Logo-DM – A Speech Therapy Optimization Data Mining System

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***Abstract*— This paper presents Logo-DM, a prototype for a data mining system dedicated to help the optimization of the personalized speech therapy. It uses data collected by TERAPERS system that was implemented at the "Stefan cel Mare" University of Suceava to assist speech therapists in the treatment of children suffering from dyslalia. Over these data, some data mining methods has been applied. The patterns obtained are useful for specialists for an efficient current activity. These can also provide knowledge that serves to improve the support offered by TERAPERS by raising the quality of its embedded expert system.**

Keywords-computer-based speech therapy; data mining; classification; association rules.

I. INTRODUCTION

Speech impairment, one of the most common issues in childhood, might be the source of adult's integration problems in the community. This is one of the reasons why a special attention was paid to speech therapy. A speech disorder can be corrected, if it is discovered and properly treated in due time. However, therapy is a complex process, which must be adapted to each child.

Since 1990-2000, computer-assisted speech therapy became a frequent practice. In this context, many Computer-Based Speech Therapy (CBST) tools or systems were developed.

For example, IBM has developed Speechviewer III system [1]. While users perform several speech actions, Speechviewer III creates an interactive visual model of speech. Another project is the ICATIANI device, developed by TLATOA Speech Processing Group, CENTIA Universidad de las Américas, Puebla Cholula, Pue, México [2]. It uses sounds and graphics in order to ensure the practice of Spanish Mexican pronunciation. The third example, Articulation Tutor (ARTUR) [3] provides an integrated speech therapy system. It contains two main components: an intuitive graphical interface named *Wizard-of-Oz* and a virtual speech tutor named *Artur*. Using 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).

The use of these systems has allowed researchers and practitioners to collect a considerable volume of data, related to children' particularities, therapeutically paths, and results. But, contrary to expectations, a large amount of data does not automatically lead to a significant increase of the volume and quality of information, because traditional data processing tools are not applicable.

For these reasons, modern methods that aim to discover new and potentially useful patterns from large volumes of data were implemented. This process is called Knowledge Discovery in Databases (KDD) [4]. Its central step is data mining that involves the application of algorithms, which with acceptable performance, provide a particular enumeration of patterns from data.

In 2008, at Research Center in Computer Science from "Stefan cel Mare" University of Suceava the TERAPERS system was implemented.

This is a CBST that aims to assist the personalized therapy of dyslalia – an articulation disorder found to a significant percentage of children from age of 3-4 years. This is the first CBST developed for Romanian language. During its exploitation, data about few hundred cases were collected. This was the starting point for the idea to try the optimization of personalized speech therapy by data mining techniques.

Our paper's purpose is to show an overview of the Logo-DM system – a dedicate data mining system, that aims to optimize the personalized therapy of Romanian children suffering from dyslalia.

This system is designed so that useful patterns can be easily discovered by speech therapists. They may use Logo-DM to analyze datasets obtained by integrating data collected in all speech therapy offices that use TERAPERS.

In Section II, some basic concepts related to the Knowledge Discovery in Databases and the position occupied by data mining stage within this process are presented. Section III refers to speech disorders and their implications on the individual's development. It highlights also the complexity of speech therapy. Section IV makes a brief description of the Logo-DM system. Finally, Section V contains some conclusion and future work.

II. KNOWLEDGE DISCOVERY IN DATABASES PROCESS AND DATA MINING

Knowledge Discovery in Databases concept was developed as a result of the emergence of very large volumes of data, whose analysis was not possible by using traditional database techniques. It aims to identify "valid, novel, potentially useful, and understandable patterns in data" [4], and is a complex, interactive and iterative process.

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In time, many models for this process have been proposed. No matter if they originated from academia [4], [5], [6] or industry [7], [8] they consist of a succession of steps, that start from the understanding the domain and the data that is represented, continues with the preparation of data for data mining algorithms and their effective implementation in order to detect existing patterns, and ends with the interpretation of these patterns.

We used for our system design and implementation CRISP-DM model, presented in Fig. 1.

It starts with a business analysis for determining the KDD goals and continues with a data understanding stage that aims to collect and describe data and to verify data quality.

In order to give data set the proper format for a certain data mining algorithm, a data preparation step is necessary. During this step data are filtered and the relevant features are selected. Data type transformation, discretization or sampling is performed also.

