An Earth Coordinate System for Earthquake Forecasting Using SLHGN

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Abstract. An attempt for an earthquake forecasting has been challenged by the current earth coordinate system. The latest architecture of mHGN which is called SLHGN requires that the observed locations must be spread out regularly, that is within regular grid-like distances. Such a requirement would not be fulfilled, as within the current earth coordinate system a longitude-difference would produce different distances. The extreme examples are locations in equator compared to those on the earth poles. Therefore, an earth coordinate system has been developed to support the ongoing earthquake forecasting technology using SLHGN. Additionally, two important positive issues related to this earth coordinate system have been developed, they are: 1) each location is not represented through two-value (longitude and latitude), but only a single value. This value does not represent a point but an area; 2) the conversion of this earth coordinate system to the x-y Cartesian System requires no angular formulas, which is therefore fast. These issues have given positive support to the SLHGN in forecasting earthquakes. Although the accuracy and the performance are not yet ready to be analyzed properly, because local weather data at the time of an earthquake occurrence is not always available, the characteristics of the SLHGN experiments show very promising results

Keywords: Hierarchical Graph Neuron (HGN), Multidimensional Hierarchical Graph Neuron (mHGN), Single Layer Hierarchical Graph Neuron (SLHGN), Natural Disaster Forecasting, Earthquake Forecasting.

1 Introduction

Despite some pessimistic opinions, there are still many researchers who are undertaking research on earthquake forecasting or predicting. The usual reasons of such pessimistic opinions among others are due to three obvious conditions. First: the location of an epicentre is changing, second: locations of faults are also changing, third: various assumed precursors have never been proven. The other important issues that also need to be discussed further are that most approaches that have worked on the ground motions and electromagnetic fields have never come up with proven formula. It is therefore quite acceptable that those researchers do not believe that the earthquake is predictable.

Some other problems that hinder the analysis is that the structure of SLHGN requires that the locations of measurements should be like a grid. It means that all the points of the measurement locations should be distributed evenly. Such a requirement would become more and more difficult when the observation takes place in the area of the poles of the earth. The reason to this is that the longitude value of either poles goes to a singularity. The other thing that also needs to be discussed further is that it is very unlikely to forecast an earthquake on particular coordinate (a point) on the earth. The more logical strategy would be that the forecasting would produce a coordinate of an area on the earth rather than a point. However, the current coordinate system does not have ways to represent the coordinate of a particular area. So, for our research we need to develop another coordinate system that would be useful for SLHGN and also for other earthquake researchers.

The following diagrams show that many researchers have difficulties to determine the coordinate of particular area on the earth.

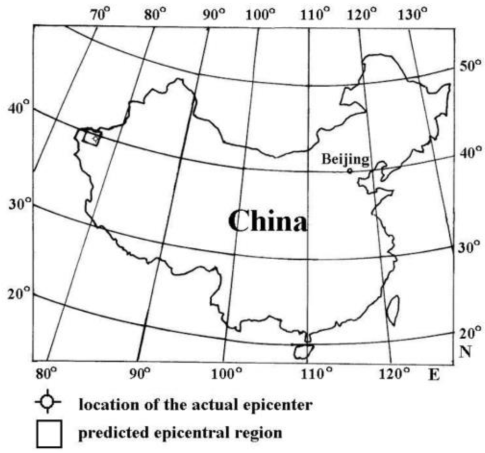

Fig. 1. Researchers focus on an area, not a point [1]

Some researchers also propose a grid-like measurement method. The following diagrams shows that.

Originally, an earth coordinate system was proposed for the first time in 1866 [4] [5]. Following that, a more precise coordinate system utilizing satellites has then been introduced in the 80s. Until now, such a coordinate system is the only coordinate system that people are using worldwide. Within the system, each coordinate actually consists of three values, they are: latitude, longitude, and altitude. But, only latitude and longitude are required when a coordinate is on the earth surface.

