Design and Implementation of a Patterns Recognition System for Analysis of Biological Liquids

Jose Aguilar[1], Luís Hernández[2], Anny Olivar[1]

Abstract—**Given the great amount of data that are generated of the experiments that are made to analyze information of the extracted chemical fluids from the brain of a rodent, arises the necessity to design and to implement data mining systems to process this data. In this work is proposed a Fuzzy System for the Analysis of Biological Liquids (FSABL) that allows to analyze and to process the data, and this way, to know a series of disorders products of alterations, storage, and liberation of the Neurotransmitters. The FSABL is constructed under the paradigm of the Classifier Systems. Our system has been tested to determine the variation of the glutamate Neurotransmitter in the cerebral tonsil of the rats. It discovers and evaluates new rules, and it generates new solutions associated to clinical disorders.**

I. Introduction

Some of the most important problems in science, industry and commerce, require of the use of great amount of complex data. This can entail to problems of classification of these data to be able to make decisions. In the case of Bioinformatic, it is necessary the interdisciplinary work between the Medicine, Informatic, Biological Sciences, among others. In these disciplines there are problems of classification, diagnosis, prediction, among others.

At this moment, one of the great challenges of the Medicine and Biological Sciences have been to understand the biological bases of the conscience and the mental processes by means of which we perceive, learn and memorize; for such reason, during the last two decades has increased the unification of the study between the emotional behavior and the molecular bases that could be implied in such behaviors [2, 12].

The brain has different functional regions. The cognitive functions are located within the cerebral cortex; some affective characteristics and aspects of the personality also are located anatomically, and the mental processes are represented in the brain by their elementary operations [12]. All this indicates the generation of functions in the brain, which are not simple motor behaviors, but also complex cognitive actions like thinking, speaking and artistic creations. The behavior disorders that characterize the neurodegenerative diseases are determined mainly by alterations in the Neurotransmitters (NT). Through the analysis of the NTs implied in specific neuronal circuits we can diagnose these types of diseases. The alterations, the storage, the liberation or the degradation of the NTs, can affect the neurotransmission and produce clinical disorders [12].

On the other hand, the Intelligent Systems (IS) are an attractive alternative to deal with highly confused and variant problems, [1]. The recent developments in IS has influenced other areas: Biological models; massively parallel computers; Integration of Reasoning, Information and Services; Fast Learning, among others. Three classic IS paradigms exist: Artificial Neuronal networks, Evolutionary Computation and Fuzzy logic. Nevertheless other paradigms exist, like for example: the cultural algorithm, the Theory of Agents, etc.

In this work is proposed an application of the Fuzzy Classifier Systems in the Medicine domain, in the problem to analyze and to classify a great amount of data from biochemical fluids extracted of the brain of a rodent, in order to measure the NTs and biomolecules present, and this way to diagnose diseases in the humans due to alterations, storage, liberation or degradation of the NTs.

II. Theoretical Aspects

A. Neurotransmitters (NTs)

The nervous system has the characteristic of being very fast, although little persistent in the time. Their "internal" (neuron to neuron) or "external" (neuron to muscle or gland) interactions are called synapse. The synapse is the connection of the dendrites with axon, being the base of the biological structure to understand the anatomy and the physiology of the nervous tissue. Two types of synapse exist that differ in their structure and in the form in which transmits the nervous impulse [11].

- Electrical synapse: It is a synapse in which the transmission between the first and second neuron takes place by the ion passage from a cell to another through unions gap. The unions gap are small channels formed by protein complexes.
- Chemical synapse: It is a synapse in which the transmission between the first and second neuron takes place by the secretion of a NT. A NT is a substance that is released by a neuron (presynaptic) that affects another neuron (postsynaptic), that is, is a chemical substance that is in charge of the transmission of the signals from a neuron to the following one through the synapse.

Most of the synapse are of chemical type, and particularly, in this project we are going to study this one because the

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objective is to analyze the release of the NTs that affects the behavior of the people [12].

On the basis of their neurochemical structure the NTs can be classified in three groups: Amines, Aminoacids, and Peptides. It this work we study the Aminoacids and Amines fundamentally [12].

