The analyze of the functional and emotional levels of development of DIR/Floortime model: a fuzzy system approach

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Abstract. The human development has a lot of different areas and the most unpredictable is the neurodevelopment, that starts at the first moments of life, and do not have any physical feature, specific exam or methodology to do their analyze and diagnostic. They have only a treatment that should start early to get better results. The process of identification is based on the specific features demonstrated by the patient, who are normally children. In this context, the DIR methodology, that covers from the approach method to the treatment, shows the stages of development that every human must pass to accomplish your healthy growth, they were defined as the functional and emotional levels of development, and through your co-relation may be possible diagnose a particular delay of development or a neurodevelopment disorder. However, this process has a lot of variable to be analyzed, and very hidden information due the difficult to obtained information by the kid. In this paper is proposed a fuzzy system to analyze the functional and emotional levels of development, through variables obtained by the psychologist professional. The neuro-fuzzy identification was used to construct the Takagi-Sugeno Rules based on a previous set of data, where your input was randomly generated, and your output were validated by the psychologist professional. The backpropagation was applied to adjust the antecedent membership function. The results shows that the system can deal with the hidden and vague information, and have a strong potential to be applied in the diagnostic of neurodevelopmental disorders.

Keywords: Fuzzy system, Neurodevelopment, Stage of Development, Diagnostic

1 Introduction

Disorders related to neurodevelopmental delays usually appear at the first moments of the childhood and create problems in the development of physical and social abilities that can last a lifetime, they have only a treatment that aims to reduce the damage in the patient abilities to they can lead a life without the consequences of this deficits.

The foundation of a new human ability are others skills already established, so, a delay in a specific point of development can infer other problems in many different aspects of the development and life, showing the necessity of start the treatment as fast as possible to deal with the delay before it reach in others skills and become harder to treat.

Delays on human neurodevelopment cannot be detected thought exam or physical features, the diagnostic is a very inaccurate process that resemble the attempt of diagnostic some pathology through the presented symptoms. The process becomes harder due the symptoms are social abilities and the patients are usually children, which makes harder the process of obtaining information. The neuropsychologist literature shows a different methodology about the Neurodevelopmental Disorders (ND), in all cases, diagnosis and treatment are analyzed together. Among the existing methodology the DIR/Floortime stands out because it promotes an analysis over the Emotional and Functional Levels of Development (EFLD) that every child must pass to reach their total development.

DIR is an initial that bring the three principal questions that guide the practice of the methodology: the D concerns

to the Emotional and Functional Development, the I concerns about the individual differences and the R is about the Relationships, besides the Floortime technique that have a crucial importance inside of the model (Pires [1]).
The DIR methodology differentiates from other because it offers a wider analysis not focused only on the detection of ND, but in the searching of Delays of Development (DD) in each EFLD, that is a condition that according the NeuroSaber institute reach 15% of the children younger then 3-year-old, after this stage, the DD can be related with a ND.
The diagnostic process is very complicated, due the uncertain feature of the data and the number of possible sources of information, in that regard, a few computational intelligent techniques were apply with the objective of accomplish the diagnostic of an isolated ND as showed in Crippa et al. [2], Chen et al. [3], Hu et al. [4], Tor et al. [5], Ucuz and Cicek [6], Eslami et al. [7] and Sharma et al. [8], however, most of these works do not take in consideration the context and the clipping where this information were obtain. In this context, this paper presents a fuzzy system to analyze the first 3 EFLD .
The main features of this work are:

- While major works in this field seeks to obtain information directly from the kid or patient without the due attention to the context or clipping of the situation, this work uses information from the psychologist professional, that leave in consideration all of the necessary aspects, increasing reliability of the data.
- Most of the existing works are specific for the detection of a unique ND, about that, this work focuses on the base of the problem, working on the analyses of the stages of development with a great potential for a general application.
- While most of the methodology seeks applications of artificial neural networks, this project seeks an application of a rule based fuzzy system.
- The work together with the psychologist, that prevent the distancing between the diagnostic method and the specialist professional to realization of the treatment.

2 Problem formulation

2.1 DIR/Floortime and the neuropsychology

The studies about the human development were based on the cognitive questions for a long time and sought reduce the disadvantages caused for the condition, however, Stanley I. Greenspan introduced a new approach based on the relation between cognition and emotional, known as DIR, that is an initial that show the three principal questions of the method, the Floortime technique is applied together with the model to improve the approach with the patient. From the relation between the analyzed questions in the DIR and the neuropsychology is possible understand a method to analysis and rehabilitation of people with a DD and ND. The focus of this work is the analyze of the first three EFLD.