The central point of KDD process is the data mining stage. Data mining performs analysis of large volumes of data using specific algorithms. These are designed to offer good performances of calculation on large amounts of data, and produce a particular enumeration of patterns from such data. Using patterns or rules with a specific meaning, data mining may facilitate the discovery, from apparently unrelated data, of relationships that are likely to anticipate future problems or might solve the problems under study. It involves the choice of the appropriate data mining task, and, taking into account specific conditions, the choice and the implementation of the proper data mining algorithm.

For the next stage, the mined models are evaluated against the goals defined in the first stage. The last stage of the process uses the knowledge discovered in order to simply generate a report or to deploy a repeatable data mining process.

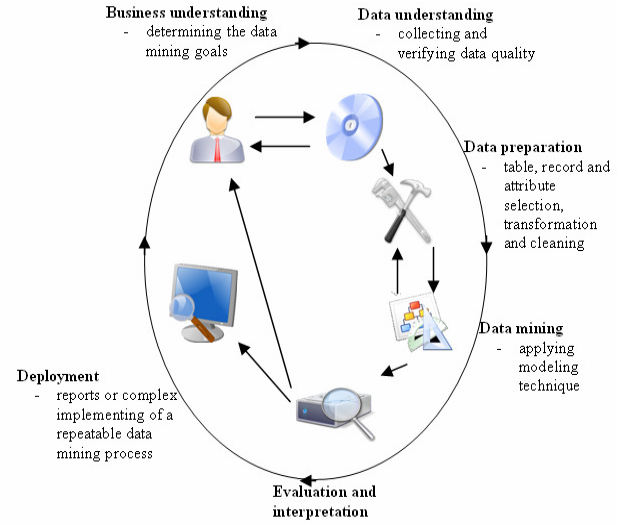

Figure 1. CRISP-DM model for KDD

So, data mining aims to discover, from apparently unrelated data, relationships that can anticipate future problems or might solve the problems under study. Using appropriate methods, data mining is able to provide answers for two wide categories of problems: prediction and description.

Although, many researchers believe that prediction is the main use of the patterns discovered by data mining, it should be noted that often it is preceded by the description. For example, prior to predict the state of a patient at certain moments, it is necessary to make a description of the profiles encountered and to find the best association between these profiles and different therapy schemes.

Both problems require the use of appropriate techniques.

Classification aims to find a model, which places data items in one of several predefined classes, based on information from a set of predictive variables.

Association rules explore relationships or affinities between different data that seem to have no dependencies.

III. SPEECH DISORDERS AND SPEECH THERAPY

Speech and language impairments address problems in communication and related areas, such as oral motor function [9]. A speech disorder is a problem with fluency, voice, and/or how a person says speech sounds.

Classification of speech into normal and disorder is a complex task. Statistics points out that only 5% to 10% of the population has a completely normal manner of speaking, all others suffer from one disorder or another.

The most common speech disorders are: stuttering, cluttering, voice disorders, dysartria, and speech sound disorders.

Dyslalia is defined as the articulation disorder that consists of difficulties in the way sounds are formed and strung together. The most encountered problems are characterized by omitting, distorting a sound or substituting one sound for another.

Dyslalia has the greatest frequency among handicaps of language for psychological normal subjects as well as for those with deficiencies of intellect and sensory. Thus, the opinion of Sheridan (1946) is that at the age of eight years dyslalia are in proportion of 15% for girls and in proportion of 16% for boys. In this context, a lot of attention is paid to its prevention and treatment.

In order to obtain the desired results, speech disorder therapy should begin as soon as possible. More studies have demonstrated that if children are enrolled in therapy early in their development, this means younger than 5 years, their outcomes are better than those who begin therapy later.

Differential diagnosis decides upon the therapy for correcting language, as psycho diagnosis allows an adequate therapeutic program, and the elaboration of a prognosis regarding the evolution of the child, along with the therapeutic process. The therapy has to be adapted to each language therapist, to each particular case, to the child's learning rhythm and style, as well as to the level of the impairment. The key issues in dyslalia therapy are shown in Fig. 2.

Modern speech therapy was deeply influenced by the use of Information and Communication Technology (ICT).

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On the one hand, the use of computers and other communication tools facilitated communication among persons with speech disorders. On the other hand, computers were used in speech therapy, contributing to the acquisition of written and verbal language, helped by various computer-based programs and software.

