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Fuzzy Logic Modeling for Prediction of the Nuclear Tracks

Ahmet SAHINER[1], Shehab IBRAHEM[1], and Ahmed IBRAHIM[2]

[1]Department of Mathematics,
Suleyman Demirel University, Isparta, Turkey
ahmetsahiner@sdu.edu.tr
mullaiq@gmail.com

[2]Department of Physics,
Kirkuk University, Kirkuk, Iraq
ahmedabd71@yahoo.com

Abstract — *In this paper, we have applied Fuzzy Logic Modeling (FLM) on nuclear track detector (CR-39) data. These data were obtained practically to find a number of effects tracks of alpha in nuclear track detector (CR-39) for different temperatures and different concentrations at different etchant times. We applied Fuzzy Logic Modeling on this physical data to make it continuous and that shows there is a match between original data and fuzzy and then we found optimal triple (temperature, concentration, etchant time) to get a clearer picture of the number of this tracks.*

Keywords: Keyword1, Keyword2, Keyword3.
Mathematics Subject Classification: 80C50, 30A40, 90C26.

1 Introduction

Solid state nuclear track detectors (SSNTDs) have been effectively connected in various territories of science including, nuclear physics, particle physics, cosmic rays physics, environmental physics, geophysics, archeology, and geochronology. (SSNTDs) are broadly utilized for enlisting nuclear tracks [1]. CR-39 is a standout amongst the most usually utilized as SSNTDs. CR-39 is straightforward in the noticeable range and consolidates an outstanding scope of characteristics which are not accessible in different SSNTDS [2]. A track is made in a SSNTD when an alpha particle hits the detector's surface as it appears in fig. 1. The development of the track is portrayed by the estimation of locator enlistment affectability $(V = Vt/Vb)$, where (Vt) is the track etchant, which is the removed layers of damaged surface of SSNTD (alpha-particle's hitting position) per unit time and (Vb) is the bulk etch rate. Vb is the rate of removing layers of the undamaged surface of SSNTD. Vb varies due to the SSNTD's chemical composition and manufacture process and to the chemical etching process. Vb can be calculated by using several methods, such as the decrease in the detector thickness method, the loss of the detector weight method, or the

Table 1: Number of tracks of nuclear track detector CR-39 (T: temperature, N: concentration, t(hr): etchant time)

$T = 65_c$					$T = 75_c$					$T = 85_c$				
No. of Tracks					No. of Tracks					No. of Tracks				
t(hr)	N=4	N=6	N=8	N=10	t(hr)	N=4	N=6	N=8	N=10	t(hr)	N=4	N=6	N=8	N=10
	1					0.5			40	0.25			34	50
1.5				100	1			50	60	0.5		50	65	70
2		116	128	132	1.5		30	55	85	1	50	76	80	100
2.5			140	164	2	40	50	60	100	1.5	76	88	102	88
3	128	132	152	174	2.5	50	60	85	90	2	90	98	76	65
3.5	136	140	160	152	3	68	70	98	64	2.5	96	80	70	58
4	140	150	176	136	3.5	75	80	75	55	3	85	72	56	40
5	155	170	150	120	4	86	96	70	50	3.5	75	65	48	28
6	160	150	140	100	4.5	90	75	60	45	4	68	60	30	
7	166	130	120	88	5	96	60	50	40	5	65	50		
8	140	100	90	70	5.5	88	55	40	30	6	60	45		
9	100	75	60		6	82	50	36	24	7	50	40		
10	90	70	50		6.5	75	42	30		9		30		
11	80	65	42		7	70	36			11				
12		50			9	64	28							
					10	56								
					11	34								

fission-fragment diameter method [3, 4]. It was hypothetically settled that adjustment in the mass of the detector $\triangle m$ and the thickness of the detector [5].

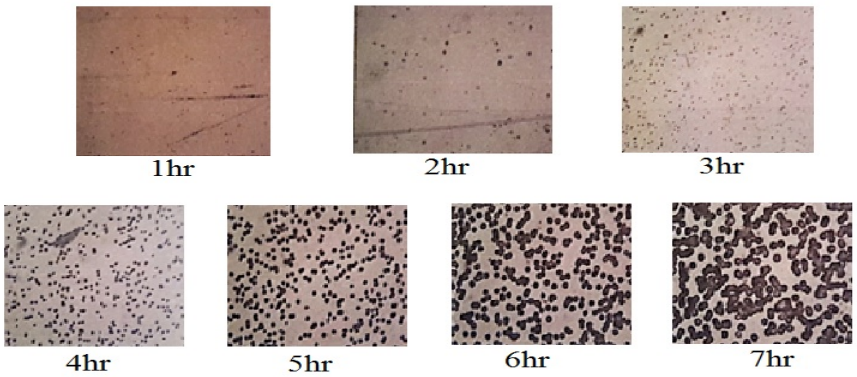

Figure 1: Tracks of Alpha particle on CR-39 detector at deferent (temperature, concentration, and etchant time)

