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A Fuzzy Logic Application for Explain Relationships Between ^{222}Rn Concentration and Earthquakes

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Abstract: Earthquake behaviors are, in general, among the non-linear topics of physics. Unfortunately researches up to now could not yet propose a complete mathematical model for earthquake behavior prediction possibilities. The main reason for not being able to establish such a model is due to the non-linear behavior of the earthquake and its generation is dependent on a variety of indigenous factors. Mathematical expressions and modeling of the non-linear systems is comparatively difficult and sometimes requires high speed and memory computers. For this reason, the expert systems as Fuzzy Logic (FL) are now commonly used for such modelling. Model is suggested a system to examine the space-time behavior of any physical phenomena through a set of convenient mathematical expressions, which describe linear or non-linear aspects. Fuzzy logic applications have a fast increase in past few years. Fuzzy logic modelling can be a very powerful explains about internal structure of dynamic system. The most commonly used indicator in earthquake prediction studies is soil radon gas (^{222}Rn). In this study, we have tried to explain relationships between ^{222}Rn and earthquakes using fuzzy logic. The application region is performed for ^{222}Rn data of Mersin region near the East Anatolian Fault System, Turkey.

***Keywords*:** Earthquake, Modelling, Radon, Fuzzy Logic, Expert Systems

^{222}Rn Konsantrasyon ve Depremler Arasındaki İlişkileri Açıklayan Bulanık Mantık Uygulaması

Özet: Deprem davranışları, genel olarak fiziğin lineer olmayan konuları arasındadır. Şimdiye kadar yapılan araştırmalar maalesef deprem davranışını tahmin etmek için tam olarak matematiksel bir model önerememektedir. Böyle bir modelin kurulamamasının başlıca nedeni, depremin doğrusal olmayan davranış gösteriyor olması ve oluşum mekanizmasının çeşitli faktörlere bağlı olmasından kaynaklanmaktadır. Doğrusal olmayan sistemlerin matematiksel ifadeleri ve modellenmesi oldukça zordur ve bazen yüksek hızlarda, geniş bellekli bilgisayarları gerektirir. Bu nedenle, uzman sistemler olarak bilinen bulanık mantık bu tür modellemelerde yaygın bir şekilde kullanılmaktadır. Bu model, doğrusal veya doğrusal olmayan yönleri tanımlayan uygun matematiksel ifadeler vasıtasıyla herhangi bir fiziksel olayın uzay-zaman davranışını incelemek için önerilmektedir. Bulanık mantık uygulamaları son yıllarda hızlı bir artış göstermektedir.

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Bulanık mantık modellemesi dinamik sistemin iç yapısı hakkında çok güçlü bir açıklama olabilir. Deprem tahmin çalışmalarında en sık kullanılan gösterge toprak ^{222}Rn gazıdır. Biz bu çalışmada, ^{222}Rn ile deprem şiddeti arasındaki ilişkiyi bulanık mantık metodu kullanarak açıklamaya çalıştık. Uygulama bölgesi olarak, Doğu Anadolu Fay Sisteminin yakınlarındaki Mersin bölgesinden alınan ^{222}Rn verilerini kullandık.

***Anahtar Kelimeler*:** Deprem, Modelleme, Radon, Bulanık Mantık, Uzman Sistemler

1. INTRODUCTION

Many observations indicated that the geophysical events in nature usually have an irregular pattern [1,4,14]. Quake events are substantial irregular and it has inconceivable a structure. Throughout the seismic behavior changes many parameters. The most one of these parameters is ^{222}Rn gas changes. It is consist of natural radioactive of decay chains in the Earth's crust. Soil levels and rocks stage include high level ^{238}U as natural source of ^{222}Rn gas. ^{222}Rn gas has 3.82 days half-life and is a noble gas emits alpha particles. Radon behaviors are significantly affected by physical rather than chemical conditions; therefore, the radon gas concentration level varies greatly with atmospheric interactions such as barometric pressure and rainfall [1,2]. The concentration levels are associated with meteorological and hydrological changes, in addition to seismic activity [3,4].