B. Fuzzy Logic (FL)

One of recent mathematical disciplines is the FL, that is the logic that uses expressions not totally certain or completely false [1, 8, 9, 10]. That is, the FL is applied to concepts that can take a value of veracity within a set of values that oscillate between two extremes, the absolute truth and the total falseness. What is fuzzy or vague it is not the logic in itself, but the object that is studied: it express the lack of definition of the concept to which is applied. The FL allows to process vague information, like low temperature, in terms of fuzzy sets that are combined in rules to define actions: if the temperature is high then to cool much. This way, the control systems based on FL can combine input variables, defined in terms of fuzzy sets, by means of groups of rules that produce one or several exit values.

The FL was investigated, for the first time, in the middle of the 70 by Zadeh, when he defined the mutual incompatibility principle [10]: "As the complexity of a system increase, our capacity to be accurate and to construct instructions over its behavior diminishes until the threshold where the precision and the meaning are characteristics excluding". He introduced the concept of fuzzy set, under which resides the idea that the elements on which the human thought is constructed are not numbers, but linguistic labels. The FL allows representing the common knowledge, that is mainly of type qualitative linguistic and not necessarily quantitative, in a mathematical language through the fuzzy set theory. It allows to work, simultaneously, with numeric data and linguistic terms; the linguistic terms are inherently less accurate that the numeric data, but in many occasions contribute more for the human reasoning [1].

A fuzzy variable is characterized by a group of fuzzy sets (for example, height variable has the set average, low and high), and each one of them has associated a membership function, which determines the degree of membership of each value of the domain of the variable to that set. Normally, that function has triangular, trapezoidal or Gaussian forms.

C. Fuzzy Classifier Systems (FCS)

The Classifier Systems (CS) were proposed by Holland like a model of learning by reinforcement, based on Genetic Algorithms (search algorithms that use techniques taken from the natural evolution), which allow a flexible representation of the knowledge. Basically, they are systems based on rules (classifiers) designed to interact with their environment, and to learn of it by means of the allocation of weights to each rule and the creation of new rules from the previous ones, that is, they learn rules syntactically simple that, as a whole, solves a given problem [1].

The CS have like fundamental characteristic, the adaptability necessary to be able to learn a behavior, which is obtained through the Genetic Algorithms, modifying the initial population of rules and guaranteeing that the new rules are better than the previous ones.

The basic characteristics of a CS can be summaries in the following aspects [1, 3, 4, 5]:

- The rules have the form of a logical sentence (condition/action), identifying a condition with an action to do, in case that the condition is fulfilled.
- A CS allows the parallel activation of rules during a given cycle.

A CS has a basic architecture of 3 subsystems:

- System of rules and messages. It coordinates the information within the CS, and processes such information to generate an action. The information arrives from the environment through the detectors, where it is transformed in one or more messages of finite length. These messages can activate to a set of rules, which can generate other messages. These new messages can activate to other rules, or take an action that must flow towards the environment through the effectors.
- System of allocation of credit (SAC). It evaluates the performance of a rule based on the times that the rule has been activated and the times that this rule has activated to other rules in a given period of time. The main function of this system is to classify rules according to its utility. The credit of a rule is the importance of the same one for the system. Traditionally have been used two different schemes from allocation of credit: the Algorithm of Bucket Brigade and the Plan of Profit- Sharing [1, 7].
- System of discovery (SD). The SD creates new, and possibly, more useful classifiers using the passed experience, this means, the old classifiers. This system is activated when the SAC reaches a situation of balance or uniformity. This way, it determines between all the possible rules the most useful. The set of new rules can be obtained in random form by means of small alterations, or recombining parts of different rules to try to improve the existing ones. Normally, we use in this phase the Genetic Algorithms.

A FCS is a system where the rules are based on the FL theory, it is composed by a CS, but working in a fuzzy way [6]. Thus, in a FCS the rules are diffuses, that is, the elements <condition> and <action> have fuzzy characteristics. This way, the activation of a rule is obtained when the conditions of the fuzzy variables are verified. The weight of each rule is the element taken into account when the value of the credit is calculated in each cycle of rules and messages, since this weight indicates the degree of activation of the condition of the rule. In a FCS also the membership function can be adapted [4, 5].