In this study, we have used the fuzzy logic approach to model the nuclear tracks of the detector (CR-39) as to obtain optimal triple (temperature, concentration, etchant time) which make the picture of some tracks clearer. We can also make the data continuous to get the results for the untested data. The model has been set up according to the results obtained practically, and this data obtained from [6] to find the Etching optimized time by alpha particle (3 mev) incident on the CR-39 as shown in the table (1).

2 Fuzzy Logic and Fuzzy Inference System

Fuzzy logic is equipped for taking care of issues in an ambiguous proclamation to loose information and furthermore in decision-making system (DMS). L. A. Zadeh designed the idea of Fuzzy Logic in 1964. He displayed his first paper on fuzzy set in 1965 [7]. Later on, Assilian and E. Mamdani grew first fuzzy logic controller in 1974 in the United Kingdom. Due to its reliability, and capability researchers are using this concept for designing, creating, and actualizing algorithms and also the working models with the assistance of a fuzzy controller. Alongside with fuzzy logic, Genetic Algorithm (GA) is likewise used to outline and execute with fuzzy logic controllers to make models and application [8]. Fuzzy also helps to solve different real world due to its systematic rule which depended on the concept. Mendel says that fuzzy logic system is as a nonlinear mapping of an input data vector into a scalar output [9]. the theory of rough set discusses a different kind of formulation and interpretations. This is also the part of fuzzy [10]. Yao clarifies similitudes and contrasts between rough set speculations and fuzzy sets on two detailing of fuzzy set and two perspectives of rough sets in 1998 [11]. Distinctive sort of uses based on fuzzy logic/fuzzy set clarified by Davidson and Harward in 2003 [12]. Fuzzy rules assume essential part in fuzzy inference system (FIS) and a similar approach from the most recent perspective are checked to give the assistance to learn such run based on model for any difficult assignment is talked about by Wang and Brigde in 2000 [13]. Fuzzy Inference System (FIS) with Neural learning is again a broad concept which is also used for decision making. It shows the reliability of FIS and gives the transformation from more than one independent variable to only one output using fuzzy logic toolbox in MATLAB. In FIS numbers of rules there are based on ”if-then” conditions. These rules are very smooth to learn, smooth to use easily being converted according to the scenario, and help to find out the conclusion easily. A. Abraham has explained FIS with neural network techniques in distinct ways in 2008 [14]. Along with Fuzzy, Neural and Neuro-Fuzzy Inference System (NFIS) are there to empower the importance of FIS. This parallel study was discussed by M. Z. Shafiq et al. in 2008 for Portscan Detection [15]. How can multi-decision making system be formulated via fuzzy?. The concept was fabricated in 2004 by Zhiyi's formula based on Mamdani type FIS to assess compost maturity and stability [16]. A fuzzy logic based application to predict risk in loan providing organizations was developed and tested on different financial organizations by Kapoor and N. Bhatia in 2011 [17]. How can the software risks be calculated by using fuzzy logic?. The answer to this question was given again by Kapoor and N. Bhatia in 2011 [18]. Gursharan Singh and N. Bhatia developed a fuzzy logic based cricket player performance evaluator in 2011, and they used input and output membership functions in the research [19]. Smithson describes the theory of FL along with Fuzzy Set in Psychology, and his theory was not only in one particular sector but in several fields as perception and memory theories to solve measurement problems [20]. There is another researcher J. Russell has contributed the logic for facial emotion recognizer based on fuzzy logic [21]. Now the major role to provide the importance of FL in social sector was given by Dimitrov in 1997. He gave the practicality of fuzzy logic to deal with paradoxical and chaotic nature of social system [22]. This kind of system provides the help to deal with opposite opinions. Yamashita in 1998 provides the concept of fuzzy system in the context of the decision aid. After the fuzzy reasoning applied on

the input values supplied by the students, the system began to act as a kind of vocational guidance [23]. Luis Teran introduced a new concept in social science which was totally web based Voting Assistance Application (VAA) used to help voters in finding the party or candidate that is most in line with their choice in 2011. This is treated as the latest concept in the field of social science [24]. Mamdani algorithm [25] is utilized to decide the yield, but (FIS) system executes in three noteworthy strides:

- Fuzzifier: It converts the crisp input into a fuzzy set. Membership Functions are used to describe a situation graphically.
- Fuzzy Inference Engine: A collection of if -then rules stored in the fuzzy rule base is known as an inference engine.
- Defuzzification: It is the process that refers to the translation of fuzzy output into the Crisp output.