Analyzing how it is possible to use the computer to support therapy, experts have concluded that it can contribute to the diagnosis of speech disorder, produces audiovisual feedback during the treatment, monitors and assesses the therapeutic progress and provides various types of practical exercises for children with speech disorders.

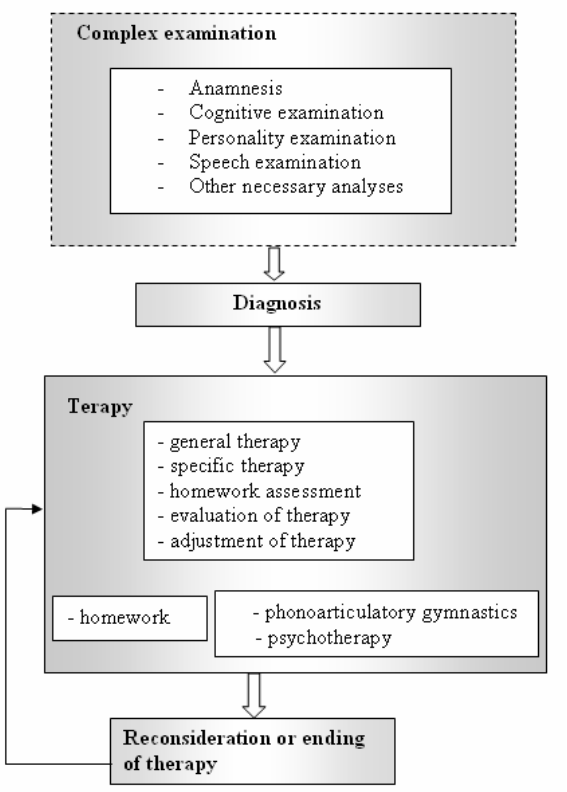

Figure 2. Key issues in dyslalia therapy

Additionally, the use of a CBST allows to collect and store a considerable amount of data about patients, diagnoses and treatment schemes.

The Center for Computer Research in the University "Stefan cel Mare" of Suceava has implemented the TERAPERS project [10]. TERAPERS is a system able to assist teachers in speech therapy of dislalya and to track how the patients respond to various personalized therapy programs. It contains two main components, as shown in Fig. 3: intelligent systems deployed on computers located in the speech therapists' offices and more mobile devices used by patients in order to solve the independent homework.

This system is currently used by the therapists from Regional Speech Therapy Center of Suceava.

During the operating period, data about 300 children were collected and stored in the TERAPERS' database, which includes about 60 tables and several hundreds of features.

Anamnesis data collected may provide information relative to various causes that may negatively influence the normal development of the language. It contains historical data and data provided by the cognitive and personality examination.

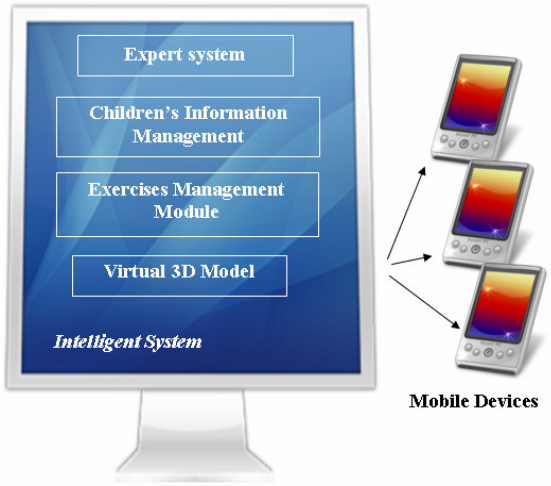

Figure 3. TERAPERS' Architecture [11]

In order to design personalized therapy programs, is useful to know: how many sessions per week are necessary for each child, exercises that are suitable for each phase of therapy, and how can be changed the original program in order to be adapted to the patient evolution. In addition, the report downloaded from the mobile device collects data on the efforts of child self-employment. These data refer to the exercises done, the number of repetitious for each of these exercises and the results obtained. The tracking of child's progress materializes data that indicate the moment of assessing the child and his status at that time.

All these data can hide useful patterns, which are very useful in personalizing speech therapy, and that could be detected using appropriate data mining techniques.

Clustering may group people with speech disorders on the basis of similarity of different features and allows creating some patients' profiles. This is a way to help the therapists to understand who they patients are.

