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An internet of things belief rule base smart system to predict earthquake

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ABSTRACT

An intelligent belief rule base (BRB) based system with internet of things (IoT) integration can evaluate earthquake prediction (EP). This ingenious and rational system can predict earthquake by aggregating changed animal behavior combined with environmental and chemical changes which are taken as real time inputs from sensors. The BRB expert system blends knowledge demonstration criterion like attribute weight, rule weight, belief degree. The intelligent BRB system with IoT predicts the probable occurrence of the earthquake in a region based on the sign and symptoms culled by the persistent sensors. The final result taken from Intelligent BRB system with IoT integration is compared with expert and fuzzy-based system. The projected method gives a better prediction than the up-to-date expert system and fuzzy system.

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1. INTRODUCTION

Natural calamities those happen in our world gives some signs and symptoms before coming but earthquake is such kind of calamity it strikes without any signs . It is recorded that there are 500,000 happened earthquakes in the world each year. Among them millions of we can feel and hundreds of them can be destructive. In the 20th century 1,741,127 people were killed because of earthquake When the surface of the earth is heavily shaken it causes movement of inner ground surface and this is named or termed as earthquake. It can also be happened when two ground surfaces slips one another [1]. Various demographic and analytical data shows that the earthquakes related information, which has been used worldwide. national research council (NRC) of United States proposed how earthquake prediction should be done: magnitude range, the demographic is where it may occur, time difference of prediction on occurrence on which the success lies [2]. It is one of the most mysterious problems in geosciences.

To predict earthquake many researches have been done. especially of U.S.A [3], Dmowska [4], Japan [5], Italy [6] Turkey [7], China [8], Netherlands [9], India [10] recording the genesis and norms of earthquake. Hossain *et al*. [11] introduced the belief rule-based expert system (BRBES) where uncertainty with rule base is used for data narration. It can handle many types of limitations which are associated with earthquake prediction, for example weight which plays an important role part in providing the result. Authors showed the BRBES gives better than fuzzy based and other expert system. Moreover, the system answers

different ‘what if’ cases which gives more feasible solution. Thus, this framework can be used to assess intensity of the earthquake. But their data taking was done manually.

Earthquake prediction is an important area of research, which is evident from the presence of various types of systems, available in the literature [12]-[24].

Various data mining methods, artificial intelligence (AI) and expert system can predict earthquake with high accuracy.[12], [15], [16]. Different applications of data mining techniques are proposed [12], [18], [19], [22] to predict the earthquake, which include artificial neural networks (ANNs), bayesian be-life networks (BBNs), decision trees, support vector machines (SVMs), as well as logistic models.

Fuzzy logic [25], [26] was also used to predict earthquakes. In combination with some modern seismological algorithms, fuzzy expert system was developed in [3]. Another fuzzy expert system was developed by taking account of human reasoning procedures to predict earthquake [15]. Human expert knowledge has been used to design this system. This system used Sugeno type fuzzy inference procedures along with a pliant fuzzy inference procedure to clarify the earthquake parameters. The correctness of this system is better than opinion of human expert.

Rule base expert system was proposed in [16], where earthquakes were predicted by taking account of historical data. Association rule mining technique was employed to discover knowledge [18]. As association itself is binary approach uncertainty can’t be handled with it [27], [28]. On the contrary, belief rule base expert systems (BRBESs) have the capability to represent various kinds of uncertainty both in the knowledge base as well as in the inference processes [29]-[34] in an integrated framework.

Hossain *et al*. [11] introduced a system which considered fuzzy based system and expert systemto predict earthquake. This system took inputs in a manual manner. So, from previous analysis it is clear that expert system with internet of things (IoT) integration is a better choice to remove the uncertainties in earthquake prediction. We move forward to the next discussion like this. Section II discusses about the structure of BRB and IoT system. Also, blending of BRB Inference methodology and iot combined with evidential reasoning (RIMER) approach, designing the system and effectuation of the raised BRB Intelligent system with IoT integration. Analyzed data and interlocution are shown in section III. The system and hardware design of the discussed model system is written in section IV. Section V shows with a conclusion why is model is more viable choice.

2. GENERAL OUTLOOK OF IOT AND BRB SYSTEM

Figure 1 demonstrates the model where IoT devices have been used using three sensors DHT11 temperature and humidity sensor, HC-SR04 ultrasonic sensor and ESP8266EX collect temperature, distance, and low power data. Filtering of data has been done after analyzing it, big data, storage of data and streaming technique. Finally the earthquake categorization will be done by data mining and machine learning process. A pictorial representation of Intelligent BRB system is illustrated in Figure 2. Here data investigation block shows that data have been taken for analyzing and storing the information. Analyzed data is aggregated by the abstraction block which is then been converted to Intelligent BRB system [35].