Fuzzy logic applications have a fast increase in past few years. In general, they are used in decision making systems for machine learning and for complex dynamics. Fuzzy logic is offer opportunities for sub-division branch of a system, which plays an important role look at the system a more detailed. In practice, fuzzy logic applications are most preferred, because in combination with neuro-computing and genetic algorithms. Fuzzy logic provides ease of implementation because of its properties, such as; easy to understand, flexible, tolerant of imprecise data and very simple. Fuzzy logic can be a very powerful explains about internal structure of dynamic system [5]. Earthquake occurrences show quite complicated features. The most commonly used indicator in earthquake prediction studies is soil radon gas and its emission of concentration measurements. The fuzzy logic applies of time series with various tools is a powerful tool to understand of the complex systems [6]. Therefore, in this study, we have tried to explain relationships between Radon gas (^{222}Rn) and earthquakes using fuzzy logic. In study, ^{222}Rn gas measurements (for one year) are analyzed with the fuzzy logic methodologies. The application is performed for data of Mersin City near the East Anatolian Fault Zone.

2. MATERYAL METHOD

2.1. Research Area

In study region is the Mersin location, which extends between east longitude 34°57'06'' and north latitude 37°16'43″ as shown in Fig. 1. It is a tectonically complicated and seismically active region of the Anatolian Peninsula, Turkey [7]. The prediction through is applied to recorded data from 1 January to 31 December 2007 and the continuous soil radon measurements are taken at 15-min intervals for one year in the study regions.

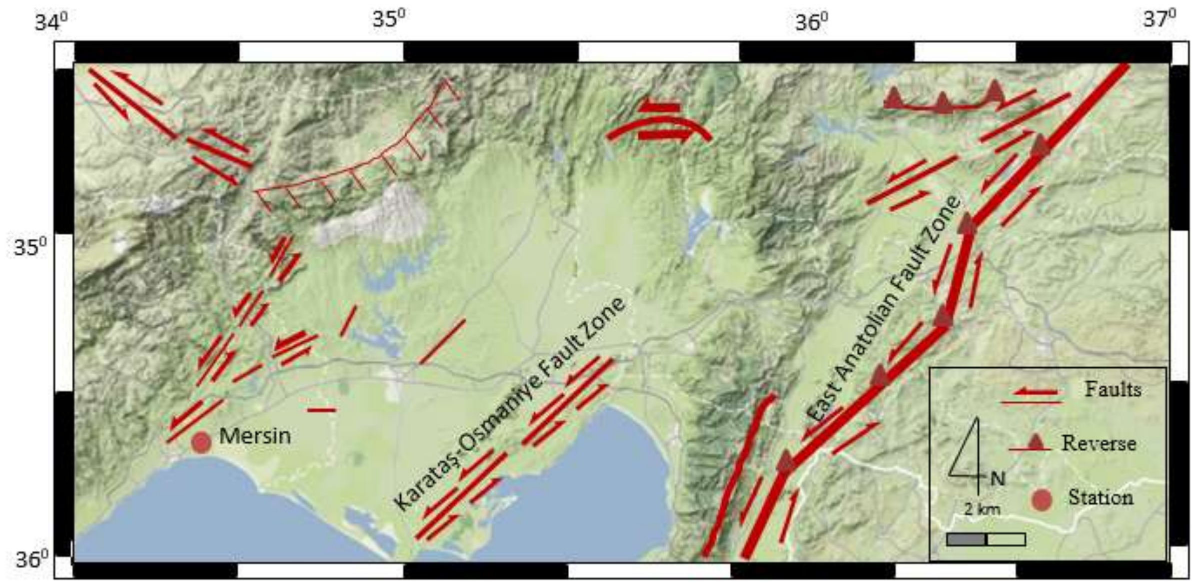

Figure 1. Location map of radon monitoring station and EAFZ.

2.2. Experimental Data Set

In this study, ^{222}Rn gas is recorded with an alpha detector, Alphameter 611 (Alpha Nuclear Inc. Canada) based on a 400 mm^2 silicon junction diode, immersed in a sensing volume open to the geo-gas. In the meantime, it has sensitivity for 1.5 MeV energy levels of continuous monitoring. The data gathered by these sensors are per 15-min unification time. After the disintegration of ^{222}Rn gas in the earth, alpha particles emerge and they are detected and the record is kept in the memory of the instrument. It has been stated by Tarakçı et al. [8] that the Alphameter 611 sensor check is very reliable in continuous soil gas environment with involvements of other ready sensors.

