A Fuzzy Rules Base for Computer Based Speech Therapy

Ovidiu-Andrei SCHIPOR, Ştefan-Gheorghe PENTIUC, Doina-Maria SCHIPOR

***Abstract*—In this paper we present our work about Computer Based Speech Therapy optimization. We focus especially in using a fuzzy expert system in order to determine specific parameters of personalized therapy i.e. number, length and content of training sessions. Fuzzy rules base contain over than 230 items and 22 linguistic variables.**

***Index Terms*—speech therapy, personalized therapy, fuzzy expert system, FCL language, fuzzy logic**

I. INTRODUCTION

THERE is a great European level concern for helping people with speech disorders and, there are a lot of *Computer Based Speech Training Systems* (CBST), for both commercial and research purposes. According to [1], a CBST is a system for teaching and training speech production for people with speech and hearing impairments.

Computer-based speech therapy aids can be seen as clinical tools. Speech therapy software can aid diagnosis of speech disorders and provides visual feed back during treatment [2]. A CBST system could not replace SLPs (*Speech and Language Pathologists* or *Speech Therapists*), but would "facilitate their assessment of speech by helping them to better target therapeutic intervention, augment their efforts in highly repetitive articulation drill and training, and assist in record keeping and reporting" [3].

Our CBST system has been developed for Romanian preschool children, to improve assessment of speech disorders, which affect pronunciation of one or many sounds. There are two different types of such disorders: *dysarthria* and *dyslalia*. Although in terms of symptoms they are similar, these two speech problems have different causes. While dysarthria is an articulation disorder produced by peripheral or central nerve damaged, dyslalia is a functional articulation disorder. Thus, dyslalia, may be produced by a maturation delay of certain organs involved in pronunciation, by some wrong speech habits or by some hearing problems [4].

We start with classic CBST architecture and we design and implement, an improved CBST system, named *LOGOMON (Logopedics Monitor)*. This CBST contains classical modules as *Children Manager, 3D Articulator Model, and Homework Manager* (installed on the child's PC or PDA) [5]. Our main contribution is to improve the classical architecture with a *fuzzy expert system*. The role of this module is to suggest *optimal therapeutic actions* for each child (number, length and content of training sessions). For each subject, our expert system can generate *optimal exercises set*, based on specific information (tests' scores and social, cognitive and affective parameters).

A. Literature Review

Statistics [6] show that 10% of children between 4 and 7 years of age, present different levels of these two type of speech problem: dyslalia and dysarthria. Although these impairments do not create major difficulties in basic communication, it has been noticed that problems are likely to appear affecting negatively the child's personality, as well as his social skills [7, 8, 9].

From the computer science point of view, the development of an intelligent system capable of doing assisted therapy can be included in a very important research area: informational technologies in response to society challenges (for health: early diagnosis, personalized therapy). Taking into consideration the fact that Romanian language is a phonetic one that has its own special linguistic particularities, we consider that there is a real need for the development of audio-video systems which can be used in the therapy of different pronunciations problems.

Research has shown [10, 11, 12] that there is a need of CBST systems that can support specifically therapeutic tasks without the presence of a speech therapist. In this context, we consider that our attempt to automatic establish personalized therapy is a step forward.

Selection of most important CBST systems is not an easy task. However, two recent projects have a special place in speech therapy field: OLP and ARTUR. For both projects, experiments' results are available [13, 14].

The OLP (Ortho-Logo-Paedia) project [15] has been started in 2002, involving the Institute for Language and Speech Processing in Athens and seven other partners from the academic and medical domains. The project aims to accomplish a three - modules system (OPTACIA, GRIFOS and TELEMACHOS) interactively capable, instructing the dysarthria suffering children. The proposed interactive environment is a visual one and it is adapted with the age of subjects using different games and animations. The audio and video interface with the human subject is the OPTACIA module, the GRIFOS module makes pronunciation recognition and the computer aid instructing is integrated in

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the third module - TELEMACHOS.