In fact, the world is an oblate spheroid [4]. It means that it is difficult to calculate the distance between two points on the earth surface precisely using the usual coordinate system, as the area that makes the earth oblate is not publicly known. The difficulty would increase when people need to work with distances on the earth surface. There are several algorithms available to be used to calculate a distance based on coordinates as parameters, but there is no appropriate algorithm to calculate coordinates based on distances as parameters.

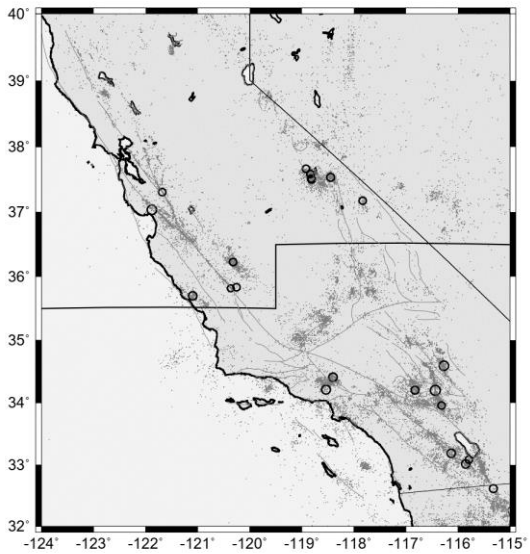

Fig. 2. So many coordinates need to be represented in the analysis [2]

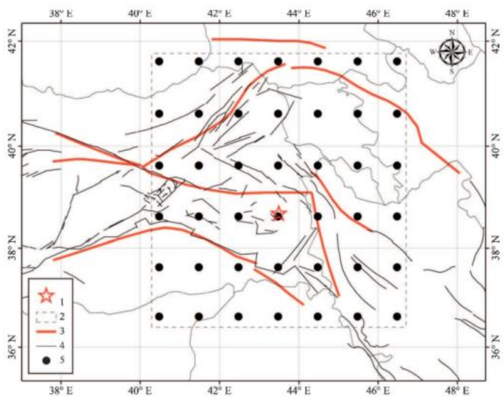

Fig. 3. Researchers propose grid-like measurement points [3]

The same difficulty will be apparent when earth coordinate system needs to be incorporated into an earthquake forecasting system using Single Layer Hierarchical Graph Neuron (SLHGN). The architecture of SLHGN requires that the positions of all neurons have to build a grid-like structure. Additionally, the earthquake forecasting system should be capable of being deployed on all parts of the earth surface, including those on both earth poles. To deal with those problems another coordinate system has been developed. This system is more appropriate to be incorporated with the ongoing earthquake forecasting system using SLHGN. Although more and thorough tests are still required, results taken from previous tests and analysis have shown promising capabilities.

2 Problems of Earth Coordinate System

The problems of earth coordinate system are strongly related to the problems within the earth itself. Although many researchers have tried to figure out all of those problems [6], the results are not satisfactory yet. The following are the elaboration of those problems.

2.1 The Oblate Spheroid

As already mentioned, the earth is oblate. This has been discovered by researchers who work with cosmology [7] and earth science. The cause of such a shape is due to the unknown force within the solar system. The deployment of common coordinate system on an oblate surface would produce imprecise locations nor distances. The exact areas of the oblate positions are publicly unknown either. By using earth surface, coordinate would be more precise. For an earthquake forecast system, precise locations and distances are essential for having accurate results. The following is an example how the oblate surface of earth inner core hinders researchers in having precise calculations for inner core of the earth.