2.2 Emotional and functional development

In Greenspan and Greenspan [9], Greenspan [10] and Greenspan [11] the EFLD was introduced, they start at the first moments of life and can accurate significant problems in the adult life. Six levels were introduced and related to troubles that are usually caused by neurodevelopmentalal disorders. The three levels analyzed in this work are:

- EFLD 1 (Regulation and interest for the world): should be observed in kids between zero and three months old. This the moment of brain expansion, where the child starts to organize his sense and physiologic answer. Lack of attention in smells or sounds can be a signal of ND.
- EFLD 2 (Relationship and engagement): observed in kids between 2 and 3 months old. This is when the child starts to perceive people around and crate emotional bonds with them. Delays at this stage create troubles in the development of non-spoken language and in the understanding of relationships.
- EFLD 3 (Communication circle): Observed in child between 3 and 10 months old. The firsts signal of communication emerges (non-speak), having volunteer exchange of signals with at least one person. Delays at this stage can cause difficulty in starting and continuing the dialogue.

A delay in one stage of development can infer troubles in others, for example if you cannot interact with your around (EFLD 1) you could have problems in perceive persons (EFLD 2) and do not have desired to exchange signals with someone (EFLD 3), what showing the necessity of a fast and accurate process, but in each EFLD a lot of questions must be approach and this information are obtained from children with less the 3 years old that brings a kind of associated noise, which made this process hard to be accomplished fast and accurate at the same time.

3 Methodology

In this paper a Takagi and Sugueno (TS) Nero-fuzzy system to analyze the first three EFLD are proposed. The input parameters of the system are the questions present on the quiz elaborated by the psychologist in the analysis process of the EFLD, where each level has different questions.
In order to create and evaluate the system a database was created in three steps: the random selection of input data, the analyses of these samples by the psychologist (in this process the answer is a qualitative level) and a determination of a numeric parameter for the qualitative level informed by the psychologist. With a random choice, 80% of the samples were selected to crate the fuzzy system rules and the 20% remain for the test set.

3.1 Input parameter

In the DIR methodology, the analysis of the EFLD is made by a quiz filed for the psychologist with the features of the patient, each of these questions are related with neurodevelopmental troubles. This methodology is subjective, and each professional can create your quiz based on your interpretation of the literature. Through the specialist, we got the following adapted quiz from Brazelton and Greenspan [12]. Each of these questions are considered as an input variable for its system. The questions analyzed in each EFLD are:
EFLD 1 Regulation and interest for the world:

1. Does the patient demonstrate interest for the things of his around?
2. Does he look for the scenes around him?
3. Does he turns around on the sounds direction?

EFLD 2 Relationship and engagement:

1. Does the kid look happy and satisfied when look at his favorite person?
2. Is he curious about the caregiver's play?
3. Does he show physical proximity to the caregiver?
4. Does he avoid looks?
5. Does he engage in huge spaces? (after 19 months old)
6. Is he uncomfortable if the caregiver does not answer in the expected way? (25 months old)

EFLD 3 Communication circle:

1. Does he show what he want with any kind of signal?
2. Does he answer the people that speak or play with him?
3. Does he demonstrate angry or aggressiveness?
4. Does he use spoken or non-spoken language?
5. Does he start intentional actions?
6. Does he answer in an appropriate way? (no more, no less)

Each of these questions have four possible levels of answer, that are related to a percentage factor. In the analysis process of this quiz, none of the questions have a different associated weight, the psychologist makes your analyses through the combinations of the questions. The possible levels for each input are:

- Yes: The patient has fully answer with autonomy in various situations. Related value 1.
- Emerging: The patient has an occasional and without support answer. Related value 0.75.
- With support: The patient answers with some type of psychical and/or speak support. Related value 0.5.
- No: The patient does not have answers or have a minimum answer. Related value 0.

The fuzzy logic models are based on mathematical ones that estimate values between true and false, black and white, hot and cold among others (Mancilla Rendón et al. [13]). Allying this with the concern about number of rules, we consider only two linguistic terms corresponding of the levels yes and no, and the values with support and emerging are interpreted as intermediary values, for this the triangular model was chosen as the membership function, with their cores in 0 and 1.
The input data are limited to four levels, and most of the EFLD have 6 input parameters what gives a lot of possible combinations, for this, a base data were crated to building the rules and validate the system. The first step is the random choice of the input data for each of the systems, after they were separated in training and test sets. The number of samples in each set and the systems are classified as:

- System EFLD 1, all of the 64 possibilities were considered, 51 samples were chosen as training set and the remaining 13 as test set.
- System EFLD 2, 204 samples were randomly generated (avoiding repeated samples), 164 were chosen as training test and the other 40 as test set (this system analyze the EFLD 2and 3).