One of the most recently CBST system is ARTUR (*Articulation Tutor)* [5]. The goal of this project is to obtain an integrated speech therapy system with an intuitive graphical interface named *Wizard-of-Oz* and a virtual speech tutor named *Artur*. Based on audio (user's utterance) and video (facial data) information, the system can recognize and reproduce mispronunciations. After that, Artur suggests the correct pronunciation (audio data) and the correct speech elements' position (virtual articulator model).

At the Romanian national level, only a few researches have been conducted to the therapy of speech impairments, and most of them are focused on traditional areas such as voice recognition, voice synthesis and voice authentication. We can mention the studies made by the *Psychology and Education Science Department* from *"Al. I. Cuza" University*, Iasi. These studies carry out the development of a software, in order to provide stammer witness therapy. [16].

As far as we know, there are not applications of fuzzy expert system in CBST field. That is why we consider our approach being a step forward. The system was developed and tested for Romanian language, but our proposed method is not limited to this language.

B. Overall Paper Organization

In section II we present the LOGOMON system architecture and the place of the expert system in dyslalia therapy diagram. Then, in section III, we highlighting some theoretical aspects regarding fuzzy approach and we motivate choosing of this paradigm. The presentation of knowledge base and how psychological validation was made are topics from section IV.

II. EXPERT SYSTEM'S ROLE IN ASSISTED THERAPY

One of the main objectives of our CBST system was the development of an expert system for the personalized therapy of speech impairments, which will allow the designing of a training path for pronunciation, being individualized in accord with the defect category, previous experiences and the child's therapy previous evolution.

The expert system is based on a therapy guide, written in a natural language. This guide was formalized using fuzzy logic paradigm. In this manner we obtained a knowledge base with over 230 rules and 22 linguistic variables [17].

The therapeutically guide formalized in knowledge base consists of [18]:

- the muscular of phonon-articulator system development methods (e.g. setting up exercises for cheeks, lips and tong);
- the rhythm of respiration controlling methods (e.g. supervised inspiration and expiration from the temporal and intensity standpoint);
- the phonomatic hear development methods (e.g. the onomatopoeic pronunciation, rhythmic pronunciation exercises, distinguish along the paronyms);
- the method for the sound consolidation (e.g. the pronunciation sound of direct, inverse and complex syllable, of words, of paronyms, etc);
- the sound's utilization in complex contexts (e.g. sentence, short stories, poems, riddles).

The objectives of speech therapy expert system developed by our team are [19]:

- *personalized therapy* - the therapy must be in according with child's problems level, context and possibilities;
- *speech therapist assistant* - the expert system offer some suggestion regarding what type of exercises are better for a specific moment and from a specific child;
- *(self) teaching* - when system's conclusion is different that speech therapist's one, the last one, should have the possibility to change the knowledge base.

The specific advantages of an expert system addressing therapy of children with speech impairments are the following:

- the automatic personalized therapy system stores the precise evolution and progress of each child and, by adapting the exercises to each child's current level and progress, the speech therapy may take less time to achieve its result;
- patience, flexibility and unlimited working time whenever the child desires;
- the possibility offered to the speech therapist in order to accurately find out why the system generated some therapeutic proposals;
- an exact evaluation of the progress is difficult to achieve for a human expert; instead, the system is designed to analyze in an objective manner, the evolution of each case on small time intervals.