III. Problem Definition

In the Physiology Department, in the Medicine Faculty of the University of the Andes, experiments are made to determine biochemical changes in the brain of the rodents, with the purpose of understanding the interactions that happen in the brain when a rodent makes an activity specifies, that is, walk, run, sleep, etc. Each activity causes that a part of the brain is activated and that specific substances act in it. This allows understanding the operations of the human brain, since many of the substances and interactions happen equal for the rodents and the humans.

When making these experiments are extracted the chemical substances of the brain of the rodents through a capillary that is introduced in the head of them, then this chemical substances are processed using the Capillary Electrophoresis [2, 6, 7]. With the collected data is generated a graphic that represents the set of interactions that happen according to the substances that act. For this, a computational system, called ONICE, is used [7]. All the data are stored in a database to be analyzed of manual form, in order to discover the substances and interactions that the process generates, and thus to generate knowledge. However, this process causes that most of the information cannot be analyzed given the great amount of data, and part of the knowledge is lost.

Thus, the problem appears when we need to analyze the enormous amounts of data present in the Laboratory of Physiology stored in immense databases which treatment and analyses exceed the possibilities of any human being. This is the reason of the urgent necessity for techniques and tools of analysis, discovery, and extraction of the information and knowledge stored in those deposits of data. In a previous work, a Data Mining System was proposed with the objective to identify the patterns of the present chemical substances in the brain of a rodent during the development of a given activity (to sleep, to eat, etc.) [2]. The system identifies the classes that represent the chemical substances, and the classes that represent the activities made by the rodents. In this work, our System based on Intelligent Techniques allows to analyze and to process the data, and in this way to know a series of disorders product of alterations, storage, release or degradation of the chemical substances.

IV. Design Of The Fuzzy System For The Analysis Of Biological Liquids (FSABL)

A. Structure of the FSABL

The structure of the FSABL is based on the architecture proposed in [5]. It is composed by four subsystems, where we add a new functionality to the Adaptive subsystem. Next, the four subsystems that composed FSABL are described:

- Subsystems of Inference: It makes the inference process, interprets and to applies the knowledge of the subsystem of Storage with the purpose of obtaining an interpretation of the possible disorders [12].
- Subsystem of Storage of Information: It is composed by a base of rules and a base of facts. The knowledge base has all the information concerning the variables and rules that describe the system, whereas the base of facts has the historical information referred to the values taken by the variables of the system.
- Subsystems of Rules: It is composed by a compiler and an editor of rules. The compiler makes the lexical, syntactic and semantic analysis. The editor of rules is the interface by means of which the user writes the rules, and modifies or eliminates them.
- Systems of Adaptation: it adapts the knowledge stored in the system to the changes of the environment. It is composed by a credit allocation system and a discoverer system. It evaluates the rules and the membership functions of the fuzzy sets, discovers and/or generates new rules, as well as membership functions. Additionally, this system allows the expert to evaluate the new rules generated by the adaptive mechanism (AM), selecting and storing the useful rules and discarding the useless rules

B. The General Structure of the rules

Now, we define the general structure of the rules:

- If <height$_{SubstanceType}$> then <effect>
- If <height$_{SubstanceType}$> and <AverageHeight$_{SubstanceType}$> then <NeuralFunction>
- If <AverageHeight$_{SubstanceType}$> and < Standardeviation$_{SubstanceType}$> then <NeuralCircuitFunction>
- If < height$_{SubstanceType}$> y <AverageHeight$_{SubstanceType}$> y <Standardeviation$_{SubstanceType}$> then <effect> and <NeuralFunction> and <NeuralCircuitFunction> and < AssociatedIllness>

C. Fuzzy Set and Fuzzy variables Definition

In this section, we define the set of fuzzy variables used in the generic rules for the analysis of the NTs. The substances studied in the Laboratory of Physiology are: Gab, Serotonin, Acetylcholine, Histamine, Dopamine, Glutamate, and Aspartate.

