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Synaptic Neural Artificial Network (RNAS): A Mathematical Model of Learning, Knowledge, Search and Predictability with Application of Artificial Intelligence

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Summary: *A machine considered intelligent, must have a system with application of artificial intelligence (AI) that is capable of performing tasks similar to human behavior. It is known that there are several approaches to intelligent systems in the area of artificial intelligence, such as cognitive, connectionist, genetic, evolutionary, fuzzy logic, neural networks, all with the objective of dealing with intelligence and acquired knowledge and the search by its representation. Expert systems have also been developed in an attempt to solve problems considered difficult to obtain by digital machines.*

It is considered that intelligent machines should be able to have greater flexibility in rule-making, knowledge base, transparency, unforeseen decision-making, and ease of learning. The behavior of these machines must satisfy the needs of the human biological system and its search based on stored knowledge in the form of information.

Expert systems are often referred to as systems that build on the knowledge gained and tracked by the experts in each specific area, which must be acquired over time. Already an intelligent system must provide solutions or responses to the unpredictability of the information required in its output and are often compared with biological systems.

Often human decisions are unforeseen and uncertain, however, in the same way, machines considered intelligent must be able to deal with such situations and for this the fundamentals of fuzzy logic apply to make the human analogy in the solution of new solutions and experiences . For today's digital machines are not capable of dealing with analogical and behavioral situations.

Fuzzy logic has the ability to assist in decision-making based on information acquired, be adaptable with the experiences and learning of its environment, and allows it to be adjusted to suit your needs. Its application can be extended in the area of artificial intelligence, neural networks and statistics.

In this work the objective is to propose a new technique of applying fuzzy logic, artificial intelligence, artificial neural networks, statistics and biological networks to propose a mathematical model that registers the form of synaptic learning with the application of vectors in space, three - dimensional geometry, storage and spatial retrieval, as well as real-time view of n-plane cells, statistical fundamentals, correlation, and regression.

Key words: *Intelligent Machines, Artificial Intelligence, Fuzzy Logic, Neural Networks, Biological System, Synaptic Learning.*

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I. Introduction

Many software applications are capable of storing and retrieving large amounts of data, in addition to presenting their searches in individual, tabular, or graphical form. However the final decisions are made by man. Often the answers can be immediate, however there are situations that must be analyzed because they are not visible or need a lot of time to be decided. It is known that a learning can be accumulated through other experiences that have been acquired over time, for that they must be stored and possible to be recovered and identified. This involves knowledge, evaluation, generalization and adjustments.

There are situations, where the solution to the real problems are contained in the interpretation of the information and their relations between them. These connections are often not visible or formulated by current digital machines. Reasoning is behavioral and analog; in addition, many human decision making is nebulous and indecisive. For this, the techniques of fuzzy logic are used for the production of knowledge, learning in dynamic environments and methods of learning of specialists.

Artificial Intelligence techniques for finding solutions, artificial neural networks for learning through synaptic connections, and the use of statistical, correlation and linear regression resources to simulate biological synaptic connections are also applied in this work. In addition, they are also applied the fundamentals of vectors and geometry in space to simulate spatial logic for the reasoning of the biological neuron. The method for this work is based on mathematical, statistical and probabilistic modeling.

The application of the presented mathematical model is based on the development and construction of results that demonstrate its viability for implementation and that can be analyzed, validated, practiced in situations of reality and solution in its specified environment.

The present work aims to present a proposal of a mathematical model for the application of fuzzy logic techniques, Artificial Intelligence, Artificial Neural Network, Statistics and Probability for intelligent machine application model.

II. Intelligent Systems, Fuzzy Logic And Expert Systems

Intelligent systems have attributes of coupling between the agent and its environment, because its quality is defined according to its behavior with its interaction and interaction environment, to fit the required states and actions. In mathematical modeling the behavior of an intelligent system is defined through the agent function in which the sequences of perceptions are mapped to the execution of a specific action. It also requires the concept of rationality, measure of performance, learning, autonomy, knowledge of its environment and definition of the types of agents for the definition and application of AI techniques to solve their problems.

