Translation of the Speech Therapy Programs in the Logomon Assisted Therapy System

Ştefan-Gheorghe PENTIUC[1], Iolanda TOBOLCEA[2], Ovidiu Andrei SCHIPOR[1],
Mirela DANUBIANU[1], Maria-Doina SCHIPOR[1]

Stefan cel Mare University of Suceava
str.Universitatii nr.13, RO-720229 Suceava
[2]*Alexandru Ioan Cuza University of Iasi*
pentiuc@eed.usv.ro, itobolcea@yahoo.com, schipor@eed.usv.ro,
mdanub@eed.usv.ro, vmdoina@yahoo.com

Abstract—**This interdisciplinary research was developed with a view to create and implement an intelligent informatics system for the treatment of dyslalic disorders, specific to the Romanian language (CBTS system – computer-based speech therapy), as a complementary speech therapy method, customised and client-oriented. The rules of the logotherapeutic guide have been expressed in pseudocode programs in order to allow a greater flexibility in expressing the logotherapeutic procedures in an informatics system. The pseudocode logopedic programs comprise the succession of stages of the therapeutic program from a speech therapy perspective, and based on what the expert system can achieve. The LOGOMON system is conceived in order to assist the physical therapist and the child during the entire therapeutic period, recording the main data related to the child, which proved to be useful in diagnosis and treatment. The experimental validation of the system proved that assisted therapy contributes to the improvement of classical therapy, to obtaining optimal results in correcting the dyslalic person's speech.**

Index Terms—**Computer Based Speech Therapy, Fuzzy Expert System, Personalized Therapy, Exercises for Dyslalia**

I. INTRODUCTION

At the level of the European Union, there is a high concern for the persons with pronunciation difficulties, which led to the emergence of several speech assisted therapy systems (CBTS - Computer Based Speech Training) both for commercial and research purposes. A CBTS is a system for training and developing speech in the case of persons with hearing or pronunciation deficiencies [1].

The idea to create a computer-based therapy in the case of pronunciation disorders, for the Romanian language, is based on two major premises:

1.　the proven efficacy of integrating computer-based programs within the classical speech therapy of dyslalia (educational and therapeutic software) for the English language, such as the OLP-Ortho-Logo-Paedia System, Laureate Learning Systems, etc.;

2.　the proven efficacy of introducing informatics methods within the speech therapy of some language disorders (stammering, logoneurosis, dyslexia-dysgraphia) for the Romanian language [2]:

   - *the LOGOPED 1.0 program* – computer programming of the method of re-education through reading for subjects with stammering;

   - *THE ECOPHONE* – experimental montage used to create the auditory feedback delay in logoneurosis;

   - *the DISLEX-TEST program* – computer-based program used in speech therapy of the dyslexic-dysgraphic;

The speech therapy systems can be used as clinical tools in the diagnosis stage and they can give feedback during the treatment. A CBTS system does not replace the speech therapist, but it can improve his/her work by guiding the therapeutic intervention, by repetitive tasks automation, and, last but not least, by providing informatics administration opportunities for all the necessary data, results and reports.

In order to reach the main objective of the project, the starting point was the classical CBTS architecture, which was improved, obtaining thus a specific CBTS system, specially designed for the Romanian language, called LOGOMON. This system comprises classical models such as the child data manager, the 3D articulation model, the homework manager (installed on the child's PC or PDA). Moreover, the proposed architecture contains a fuzzy expert system. The role of this module is to suggest the optimal therapeutic actions for every child (the number, the length and the content of the training sessions). For each subject, the expert system indicates the optimal set of exercises, based on certain information (tests results, various social, cognitive and affective parameters).

II. METHODOLOGY

The present paper will focus on the translation methodology of the classical speech therapy demarche into pseudocode programs, in the form of logigrams and decisional trees for the implementation of the therapeutic software in view of correcting the speech disorders. The elaboration of the rules of the therapeutic guide is essential to the development of an expert system for the customised therapy of language disorders. The objective pursued was the creation of an individualised system of pronunciation practice according to the disorder category, previous experience in pronunciation therapy and previous development of the child.

It was established that the rules of the therapeutic guide be expressed in pseudocode in order to allow a better flexibility in expressing the therapeutic procedures. The conditions for the elaboration of the pseudocode programs are:

1. detailed presentation of the classic logotherapeutic program organised in two stages: the general therapy stage and the stage of therapy specific to every sound;
2. presentation of the logotherapeutic program for each sound, exemplifying each procedure and technical type from a logotherapeutic point of view;
3. presentation of the speech therapy with a view to use it within a LOGOPEDIC-PSEUDOCODE PROGRAM that could allow the transposition of these procedures and techniques within an informatics program that the child could use in the impostation, consolidation and automation stages of the acquisitions obtained during the speech therapy sessions;
4. the establishment of a system of rules for the expert system that could allow the use of this program according to the deficiency category, previous experience in speech pronunciation and previous development of the child [3][4].