- height$_{SubstanceType}$: it represents the changes in the peaks of a certain NT in the graphic generated by ONICE. It measures the concentration of the present NT in the sample. This variable has 3 possible characterizations, each one with its fuzzy set: low, equal, high. This way, we can define the fuzzy sets for the fuzzy variables: heightGab, height Serotonin, heightAcetylcholine, heightHistamine, heightDopamine, heightGlutamate, heightAspartate.
- AverageHeight$_{SubstanceType}$: it represents the average of all the values of height of the peaks that can reach a certain NT in the total number of samples taken in the experiment. The fuzzy sets are: low, intermediate, high. This way, we can define the fuzzy sets for the variables: AverageHeightGab, AverageHeightSerotonin, AverageHeightAcetylcholine, AverageHeightHistamine, AverageHeightDopamine, AverageHeightGlutamate, AverageHeightAspartate.
- Standardeviation$_{SubstanceType}$: It measures the existing variability in the average of the height of a certain NT. The fuzzy sets are: low, high. This way, we can define the fuzzy sets for the rest of the variables: StandardeviationSerotonin, StandardeviationAcetylcholine, StandardeviationHistamine, StandardeviationDopamine,

StandardeviationGlutamate, StandardeviationAspartate,

- effect: it represents the consequence of a certain NT due to variations of height in its peaks. The fuzzy sets are: inhibitor, withoutEffect, and exciter.
- NeuralFunction: it reflects the action that fulfills the nervous cells for the effect of a NT. In a nervous circuit, due to the experiments, there are neurons that produce and deliver certain NT, don't deliver more this NT, or are not affected. The fuzzy sets are: to deliver, NotAffected, NotDeliver.
- NeuralCircuitFunction: represents the effect of a NT over the nervous circuit in different rodents, indicating if the nervous circuit works equal in all the rodents or differs in certain animals. The fuzzy sets are: produceChanges, NotProduceChanges
- AssociatedIllness: it represents the type of disorders associated due to alterations, storage, release or degradation of the NTs. These diseases are characterized by the levels of action of the NT:
    - Anxiety: it reflects a diminution of the levels of Gab. This variable has three possible characterizations: low, average, high.
    - Depression: it reflects a diminution of the levels of Noradrenalin and Serotonin. This variable has three possible characterizations: low, average, high.
    - Disease of Alzheimer: it reflects certain variation in the levels of Acetylcholine. This variable has three possible characterizations: low, average, high.
    - Disease of Parkinson: it reflects variation in the levels of Dopamine and Noradrenalin. This variable has three possible characterizations: low, average, high.
    - Epilepsy: it reflects a diminution of the levels of Gab. This variable has three possible characterizations: low, average, high.
    - Schizophrenia: it reflects an increase in the Dopamine levels. This variable has three possible characterizations: low, average, high.
    - Cerebral Injury: it reflects an excessive increase in the levels of the Glutamate. This variable has three possible characterizations: low, average, high.
    - Migraine: it reflects imbalance in the levels of Serotonin, associated to headaches, nauseas, vomits and hypersensitivity to the light and the sound. This variable has three possible characterizations: low, average, high

D. Definition of the Membership Functions

Next, the membership functions of each one of the fuzzy sets associated to each fuzzy variable are defined. We use membership functions of triangular and trapezoidal type.

- The fuzzy variables heightGab, height Serotonin, heightAcetylcholine, heightHistamine, heightDopamine, heightGlutamate, heightAspartate, are characterized by the membership function shown in figure 1. The domain is [0 mv, 4000 mv], indicating the minimal and Maximal height that can reach each peak that represents a substance in an individual.

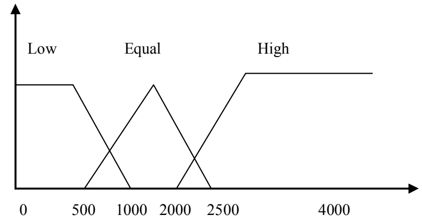


Figure 1: membership function of the fuzzy variables of the height of the NTs

- the fuzzy variables AverageHeightGab, AverageHeightSerotonin, AverageHeightAcetylcholine, AverageHeightHistamine, AverageHeightDopamine, AverageHeightGlutamate, AverageHeightAspartate, are characterized by the membership function shown in figure 2. The domain is [0 mv, 4000 mv].