The application of fuzzy logic techniques allows the implementation in intelligent systems to be more efficient, since they allow the insertion of knowledge and human experiences. The principle of fuzzy logic is based on the concept of multivalence, logic of uncertainty and the application of intuitive logic, in addition, real numbers can be translated into percentages (%) for the representation of intelligence (through a fuzzy inference) in a machine intelligent.

A fuzzy operation allows quantitative values to be classified into qualitative values (such as: high, medium, low), which define the information required for the activities of the human brain and vice versa (qualitative and quantitative) for intelligent machines.

Fuzzy logic uses linguistic variables (symbolic elements) to represent their knowledge (can be: high, medium or low) and measure a measure. They are also associated with degree of pertinence or functions of pertinence. In addition, the representation of its behavior by the variables is established by the rules of its linguistic variables of the type (If ... then), as shown in table-01, a model with the linguistic variables of fuzzy logic with the application of the rules of Likert scale.

Adequação funcional	"X" OU "( )"	Pontuação	Pertinência (μ)
Discordo totalmente	( )	10	[0,1]
Discordo	( )	20	[0,1]
Indiferente	( )	30	[0,1]
Concordo	( )	40	[0,1]
Concordo Totalmente	( )	50	[0,1]

Table-01 Rules and linguistic variables.

Fuzzy relevance functions

The main functions of fuzzy pertinence are z, type π, type λ and type S. These are the functions in which they define the degree of pertinence (μ) for a given linguistic term, which can vary between 1 (100% of relevance) to 0 (0% relevance), however it is known that there are other types of membership functions. Figure-01 shows the graphical model for the description of the "triangular" type of membership function, in which it was used to exemplify the analysis of a patient's blood glucose level. Figure-02 shows the application of the linguistic variables (P = Perfect, VS = Very Strong, S = Strong, M = Midle, VL = Very Low, Null).

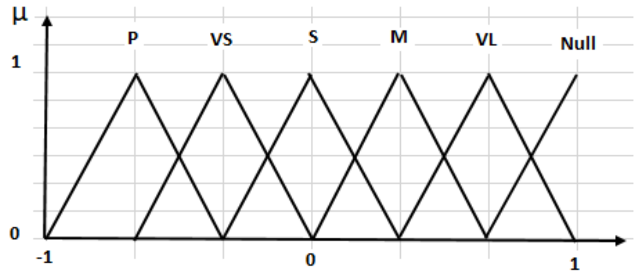

Figure-01 Fuzzy graph and linguistic variables.

III. Neural Network, Artificial Intelligence And Fuzzy Logic

The area of Artificial Intelligence seeks to understand how humans think, understand, predict to act with their environment, and also seeks to build intelligent machines that can replace human beings in the execution of difficult tasks, where digital machines are not capable of due to its limitations.

A biological neuron system has, among other important functions, many inputs and outputs known as synaptic connections that are connected to its axons. These synapses are regions where neurotransmitter substances are found, where changes in their electrical potentials occur.

An Artificial Neural Network is composed of a network of multiple neurons or perceptrons, consisting of input layers, intermediate layers and output layers. Like biological neurons, an Artificial Neural Network must also be able to acquire learning.

IV. Synaptic Neural Network (Synaptic RNA)

A Synaptic RNA can be described as a composition of vector plane sets divided into layers. Each layer has sets of cells for each plane with their respective defined positions. Each cell consists of the geometric axes of type (x, y), in which it defines the point and value of each cell in the relation x and y. These functions are transformed for each cell and each plane into vectors in space, where they obey the rules of vector fundamentals.

The resulting vectors define the learning of each cell and each plane with its sets of cells. In a vision in space each plane has its layer levels that are composed of a set of planes and cells. In this structure are formed the synaptic vectors of each cell and also the synaptic vector of the whole set of plans for the registration and learning of the entire synaptic neuron network. Mathematical formulas are described as: $| Cr | 2 = Vn 2 + Un 2$ (for each cell) for the cell vector. $| Dn | 2 = Xn 2 + Yn 2 + Zn 2$ for the set of planes.