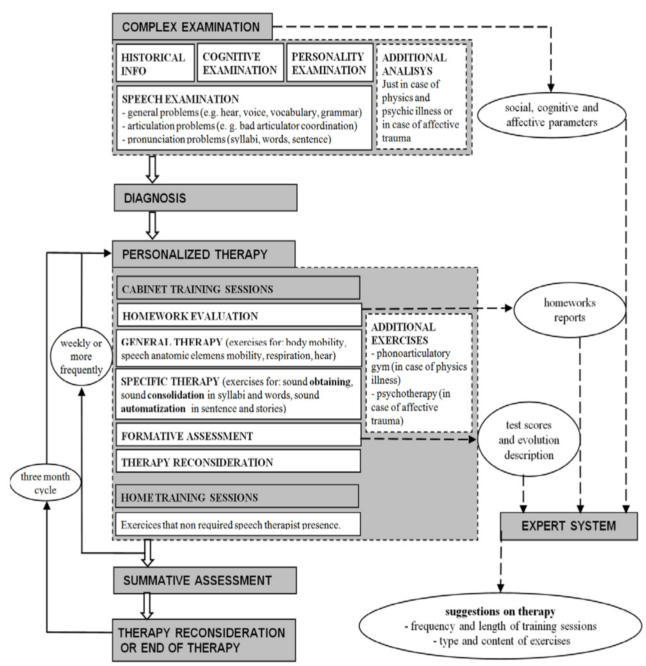

Fig. 1. The dyslalia therapy diagram.

Psychological researches [4, 19] have indicated the main aspects regarding dyslalia therapy (Figure 1). In the first step, which is *Complex Examination*, the speech therapist collects the base data set of information used for the child's diagnostic and future therapy. Part of this data is obtained from specific speech tests (9 scores from each affected sounds). The other part, more than 50 variables, refers to cognitive, affective, and social parameters. If in this stage the speech therapist detects other problems like specific illness or affective trauma, he may require additional analysis.

A full computer based speech therapy system must contain at least following items [2]:

- monitor program (installed on speech therapist computer, helps on children data management);
- expert system (based on children related information's obtain a personalized therapy path);
- exercises set (for cabinet and home use);
- home training possibility (exercises on personal computer or mobile device).

Architecture of our developed speech therapy system is presented in Figure 2.

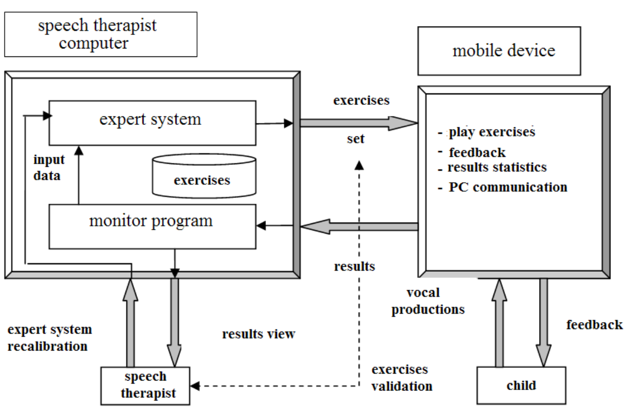

Fig. 2. System architecture.

In according with [4], speech therapy software can help speech problems diagnostic, can offer a real-time, audio-visual feedback, can improve analyze of child progress and can extend speech therapy at child home. Specific therapy information can be found in:

- dyslalia therapeutically guides;
- speech therapy centers experience;
- dyslalia exercises sets;
- historical therapy data.

III. EXPERT SYSTEM INPLEMENTATION

With fuzzy approach we can create a better model for speech therapist decisions. Fuzzy logic has ability to create accurate models of reality. It's not an "imprecise logic". It's a logic that can manipulate imprecise aspects of reality. In the latest years, many fuzzy expert systems were developed [20], [21], [22].

In the next set of pictures, we present an example of fuzzy inference. There are three input linguistic variables (speech problems level – Figure 3, family implication – Figure 4 and children age – Figure 5) and one output linguistic variable (weekly session number – Figure 6). We consider five fuzzy rules and, base on these rules, we illustrate specific fuzzy result (Figure 7). If system user wants a crisp value, deffuzification is a good solution (Figure 8).

To express a number in words, we need a way to translate input numbers into confidences in a fuzzy set of word descriptors, the process of *fuzzification*. In fuzzy math, that is done by *membership functions* [23].

Defuzzification is the reverse process of fuzzification. We have confidences in a fuzzy set of word descriptors, and we wish to convert these into a real number.