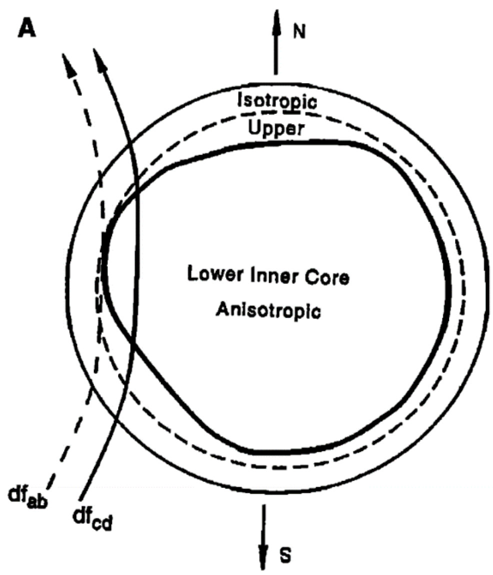

Fig. 4. The Oblate shape of earth inner core [8]

2.2 The Rotation and the Rotation Axis

The rotation axis is another problem within an earth that would affect the coordinate system. First, it is not clear what the cause of earth spinning is. When the cause of it is known, researchers would be more confident with analyzing the coordinate, since precise coordinate is important to measure correct time. Second, the spinning time is not entirely constant. The spinning time would be important to measure the time-series events that would lead to the discover patterns, for example earthquake patterns. Third, the spinning axis is not stable. Researchers have reported that the axis shifts (precession) and vibrates (perturbation). When the axis is not stable [9], then the poles have different positions either. The following figure shows the phenomenon.

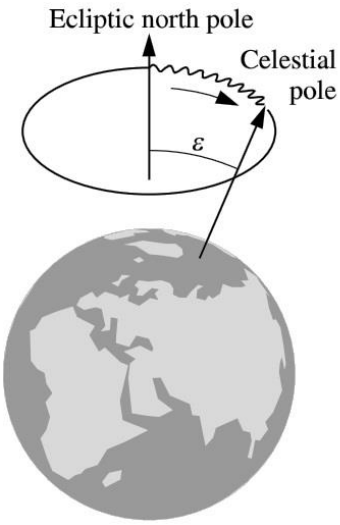

Fig. 5. The precession and perturbation of the earth axis [10]

2.3 Magnet Axis of the Earth

The planet's (earth) magnet field is generated within the core [8]. It is a result of thermal and chemical reaction between the core and its mantle. The substance between the outer core and the mantle is fluid. The magnet field is very important as it together with electric field builds the electromagnetic field that influence the earth rotation [8].

Again, based on long time measurements the axis of the magnet field is not constant either. It changes dynamically. Not only the axis, the rotation speed of inner core is not the same as the rotation speed of the mantle, sometimes faster sometimes slower. Due to fact that the magnet axis and the rotation axis of the earth are not stable, the calculation and the measurement using rotation axis and magnet axis are not very accurate. It is not surprising that the values of latitude and longitude, that are determined by GPS system using satellite, are not based on instrument measurements on the surface. Additionally, the accuracy of the coordinate will be within 100 m if the coordinate is provided by the unpaid GPS system, and the accuracy will be within 10 m if the coordinate is provided by the paid GPS system.

2.4 Malfunction of GPS Components

Until now, it is not common that people know the coordinate of a place or building. Only particular places such as airports and train stations have their coordinates been determined. Such a coordinate in those areas and buildings is not published broadly. The information about the coordinate is usually established through a metal plate in front of a building.

There are some questions related to the current coordinate system that need to be addressed. What is the benefit of knowing the coordinate of a place or a building? Is it possible for people without using GPS components to pinpoint a building if its coordinate is given? Can a GPS system—with 100 m accuracy—be used to measure land borders? What would happen to a GPS system when the connected satellites have troubles? What if the base stations on the earth surface have troubles as well? Would people still be able to determine or to calculate the coordinate?

All the answers of the above questions are very important for handling disasters such as earthquakes. They are also important for people who need to be aware of those during a disaster. For instance, during an earthquake, infrastructures are the first items that will be destructed, or even destroyed. In such a situation accurate coordinate is essential during recovery processes and for work coordination. Despite no equipment can be used during recovery state, there should be a sophisticated approach that can be utilised to find the coordinate of an important location.