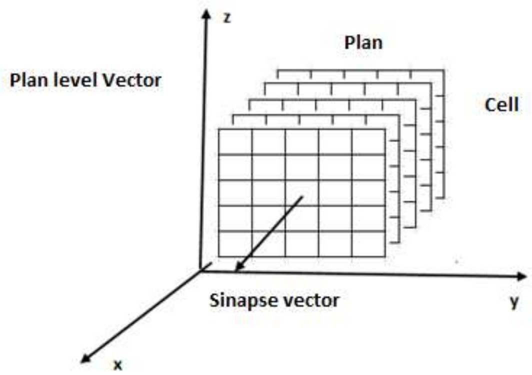

Figure-02 Structure of the synaptic neuron network.

The figure below shows the architecture of the Synaptic Neural Network, in which it is composed of the tables of data collected, the function that defines the equation that can be linear, logarithmic, exponential or other types of functions developed by specialists of each area, fuzzy logic and its linguistic variables the vector spaces and their transformations with their vector structures, the indicators that define synaptic adjustments, space vector with their synaptic adjustments and the space vector table with their stored information.

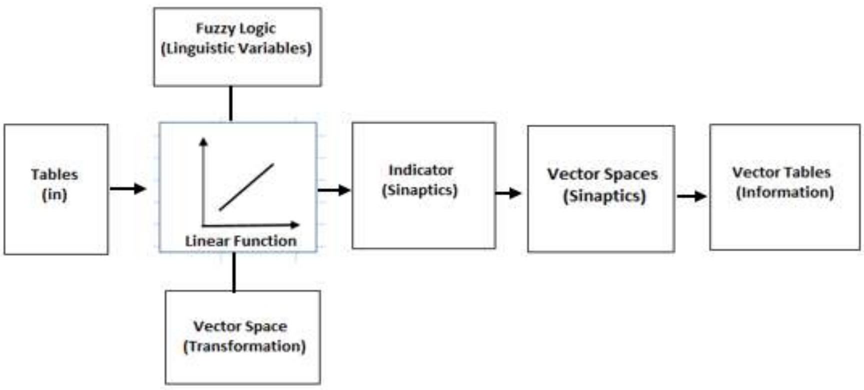

Figure-03 Architecture of the Synaptic Artificial Neural Network.

V. Application And Analysis Of The Mathematical Model Of The Synaptic Artificial Neural Network (Synaptic RNA) For Glycemic Control.

The Figure-08 shows the results of the two-month insulin regimen, in addition to the annotations of diabetes levels, period, measurement and insulin consumption. The linguistic variables of the fuzzy logic were defined, using the information of the degree of correlation (Null, Weak, Average, Strong, Very Strong and Perfect). The structure of the form is represented in the figure below.

Diabetes Control							
n	**Measure**	**Month**	**Data**	**Hour**	**Diabetes**	**State**	**Insulin (Unit)**
1	1	11	4	22:20	342	After dinner	10
1	2	11	5	07:00	151	Before coffee	10
1	3	11	5	20:20	287	After dinner	10
1	4	11	6	07:45	122	After dinner	10
1	5	11	7	07:45	160	Before coffee	10
1	6	11	8	08:00	188	Before coffee	10
1	7	11	9	07:35	191	Before coffee	10
1	8	11	10	06:30	228	Before coffee	10
1	9	11	11	06:00	225	Before coffee	10
1	10	11	12	08:00	157	Before coffee	10
1	11	11	12	21:10	169	After dinner	10
1	12	11	13	07:45	138	Before coffee	10
1	13	11	14	08:00	142	Before coffee	10
1	14	11	16	07:30	163	Before coffee	10
1	15	11	17	08:00	179	Before coffee	10
1	16	11	18	07:00	151	Before coffee	10
1	17	11	19	08:00	161	Before coffee	10
1	18	11	20	07:00	188	Before coffee	10
1	19	11	21	09:15	127	Before coffee	10
1	20	11	22	06:00	162	Before coffee	10
1	21	11	23	06:30	132	Before coffee	10
1	22	11	24	08:30	147	Before coffee	10
1	23	11	25	07:00	151	Before coffee	10
1	24	11	27	07:00	167	Before coffee	10
1	25	11	28	07:00	142	Before coffee	10

Figure-04 Structure of the form for recording data collection for November.