2.3. Theoretical Background: Fuzzy Inference System (FIS)

Fuzzy logic approach is discussed as a sub-branch of artificial intelligence studies. It has developed as a result of multi valued logic studies carried out against the two valuable logic proposals of Aristotle. Fuzzy logic was improved by Zadeh [9] and has been used for the modeling of the non-linear functions and the estimation of the chaotic time series.

The fuzzy if-then rules reflect human thought. The FIS, which reflects the human thought and the knowledge system with fuzzification. Fuzzy system, which after the learning phase works without any need to intelligent skills [10].

Fuzzy interference system route, there aren't model parameters. However most of the indefiniteness and design disturbance are contain in the figurative fuzzy inference procedure in the form of IF-THEN express. IF-THEN expression, are applied to characterize the state of a system and the truth-value of the proposition is a measure for how well the description matches the state of the system [11]. In the present study, fuzzy logic is utilizing for the estimation of earthquake magnitude with various parameter. For control purposes, fuzzy sets can be applied to set up rules of the as follows;

IF the value of variable ^{222}Rn is “large” and variable depth is “medium” and latitude “normal” and longitude is “low” THEN the result earthquake magnitude is “small” as expressed.

This expression like more closely human thinking than any obvious mathematical rules. Herein, fuzzy control rules can be applied for modeling the movement of a human expert. The learning involves two steps: The first produces the input values into the system and the appropriate outcome parameters are acceptable by the least squares method. In the second steps, these parameters take the place of previous parameters. After this step, the model can control the problem [12]. FIS is an off-line learning model and it is widely used in modeling and control of nonlinear systems by constructing a set of fuzzy IF-THEN rules with appropriate MFs [11]. Literature there is modelling complex dynamic system [12]. FIS model diagram in this research consists of five layers and its architecture is shown in Fig. 2.

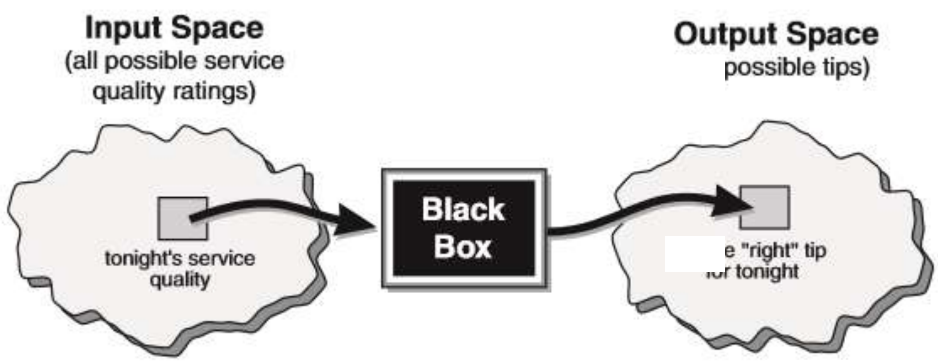

Figure 2. Fuzzy Logic model diagram (architecture) [13].