We should emphasize the fact that the elaboration of rules on the basis of which we could transpose the logopedic programs into therapeutic software, the establishment of decision trees and based on this to decide whether or not it is necessary to continue certain types of speech therapy exercises, represents indeed a premiere within the frame of the speech therapy of pronunciation disorders in the Romanian speech therapy.

The mixed team of psychologists and speech therapists had to analyse the complex programs of speech therapy in order to transpose into informatics the speech therapy procedures and to carry out a pseudocoded therapeutic program useful in the realisation of the expert system program. This expert system comprises two parts: a working program designed for the activities of the speech therapist with the child and a program to be used at home by the child, in order to practise and consolidate the acquisitions realised with the speech therapist during the treatment sessions. This pseudocoded speech therapy program comprises the succession of theoretical program stages, from a speech therapy perspective, and from what the expert system can do.

Starting from the model of the speech therapy programs (theoretical and pseudo-coded), specific logopedic programs have been created for each particular sound: each exercise from the general and specific therapy was exemplified, and they functioned as a basis for the set of exercises used by the expert system.

The pseudocoded therapeutic programs used in the creation of the expert system establish decision trees on the basis of a system of decision rules that takes into consideration the following variables: **the type of deficiency, the previous experience in pronunciation therapy, and the previous development of the chid.**

The therapeutic techniques specific to each type of dyslalia have been determined, both to the general methods and procedures: gymnastics and myo-gymnastics of the body and of the organs participating in the pronunciation, breath education and the education of the balance between inspiration and expiration, education of the phonematic hearing, as well as the specific methods for the realisation of sound impostation, consolidation and automation, according to the general scheme of the speech therapy intervention.

III. GENERAL SCHEME OF THE SPEECH THERAPY INTERVENTION

We consider that it is necessary to present the general scheme of the speech therapy intervention in order to detail the therapeutic stages and sub-stages that comprise many applications, exercises and speech therapy procedures that have to be carried out according to the phonematic structure of each sound deficiently pronounced or articulated.

On the basis of the therapeutic scheme, extremely detailed classic speech-therapy programs have been elaborated, and then, on the basis of the same structure, psudocode programs have been elaborated for the Romanian consonants (22 consonants: B, P, T, D, M, N, C, G.,F, V, L, H. S, Ș, Ț, Y, J, CE, CI, GE, GI, R.)

I. General therapy
　　I.1. Development of the general mobility (speech therapist)
　　I.2. (Development of the articulatory apparatus mobility)
　　　I.2.1. General exercises (software)
　　　I.2.1.1. face mobility (software)
　　　I.2.1.2. maxilla (software)
　　　I.2.1.3 oral cavity (speech therapist)
　　　I.2.1.4. lips (software)
　　　I.2.1.5. tongue (software)
　　　I.2.1.6. soft palate (software)
　　　I.2.2. Specific exercises (speech therapist, 3D image)
　　I.3. Exercises for developing a correct breath (software)
　　I.4. Phonematic hearing education
　　I.4.1 onomatopoeia (software)
　　I.4.2. sets of monosyllabic words with consonants correctly pronounced by the child, and close in pronunciation to the consonant deficiently pronounced (software)
　　I.4.3. pronunciation of opposed simple syllables (software)
　　I.4.4. differentiation of the sounds in paronyms (software)
　　I.4.5. transformation of the words by replacing sounds or syllables (software)

II. Specific therapy

II.1. Sound generation
II.1.1. Preparation (speech therapist)
II.1.2. Sound utterance
II.1.2.1. Demonstration of sound articulation (speech therapist, 3D)
II.1.2.2. Sound pronunciation by specific procedures (mechanic, by derivation) (speech therapist)
II.1.2.3. Practicing the sound pronunciation (software)

II.2. Sound consolidation
II.2.1.Into syllables (software)
II.2.1.1. pronunciation of direct syllables with sound prolongation

II.2.1.2. pronunciation of direct syllables

II.2.1.3. pronunciation of syllables in which the consonant occupies an intervocalic position

II.2.1.4. pronunciation of syllables with the deficiently pronounced sound placed in an intervocalic position, with different vowels