Classification places people with different speech impairments in predefined classes. Based on the information contained in many predictor variables, such as personal or familial anamnesis data or related to lifestyle, it can be used to join the patients with different segments and to track the size and structure of various groups.

The goal of association rules mining is to identify combinations of items that often occur together. In the personalized speech therapy area, its task is to determine why a specific therapy program has been successful on a segment of patients with speech disorders and on the other was ineffective.

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Those mentioned above, were the basis of the initiative to develop a data mining system, dedicated to support efforts to better personalize the speech therapy.

IV. LOGO-DM - A DATA MINING SYSTEM FOR SPEECH THERAPY OPTIMIZATION

A. System Objectives

The sustainable development, in which special attention is given to all aspects of health care and the need to respond to the high efficiency requirements have led to the need for handling information, such as [12]: "what is the predicted final state for a child or what will be his/her state at the end of various stages of therapy, which are the best exercises for each case, and how patients can focus on their effort to effectively solve these exercises, or how the family receptivity - that is an important factor in the success of the therapy - is associated with other aspects of family and personal anamnesis". For all of these, the answer may be obtained by applying data mining techniques on data collected by TERAPERS.

It is also interesting to try to enrich the knowledge base of expert system embedded in TERAPERS, with knowledge discovered in data mining process. In order to achieve these goals, we have proposed the development of Logo-DM system.

Essentially, its objectives aim to perform an analysis of available data collected from children assisted by TERAPERS system and to prepare them in order to assure a proper quality for data mining algorithms, to try to select only those features that contribute to the model building by removing those that are irrelevant or redundant, to choose the most appropriate methods and algorithms for data mining, to find models that can help to solve problems raised in speech disorders therapy, and to validate these models on new cases.

It is worth mentioning that the patterns, represented as rules, provided by Logo-DM, could, after some post-processing operations, be used to enrich the knowledge base of the embedded expert system in TERAPERS.

Although, market claims many systems that allow data mining implementation, such as Weka and RapidMiner, their use implies IT skills. Our system is designed so that patterns can be easily discovered by speech therapists. They process a real dataset obtained by integrating data collected by all speech therapists that use TERAPERS.

B. General Architecture

The proposed architecture for Logo-DM system is presented in Fig. 4.

The graphical user interface allows the successive operations required by the knowledge discovery process.

The preprocessing module prepares data for data mining algorithms and performs data transformation and feature selection for patterns building. These operations can be made both in centralized, distributed, or parallel ways.

In order to achieve the proposed goals, the data mining kernel performs classification and association rules mining. Finally, the extracted models are evaluated by experts. If they meet the requirements of novelty and utility, they are considered knowledge.

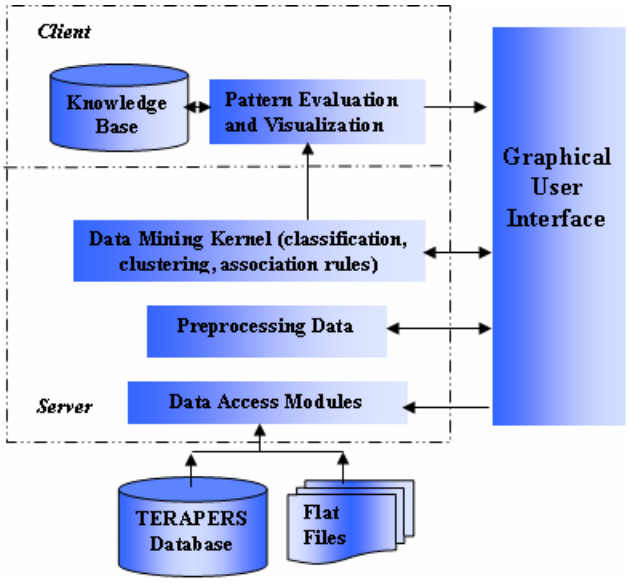

Figure 4. Logo_DM Architecture

C. Sistem implementation

As previously mentioned, the graphical interface connects the system with the speech therapist, which is able to control the KDD process. The access can be achieved through menu options or, for the most common tasks, via shortcuts, as presented in Fig. 5. It should be noted that the following figures contain Romanian texts, because they are screenshots from Logo-DM, which is implemented in Romanian.