2.5 Area and Coordinate for Distance Conversion and Vice Versa

The other problem in the current coordinate system is that it only generates the coordinate of a point on the surface of the earth. There is no option the current coordinate system can generate a coordinate of an area. For an earthquake forecaster like SLHGN it is difficult to obtain earthquake related data on an exact location, because the hit epicentre vary. Seismic data shows that earthquakes occur in particular areas, which are normally in areas of a fault. Using SLHGN, an area of the previous earthquake area should have data that does not describe a point, but an area. Therefore, the more suitable coordinate system for SLHGN is the one that can represent an area.

Not only that such a coordinate system should be able to represent an area, but it should also be easy to be used for converting a distance using the coordinate system. The conversion capability is required, because the SLHGN should have a grid-like structure, in which the distance between points (two coordinate data) plays a big role. Through various algorithm, the current coordinate system can be used for converting two points of coordinates to a distance, but unfortunately not the other way around.

3 Earthquake Forecasting using SLHGN

SLHGN is the latest version of its predecessors of pattern recognizers. They are HGN, and mHGN. There are already several pattern recognition related problems that have been solved using SLHGN. As some problems depend on the sequence of data appearance, some of the implementations have utilized time-series data. As already mentioned, earthquake data is an example of time-series data. The convincing result of the previous pattern recognizer using time-series data indicates that the earthquake forecaster using SLHGN would produce convincing result as well. The description of HGN and mHGN can be found in [11 - 15].

3.1 Another Coordinate System

The beginning stage when developing this coordinate system is finding shapes and the structure that can cover the surface of the earth evenly. Based on mathematical analysis, only the combination of pentagons and hexagons will be the answer. The lowest number of them are: 12 pentagons and 20 hexagons. This combination is the same as of the one we have known for a long time, that is a football (soccer ball),

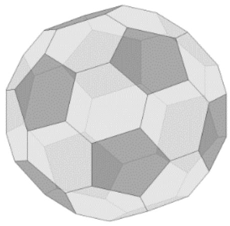

Fig. 6. A football consists of 12 pentagons and 20 hexagons

When required, each hexagon can be divided into 4 small hexagons and each pentagon can be divided into 1 pentagon and 2.5 hexagons. The following shows the divisions.

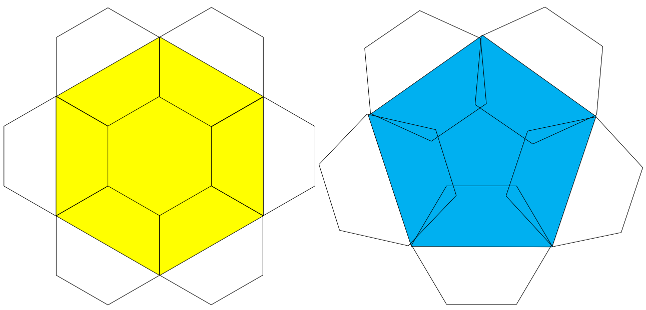

Fig. 7. The division of a hexagon and a pentagon

After dividing each pentagon and each hexagon, the number of hexagons will be 20X4 + 12X2.5 = 110, and the number of pentagons remains the same, that is 21. In total, there are 122 faces on the surface of the ball. The following is the figure.

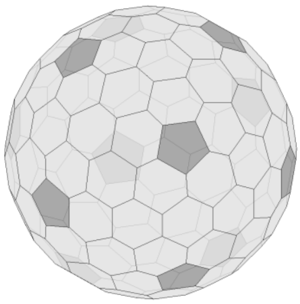

Fig. 8. A ball consists of 12 pentagons and 110 hexagons

The next step is to determine the position of a reference point. In this case, the coordinate latitude = 0 and longitude = 0 has been chosen as the reference point. In the following figure, the reference point is the corner between shape A, shape B, and shape C. To help identifying which pentagon or hexagon is under scrutiny, identities have been given to each shape. The shape AA is exactly on the other side of the ball if it is observed from the shape A. The shape BB is exactly on the other side of the ball if it is observed from the shape B, and so forth.