II.2.1.5. pronunciation of opposite syllables, with the prolongation of some sounds

II.2.1.6. pronunciation of opposite syllables, without prolongation

II.2.1.7. pronunciation of the consonant in logatoms, with consonants that are articulated in about the same place

II.2.1.8 pronunciation of the consonant in syllables closed by other consonants

II.2.1.9. pronunciation of the consonant in syllables with consonantal combinations

II.2.1.10.pronunciation of the consonant in syllables with difficult consonantal combinations

II.2.1.11. pronunciation of the consonant in syllables with final consonantal combinations

II.2.2.In words (software)

II.2.2.1. Pronunciation of the consonant in mono-, di-, and polysyllabic words

II.2.2.1.1. Monosyllabic words

II.2.2.1.2. Disyllabic words with a phoneme in initial position

II.2.2.1.3. Disyllabic words with a phoneme in intermediary position

II.2.2.1.4. Disyllabic words with a phoneme in final position

II.2.2.1.5. Polysyllabic words with a phoneme in initial position

II.2.2.1.6. Polysyllabic words with a phoneme in intermediary position

II.2.2.1.7. Polysyllabic words with a phoneme in final position

II.2.2.2. Verbal structures progressive by addition

II.2.2.3. Differentiation of sounds with a similar articulation point

II.2.2.4. Exercises with paronyms

II.2.2.5. Transformation of words by substituting sounds or syllables

II.3. Automation

II.3.1. Practice of the sound in sentences (software)

II.3.1.1. sentences with words having the consonant in initial position

II.3.1.2. sentences with words having the consonant in median position

II.3.1.3. sentences with words having the consonant in final position

II.3.2. Introduction of the sound into short texts (songs, poems, riddles) (speech therapist)

II.3.3. Storytelling and retelling starting from images (speech therapist)

IV. DESCRIPTION OF THE PROCEDURE

The procedure for the sound „ş" is presented as follows:

1. The speech therapist chooses the complexity level of the sentences, according to 2 criteria: a. the number of words $z \in [2, 4]$ and b. the number of Ş letters, q;

2. The speech therapist establishes the number of sentences for the chosen complexity level, $n \in [3, 7]$ (eg. The speech therapist chooses the sentences P1, P5, P17 from the category 2words + 3Ş);

3. The speech therapist establishes the number of repetitions for all the sentences, $i \in [2, 4]$;

4. The computer gives the child the following signal „Pronounce the first sentence (P1)";

5. The child pronounces the indicated sentence;

6. The computer assesses the child's pronunciation for each Ş that appears in the z words. The interval [0, 100%] is divided into q subintervals, where q is the total number of Ş sounds in the sentence (eg. 4). Each subinterval is then divided into 4 subintervals, exactly as in the previous procedures ([0, lim1], [lim1, lim2] etc.), each subinterval symbolising a petal, with the mention that, in this case, lim1 = 25% (not 33%), lim2 = 50%, lim3 = 75% (the subintervals are equal, 25% each). The maximum number of petals is 4q, in our example 4x4 = 16 petals.

7. The computer grants 1-4 petals for every Ş, at the end adding the petals and giving the child a feedback:

"Good job, you have obtained X petals from 4q!"

The process in the points 4, 5, 6 is resumed n times for the first sentence, and then the second sentence is introduced, following the steps 4, 5, 6, 7;

8. The computer uses the same procedure (the steps 4, 5, 6, 7) for all the n sentences, adding and memorising the total number of petals for the n sentences.

Decisions:

1. If $h \leq x$ % from 4q x i x n (for example 50%), go back to the WORDS procedure;

2. If $50\% < h \leq 70\%$, go back to the PROP procedure, with other examples of

propositions, of the same difficulty level;

3. If $h > 70\%$, go back to the PROP procedure, with a higher difficulty level.

V. THE LOGOMON SYSTEM

The psychological research was aimed at the identification of the essential aspects of dyslalia therapy. In the first stage, that of the Complex Examination, the speech therapist gathers the main data about the child, data intended to be used in diagnosis and treatment. A part of these data is obtained on the basis of the pronunciation tests (9 results for each deficient sound). The other part (over 50 variables) refers to cognitive, affective and social parameters.

The LOGOMON system is designed to assist the speech therapist and the child during the entire therapy. In its database there are over 1000 exercises conceived to support:

- the general therapy (mobility development, control of the breathing rhythm, development of the phonematic hearing);

- specific therapy (sound generation, consolidation and automation).