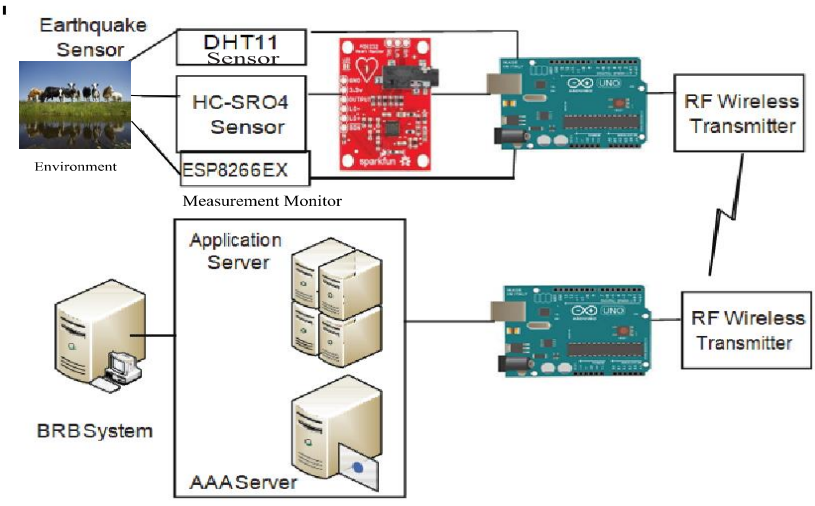

Figure 1. Pictorial representation of the model

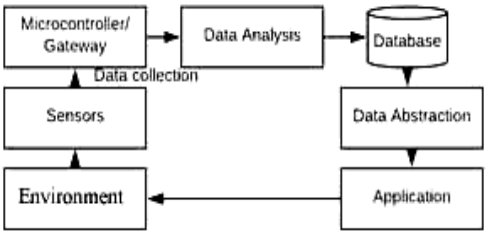

Figure 2. Intelligent BRB system architecture describing range of operation of different parts

The following discussion will be on IoT and BRB.

a. loT

In internet of things each element of network is inlaid with software, electronics, and sensors. Also, these elements can be attached to the internet. Figure 1 shows the structural design of the WSN, used to store and collect data from the environment. DHT11(temperature and humidity sensor), HC-SR04 (ultrasonic sensor) as well as ESP8266EX is used in each IoT element. In each IoT branch, DHT11, HC-SR04 and ESP8266EX sensors have been used. The DHT11 measures the air in the environment i.e. temperature, and spit s out a digital signal on the data pin, the HC-SR04 sensor can collect measuring distance or sensing objects and ESP8266EX achieves low power consumption data from each subject. The reading of these sensors are stored in the memory of Arduino and after filtering, the built-in RF module of Arduino will sent the readings to database serv

b. BRB

We can consider BRB as an alternative which can resolve complicated relationships with various kinds of data with uncertainties [36]-[38]. Each belief has a possible consequence of a rule in a Belief rule-base expert system. Belief rules structures the knowledge base and evidential reasoning which acts like nference engine of the expert system. The complicated relationships between different constituent can be fetch by belief rule-base expert system which can be done with orthodox IF-THEN rules. Fuzzy logic comprises three parts: a consequent part, belief rule base and an antecedent part. Referential values can be assigned to each antecedent and each consequent refers to the degree of belief [39]-[41].

In BRB belief degrees of all input strengthen resolving the uncertainty. Like this, a rule base is created with degree of beliefs associated with all possible coutcomes of a rule. For example, a rule base is capable of removing incompleteness, vagueness from various values which are involved with earthquake prediction. Figure 3 demonstrates the principal parts of the Belief Rule Base structure. Combining all these makes BRB flawless and also designs an ER based system which is called RIMER methodology [42]. Each of the components of the BRB architecture is discussed below [43].

- Presentation layer: It helps the users to interact with the system. The users of BRB can be connected with the system by the interface created by this layer.
- Application layer: This part facilitates transferring data from computer to system and vice versa. Application layer works with the deduction motor and prepares module of this BRB framework. The induction part of BRB is created with some elements, for example, input change, handling devices.
- Data processing layer: This layer rule base of BRB and the sensors data.