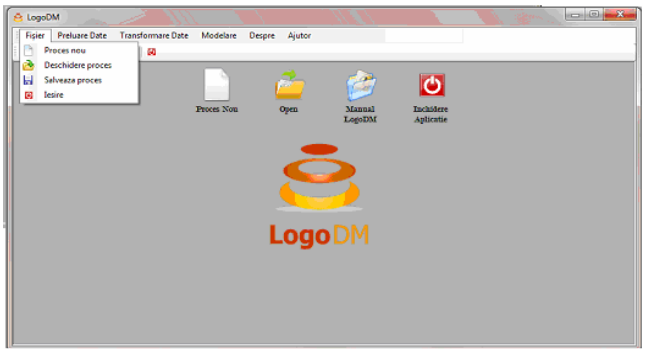

Figure 5. Logo-DM- Main page

The main source of data for Logo-DM is the database from TERAPERS, which is implemented in Access. In these conditions, modules for data acquisition from Access were implemented, as shown in Fig. 6. If other data sources are required, data can be retrieved from Excel, if they were previously converted in this format.

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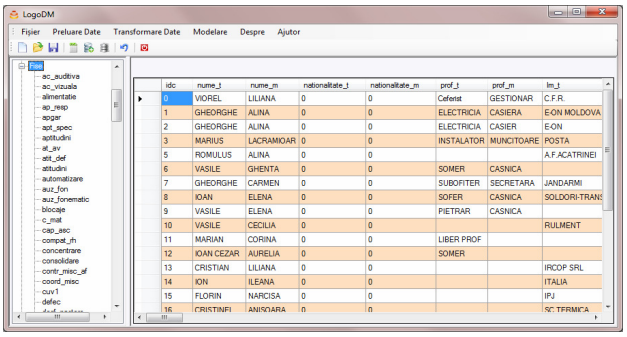

Figure 6. Logo-DM – Data aquisition

In order to implement the data transformation, we have considered operation, such as: data type conversion, data discretization, or role setting as shown in Fig. 7.

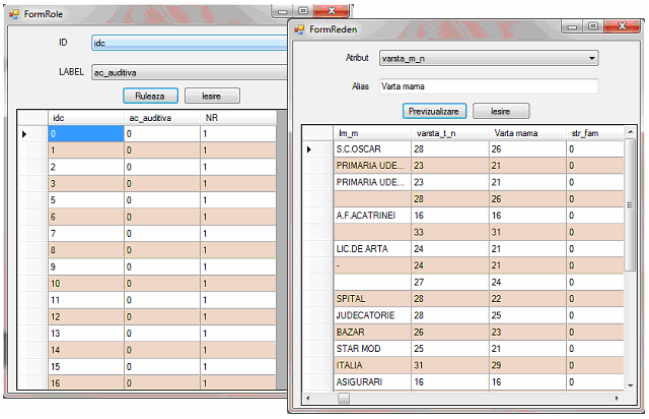

Figure 7. Logo-DM – Data transformatiom

For the first version of the system, we have considered, as modeling techniques, classification, and association rules mining.

For convenience of operating, interfaces have been dedicated exclusively to methods that, after some tests made during the implementation, have been shown to provide the best performance over a sample of real data set.

As shown in Fig. 8, for classification were considered: rules-based classification, decision trees, classification by association rules (CBA) and the CART algorithm.

For association rules, we used an implementation of the Apriori algorithm to detect frequent itemsets from which, subsequently, we build association rules. Obviously, it is possible to adjust the values for support and confidence. It is also possible to choose, from a set of items, those that will be contained in the rules or will be placed in the rule's consequent. Fig. 9 shows the interface that allows all these operations.