3.2 Output data

The second step is the formation of the output data, when all the samples generated in step 1 pass for an analysis of the psychologist, thus creates a database with a qualitative output, but in this process, we can have two patients with the same diagnosis or qualitative output but with different levels of intensities in their associated loss, and the majority of the ND are characterized for some common features with different levels of intensities in each patient, for this, and the features of the fuzzy logic introduced by Zadeh [14], the qualitative output must pass for a numeric formatting.
The numeric formatting is based on the means of the input data, each level has a lot of overlap in its values, for this, the process is based on an interpolation of the input parameters means in a new range of values, keeping a symmetry around the value related to the level. This process is computed by the following equations:

$$\begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} M_{min} & 1 \\ M_{max} & 1 \end{bmatrix}^{-1} \begin{bmatrix} P_{Start} \\ P_{final} \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} M_{min} & 1 \\ M_{r} & 1 \end{bmatrix}^{-1} \begin{bmatrix} P_{start} \\ M_{r} \end{bmatrix} \tag{2}$$

$$\begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} M_{r} & 1 \\ M_{max} & 1 \end{bmatrix}^{-1} \begin{bmatrix} M_{r} \\ P_{final} \end{bmatrix} \tag{3}$$

$$r_s = ax + b \tag{4}$$

Where M_{min} e M_{max} are the maximum and the minimum mean of the input parameter in a specific level. M_r is the value related with the level. In eq. (4) the outuput of the data set is computed. The values of M_{min}, M_{max}, P_{final} e $P_{inicial}$ follow Table 1.

Table 1. Parameters of interpolation

Output level	M_{min}	M_{max}	P_{final}	P_{start}
Yes (1)	0.83	1	1	0.95
Emerging (0.75)	0.375	0.91667	0.91	0.64
With Support (0.5)	0.25	0.8	0.62	0.32
No (0)	0	0.291667	0.3	0

3.3 Neuro-fuzzy identification

In this paper, a rule based fuzzy system of Takagi and Sugeno model is proposed, which according da Silva et al. [15] can be used as a system approximator and can be complete or only represented by your input output relation. The consequent proposition is a crisp function that computes the relation of the input and output variable, the rule structure follows the pattern of the eq.(5).

$$R_i : \text{If } x \text{ is } A_i \, e \, ... \text{ Then } y_i = f_i(x), \; i = 1, 2, ..., K, \tag{5}$$

Adaptive systems are used to construct the rules in order to get better results. In this work we use the neuro-fuzzy what according Sremac et al. [16] are described as artificial neural networks characterised by fuzzy parameters. By combining two different concepts of artificial intelligence we can try to exploit the individual strengths of fuzzy logistic and artificial neural networks in hybrid systems of homogeneous structure.
There is a wide area of expertise for fuzzy systems, because it combine the human knowledge and computational techniques in a white box modeling, where we can understand the rules and variables by linguistic terms, for this we can see many different applications for fuzzy systems as in: Das et al. [17], Wu et al. [18], Ozkan [19], Alahyari

and Pilevari [20] and Dionova et al. [21].
The structure of a neuro-fuzzy inference scheme is represented by Figure 1. Where the first node compute the input variable membership degree, the next node is the product node that represent the conjunction operator of the antecedent, after, the normalization N and the sum $\sum$ nodes realize the fuzzy-mean operator (Babuška [22]).

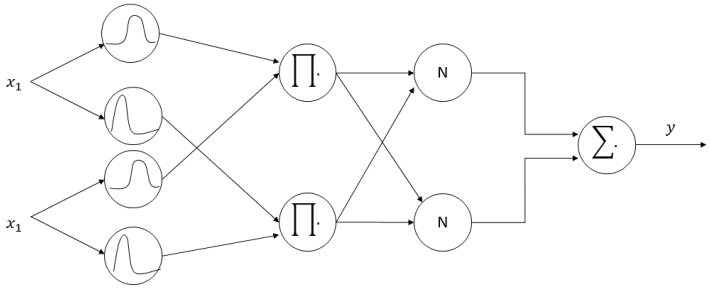

Figure 1. Example of a two rule fuzzy system represented as a neuro-fuzzy network.

4 Test and results

The systems training was carried out with an error criteria of 0.015. In Figure 2 and 3 the comparison between the expected result in each sample and the system response are shown. In both cases the proposed system had a response very closed to expected.