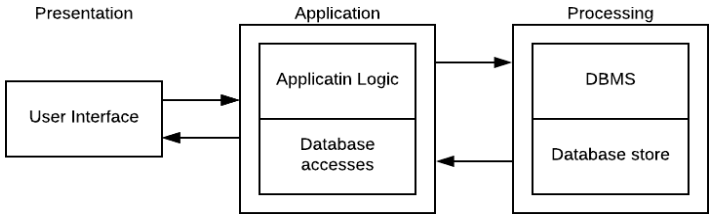

Figure 3. An intelligent BRB model

The BRBES assessed the intensity of earthquake. This system gives the result cbased on various signs and symptoms related with earthquake. signs and symptoms which are found in environment. It is a system which is just like produces as like as human expert opinion and can resolve many real-world problems using IoT components. Wireless sensor networks collect raw data from the environment can be

used to assess the intensity of earthquake. While collecting sensor data main challenges are are sensor energy efficiency, memory capacity, and data storage mechanism. Life time of the network is also important in unvarying sink scenarios. Storage capacity is also important while collecting data. A good model for storing data can improve the quality [44]. BRB GUI is iillustrated in Figure 4. The belief degree of the level-2 points of the BRB tree has been calculated by taking fuzzy value. Prediction of the earthquake of environment has been done in terms of crisp value. Earthquake prediction by different expert system as shown in Table 1

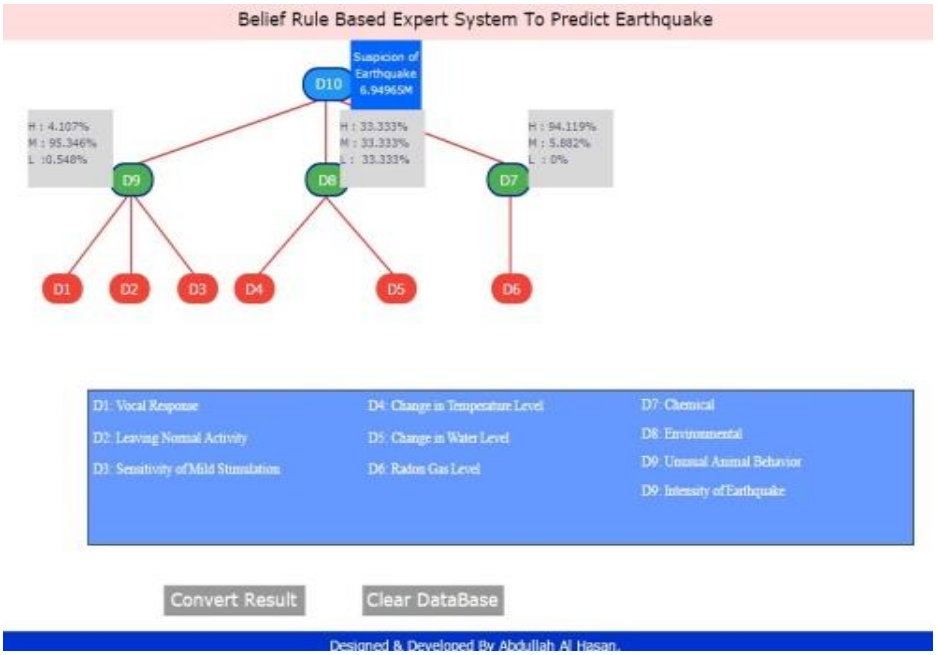

Figure 4. BRBES GUI

Table 1. Earthquake prediction by different expert system

Earthquake	IoT- BRBES Output	BRBES Output	Fuzzy Logic	Original Result	Benchmark Data
E1	7.8761	7.65	8.09	8.2	1
E2	6.9768	7.01	8.08	7.0	1
E3	8.494	8.494	8.11	8.5	1
E4	7.7128	7.77	8.09	7.8	1
E5	8.3501	8.27	8.10	8.3	1
E6	7.3316	6.98	8.10	7.0	1
E7	8.442	8.41	8.09	8.4	1
E8	7.893	8.13	8.08	8.1	1
E9	7.0174	6.97	8.11	7.0	1
E10	7.2291	7.37	8.09	7.4	1
E11	7.3618	7.438	8.09	7.5	1
E12	7.1241	7.278	8.09	7.3	1
E13	7.2263	7.267	8.09	7.3	1
E14	7.6342	7.456	8.08	7.5	1
E15	7.0513	7.214	8.09	7.3	1
E16	7.0127	6.976	8.08	6.8	0

