Intelligent Classification System for Childhood Neurodevelopmental Disorders

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ABSTRACT

The diagnosis of neurodevelopmental disorders in children from 0 to 18 years of age is an extremely complex process which involves the participation of professionals from various medical specialties. Late detection and treatment of these disorders can lead to significant complications in educational development, social interactions, as well as mental health, generating stress and other difficulties in both children and their families. Access to specialized personnel for the diagnosis of these disorders becomes complex, in particular in developing societies, therefore teachers who interact directly with these children in educational centers require tools that facilitate the early detection of these cases so that they can be attended to by the different institutions or multidisciplinary groups dedicated to this purpose. Therefore, the objective of this research is to develop a computer tool for mobile devices that allows teachers and family doctors to obtain a preliminary diagnosis of neurodevelopmental disorders in childhood. In this paper we have applied several research methods, i.e., Analysis-Synthesis, modeling, system approach, interviews with experts, and a comparative study, in order to determine the accuracy of the diagnostic agreement to validate the use of the application in the diagnostic process.

CCS CONCEPTS

• **Information systems → Expert systems**.

KEYWORDS

App, Healthcare, Diagnosis Mental Disorders

1 INTRODUCTION

The classification of diseases aims to facilitate the collection of medical information to study the treatment of patients with a certain diagnosis and for follow-up studies.

The first attempt at classification was made more than 300 years ago by John Graunt in England, when creating the first mortuary tables. After several attempts, in 1883, the World Health Organization (WHO) presented the first International Classification of Diseases, and it was not until the Second World War that the WHO began a periodic classification system in which the criteria and nomenclatures were identified under the participation of experts from different countries, who help medical personnel to establish the causes and manifestations of different diseases [3].

The International Classification of Mental Disorders (DSM-V) in its chapter five, in its 5th edition appears a section dedicated to "Diseases of the Nervous System and the Senses Organs", since then, this section has been subjected to different updates. On the other hand, in the International Classifier of Diseases (ICD-10), chapter five is dedicated to Mental and Behavioral Disorders. Among the changes produced regarding the previous one, the following stands out: the expansion of the system of categories grouped into very practical criteria from the etiological, evolutionary or prognostic point of view. This version is probably the most used, intended for general clinical, teaching and administrative purposes, containing clinical descriptions and guidelines for the diagnosis of each of the coded disorders [3].

Based on the International Classification of Diseases, each country has the possibility of developing its own glossaries, in accordance with its practical and professional interests, as long as the basic and essential contents are not modified. In Cuba, the glossaries have evolved, since 1974, in their first version, to the current one, prepared from the CIE 10. The specialists have several classification manuals, which, despite having elements in common, also have their differences [3].

According to the WHO, neurodevelopmental disorders are cognitive and behavioral disorders that arise during the period of development and that involve significant difficulties in the acquisition and execution of specific intellectual, motor, language or social functions [10].

In Cuba, children with neurodevelopmental disorders are detected through the following means:

- The Diagnosis and Guidance Center, which consists of a multidisciplinary group of specialists that allow a child from 1 to 18 years of age to be evaluated psychopedagogically.

- The school institution, where there is teaching and psycho-pedagogical personnel who identify children who, due to their behavior or school difficulties, have manifestations associated with neurodevelopmental disorders, these children can be referred to specialized care centers, (where they are diagnosed, guide treatment, intervention actions are applied, and it is assessed whether they require assistance from a Special Education Center) or they remain in primary education where they can receive specialized care, always with the consent of the parents.
- The family doctor, from the office in the community, has the task of characterizing the entire population he/she serves.
- The Provincial Consultation for Neurodevelopmental and Child Disability is a service in which 11 specialties participate (Neonatology, Genetics, Psychology, Neurology, ENT, Ophthalmology, Speech-phoniatry, Physiatry, Orthopedics, Neurophysiology and Psychiatry) works on the diagnosis of children from 0 to 6 years old who present neurodevelopmental disorders and offers personalized attention according to the result obtained.