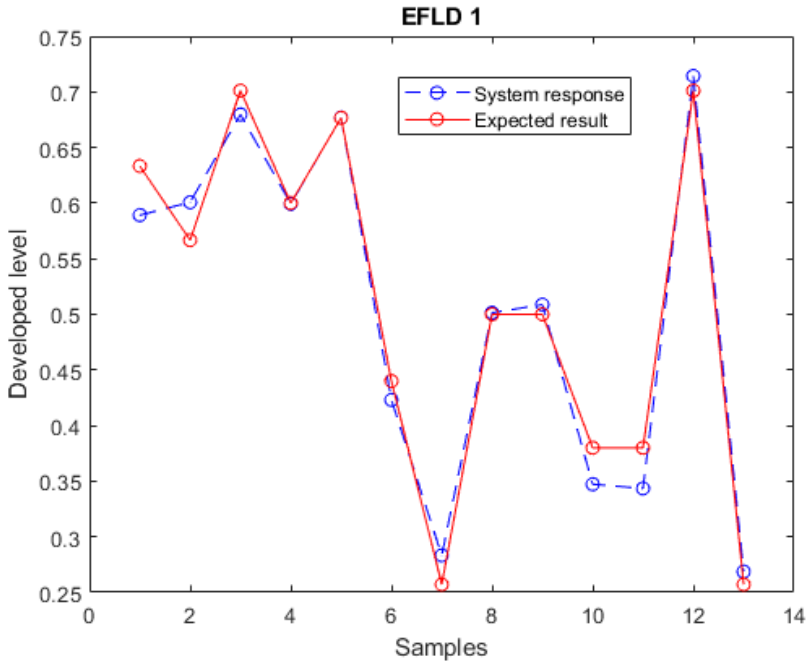

Figure 2. Comparison between the system EFLD 1 output and the expected result.

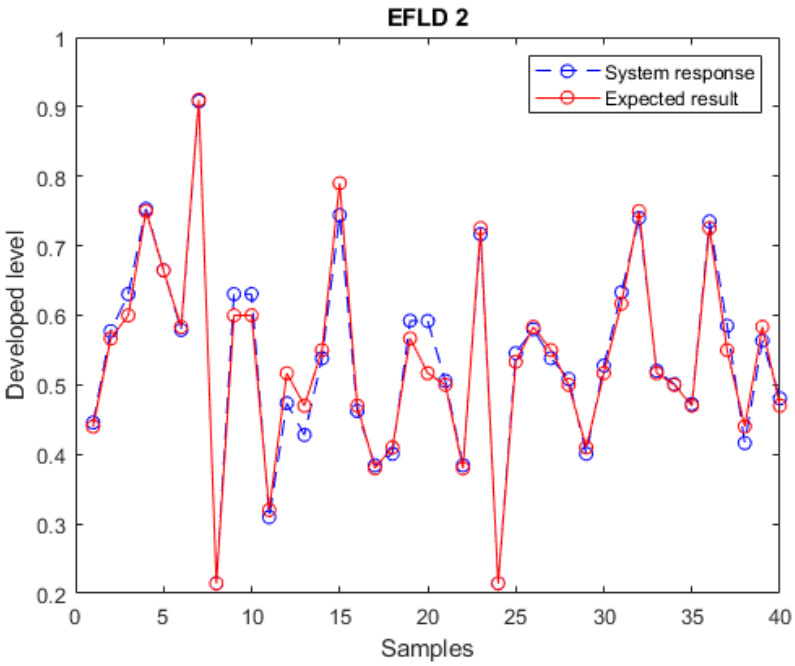

Figure 3. Comparison between the system EFLD 2 output and the expected result.

In order to have a more detailed analysis, the Table 2 presents the maximum and the average values of percentage error to each system, both systems have a short average error. When we consider the maximum error, the worst situation in both systems are similar, in ELFD 1 the expected output and the output of the system are located in the overlap between emerging and with support and in the EFLD 2 the expected result and the output of the system are located in the level with support. In the worst situation for both systems the outputs have memberships degree closed to the expected.

Table 2. Maximum and average percentage error

System	Maximum error	Average error
EFLD 1	6.97%	2.3%
EFLD 2	14.5%	2.79%

The new output proposed in this paper have a large chance of possibilities what is interpreted as different intensities, for this, the proposed systems have two strong features:

- The approach of the neurodevelopmental problems in their foundation (the EFLD), in other words, the system can deal with every type of patient, with a DD or ND.
- A potential to be used in the diagnostic of ND, due the ND are defined by some features related to the EFLD and can appear in different intensities in each patient, what can be deal for the large number of possibilities in the output of the new system.

5 Conclusions

The proposed systems are based on information obtained by the psychologist, the behavior of the system is closed to the expected with a good response even in the worst situation, where the output level continues with relevant membership degree in the expected level.
The result of the second system shows that is possible construct a Nero-fuzzy system with a short number of data (approximately 4% of all possible combinations). The satisfactory response for both systems suggest a strong potential in applications of diagnostic of neurodevelopmental disorders, because the output of EFLD compute different intensities in each prejudice related to the neurodevepmetal disorders.

Acknowledgements. The authors are grateful to IFMA and FAPEMA for the fostering and supporting to this work.

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