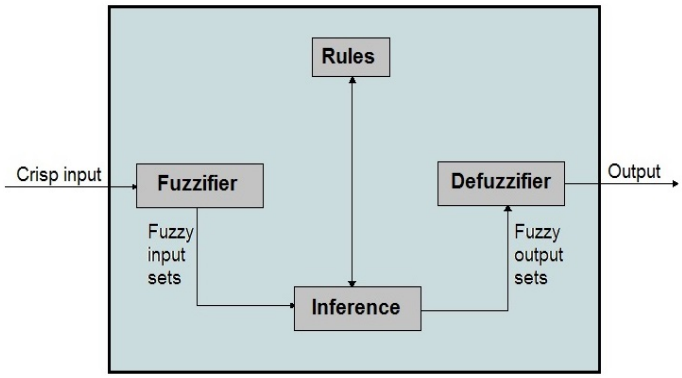

Figure 2: Block Diagram of Fuzzy Logic system with fuzzifier and defuzzifier

3 Methodology and Results

In this study, to set up a model, the fuzzy logic model was built by using three inputs and one output. Inputs parameters were (temperature, concentration, and etchant time) and the output was the number of tracks. The membership functions; the first input variable is the temperature, the second input variable is the concentration, and the third input variable is the etchant time, while the number of tracks is the output variable which is shown in Fig. $3, 4, 5$ and 6, respectively. The first input (temperature) is increased by a step of $(10c)$ starting with $(65c)$ and ending with $(85c)$ while the second input (concentration) is increased by step of $(2M)$ starting with $(4M)$ and ending with $(10M)$ and the third input (etchant time) is increased by step of $(60m)$ starting with $(0m)$ and ending with $(650m)$, so we have three fuzzy numbers for the first input, four for the second input and thirteen for the third one. The first input values (Te_1, Te_2, Te_3), the second input values (N_1, N_2, N_3, N_4), and the third input values $(T_1, T_2, ..., T_{13})$ are considered as input data and the number of tracks values $(S_1, S_2, ..., S_{16})$ is considered as output data in our model.

The rule structure is designed basing on how the experts interpret the characteristics of the variables of the system. It is possible to write down "if-then" fuzzy rules and some of the rules used in the model are as the following:

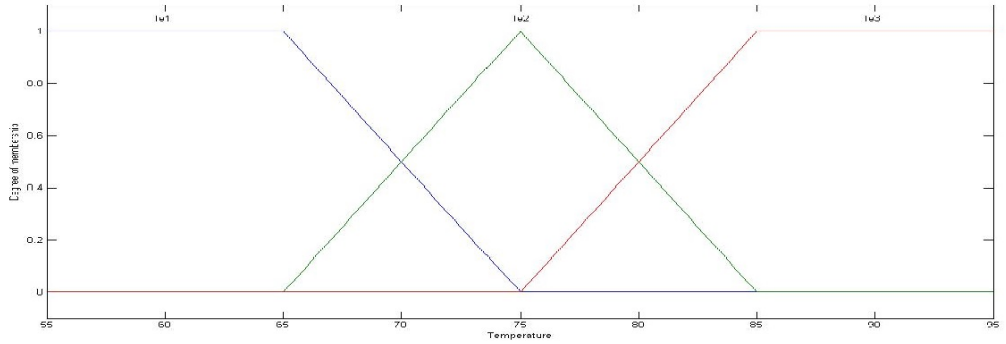

Figure 3: Membership Functions for input Variable Temperature

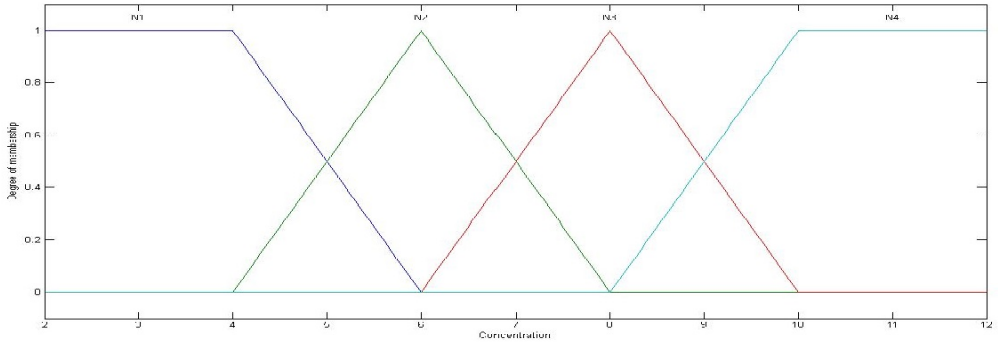

Figure 4: Membership Functions for input Variable concentration

- If (Temperature is Te_1) and (Concentration is N_1) and (Time-Of-Etchant is T_5) then (No.-Of-Track is S_{11}) (1)
- If (Temperature is Te_1) and (Concentration is N_1) and (Time-Of-Etchant is T_5) then (No.-Of-Track is S_{12}) (1)
- If (Temperature is Te_1) and (Concentration is N_1) and (Time-Of-Etchant is T_6) then (No.-Of-Track is S_{12}) (1)
- If (Temperature is Te_1) and (Concentration is N_1) and (Time-Of-Etchant is T_6) then (No.-Of-Track is S_{13}) (1) ... etc.

The relationship between input and output data was modeled by fuzzy logic. The fuzzy logic approach sets the continuous function between inputs (temperature, concentration, etchant time) and outputs the number of tracks. The correlation coefficient R2 which is obtained by regression analysis shows that the experimental results and fuzzy logic results are close to the rate of 99.38% as shown in Fig. 8.

4 Discussion

The maximum number of alpha particles on the nuclear detector CR-39 was determined by using the fuzzy logic control. Different variables (temperature, concentration, and etchant time) was played a role in the number of the tracks and then all results were

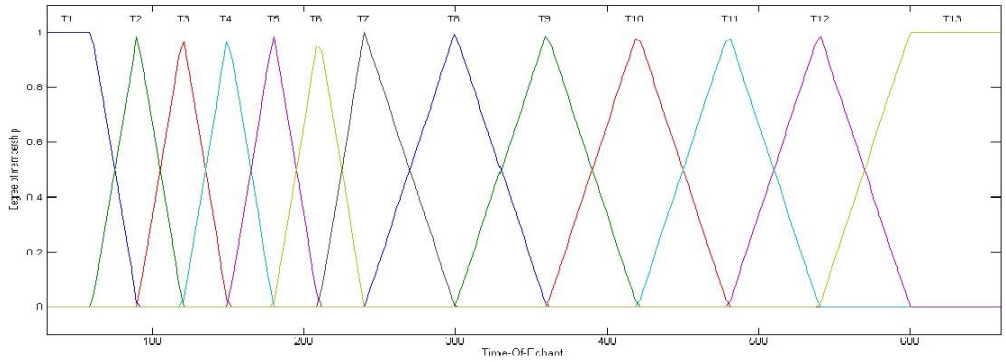

Figure 5: Membership Functions for input Variable Etchant time

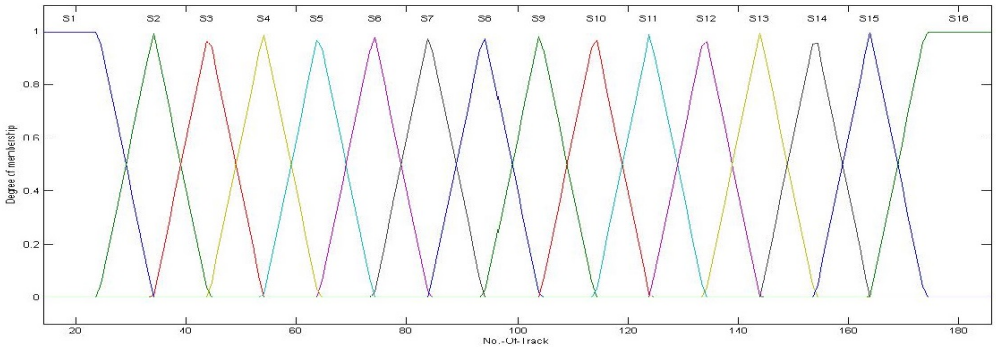

Figure 6: Membership Functions for output Variable number of tracks

compared with the original data. As well as we have aimed to make the data continuous we have also got the results for the untested data. For comparison with the original data. Moreover, fuzzy logic was applied to extend the data collection with $R2$ which gives a regression analysis and it shows that original data and fuzzy logic results are close to the rate 99.38%. Furthermore, some maximum number of tracks can be obtained at input variables (temperature, concentration, etchant time) such that the original data may not catch these points. Also, the global maximum number of tracks is attained at the point $(65, 8, 240)$ which is the same point with the same value of (178) tracks calculated by the original data. On the other hand, the points that made the global maximum number of tracks obtained from the fuzzy logic may be the same as original data or not but must be very close to it.