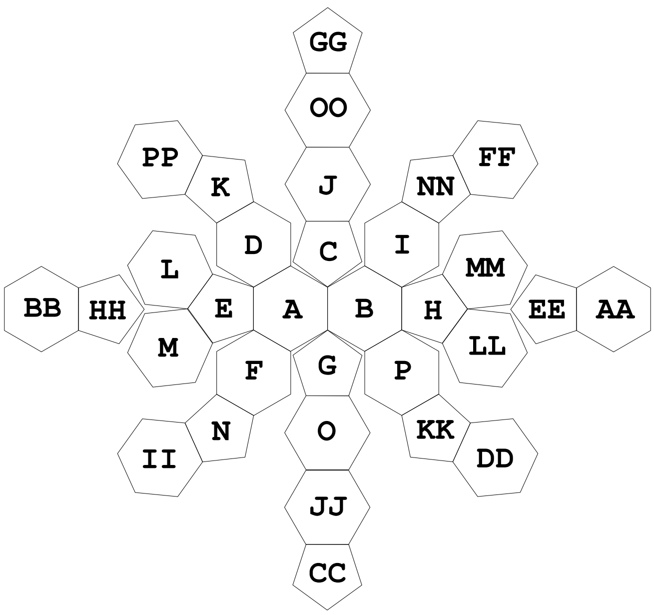

Fig. 9. Faces of the football lies on a flat surface

After all the shapes have been labeled with identities, an algorithm needs to be developed that will generate a coordinate for any face of the surface. The coordinate will be calculated from the reference point. By doing so, there will be three possible directions from the reference point. Each direction has an identity, either 1, or 2, or 3. After the first direction from the reference point, the next direction can only be 1, 2, 3, 5, or 6. The following figure shows those possible directions. The red color arrows would build all the directions to the destination before entering a face of the destination. When the face of the destination has been reached, the direction will be one of the blue color arrows.

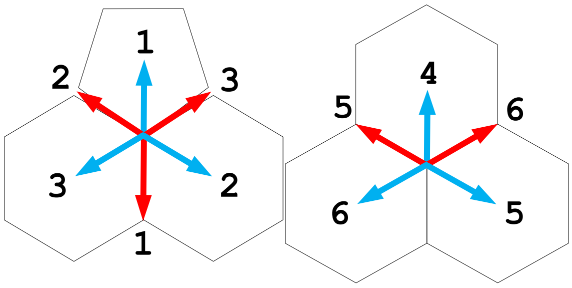

Fig. 10. All the possible directions (red) before entering (blue)

The coordinate will look like the following: **Tabcdefghi+jklmno…**

The letter T means type, it can be 1, 2, 3, etc. The type shows which version of the ball the coordinate refers to. For the football, the version would be 1. The other letters a, b, until i shows the identity of the direction starting from the reference point. The letter j shows the direction to the middle of the shape of the destination (blue colour arrow). The letter k shows the area of triangle within the face. If the shape is a pentagon, the value of j would be: 0 till 4, whereas if the shape is a hexagon, the value of j: 0 till 5. The following figure shows the division of the face into triangles.

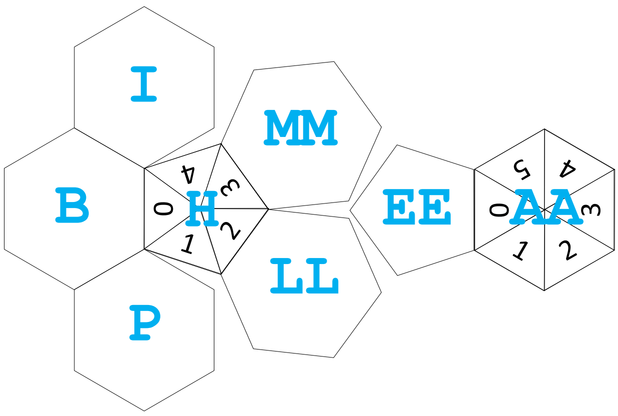

Fig. 11. Divisions of a face into triangles

When the destination area is smaller than a triangle of a face, then a triangle can be divided into four smaller triangles. The process continues until the appropriate area has been reached.