The figure shows the results in graph form with the application of central tendency (arithmetic mean) and the linear equation for calculation of projection of diabetes control for the month of November. The definition of the calculated linear correlation equation was f (x) = - 6 (x) + 250 where - 6 is its angular coefficient and 250 is the linear coefficient value.

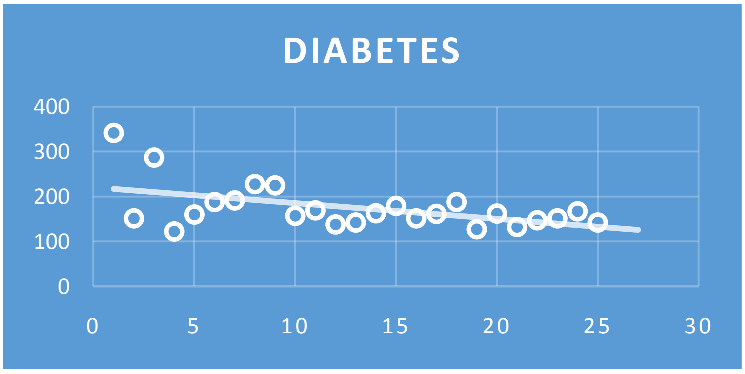

Figure-05 Result of November diabetes data collection (Graph: Linear Learning Curve).

The figure below shows the results of the calculations for the synaptic correlation "SR" of 6 days of sampling of the month of November, besides the table in which are the values and the linguistic variables of the fuzzy logic.

Measure (X)	**Diabetes (Y)**	**X*X**	**Y*Y**	**X*Y**	**n**	**SR**
15,00	1062,00	225,00	1127844,00	15930,00	5,00	1

Figure-06 esults of the synaptic correlation.

|SR|	Sinaptic Conection
[0,0]	Perfect
[0,0 ; 0,35]	Very Strong
[0,35 ; 0,65]	Strong
[0,65 ; 0,95]	Midle
[0,95;0,99]	Very Loose
[1]	Null

Figure-07 Synaptic Correlation Table.

In the figure shows the values of the indication for the synaptic connection intensities "SR" in relation to the central tendency line in which it represents the learning relation with the cell nucleus of the network of a plane in the three-dimensional space. Next, the synaptic connection intensity indicator is shown in relation to the central tendency. The value of SR2, however, describes the degree of dependence of the "y" function on the "x" values. For "x" close to 1 the dependence is strong, while for SR2 close to zero the dependence is weak.

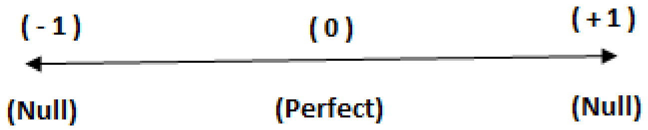

Figure-08 Indicator of synaptic connection intensity.

The figure below shows the behavioral data graph for analysis and definition of the angles and the equation for the construction of the two-dimensional and three-dimensional vector structures. In this way, we develop the structure of the Synaptic RNA and the spatial vector equations and synaptic adjustments of this network.