5 Conclusion

In the end, we see that fuzzy logic is suitable for the many physical, engineering, medical, chemical and mathematical problems. In the next studies, we Could expand our study to include more than three inputs such as (alpha energy, temperature, concentration,...) and also to use more than one output, such as (number of tracks, the diameter of the track, the angle of the track,...).

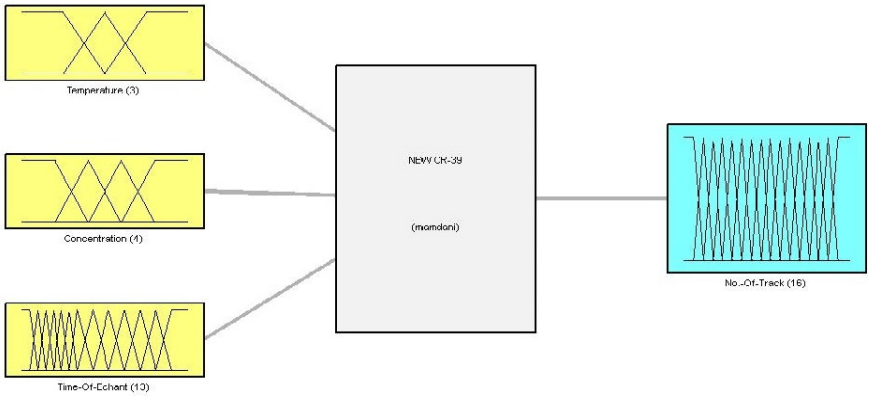

Figure 7: Number of tracks Prediction Model

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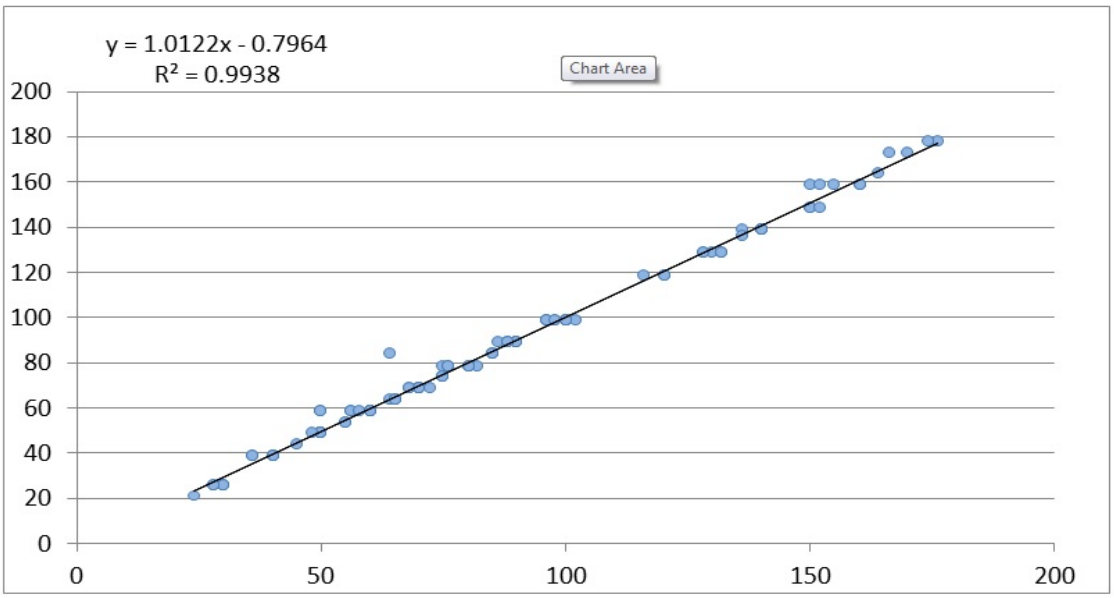

Figure 8: Comparison of the original data values and Mamdani type FLM prediction

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