Despite the different routes that exist, the most expeditious and frequent is through the family doctor's clinic, with the dispensary and screening of the child population and the diagnosis made by the teaching staff in school institutions, where they interact frequent with children from 3 years of age, from their connection to the children's circle and/or the Educate your Child program until Basic Secondary School. For the diagnosis of neurodevelopmental disorders, a multidisciplinary team or a deep mastery of the clinic associated with each of them is required, which are also corroborated through a clinical diagnosis, psychological, psychometric and neurophysiological examinations. From the above, we conclude that both the teaching staff and the family doctor do not have specialized knowledge for the detection of neurodevelopmental disorders and its late diagnosis can lead to difficulties in academic performance, problems in social relationships, difficulties in emotional development, limitations in early attention to specialized services, increased stress and anxiety, among other factors.

Based on the above, we have developed an application for smartphones that helps to detect a preliminary diagnosis of children with neurodevelopmental disorders, taking as a reference the signs and clinical manifestations, allowing educators to use it with students and enabling early detection of potential disorders.

In this paper, we aim to argue the criteria considered for the development of a computer tool for mobile devices that allows the preliminary diagnosis of neurodevelopmental disorders in childhood.

2 BACKGROUND

2.1 Disease classifiers (Neurodevelopmental disorders)

According to the bibliographical consultation we have carried out, neurodevelopmental disorders are classified as [7]:

- Intellectual disability
- Communication disorders
- Autism spectrum disorders
- Coordination or motor development disorder
- Attention deficit and hyperactivity disorder
- Specific learning disorders

In the analysis we carried out, thanks to the DSM-V, ICD 10, and GC-3 classifiers, we identify the common characteristics of subjects with neurodevelopmental disorders in childhood.

- They present difficulties in the development of motor, cognitive, emotional, and social skills.
- The cognitive processes most affected are language, communication, attention, and memory.
- They present difficulties in the development of executive functions that involve planning, organizing, regulating behavior, solving problems, and making decisions.
- They often have problems adapting to new or unexpected situations such as communication, self-care, home life, social interaction, use of community resources, self-direction, health, and safety.
- They may present repetitive or stereotyped behaviors.

Depending on the content of the classifiers, there are some differences in the classifications. The disorders identified in each of the documents consulted are summarized in table 1.

As can be seen in the naming and assimilation of developmental disorders in each document, their internal structure and description tend to change. The DSM-V, which is the best known by teaching staff in educational institutions, has a specialized vocabulary from the health sciences, which makes it difficult to understand. On the other hand, the ICD-10 used to date by medical personnel includes exclusions and inclusions for each diagnosis and conceives the combination of several disorders in the same subject. Intellectual disability is addressed separately from "Generalized and Specific Developmental Disorders." . It is valid to clarify that since February 2024, the ICD-11 has been available, which contains updates on the different disorders. Finally, the GC-3 is supported by the ICD-10 and DSM – IV is currently the reference in Latin America for the treatment of psychiatric diseases. It is very similar to the ICD-10, although in some cases it changes the names of the disorders, among other modifications. according to the context and development of medicine in Cuba.

2.2 Artificial intelligence and its applications in the diagnosis of diseases

The ability of a machine or computer system to perform tasks that normally require the intervention of human intelligence is what we call Artificial Intelligence (AI). This includes learning, adapting to new situations, reasoning, problem-solving, understanding natural language, etc. Artificial intelligence is based on algorithms and mathematical models that allow machines to imitate human thinking and make decisions. autonomously [5].

The interrelation between artificial intelligence and medicine is astonishing due to the variety of applications and the use of "diagnostic means, artificial intelligence techniques and various types of educational and management applications". Despite their impressive successes, offer only a pale image of what, which may represent the development of artificial intelligence for medical purposes [4].