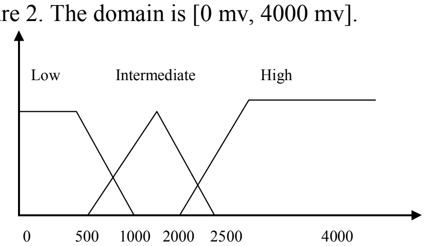


Figure 2: membership function of the fuzzy variables of the Average Height of the NTs

- The fuzzy variables StandardeviationSerotonin, StandardeviationAcetylcholine, StandardeviationHistamine, StandardeviationDopamine, StandardeviationGlutamate, StandardeviationAspartate, are characterized by the membership function shown in figure 3. The domain is [0 mv, 1000 mv].

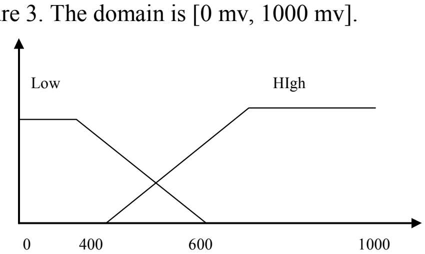


Figure 3: membership function of the fuzzy variables of the Standardeviation of the height of the NTs.

- For the fuzzy variable effect we propose to use the membership function of figure 4. The domain is [0%, 100%].

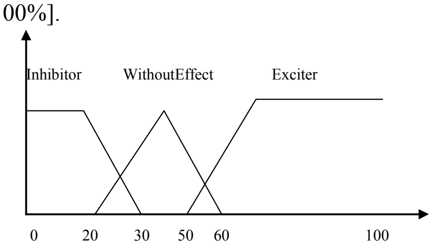


Figure 4: membership function of the fuzzy variables effect

- For the fuzzy variable NeuralFunction we propose to use the membership function of figure 5. The domain is [0%, 100%].

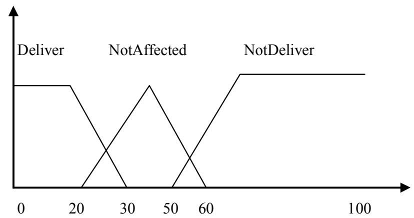
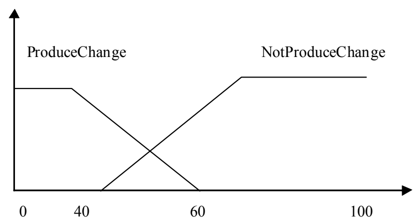


Figure 5: membership function of the fuzzy variables NeuralEffect

- For the fuzzy variable NeuralCircuitFunction we propose to use the membership function of figure 6. The domain is [0%, 100%].



- Figure 6: membership function of the fuzzy variables NeuralCircuitFunction

- The fuzzy variables Anxiety, Depression, AlzheimerDisease, ParkinsonDisease, Epilepsy, Schizophrenia, CerebralInjury, Migraine, are characterized by the membership function shown in figure 7. The domain is [0%, 100%].

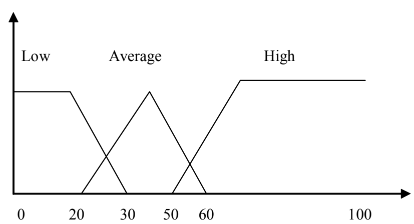


Figure 7: membership function of the fuzzy variables: Anxiety, Depression, AlzheimerDisease, ParkinsonDisease, Epilepsy, Schizophrenia, CerebralInjury, Migraine

I. Study Case

A. Definition of the study case

In section 3 we present the problem to study. In specify, in our case of study we evaluate the variations of the extracellular level of the Glutamate in the nucleus of the Cerebral Tonsil, and its implications in the emotions, mainly with the fear and the disorders of anxiety.

B. Experiment

The objective of the experiment is to determine the variation of the extracellular level of the glutamate NT in the tonsil of the brain of rats, under the effect of the substances: Juice, Lithium Chloride (LiCl) and Sodium Chloride (NaCl).