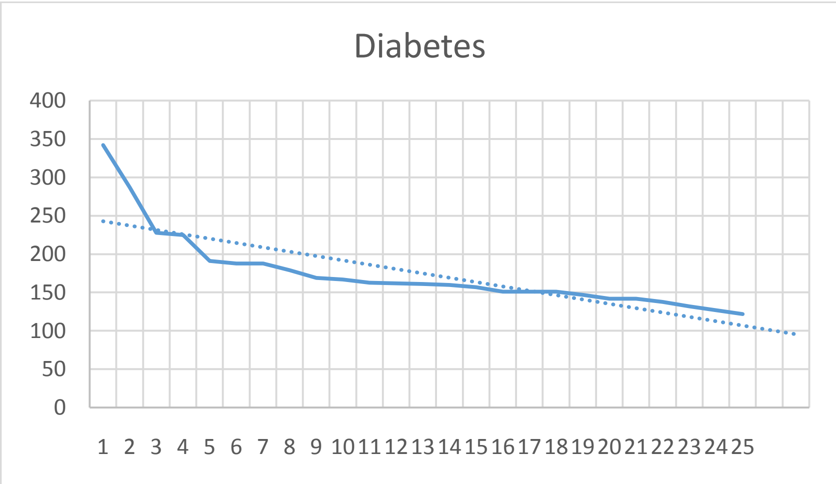

Figure-09 Definition graph of the formula of the general equation of central tendency.

The equation of the tendency to calculate the mean of predictability during the treatment of diabetes was f (x) = - 6 (x) + 250. The angle of the slope (α) of the equation (or coefficient) was - 6, linear coefficient was 250. The equations can be linear, logarithmic, exponential or any other type of function, since it must be developed by specialists in the field.

f(x)= - 6(x)+250	
y	x
250,00	0
244,00	1
238,00	2
232,00	3
226,00	4
220,00	5
214,00	6
208,00	7
202,00	8
196,00	9
190,00	10

Simulation	
Diabetes	Measure
342	1
287	2
228	3
225	4
191	5
228	Average

Diabetes	Measure
342	1
287	2
228	3
225	4
191	5
188	6
188	7
179	8
208	Average

Figure-10 Result of simulation of the predictability function of the calculation of means for the treatment of diabetes.

The results obtained with approximation, as shown in the figure above, represent the calculations made for a predictability of the mean of diabetes for the amount of insulin injected according to the quantities of days, thus, it is possible to predict and analyze the results obtained with the medication.

The figure below shows part of the data collected in the month of November, in the figure the execution of the synapse vector and adjustment for the first ten records with their values adjusted according to the synapses of each cell.

Diabetes Control							
n	Measure	Month	Data	Hour	Diabetes	State	Insulin (Unit)
1	1	11	4	22:20	342	After dinner	10
1	2	11	5	07:00	151	Before coffee	10
1	3	11	5	20:20	287	After dinner	10
1	4	11	6	07:45	122	After dinner	10
1	5	11	7	07:45	160	Before coffee	10
1	6	11	8	08:00	188	Before coffee	10
1	7	11	9	07:35	191	Before coffee	10
1	8	11	10	06:30	228	Before coffee	10
1	9	11	11	06:00	225	Before coffee	10
1	10	11	12	08:00	157	Before coffee	10
1	11	11	12	21:10	169	After dinner	10
1	12	11	13	07:45	138	Before coffee	10

Figure-11 Result of the synaptic vector calculations.

The figure below shows the representation of vectors in the two-dimensional plane and the results presented for each vector of the vector space plane. The synaptic values are represented by the vector | C |.

|Cn| =x2+y2	x2	y2	x	y	x2+y2
342,00	1	116964,00	1	342	116965,00
151,01	4	22801,00	2	151	22805,00
287,02	9	82369,00	3	287	82378,00
122,07	16	14884,00	4	122	14900,00
160,08	25	25600,00	5	160	25625,00
188,10	36	35344,00	6	188	35380,00
191,13	49	36481,00	7	191	36530,00
228,14	64	51984,00	8	228	52048,00
225,18	81	50625,00	9	225	50706,00
157,32	100	24649,00	10	157	24749,00

Figure-12 Values of the adjusted synaptic vectors.

The figure shows the results in different planes of space for equal values. The synaptic values are represented in the vector | P |. Each plane represents their planes and synaptic cells.

|P|=(x, y, z)	x	y	z	x+y+z	Planos no espaço
342,00	1	342	1	116966	1
151,02	2	151	1	22806	1
287,02	3	287	1	82379	1
122,07	4	122	1	14901	1
160,08	5	160	1	25626	1
342,01	1	342	2	116969	2
151,03	2	151	2	22809	2
287,02	3	287	2	82382	2
122,08	4	122	2	14904	2
160,09	5	160	2	25629	2

Figure-13 Result of allocation of the synaptic vector space three dimensions and planes in space.