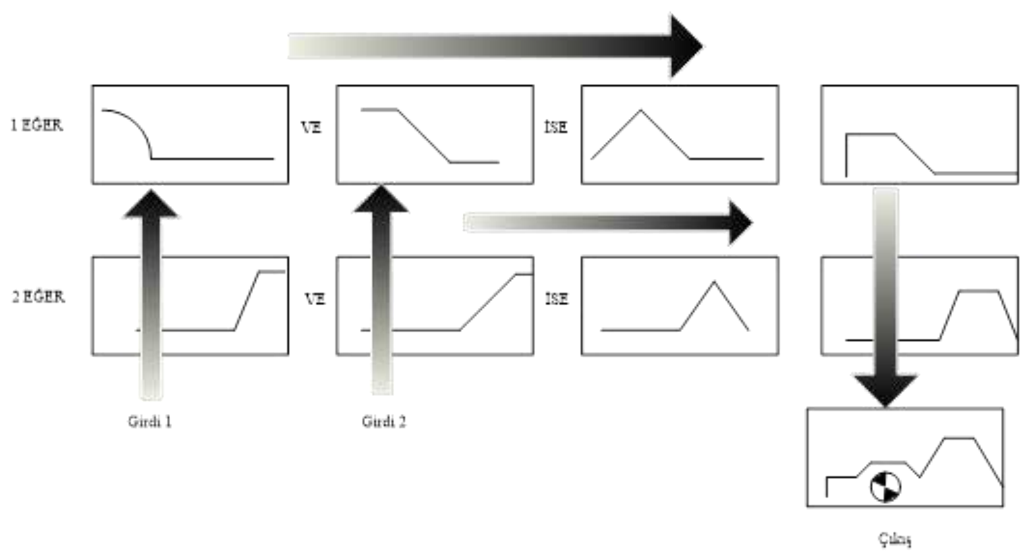

Figure 3. Fuzzy Logic IF-THEN rule base of model diagram [13].

In this research, latitude, longitude, depth, ^{222}Rn as input to the model and earthquake magnitude as output to the model are entered (Fig. 3). If-then rules, which have been used in the model architecture, can be written as follows:

If $x_1 A_1 x_2 B_2 x_3 C_3 x_4 D_4$

then $f_1 = px_1 + qx_2 + rx_3 + sx_4 + m$,

where p, q, r, s, and m are the linear output parameters. Architecture of the proposed model has five layers and sixteen if-then rules.

3. RESULT and DISCUSSION

The average values of environmental measurements in the same stations for 1 years are shown in Table 1. 20% of forty data are selected as test data, while the remaining values are selected as training data (Table 1).

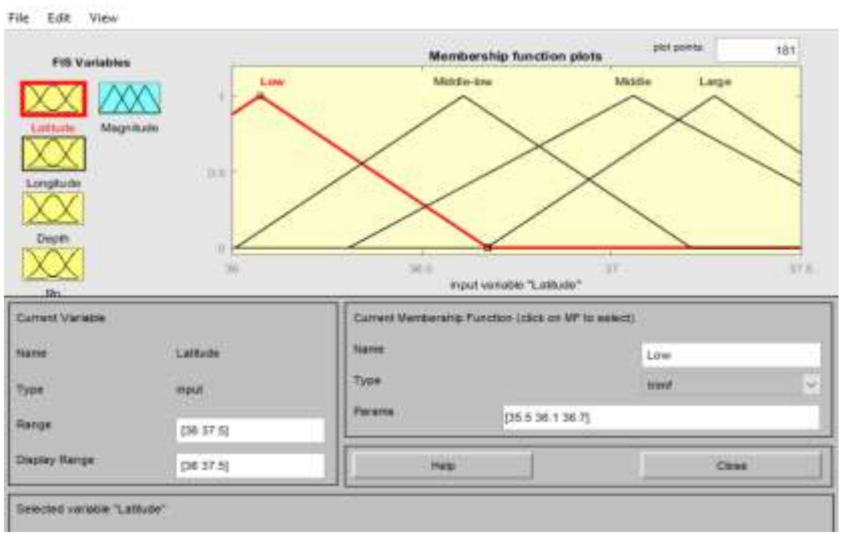

Figure. 4. Fuzzy logic for input data IF-THEN rule base of model diagram [13].

