A Cooperative Decision Support System for Children's Neurodevelopment Monitoring

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Abstract. Decision Support Systems can enhance e-Health monitoring and IoT scenarios on the early detection of neurodevelopmental disorders in children. Thus, Ambient Intelligence could support innovative application domains like motor or cognitive impairments' detection at the home environment. The paper describes the design of an innovative cooperative system (Galatea) that supports the refinement process of a Knowledge Base expressed as an OWL ontology. The ontology supports decision-making process and is the core of: (1) a Web-Based Smart System aimed to enhance the screening of language disorders at medical centers and schools by fostering the identification of a developmental disorders before 4 years old of age; (2) a set of child smart care services that use Ambient Intelligent paradigm for early attention of motor impairments in children who are often not diagnosed or treated by health care entities.

Keywords: E-health · Smart systems · Disabilities · Healthcare services

1 Introduction

Detection of neurodevelopmental disorders in early childhood remains an outstanding task. In fact, current rates of detection of development disorders are lower than their real incidence [1]. Pediatricians and education professionals can play a valuable role in early detection during their routine interactions with a child. However, the lack of resources to perform individualized exhaustive evaluations of all children makes the use of efficient and reliable methods of detection necessary [2]. On the one hand, the availability of smart monitoring solutions at home can provide medical doctors, physiotherapists and health professionals with reliable data about people's health status [3]. On the other, since early childhood educators are considered, along with parents, leading observers in child development, the availability of this system in the nursery will facilitate early detection of possible pathologies in the development of children in the 0-3 year stage [4].

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Gades [5] is a Web Based Support System (WBSS) developed with the primary purpose of serving as an automatic tool to improve the efficient screening of language disorders at the early stages of a child's development. This decision support system, developed with the collaboration of a multidisciplinary team of professionals, defined a few questions to evaluate the degree of language acquisition in children. To achieve a consistent system operation was necessary to provide Gades with a questions refining process to make it more reliable according to the criteria of the team professionals. Hence, Galatea is an innovative Cooperative Decision Making (CDM) system that supports the refinement process of the knowledge base (expressed as an ontology) of Gades WBSS. This solution paves the way for EDUCERE project to support adaptable home healthcare services by embedding sensors on toys and pieces of furniture according to the Internet of Things (IoT) paradigm. In this way, it aims to smart cooperative prevention and early attention of motor and language impairments by monitoring and stimulating children's activities.

The core of this Healthcare Cooperative System that incorporates previous Galatea work and EDUCERE project is a rules-based ontology that integrates children's developmental items according to the age. The ontologies also support the communication between all professionals involved in the system construction, allow reuse domain knowledge and facilitate recovery, integration and interoperability between heterogeneous sources of knowledge. Furthermore, the ontology was created using as a representation language OWL-DL.

This paper describes the design and deployment of a tool for refinement process of the ontology in a collaborative way in order to fasten the correct evolution of the Decision Support System (DSS) [6] developed under an IoT based children´s development model.

2 Methods

A multidisciplinary team of 10 people (2 neonatologists, 3 psychologists, 2 educators and 3 engineers) developed Gades. This WBSS was validated starting from an analysis of 237 children enrolled along two years in a nursery school.

The improvement of the decisions gathered from the sensors embedded Smart Toys (developed by EDUCERE project) and Gades WBSS require an ontology refinement process to improve language evaluations at daily routine with the therapist and educators, both at the nursery school and the health care unit. It could be performed through a manual process or by using the Galatea System. Ontology evolution process does not require generating new knowledge as experts have this knowledge.

The new system must focus on knowledge agreements coming from the experts' experience. Hence, the ontology should dynamically evolve to achieve efficient and effective Decision Systems and Smart Toys performance.

Figure 1 shows the interaction process between the children, the IoT based in smart toys, Gades Web Based Decision Support System, the Galatea Web platform and the health professionals, aimed to achieve the better health prescription as possible.