The figure shows the structure of the synaptic vectors and their results of the adjustments made for the storage and retrieval of their data in the form of vectors, in a vision for analysis in the two-dimensional space.

|C| = (xi + yj)	xi	yi
250,00	0	250
244,00	1	244
238,01	2	238
232,02	3	232
226,04	4	226
220,06	5	220
214,08	6	214
208,12	7	208
202,16	8	202
196,21	9	196
190,26	10	190,00

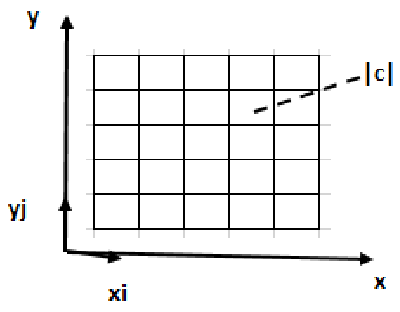

Figure-14 Structure and data in table and graph of the synaptic two-dimensional space vector.

The figure below shows the result of the storage performed by the Synaptic Neural Network (Synaptic RNA). In this structure the structures for storage and retrieval of the space vector (three-dimensional), the values of the vector axes (xi, yj, zk) (adjusted values to achieve the ideal values of 110 units), adjusted values (results after synaptic adjustments), ideal values (the ideal values for adjustments to reach the ideal values of 110 units), duration of treatment (in percentages), mean values (mean values achieved), total days of treatment, days of treatment, number of days for treatment to reach desired levels of 110 unit.

|C| = (xi + y j+ zk)	xi	yi	zk	level	Diabetes	Adjust Sinaptic factor (unit)	Value Adjust Sinaptic	Value Ideal (110 unit)	Date treatement
250,00	0	250	0	1	342	0,00	0,00	0,00	0,00%
244,00	1	244	1	1	287	43,00	244,00	134,00	1,00%
238,01	2	238	2	1	228	-10,01	238,01	128,01	2,00%
232,02	3	232	3	1	225	-7,02	232,02	122,02	3,00%
226,04	4	226	4	1	191	-35,04	226,04	116,04	4,00%
220,06	5	220	5	1	188	-32,06	220,06	110,06	5,00%
214,08	6	214	6	1	188	-26,08	214,08	104,08	6,00%
208,12	7	208	7	1	179	-29,12	208,12	98,12	7,00%
202,16	8	202	8	1	169	-33,16	202,16	92,16	8,00%
196,21	9	196	9	1	167	-29,21	196,21	86,21	9,00%
190,26	10	190,00	10	1	163	-27,26	190,26	80,26	10,00%
184,33	11	184,00	11	1	162	-22,33	184,33	74,33	11,00%
178,40	12	178,00	12	1	161	-17,40	178,40	68,40	12,00%
172,49	13	172,00	13	1	160	-12,49	172,49	62,49	13,00%
166,59	14	166,00	14	1	157	-9,59	166,59	56,59	14,00%
160,70	15	160,00	15	1	151	-9,70	160,70	50,70	15,00%
154,83	16	154,00	16	1	151	-3,83	154,83	44,83	16,00%
148,97	17	148,00	17	1	151	2,03	148,97	38,97	17,00%
143,14	18	142,00	18	1	147	3,86	143,14	33,14	18,00%
137,32	19	136,00	19	1	142	4,68	137,32	27,32	19,00%
131,53	20	130,00	20	1	142	10,47	131,53	21,53	20,00%
125,77	21	124,00	21	1	138	12,23	125,77	15,77	21,00%
120,03	22	118,00	22	1	132	11,97	120,03	10,03	22,00%
114,34	23	112,00	23	1	127	12,66	114,34	4,34	23,00%
108,68	24	106,00	24	1	122	13,32	108,68	-1,32	24,00%
103,08	25	100,00	25	1	139	35,92	103,08	-6,92	25,00%
							169,54	119,08	
							50,46	17 dias	17,70%

Figure-15 Storage of the Artificial Synaptic Network for the control of diabetes.