ICD-11	DSM-V	GC-3
6A00 - Intellectual development disorders	Intellectual disability	F80 - Specific disorders of speech and language development
6A01 - Developmental speech or language disorders	Communication disorders	F81 - Specific disorders of the development of scholastic skills
6A02 - Autism spectrum disorder	Autism spectrum disorder	F82 - Specific disorder of the development of motor function
6A03 - Developmental learning disorder	Attention-deficit/hyperactivity disorder	F83 - Specific mixed developmental disorders
6A04 - Developmental disorder of motor coordination	Specific learning disorder	F84 - Pervasive developmental disorder
6A05 - Attention deficit hyperactivity disorder	Motor disorders	F88. - Other disorders of psychological development
6A06 - Stereotyped movement disorder	Other neurodevelopmental disorders	F89 - Disorder of psychological development unspecified
6A0Y - Other specified neurodevelopmental disorders		
6A0Z - Neurodevelopmental disorders unspecified		

Table 1: Neurodevelopmental disorders identified in the different classifiers analyzed.

Expert Systems (ES) can be considered as a subset of AI The name Expert System derives from the term "knowledge-based expert system". An Expert System is a system that uses human knowledge captured in a computer to solve problems that normally require human experts. Well-designed systems mimic the reasoning process that experts use to solve specific problems. Such systems can be used by non-experts to strengthen their problem-solving skills. ESs can also be used as assistants by experts. Furthermore, these systems can perform better than any individual human expert making decisions in a specific and limited area of expertise, called a domain [2].

Rule-based systems are a type of expert systems that work by applying rules, comparing results and applying new rules based on modified situation. They can also work by directed logical inference, either starting with initial evidence in a given situation and working toward a solution, or hypothesizing about possible solutions and going back to find existing evidence (or a deduction from a solution). existing evidence) that supports a particular hypothesis [1].

Expert Systems (SE) today constitute one of the most successful areas of application within medicine. SEs allow the knowledge of one or more human experts to be stored and used in a specific application domain. Its use increases productivity, improves efficiency in decision-making, or simply allows problems to be solved when experts are not present. An expert system refers to software capable of imitating the behavior of one or more human experts in solving specific problems; This has the characteristic of storing the knowledge of several experts and offering a solution, through robust algorithms and logic [8].

One of the main characteristics of an expert system is the ability to gain experience; that is, to learn in each of its previous tasks, collecting important information that will allow future searches or diagnoses to be more accurate and faster [6].

The proposed system has the operating structure shown in Figure 1.

3 MATERIAL AND METHODS

We followed the following stages to develop the research:

(1) Determination of the similarities and differences between the different disease classifiers used in Cuba.
(2) Description of neurodevelopmental disorders based on their clinical manifestations, defining exceptions and inclusions.
(3) Analysis of requirements of the diagnostic process in schools and family doctors.
(4) Application design and implementation.
(5) Implementation of decision trees technique for data processing.

The Extreme Programming (XP) development methodology is applied to prepare the proposal. This was selected based on its advantages:

- Early delivery of functional software, which is possible with progress in development in an iterative and incremental manner that guarantees optimal use of time.
- Adaptability to changes even in late stages of the development process.
- Effective communication and collaboration based on close collaboration between team members and clients.
- Improved quality and efficiency through frequent code reviews and unit testing, bringing more efficiency to the process.
- Constant customer feedback, which helps ensure end-user satisfaction [9].

Among the requirements of the intelligent classification system, the following were defined:

- Allow to select the clinical manifestations of the subject (child) to determine the diagnosis.
- Once the result is obtained, it can be saved in the app.
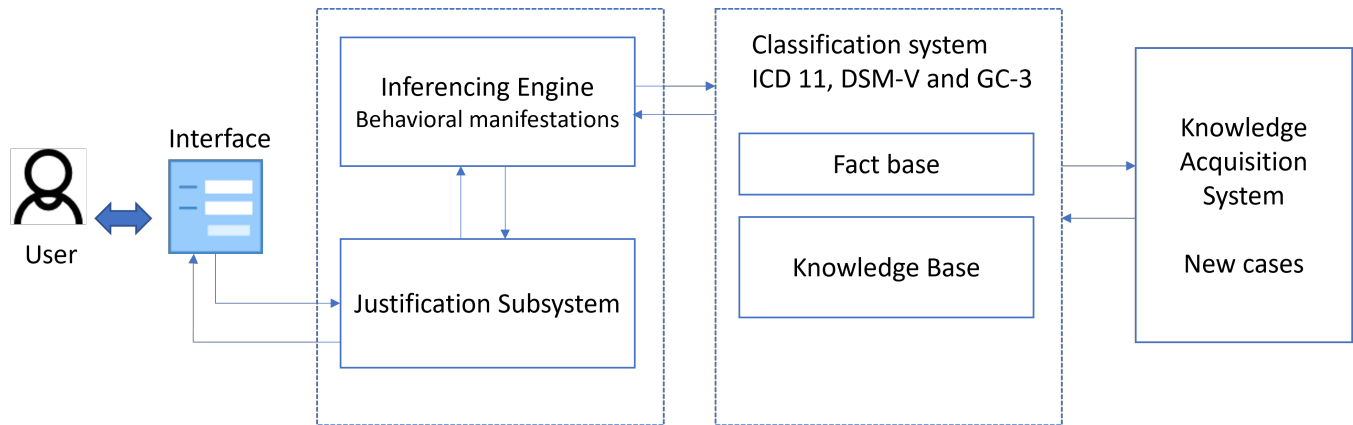- A subject may be subject to several evaluations.

Figure 1: Structure and operation of the intelligent classifier for the early diagnosis of Neurodevelopmental Disorders in childhood.

- Each disorder must be evaluated independently.
- The language must be clear and easy to understand by users (teachers and doctors).
- The app must have other functionalities that facilitate the user's work (contacts of specialized places for the treatment of neurodevelopmental disorders, access to a glossary with the meaning of medical terms that are difficult to understand, possibility of consulting the ICD-11 classifiers, DSM-5, and Cuban Glossary of diseases).
- The results must show the percentage in which the diagnosis of the disorder corresponds to the different levels of severity.

3.1 Interface Design

The interface design, shown in Figure 2, was conceptualized based on the topic in question, the type of user, the intended functionalities and usability in mobile applications.

According to the research topic, the color palette of green in different shades was selected. It has a top title bar where the system name appears. And the help icon, with a hamburger menu that gives access to the rest of the system's functionalities.

In the background, it has an image as a watermark that illustrates an electrical circuit in tune with the application of technologies and its association with the functioning of the brain. To access the functionalities, icons were designed that correspond to the functionalities they represent. On the home page you can access the description of neurodevelopmental disorders, the diagnosis, the list of consultations and polyclinics in Santiago de Cuba where these disorders are treated by specialized personnel; In addition, there are resources to deepen the study of the topic, including international classifiers and the Cuban Glossary of Psychiatry. The home page also has a slider that animatedly shows images associated with work in Cuban schools with children who have neurodevelopmental disorders and sensory disabilities.

The launch icon represents a brain and a magnifying glass, denoting the search for Neurodevelopmental Disorders with the acronym TND. Gear symbols are located around the brain that show the configurations that exist in the central nervous system that make each subject a unique being.

The diagnosis is made by the user through a questionnaire where they can mark the clinical manifestations observed in the subject, which will allow issuing a quantitative result that represents the percentage of confirmation of the disorder for each of its depth levels according to the selected demonstrations.

4 TECHNOLOGIES USED

4.1 Tools

For the development of the application, we used the Android Studio IDE, since it is the IDE by nature for the development of mobile applications, in this case Android applications.

Moreover, we used Java since it is the language for the Android development environment, which has numerous libraries and classes already implemented that speed up the programmer's work and ensure the efficiency of the code.

Last, but not least, we used Axure RP to create and design interfaces for the app, which is a cloud-based, on-premise prototyping solution designed to help organizations create software prototypes and functional wireframes without programming for send them to the developers.