The experiment was made with 3 experimental groups, taking 15 electropherograms by rat belonging to each experimental group, the time between each electropherograms is of 2 sg. Each electropherograms represents a sample under certain conditions (with effect or without effect of substances), it is stored in a .elf file, and through the ONICE is obtained a graphic (see figure 8). Next we detail the experimental groups:

- Group 1 (without the effects of the substances): this group was conformed by 6 rats. This group represents the basic samples; these are samples where the rats were not dealt with any substance.
- Group 2 (under the effects of the substances): this group was conformed by 6 rats. This group was treated under the effects of the juice and LiCL substance, where after the first three samples without giving anything, the rats drink juice, and after sample 6 they drink LiCL.
- Group 3 (under the effects of the substances): this group was conformed by 4 rats. This group was treated under the effects of the juice and NaCl substance, where after the first three samples without giving anything, the rats drink Juice, and after sample 6 they drink NaCL.

The extension .elf defines to a file of the type capillary Electrophoresis, these archives contain in code ASII the data of a given sample.

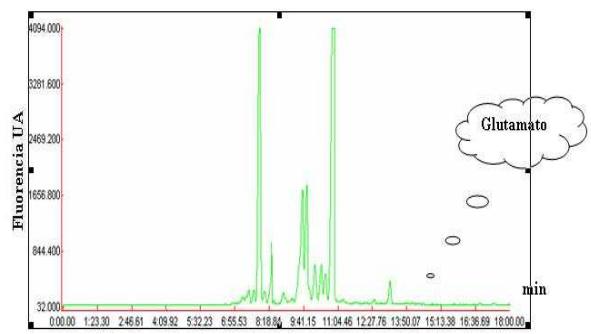


Figure 8: Sample of Group_A _ 01 extracted of a rodent

In the example of figure 13 we identify the peak that represents the NT in study, which in our case is the Glutamate. In table 1 are shown the specific variables for the analysis of the glutamate, in each sample.

TABLE I
INPUT AND OUTPUT FUZZY VARIABLES

Variable type	Fuzzy Variable
Input	HeightGlutamate
	AverageHeightGlutamate
	StandardeviationGlutamate
Output	Effect
	NeuralFunction
	NeuralCircuitFunction
	Fear
	Anxiety

Using ONICE [7], we identify the peak that represents the glutamate and obtain the respective values of the height, average, like its standard deviation.

In table 2 are shown the data corresponding to Group 1 (without effects of substances): average and standard deviation of the height of the glutamate of the 6 rats for each graphic.

TABLE II
DATA GROUP 1

	Average Height Glutamate	Standard Deviation Glutamate
Graphic #1	218.2	64.32
Graphic #2	222.25	65.15
Graphic #3	350	188.42
Graphic #4	269.4	167.62
Graphic #5	204	142.75
Graphic #6	171.25	41.44
Graphic #7	170.67	23.71
Graphic #8	195	61.49
Graphic #9	337	83.44
Graphic #10	295.67	174.59
Graphic #11	181.67	27.93
Graphic #12	209.67	24.17
Graphic #13	333.67	139.47
Graphic #14	240.5	186.78
Graphic #15	188.25	65.05

For the rest of the groups, see [2]. Remember that the input/output variables, with their respective fuzzy sets that are used by the fuzzy System for the analysis of the NT Glutamate were defined in section 4.3. Similarly, the fuzzy System has defined the membership functions of each associated fuzzy set to each fuzzy variable (see section 4).

According to the structure of generic rules that describes the fuzzy System for analysis Glutamate, and investigations made in the implications of the substance in the cerebral tonsil, we defined initially the following rules:

- If heightGlutamate is high then effect is excitatory
- If heightGlutamate is low and AverageHeightGlutamate is high then Neuralfunction is deliver
- if AverageHeightGlutamate is high and StandardeviationGlutamate is high then NeuralCircuitfunction is produceChanges
- If heightGlutamate is high and AverageHeightGlutamate is high and StandardeviationGlutamate is low then effect is excitatory and Neuralfunction is deliver and NeuralCircuitfunction is notProduceChanges and AssociatedIllness is Anxiety

According to the described experiment and the data previously presented, the prototype corresponding to the glutamate was constructed making use of the tool for the development of fuzzy systems presented in [4, 5]. We need to create the knowledge base (in our case of study under the name protoGlutamate). There are three user types: the designer has the faculty to design, to modify and to use the fuzzy system, to execute the adaptive mechanism (AM), and to evaluate the rules that are generate by the evolution process. The Normal user can use the chosen system to obtain a solution. The Special user can use the chosen system to obtain a solution, and in addition, to receive a report of the rules activated with its respective degree of firing.