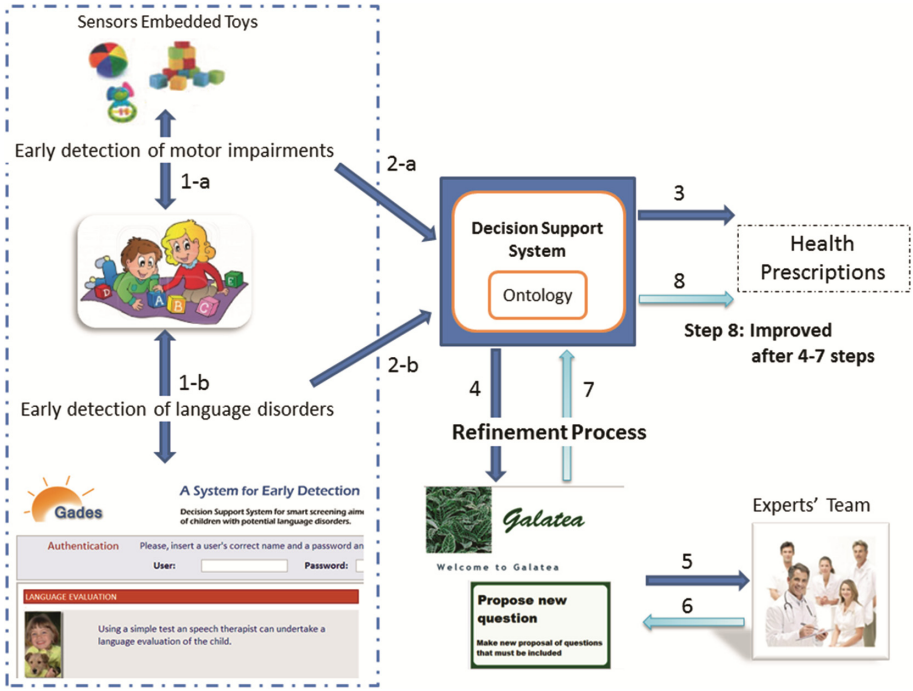

Fig. 1. Functional architecture of the smart children's monitoring system

As Fig. 1 shows, it is possible to improve the results provided by the developed early detection systems in order to detect both motoric disorders (steps 1-a, 2-a) and language disorders (steps 1-b, 2-b). By steps 4–7 the team of experts will be able to facilitate a refinement process in the ontology core of the Decision Support Systems developed. In fact, health recommendations provided by the Smart Toys will be more accurate after the execution of existing steps between step 3 and step 8.

Furthermore, the CDM process carried out by Galatea involves the cooperation of a group of people through technological tools that support joint decisions [7].

In collaborative decision, several individuals make a decision among a number of valid alternatives. Galatea system supports to the WBSS and the sensors embedded toys developed with two main tasks: Task 1. Generate suggestions for improvement of professionals who work with the WBSS and the smart toys through the introduction, modification or elimination of questions or items in the ontology (developed in the first stage of Galatea System construction). Task 2. Acceptance or rejection of proposed improvements introduced in previous step to be performed by a group of experts in neurodevelopmental disorders who are grouped according to their experience levels. After a telematics consensus mechanism experts grouped at least in two level of experience provide clear and well-structured information changes proposed on the ontology for the IoT/items model. This telematics consensus process was accepted by the professional team who participated in the validation process outlined at the beginning of this

section (this telematics consensus covers the second stage of Galatea construction, currently in design and development process).

3 Results: Galatea Collaborative Health Monitoring System

The evolution model led to analyze Galatea and its integration with the Smart Toys developed by the EDUCERE project. Galatea tool identified two groups of operations performed by specific actors: Gades users and sensors embedded toys users that make proposals for change in the ontology. The Galatea users groups are responsible for validating or not the proposed changes introduced by the DSS users. Furthermore, the users are grouped into two levels of expertise to facilitate the ontology enhancement:

Level 1: Professionals justify using assertions whether they accept each propose of changes. According to the expert answer weighing Level 1, associated with the proposal, will be modified. If expert accepts the proposal the weight will increase by one. If he/she disagrees with the proposal current weight is maintained. The expert level 1 must justify the reasons that have guided its decision, as Fig. 2 shows with comments text area.

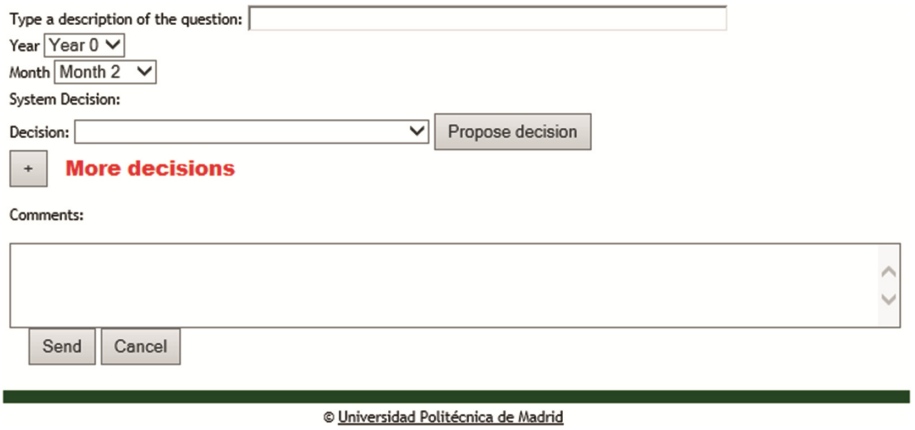

Fig. 2. Galatea-propose of new question/developmental item

Level 2: Experts are responsible for making the final decision for each of the proposals. Therefore, they are based on their expertise and the information provided by level 1 experts. They use weights and level 1 expert's assertions. Besides, the proposal has an associated weight related to these level experts' decisions: the weight of level 2 experts. The way to manage it is similar to level 1 experts. When a level 2 expert accepts the proposal then he/she increases the level 2 weights by one. If he/she disagrees with the proposal current weight is maintained. Then, the level 2 expert must justify the decision to accept or reject the change.

Galatea allows the evolution through the consensus techniques implemented inside. Furthermore, these techniques provide information to users as a flowchart graphic.

This method eases the understanding of a discussion about specific topics. The flowchart and consensus techniques have been developed taking into account the behavior, needs and activity of experts during the manual refinement process. Finally, the consensus technique will be developed in a completely usable way. This method will allow a process of debate necessary to achieve the refinement of the ontology core in the DSS.

4 Conclusions

Gades validation stage showed that open web applications allowed the easy utilization and refinement of ontologies by different kinds of professionals (educators, psychologists, therapists, etc.). EDUCERE smart toys such us the stackable cubes help to register, obtain and provide dynamic information about children's development. Galatea system facilitates the automation process of refining the DSS ontology for an IoT cooperative system.

The design task of the Galatea system has involved a multidisciplinary team of 10 experts. They have positively validated the decisions taken and the design of the user interface and most important they proposed ideas that will achieve a faster consensus in decision-making process to improve both Gades ontology and the integration of the IoT smart toys monitoring service.

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