3. A SYSTEM SETUP

The following software and hardware are used for designing intelligent BRB system as shown in Figure 5. The hardware components are:

- DHT11, HC-SR04 and ESP8266EX
- Arduino (UNO)
- Arduino ethernet
- RF wireless encoder/decoder

Used language in the software part:
- Arduino IDE
- PHP
- Database: MySQL

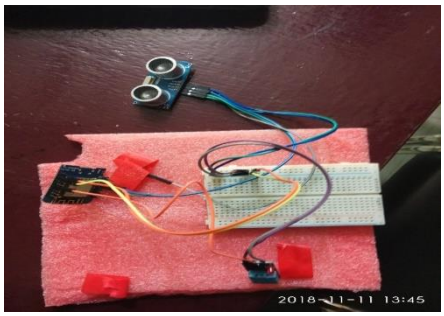

Figure 5. Real arrangement of Intelligent BRB with IoT components

4. ANALYZED RESULTS

Ten real historical data of different earthquake and real time environment data which (CHATTOGRAM city of Bangladesh) have been collected using IoT sensor nodes. The collected data are then analyzed by BRB system.

a. Collection of data

Among three sensors have been used the DHT11 sensor measures the air in the environment, and spit s out a digital signal on the data pin, the HC-SR04 sensor can collect measuring distance, environment interaction data whereas the ESP8266EX achieves low power consumption data from each subject.

b. Data analysis and Knowledge Discovery

These values are transferred to assess the earthquake of each case. Receiver operating characteristic (ROC) curve has also been used to verify the trustworthiness of the result. The performance of the proposed system is calculated using the area under curve (AUC). It can be seen that AUC of the proposed system is higher than fuzzy system. Figure 6 shows ROC curves which are performance of the intelligent IoT BRBES, BRBBES, original and fuzzy system. Table 2 shows the AUC for intelligent BRBES with Iot is higher than any of other expert system.

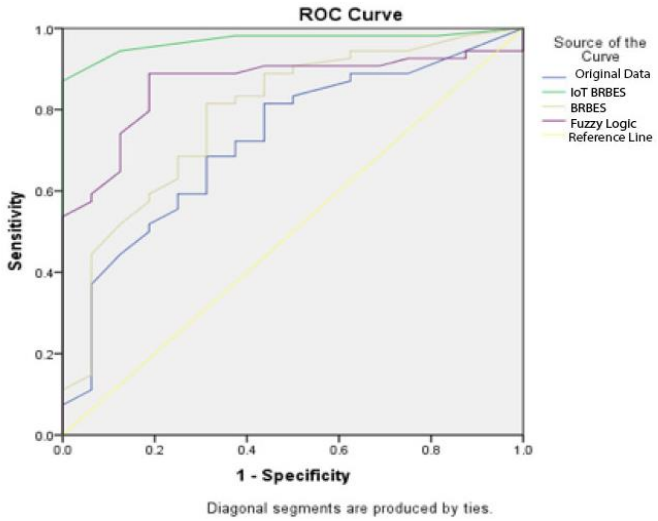

Figure. 6. ROC curve representing original data, IoT BRBES, BRBES and fuzzy logic sensors can collect real environment data form each subject separately

TABLE 2. Area under curve (AUC) of different system

System	AUC
Intelligent BRBES with IoT	0.953
BRBES without IoT	0.933
Original	1.000
Fuzzy Logic	0.900

5. CONCLUSION

In this work, we designed an Intelligent BRB system with IoT integration to predict the intensity of arthquake. Not only this system can resolve various uncertainty which do exist in environment but also includes criterions which has an ability to represent knowledge. The final result from Intelligent BRB with IoT integration is outperforms the BRBES and fuzzy based system which means this system is robust and can be used to predict earthquake with higher accuracy. In future, more sensors can be added to improve the consistency and accuracy of Earthquake prediction by the existing system.

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Rahman Atiqur received his Bachelor of Science (B. Sc) and Master of Engineering (M. Engg.) degree from the Department of Computer Science and Engineering at the University of Chittagong, Chittagong, Bangladesh. In profession, he worked in the Department of Computer Science and Engineering, University of Chittagong, Bangladesh as an Assistant Professor since April 2016. Former he was a lecturer in the Department of Computer Science and Engineering, University of Chittagong, Bangladesh. He is now conducting his Ph.D. research works under the Chinese Government Scholarships (CGS) Program at Chongqing University of Posts and Telecommunications, Chongqing, China. His current research interest lies in the field of edge computing-based IoT systems

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