Each therapeutic stage contains a formative evaluation and it can be continued with the therapy in the family

environment. After a certain amount of time, the speech therapist can complete or reanalyse the therapy.

The expert system uses three types of information:
- social, cognitive and affective parameters (obtained from the complex examination);
- reports corresponding to homework;
- the test results and their development (obtained from the formative evaluation).

On the basis of this information (codified according to the fuzzy logics), the expert system provides an answer to the following questions:
- How often should the therapy sessions be organised?
- How long should each session be?
- What types of exercises should be used, and what should they comprise?

Figure 1 presents the main modules of the suggested architecture. Assisted therapy is based on the interaction between six functional blocks: the child, the speech therapist, the monitor program in the office, the expert system, the 3D model and the child monitoring program. This image also contains the informational fluxes of the system [5].

1. Between the child and the speech therapist there is a strong, interpersonal connection. All the other modules aim at optimising this relationship.
2. The monitoring program allows the introduction of the information corresponding to the complex examination and gives the possibility to periodically record the children's pronunciation. The child receives immediate audio feedback and can listen to previous recordings.
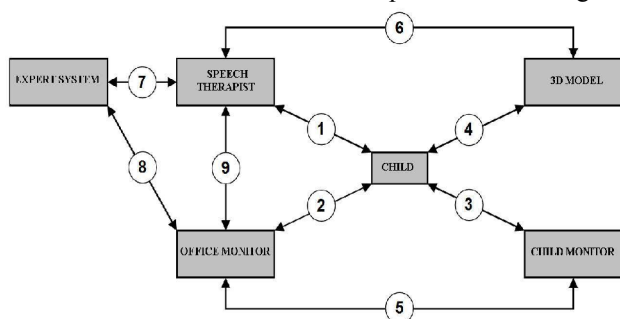

Figure 1. Architecture of the LOGOMON system.

3. The role of the monitoring program to be used at home is to create a virtual interface between the speech therapist and the child (therapy within the family environment). This component is implemented both for the PC and for the PDA. It can reproduce the exercises in the form of games; it gives feedback and provides statistic information.
4. The 3D model gives the opportunity to visualize the correct positioning of the tongue, lips and teeth for each sound. The child can modify the transparency of these items.
5. The monitoring program realises the transmission of the homework to the child's PC or PDA. Subsequently, when the child returns to the medical office, this program can take over the activity report.
6. The speech therapist analyses the images provided by the3D model and includes them into the therapeutic demarche. Also, he can create new and more suggestive

positions, from various angles and with different degrees of transparency and at certain points of sound generation. These positions can be saved under suggestive names and used later on.

7. (If activated,) the expert system provides suggestions concerning certain parameters of the therapeutic evolution, such as frequency, length and content of the sessions, on the basis of certain input variables. Should the therapist notice wrong conclusions, he could visualise the inferential chain and modify the knowledge base (ongoing learning) [6].
8. The expert system takes the input data from the monitoring program and generates (on demand) sets of customised exercises.
9. The monitoring program (figure 2) is an interface between the speech therapist and other components such as the database, the expert system and the monitoring program of the child. At this level, the speech therapist can gather textual and audio information concerning the child, it can administer the exercises and manage all the aspects of the treatment (selection of the subjects, programming for the therapy, obtaining statistical reports demanded by the functioning of the Logopedic Centre).

The main results of the LOGOMON project are [7]:
- formalisation of the dyslalia treatment and the realisation of a therapeutic guide;
- an improved CBTS architecture, by including a fuzzy expert system, adapted to the Romanian language;
- a monitoring program with all the necessary management facilities included;
- an animated 3D model for the correct sound pronunciation presentation;
- an expert system that gives suggestions concerning certain parameters of the personalised therapeutic demarche, such as sessions frequency, length, and content;
- a mobile device (PDA) for therapy follow up within the familial environment;
- over 20 types of exercises, over 1000 exercises created on the basis of over 1500 image files and over 10000 sound files;
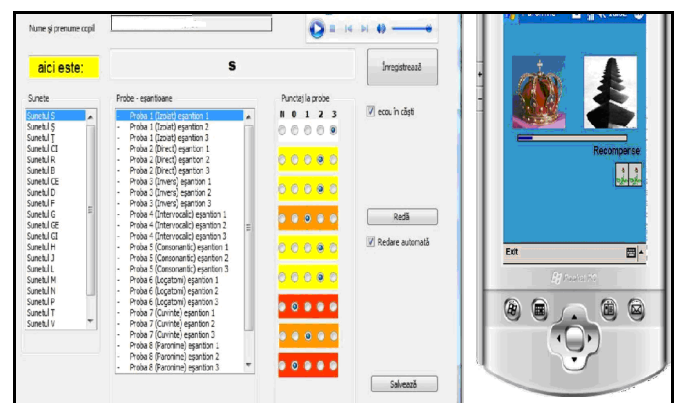

Figure 2. Examples of child interfaces (assessment, PDA exercise, 3D model).

