tributsch, H. *When the Snakes Awake: Animals and Earthquake Prediction*; MIT Press: Cambridge, MA, USA, 1982.

Wattananikorn, K.; Kanaree, M.; Wiboolsake, S. Soil Gas Radon as an Earthquake Precursor: Some Considerations on Data Improvement. *Radiat. Measur.* 1998, *29*, 593–598.

Grant, R.A.; Halliday, T.; Balderer, W.P.; Leuenberger, F.; Newcomer, M.; Cyr, G.; Freund, F.T. Ground Water Chemistry Changes before Major Earthquakes and Possible Effects on Animals. *Int. J. Environ. Res. Public Health* 2011, *8*, 1936–1956

Hussain, M. S., & Asif, S. M. (2012). Signals, animal response and earthquake. *Journal of Theoretical and Applied Information Technology*, *39*(2), 218–224.

Buskirk, R.E.; Frohlich, C.; Latham, G.V. Unusual Animal Behavior before Earthquakes: A Review of Possible Sensory Mechanisms. *Rev. Geophys.* 1981, *19*, 247–270

Wadatsumi, K. *1591 Witnesses Phenomena Prior to Earthquakes (in Japanese)*; Tokyo Publisher: Tokyo, Japan, 1995.

Ikeya, M. *Earthquakes and Animals: From Folks Legends to Science*; World Scientific: Singapore, 2004.

Heffner, H.E. Auditory Awareness. *Appl. Anim. Behav. Sci.* 1998, *57*, 259–268.

Shier, D.; Butler, J.; Lewis, R. *Hole's Human Anatomy and Physiology*, 10th ed; McGraw-Hill: Boston, MA, USA, 2004.

Hart, B.L. Olfaction and Feline Behavior. *Feline Pract.* 1977, *7*, 8–10.

Beadle, M. *The Cat: History, Biology, and Behavior*; Simon and Schuster: New York, NY, USA, 1977

Halász, N. *Vertebrate Olfactory System*; Akaderniai Kiado: Budapest, Hungary, 1990.

Passe, D.; Walker, J. Odor Psychophysics in Vertebrates. *Neurosci. Biobehav. Rev.* 1985, *9*, 431– 467.

Smartphone Users Worldwide Will Total 1.75 Billion in 2014 - eMarketer. Retrieved January 20, 2016, from http://www.emarketer.com/Article/Smartphone-Users-Worldwide-Will-Total-175-Billion-2014/1010536

Telecom sector: Pakistan to have 40 million smartphones by end of 2016. Retrieved February 28, 2016, from http://tribune.com.pk/story/953333/telecom-sector-pakistan-to-have-40-million-smartphones-by-end-of-2016/

Ali, Q., & Khan, A. N. (2004). 13 th World Conference on Earthquake Engineering A critical review of the seismic risk zoning and development of Design spectra Department of Civil Engineering , NWFP, (50).

KARACHI: Study identifies most vulnerable quake zones in Pakistan - - DAWN.COM. (2009). Retrieved February 29, 2016, from http://www.dawn.com/news/509742/karachi-study-identifies-most-vulnerable-quake-zones-in-Pakistan

Bott, M., & Young, G. (2012). The role of crowdsourcing for better governance in fragile state contexts. *Praxis*, *27*, 47–70. http://doi.org/10.2307/1566844

Karachi Divided into Six Districts with Korangi New One. (2013). Retrieved March 2, 2016, from http://www.pakimag.com/politics/karachi-divided-into-six-districts-with-korangi-new-one.html