For our case of study we have initially 14 useful rules (see figure 9), when we call to the AM for each rule, it introduces new relationship between the fuzzy sets of the condition and the action, generating 14 new instances of rules, which must be evaluated by the expert. In order to make the evaluation of the rules the system show a check box at the beginning of each new rule, if the expert considers the rule is useful the check box must be selected, otherwise the rule is considered useless (see figure 10).

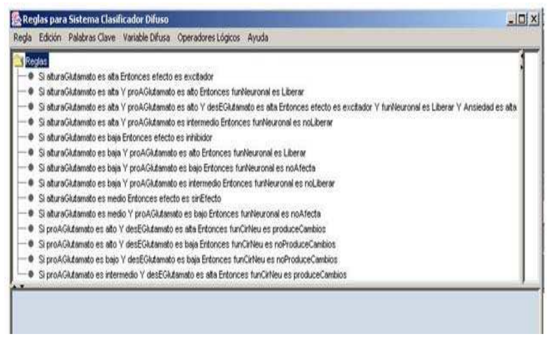


Figure 9: Rules

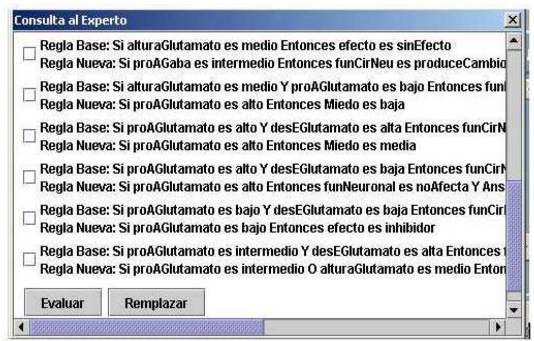


Figure 10: Results of the MA

In order to make the evaluation of the new rules, we select them (see figure 10) and press the button to evaluate them, the system automatically evaluates if the new rules are contained in other rules of the knowledge base, and if they are not contained in other rules, the system allow to store them in the knowledge base. For our case of study, in the evolution of the rules the variable Fear were included for the analysis of the cerebral tonsil, this variable did not exist like part of the specified rules. In this case, the system allows introducing new implications in anxiety disorders, like the fear, for the zone of the brain in study.

The AM establishes new ranks for the defined fuzzy sets, and generates membership functions of type different from which were presented/displayed originally. The evolution of the membership functions allows to correct design errors and/or to update the information of the system to the changes that are happening in the environment. In figure 11 is shown the evolution of the membership functions for the heightGlutamate fuzzy variable and the high fuzzy set, where the membership functions initially is of trapezoidal type in the rank (500, 650, 850, 1000), which is replaced by the rank (432,36, 650, 850, 1000). Similarly, we can observe the evolution of the membership function for the AverageHeightGlutamate, initially it is defined of trapezoidal type and when evolving the membership function changes to triangular type in the rank (0, 110, 220).

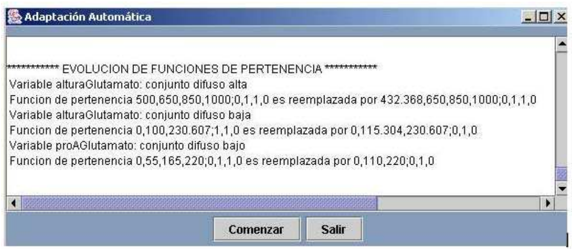


Figure 11: Evolution of the membership functions.