In order to continue the preparation outside the sessions with the speech therapist, and keeping at the same time the continuity and the coherence of the therapeutic process, a

mobile device was created (figure 2). One of the most important functions of the Logopedic Mobile Device is the recording / playback of the audio samples. Since the available RAM is reduced, the choice of the audio compression codec is extremely important. Therefore, the compression algorithm IMA-ADPCM was implemented in C language (with the help of the GCC compiler, specific to the Microblaze processor) [8].

For the evaluation, the following techniques were used: playing the .wav files specific to the Windows environment, recording with the help of the mobile device, data transfer toward and from the PC with the help of a RS232 connection.

VI. CONCLUSION

The CBTS systems must allow the adaptation and the refinement of the exercises according to the pronunciation deficiency level and the child's motivation expressed during the therapeutic sessions. A computer-based system must comprise exercises for all the sounds/phonemes [9].

The speech-therapist cannot be replaced and has to be present during all the treatment stages (evaluation, generation, consolidation, automation).

Speech automation involves repetition of the sound, until it can be uttered spontaneously, without the patient being aware of the basic pattern. Usually, this goal cannot be achieved through the exercises during the speech therapy sessions alone. Therefore, the creation of such a system of monitored practicing of the deficiently pronounced phonemes without the physical presence of the therapist is extremely useful to the therapeutic success.

The LOGOMON system supports speech development. The speech therapist does not only correct the phonetic difficulties, but he also selects the general structuring of language and the development of the linguistic skills out of a diversified material. The material used by the LOGOMON system is related to the everyday experiences of the children, and adapted to the subjects' age and gender. The

experimental validation of the system proved that assisted therapy is superior to classic therapy.

REFERENCES

[1] Tobolcea, I. (2001), Tehnici audio-vizuale moderne în terapia logonevrozei [Modern Audio-visual Techniques Used in the Treatment of Logoneurosis], Ed. Spanda, Iaşi;
[2] Tobolcea, I., (2002), Intervenţii logo-terapeutice pentru corectarea dislaliei la copilul normal [Logotherapeutic Interventions for Correcting Dyslalia in the Normal Child], Ed. Spanda, Iaşi;
[3] Vadim Mukhin, Elena Pavlenko, Adaptative Networks Safety Control, Advances in Electrical and Computer Engineering, Suceava, Romania, ISSN 1582-7445, No 1/2007, volume 7 (14), pp. 54-58.
[4] Bui Ta Long, D.V. Olinici, V.F. Krapivin, Expert System for the Water Quality Control in the Estuary Zone, Advances in Electrical and Computer Engineering, Suceava, Romania ISSN 1582-7445, No 1/2004, volume 4 (11), pp. 5-8.
[5] Pentiuc, S.G., Schipor, O.A., Danubianu, M., Schipor, M.D. (2008), Therapy of Dyslalia Affecting Pre-Scholars, in: Proceedings of Third European Conference on the Use of Modern Communication Technologies - ECUMICT, Gent, Belgium.
[6] Schipor, O.A., Pentiuc, S.G., Schipor, M.D. (2008), Knowledge Base of an Expert System Used for Dyslalic Children Therapy, in: Proceedings of Development and Application System International Conference, Romania, pp. 305-308.
[7] Danubianu M., Pentiuc, S.G., Schipor, O.A., Nestor, M.T., Ungurean, I., (2008), Distributed Intelligent System for Personalized Therapy of Speech Disorders, in: Proceedings of ICCGI08 International Conference, Atena, Greece.
[8] Cerlinca, M., Graur, A., Pentiuc, S.G., Cerlinca, T.I. (2007), Developing a Logopaedic Mobile Device Using a FPGA, in: Proceedings of SACI '07. 4th International Symposium on Applied Computational Intelligence and Informatics, Romania, pp. 89-92.
[9] Tobolcea, I., (2007), Sisteme informatice pentru asistarea logopedului în stabilirea terapiei personalizate a tulburărilor de limbaj [Informatics Systems Used for Assisting the Speech Therapist in Establishing the Individualised Treatment of Speech Disorders], in Sisteme distribuite, Editura Universităţii, Suceava.