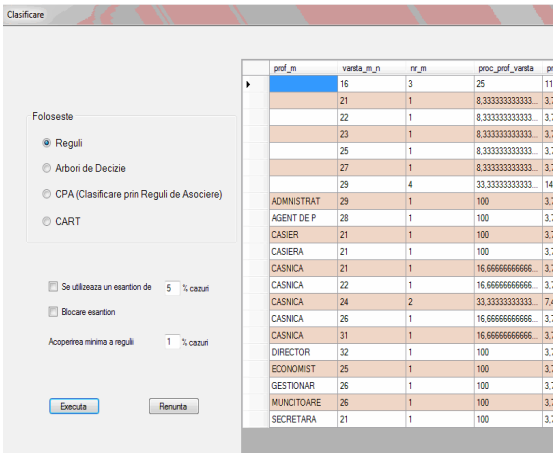

Figure 8. Logo-DM – Classification interface

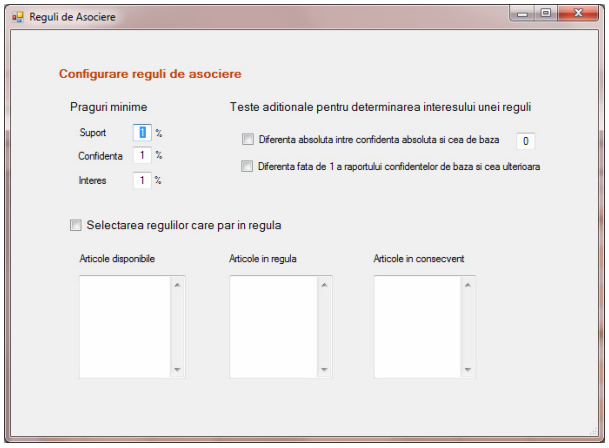

Figure 9. Logo-DM – Association rules mining interface

D. *Experimental Results*

In present, we are at the stage where, although the amount of data is still low for data mining, the system can be tested on the available data.

At this point, we have considered a real data set containing more than 300 cases described by 102 features related to personal and familial anamnesis and to complex speech examination, expresed in Romanian terms. After the feature selection process achieved through an unsupervised information-based method [13], we have obtained a set of 52 relevant features.

Fig. 10 shows a decision tree built on this data set. It is a classification model in which class label is represented by the diagnosis. The calculated model accuracy, obtained using a test dataset that is about 10% from the training set is 56,67%, as shown in Fig. 11.

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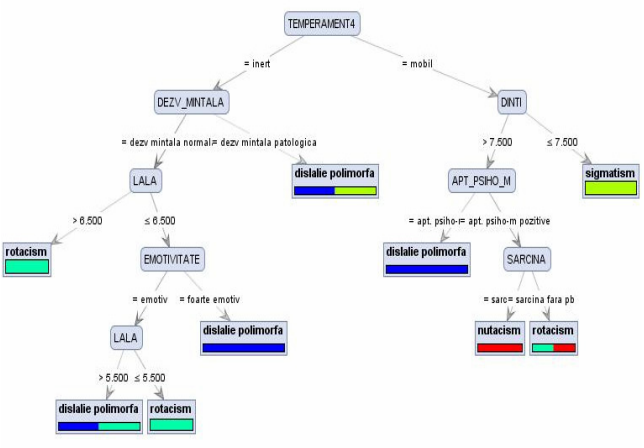

Figure 10. A classification model

PerformanceVector

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PerformanceVector:
accuracy: 56.67% +/- 28.09% (mikro: 56.52%)
ConfusionMatrix:
True:   dislalie polimorfa      rotacism        sigmatism       nutacism
dislalie polimorfa:     2       1       0       0
rotacism:       3       7       1       3
sigmatism:      0       0       4       0
nutacism:       1       1       0       0
classification_error: 43.33% +/- 28.09% (mikro: 43.48%)
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Figure 11. Classification performance

Speech therapy experts have analyzed this model and admitted that in addition to the complex examination of language, there are features related to the child's evolution or temperament, such as excitement ("emotivitate") that may lead to a specific diagnosis, such as :"dislalie polimorfa", or "rotacism", or "stigmatism", as shown in pattern presented above.

V. CONCLUSION AND FUTURE WORK

Speech therapy is a complex process that must be personalized according to the characteristics of each patient, especially since they are in very high proportion children.

The use of information technology in order to assist the speech therapy has some immediate benefits and allows the collection of a considerable amount of data related to personal and familial anamnesis, to the complex evaluation, to the therapeutically applied schemes and to the results of the various stages of therapy.

Studies have shown that it should be appropriate to apply some data mining methods on these data, such as classification, clustering, and association rules, because they lead to patterns that can increase the efficiency of speech therapy.

In this paper, we have presented the first version of a data mining system, called Logo-DM that was implemented on data collected by TERAPERS system. Its aim is to try to increase the efficiency of therapy of dyslalia that is assisted by TERAPERS.

Furthermore, we have proposed to finish testing the association rules mining, and to complete the data mining kernel with clustering algorithms.

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