C. *Analysis of Results of the FSABL*

The fuzzy system shows the rules activated in the inference process and generates the respective solutions. Figure 12 shows the results to the received message from the outside corresponding to Group 2: heightGlutamate = 600, 504,75 AverageHeightGlutamate and StandardeviationGlutamate = 273,58, which have activated rules 1, 2, 5, 11, 12. The fuzzy system generates a solution associated to the variable "effect" (76,77%), indicating an exciting effect given by an increase of height in the peak that represents the glutamate by the action that produces the LiCl. The "NeuralFunction" variable (59,92%), in our case indicates that the function of the cerebral tonsil is more of less affected by the LiCl and causes that some neurons release a little of glutamate. On the other hand, the "NeuralCircuitfunction" (24,69%) in our case indicates that for the 6 rats that comprise the experiment, they have few changes that take place in the zone of the brain in study (cerebral tonsil) and the operation of this cerebral zone works equal for all the rates of group 2.

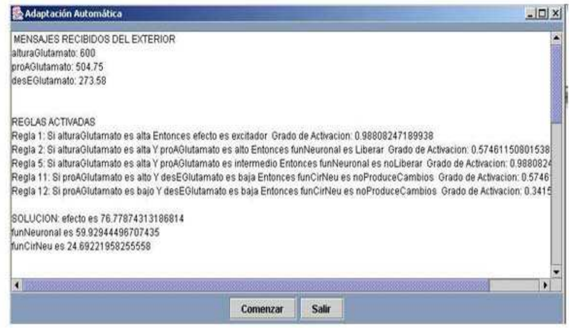


Figure 12: Results

According to the variations in the levels of the glutamate, the cerebral tonsil can have disturbances, and the fuzzy system is able to generate new solutions and to associate possible disorders to it, like the fear, anxiety, depression (see figure 12).

D. *Analysis of the Expert*

According to the experimental groups in study, we can observe that the LiCl increases the glutamate and affects the cerebral tonsil, that is due because we inject to the group 2 LiCl between samples 6 and 7, as is shown in figure 13 where the average of height of the glutamate from sample 6. However, in groups 1 and 3 differences are not observed, identifying that NaCl does not make anything to the rats (Group 3), and the behavior of this group is similar to the Group 1 (basic samples). Thus, comparing the scales of the average of height of the glutamate for the three groups, a difference is observed in the group 2 since the LiCl increases the glutamate.

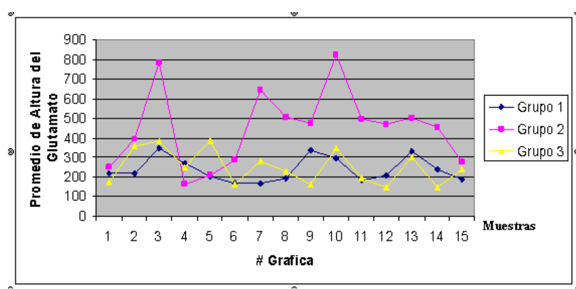


Figure 13: Average of height of the glutamate for the different experimental groups

Comparing the results of the FSABL with the analysis made by the expert, we can observe that using the system we can reach the conclusions that the expert would generate

II. CONCLUSIONS

The fuzzy System for the Biological Liquid Analysis allows to analyze and to classify data of the extracted biochemicals fluids of the brain of rodents, and this way to manipulate great amount of information that is impossible to handle manually when the amount of electropherograms in the experiments increase.

The design of the proposed fuzzy System was developed under the paradigm of the fuzzy Classifier System, allowing to represent of flexible way the knowledge, to process facts and to obtain inferences or conclusions from that processing.

With the objective to test the fuzzy System we implement a prototype to determine the variation of the Glutamate in the tonsil of the brain of the rat, induced by the action of several substances (juice, LiCL, NaCl). Initially, an experiment was considered to analyze the Glutamate specifically, by the facility to locate it and/or to detect it in electropherograms, nevertheless would be interesting to use the FSABL in other experiments analyzing other NTs.

Comparing the results obtained by the FSABL with respect to the analysis made by the expert for the implemented prototype, they reach similar conclusions: the LiCl increases the glutamate and affects the cerebral tonsil. Nevertheless, the Fuzzy System allows defining in fuzzy terms that the cerebral tonsil was little affected by the LiCl.

In general, the Fuzzy System allows to discover and/or to generate new rules, and to diagnose diseases product of alterations of the neurotransmitters.

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