4.2 System Architecture

The architecture shows the way the application is designed, where it is necessary to separate responsibilities, allowing for the specification of workforces. Architectural style defines the general rules of organization in terms of a pattern and the constraints on the form and structure of a large and varied group of software systems, more specifically. For this, five classes were defined (patient class, disorder class, depth degree class, diagnosis class1, and diagnosis class2). For the development of the system, a layered architectural style was used, specifically in two layers: presentation layer and business logic layer.

- **Presentation layer**: It communicates only with the business layer, transporting the necessary data or records. It contains the graphical interfaces of the program, which will allow the user to interact with the application.
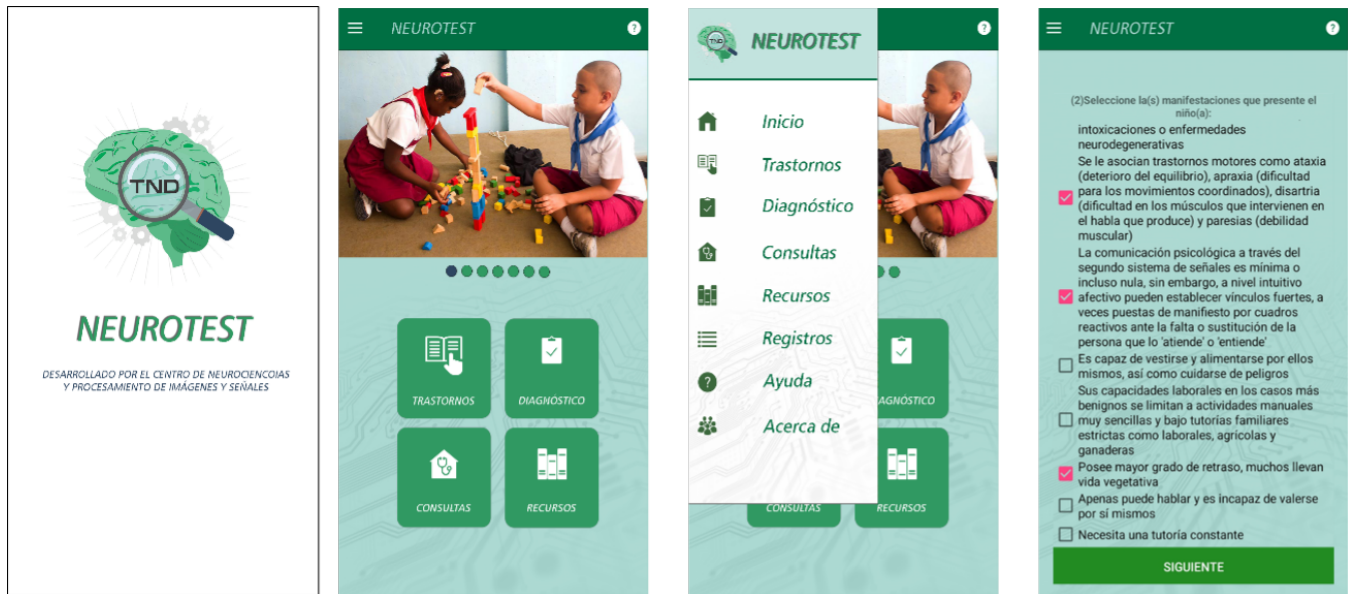
Figure 2: Interface designed

- **Logic layer**: This layer is where the functionalities that are going to be executed are located, user requests are received, and responses are sent after the process.

5 PRELIMINARY RESULTS

To validate the results, a test was designed with the objective of verifying the effectiveness of the classification obtained by the system from a study compared with diagnoses made by experts.

Subjects in special schools ranging from 3 to 11 years old were taken as a sample. Three speech therapists, four psychologists, two defectologists, and one psychiatrist participated. Each of them provided a list of five patients that they had treated in their professional experience, taking as reference the clinical manifestations evident at the time of the first consultation.