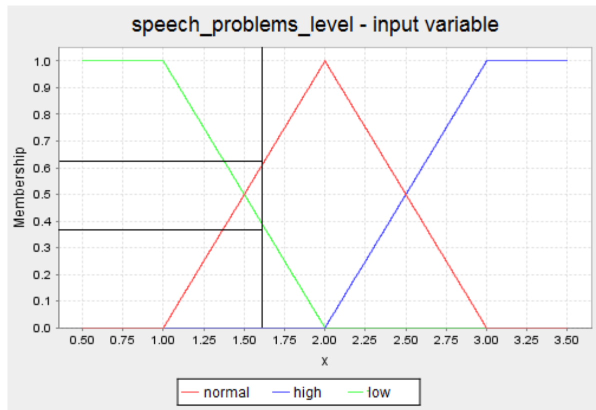

Fig. 3. Speech_problems_level language variable.

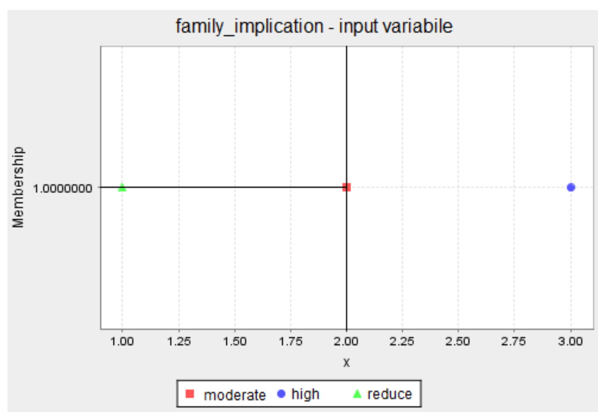

Fig. 4. Family_implication language variable.

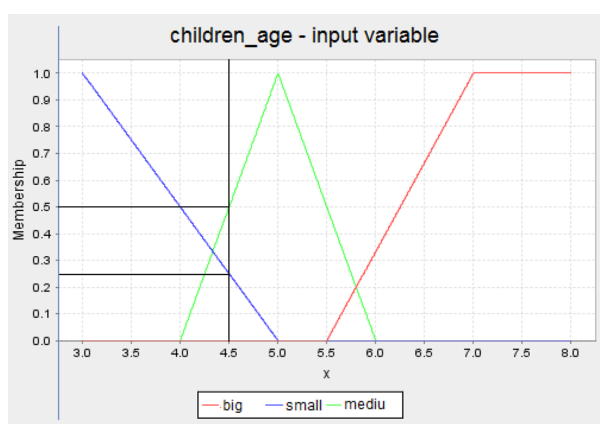

Fig. 5. Children_age language variable.

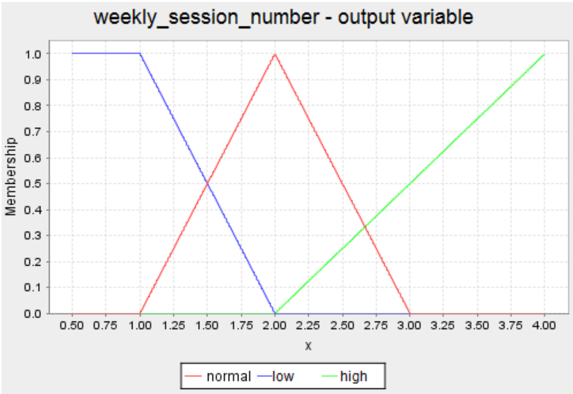

Fig. 6. Weekly_session_number language variable.

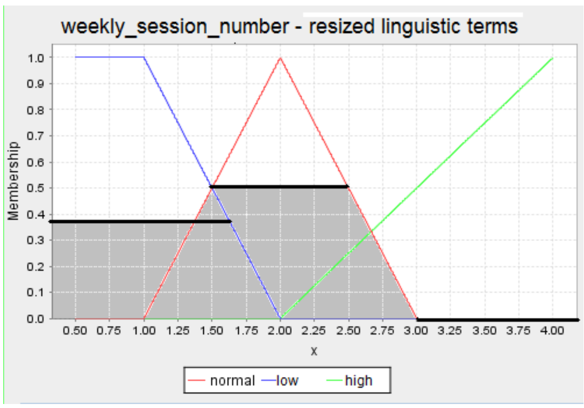

Fig. 7. Obtain a fuzzy result.