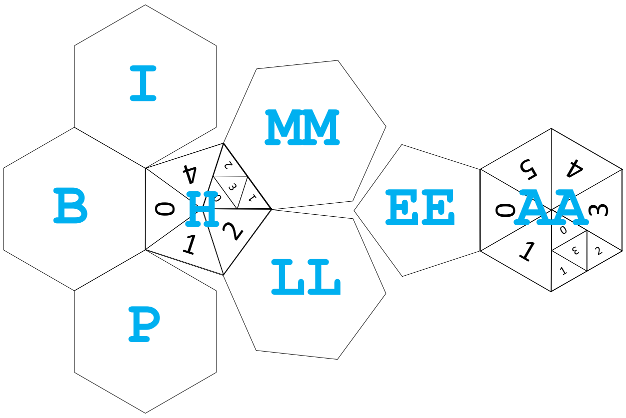

Fig. 12. Divisions of a triangle into four triangles

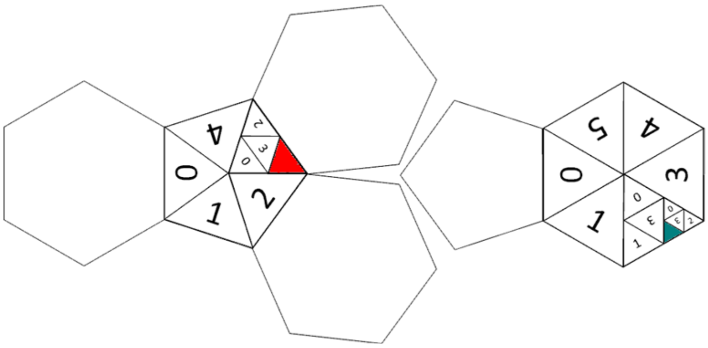

Fig. 13. The coordinate for red: 131+131, for green: 13122133+2221

The following figure shows some coordinates of particular faces.

4 Further Steps

The following are the further steps that will be carried out after the coordinate system has been finalized. The steps are basically dealing with other problems, such as the scarcity of earthquake data, how the forecasting is prepared, and remaining issues.

4.1 Collecting Data Strategies

Although additional and various data will be required, we are lucky that the seismic data of earthquakes happening from around the world are recorded and publicly available. The data will then be collected according to the time of the occurrence, for instance every one hour, every day, every month, every year. Collecting data based on the time of the occurrence would be known as time-series-data. This time series data of strong earthquakes will be prepared as patterns that will be fed to SLHGN. Weather-related data will also be collected, including various data related to galaxy components.

```
A     → 1+3
B     → 1+2
C     → 1+1
G     → 11+1
D     → 12+3
E     → 121+1
F     → 113+2
J     → 122+3 or 133+2
O     → 1133+2 or 1122+3
AA    → 13122122+3 or 13122133+2 or 13121312+3
BB    → 12133133+2 or 12133122+3 or 12131213+2
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Fig. 14. Some samples of coordinates

4.2 Forecasting Strategies

The common earthquake forecasting approach researchers have develop is named as now-casting. The time window of now-casting is short, for instance: 20 minutes, or up to an hour. Although this approach has been utilised for long time, such earthquake now-casting has not yet produced satisfactory results. The number of casualties and traumatized people is still high. Not only now-casting, other earthquake technologies have produced location and the time, they are not yet able to provide data about when? how long? which part? More specific and detailed data of an earthquake is important for many people.

4.3 Remaining Forecasting Issues

Due to the devastation caused by an earthquake, important data such as weather data before, during, and after an earthquake is often very difficult to be gathered. For this research, historical data must be gathered from the location of the affected area. Temporal and spatial data is important for an earthquake forecasting through a pattern recognition. The remaining steps that need to be worked out in the future are: 1) How can time series data related to earthquakes build patterns? 2) How can seismic and weather data be fed to SLHGN architecture? 3) How can it be proven that it is effective?

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