For the development of the comparative study, the following variables were defined to measure the effectiveness of the diagnosis made by the system:

- **Accuracy**: The overall accuracy of the system compared to actual diagnoses, considering both positive and negative diagnoses.
- **Diagnostic agreement**: The degree of agreement between the diagnoses of the intelligent classification system and the actual diagnoses made by expert personnel.
- **Diagnosis time**: The time required to obtain a diagnosis through the intelligent classification system compared to diagnoses made by expert personnel.
- **Diagnostic cost**: The economic cost associated with the use of the intelligent classification system compared to diagnoses made by expert personnel.

As per Table 2, our results show that our system reached only an 84% overal accuracy diagnose, compared to diagnoses made by experts. The results suggest that the sensitivity of the system for classifying children with neurodevelopmental disorders still needs to be further improved. However, although the accuracy is not high, the tool certainly may help teachers and doctors to early diagnosis or at least early detect potential disorders.

6 DISCUSSION

The disorder with the lowest level of accuracy index was Autism Spectrum Disorders, in this case it is more complicated, given its characteristics in which several disorders associated with the same subject can coexist. On the other hand, the time in which a result is obtained with the use of the system was considered. This variable, as well as the cost of the diagnosis, allows us to assess the economic feasibility of the path used, the average time to obtain the response after having selected the manifestations of the behavior of the subject being diagnosed, it is 0.08 seconds. Once the preliminary diagnosis for one disorder has been completed, another can be made for the same subject. The system's ability to reach a higher level of accuracy depends on the observation made by the user (teacher or doctor) and the user's ability to discern between one manifestation or another, selecting the one that best corresponds to the subject's behavior that is diagnosed.

The use of this intelligent classification system for the preliminary diagnosis of children with neurodevelopmental disorders will allow teachers who work in the Early Childhood, Primary, Special and Basic Secondary Education System, in addition to family doctors who work in the communities know the children who present manifestations associated with different neurodevelopmental disorders, which favors early attention by specialized personnel. It constitutes a tool to promote public health, improve the quality of life of the population and strengthen health systems at the local level, through the early identification of health problems and the implementation of effective preventive and corrective interventions.

Disorder	Amount	Diagnostic Positive	Diagnostic Negative	Accuracy
Intellectual disability	7	7	0	100%
Communication disorders	10	8	2	80%
Specific learning disorders	13	11	2	84.6%
Autism spectrum disorders	4	2	2	50%
Coordination or motor development disorder	6	5	1	83.3%
Attention deficit and hyperactivity disorder	10	9	1	90%
Total	50	42	8	84%

Table 2: Diagnostic Agreement and Accuracy Results

In summary, the developed system constitutes a result of high value for the management in educational institutions of Primary Education, as well as for mental health institutions because it makes possible, facilitates and specifies the preliminary diagnosis at the teaching level of children with mental disorders. neurodevelopment from the first stages and years of life, which subsequently guarantees early diagnosis and rehabilitation, thus contributing to the advancement of society.

Having a rule-based expert system, designed for mobile devices, provides great relevance as it allows teachers and non-specialized medical personnel, mental health workers and multidisciplinary teams, with clear language, free of the technicalities typical of manuals for this purpose, preliminarily diagnose children with neurodevelopmental disorders in an intuitive, easy, fast and efficient way. It also makes available to medical and educational professionals the diagnostic manuals, DSM-V, ICD-10, GC-3, which are usually inaccessible to professionals outside of psychiatry and psychology.

7 CONCLUSION

The diagnosis of neurodevelopmental disorders carried out by teachers and family doctors in children from 0 to 18 years of age constitutes a highly complex process, as it requires the intervention of medical personnel from 11 different specialties. The late diagnosis and care of these children can cause multiple difficulties in the subject both in the learning process, social relationships, anxiety and stress and other multiple complications that affect children and parents. The research carried out allowed us to analyze the different classifications of neurodevelopmental disorders according to the different diagnostic manuals, which made it possible to describe the manifestations for each of them with a greater level of detail. The Intelligent Classification System for Child Neurodevelopmental Disorders will facilitate non-specialized teaching and medical personnel in the preliminary diagnosis process of children with these disorders and quickly know the probability that the evaluated subject may potentially have or not a disorder.

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