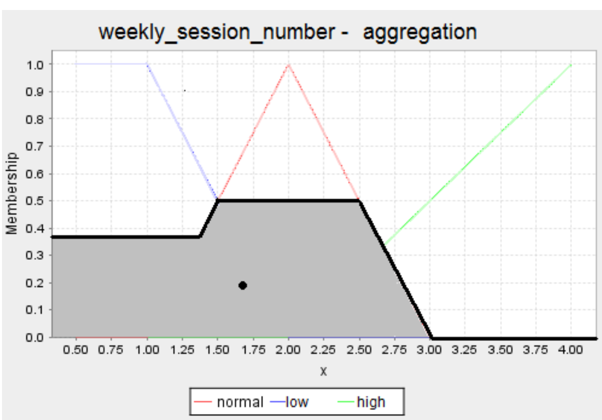

Fig. 8. Obtain a crisp value.

First three variables have following representation:
speech_problems_level (1.62)
= {“low”/0.37,”normal”/0.62,”high”/0.0}
family_implication (2.00)
= {“reduce”/0.0,”moderate”/1.0,”high”/0.0}
children_age (4.50)
= {“small”/0.25,”medium”/0.5,”big”/0.0}
We consider five rules for illustrate the inference steps:

- *IF (speech_problems_level is high) and (child_age is medium) and (family_implication is reduce) THEN weekly_session_number is high;*

min (0.00, 0.50, 0.00) = **0.00** for linguistic term **high**

- *IF (speech_problems_level is low) and (child_age is small) and (family_implication is moderate) THEN weekly_session_number is low;*

min (0.37, 0.25, 1.00) = **0.25** for linguistic term **low**

- *IF (speech_problems_level is low) and (child_age is medium) and (family_implication is moderate) THEN weekly_session_number is low;*

min (0.37, 0.50, 1.00) = **0.37** for linguistic term **low**

- *IF (speech_problems_level is normal) and (child_age is small) and (family_implication is moterate)THEN weekly_session_number is normal*

min (0.62, 0.25, 1.00) = **0.25** for linguistic term **normal**

- *IF (speech_problems_level is normal) and (child_age is medium) and (family_implication is moderate)THEN weekly_session_number is normal*

min (0.62, 0.5, 1.00) = **0.50** for linguistic term **normal**

Final confidence coefficients levels are obtained using max function:

- **high** = *max (0.00)* = **0.00**
- **low** = *max (0.25, 0.37)* = **0.37**
- **normal** = *max (0.25, 0.50)* = **0.50**

Each linguistic term of output variable has another representation and in this manner is obtained final graphical representation of weekly_session_number variable. If system user wants to get a single output value, then area center of gravity is calculated. In our case (value 1.62), child must participate at one to two session (but two is preferred).

IV. KNOWLEDGE BASE VALIDATION

In order to validate obtained inference engine, we develop a specific interface (Figure 9).