The figure below shows the relationship in a vector space view of the relationships obtained from the diabetes information, the values after the synaptic adjustments, and the desired "desired" desired results of diabetes levels and their synaptic control.

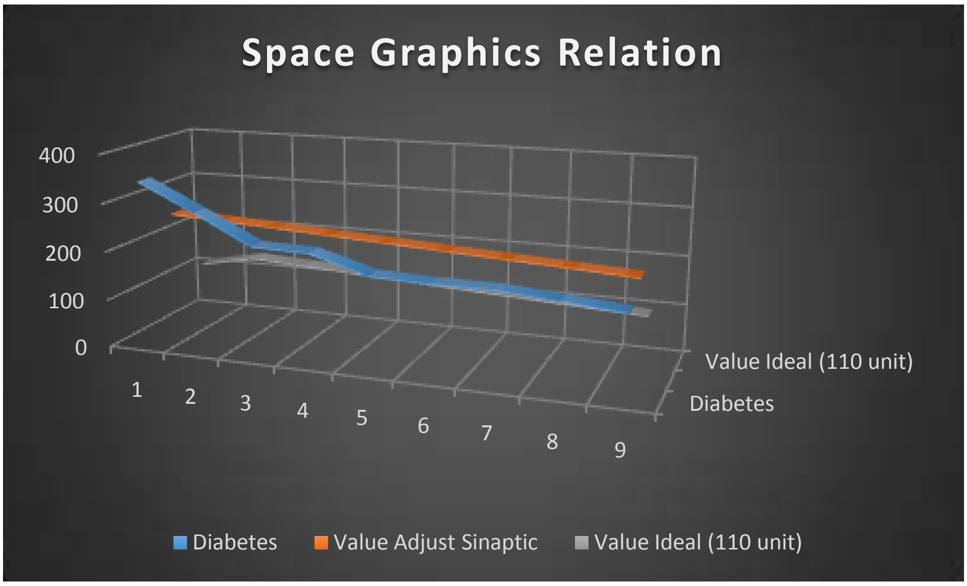

Figure-16 Relationship of information obtained between diabetes, adjustments and levels of ideas values.

In this study they were simulated using data collected by the author during his treatment of diabetes during the month of November. The assigned values were applied in this proposal of the development of a model of neural networks with synaptic adjustments to assist in the treatment and medication of insulins, besides offering a projection of the results of days of treatment in dates to analyze the amount of days to reach the goal, and values in percentages of diabetes treatment. The Synaptic Artificial Neural network, made its adjustments of its vectors from the space to the behavioral and analog levels for the storage and retrieval of its information.

The result of the application in the construction of the synaptic artificial neural network is compared with data from the data table with the information stored by the Synaptic Neural Network and present the desired synaptic values and adjustments. It shows the input of the data collected, its transformation of this data into information after the synaptic adjustments, in addition, the results of the capture of the information stored through this network are presented, for presentation and comparison with the data collected from its input. During the development and application phase of the network, the mechanisms, the structure of the vectors in the two-dimensional and three-dimensional space, and the presentation and description of the fuzzy logic variables for the information storage are presented. In the same way, the adjusted values for the correlation line of the intensity indicators of their synaptic relationships for the cells and planes of the Synaptic Artificial Network were compared.

VI. Conclusion

The main definitions for this work are based in the foundations of Artificial Intelligence (to search), Biological and Artificial Neural Networks (to synapse adjustments), Vectors in space (to spatial allocation), Fuzzy Logic (to creation of linguistic variables), equations of functions of geometric spaces (to contruct de graphics), besides the indicators of relation and synaptic correlation (to indicate the level of synaptic intensity).

As presented through the application of the functions, graphic results and tables during the development of this work it was observed that the proposal of the mathematical model with the resources of the Synaptic Artificial Neural Network is feasible and also possible to be extended to several other areas as well as services and products. The objective can help in qualitative and quantitative decision making. For future work it is intended to extend these applications in areas that act on statistics, probability and hypothesis tests.

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