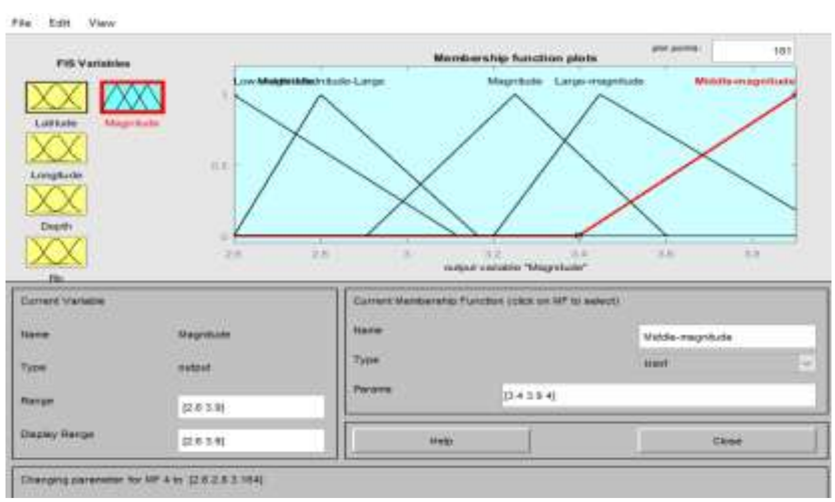

Figure 5. Fuzzy logic for output IF-THEN rule base of model diagram [13].

Fig. 4 and Fig. 5 is showed that Fuzzy Logic system input and output IF-THEN rule base of model diagram. The FIS Editor shows general information about a fuzzy inference system. There is a simple diagram at the top that shows the names of each input variable on the left, and those of each output variable on the right. The sample membership functions shown in the boxes are just icons and do not depict the actual shapes of the membership functions [13].

Table 1. Architecture and parameters of the proposed FIS [14].

No	^{222}Rn	Latitude	Longitude	Depth	Earthquake Magnitude (Mw)
1	163.6042	37,0468	34,5403	7	2.7
2	159.7813	36,5552	34,1278	6.93	3
3	160.4583	37,3798	34,9568	7	2.7
4	157.7917	36,8655	34,6188	7	2.6
5	150.5104	36,946	34,7103	3.77	2.9
6	146.3646	37,298	33,2423	7	2.8
7	142,3333	37,4655	35,157	6.99	2.7
8	140.8542	37,4608	35,1298	6.99	2.8
9	145.4375	37,54	35,0763	7	2.9
10	144.0938	36,3387	34,0338	7,04	3.3
11	149.2083	37,5828	35,0627	7	2.6
12	172.2188	37,5393	35,0947	7.32	2.6
13	171,2917	37,6343	35,0518	7	2.8
14	203.25	36,4883	34,5762	6.99	3.5
15	209.5729	36,9435	34,4737	7	2.8
16	200.4896	37,3972	33,7147	7	2.7
17	199.9167	37,4208	35,129	7	2.7
18	211.8854	37,5072	35,1533	7	2.8
19	214.9375	36,7998	34,7263	7.97	3.1
20	212.2292	36,8205	34,8705	7.13	2.6
21	208.0938	37,332	34,9688	7	2.7
22	199.8333	37,131	35,1532	7	3.1
23	193.8438	37,4543	34,4743	6.74	2.9
24	193.1979	37,522	35,0977	7.03	2.7
25	187.5625	37,5142	35,0817	6.95	2.9
26	237.9271	37,6383	34,3275	7.04	3.1
27	250.1667	37,389	33,9197	7.02	2.9
28	247.9063	37,1733	34,5887	26.69	2.8
29	245.8958	36,9685	34,4427	15.47	2.8
30	236.8438	36,8892	33,4708	7	2.8
31	234.3021	36,7957	33,2135	7.11	2.6
32	201.2917	36,9287	35,2623	6.98	2.8
33	175.9688	37,5142	35,0702	6.98	2.9
34	176.3958	37,654	34,442	7.02	2,9
35	186.3542	37,4525	34,8873	6,97	3
36	187.3438	37,6273	34,7548	7.06	2.6
37	178.7083	37,5253	35,113	7.01	2.8
38	170.1563	36,8655	33,3715	6.96	2.8
39	170.0104	37,5368	35,0798	6.9	3
40	182.5625	37,094	34,742	3.77	2.9

4. CONCLUSIONS

The earthquake magnitude of Mersin City ^{222}Rn measurements (for 2007 years) are investigated by using the FIS model. These complex dynamic system behaviors can be controlled with the proposed model by limiting the amounts of the environmental parameters. Removing and control of earthquake magnitude in rock and/or any micro crack system are quite difficult, expensive, and time-consuming. The proposed model is the easier and takes less time than the classical methods. It is showed that the FIS model is compatible with the experimental results. The FIS model, which has the learning ability and the parallel computation of FL method. Because of the proposed FIS model does not require complex mathematical operations.

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