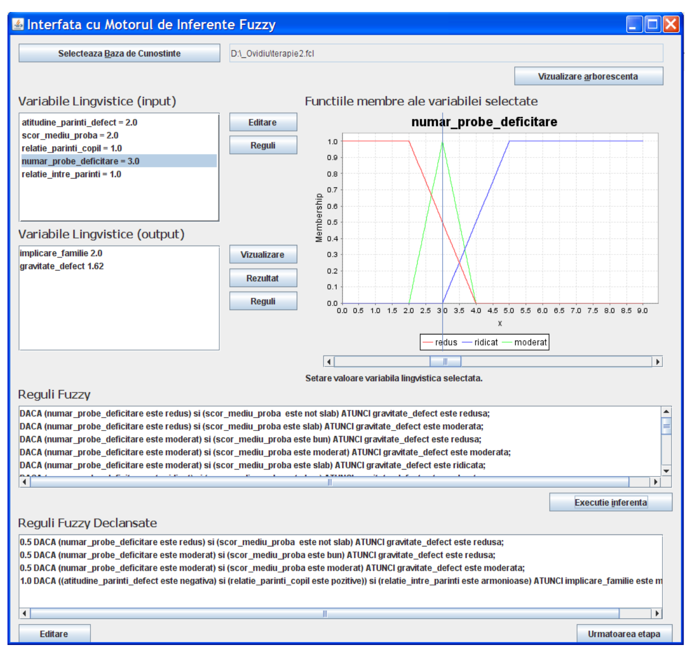

Fig. 9. Expert system validation interface.

This interface is detailed presented in papers [24]. We implement over 150 fuzzy rules for control various aspects of personalized therapy (19 variables presented in Figure 10). These rules are currently validated by speech therapists and can be modified in a distributed manner.

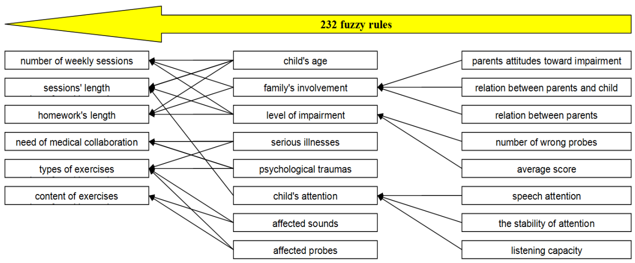

Fig. 10. Fuzzy variables used for expert system.

The objective of the research is to study the possibility of automatic selection of exercises during the training sessions, using a fuzzy expert system. We used an unifactorial experimental plan S10 < A2 > where *factor* is the choice of exercises.

This factor has two modalities: a1 - the selection of exercises is made at the beginning of the session by speech therapist and a2 - exercises are generated by the system expert.

As a dependent variable it was used the correctness of the pronunciation. This variable consists of the 9 test's results (scores from 1 to 5) obtained from children.

The subjects were 20 children, boys and girls selected from RSTC Suceava, with age between 5 and 6 years, with difficulties in pronunciation of R and S sounds. They were divided into 2 equivalent groups: control group - modality a1 of factor A and program group - modality a2 of factor A. Each child attends two meetings weekly and was rated weekly. The two lots were constructed so as to be equivalent in terms of characteristics (Table 1) and in terms of pretest assessment scores.

The research hypothesis was that the two modalities of factor A do not lead to different effects on the dependent variable (correctness of pronunciation).

The instrument used to measure dependent variables is an observation table, integrated in monitor program.

Because the small number of subjects in each group (under the limit of 30), scores' distribution was not in generally normal. That is why, statistic data were processed using nonparametric tests: *ManWitney* test for difference between groups and *Wilcoxon* for difference between pretest and posttest scores. According with experimental results, we can observe that:

- groups were parametrically and statistically equivalent (ManWitney, session 0);
- both groups have progressed (Wilcoxon);
- both groups have arrived at the same performance (ManWitney, session 24).

Because have not achieved significant differences between the two groups at the end of the 24 meetings, we may consider that the exercises' choice can be performed either by speech therapist or expert system. This result can be explained by the existence of a period of 6 months earlier, in which expert system has been tested. In this period, speech therapist has compared its decision with those suggested by the expert system and has adjusted knowledge base.

V. CONCLUSION

During the experiment were observed certain advantages of expert system utilization:

- speech therapist has possibility to be more concentrate on therapy because he
- don't spent time creating exercises (average time is 7 minutes per session);
- rigor and predictability.

Although we demonstrated our technique and experiment with the Romanian language only, we believe that the same methodology should lead to same improvements for other languages as well. We believe that the use of expert systems in the CBST is possible and add certain advantages. In the future we want to extend knowledge base to provide information about other aspects of therapy.

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