A REAL-TIME BIOFEEDBACK HEALTH ADVISORY SYSTEM FOR CHILDREN CARE

Hawazin Badawi[1,3], Mohamad Eid[1,2], and Abdulmotaleb El Saddik
[1]*School of Electrical Engineering and Computer Science - University of Ottawa*
[2]Division of Engineering, NYUAD, United Arab Emirates
[3]Department of Computer Science, College of Computer and Information Systems-Umm Al-Qura University
{hbada049, meid@eecs., elsaddik}@uottawa.ca

ABSTRACT

Biofeedback sensors for health monitoring are rapidly growing in terms of ubiquity and cost. They enable remote, accurate, and low-cost health monitoring and can provide personalized health monitoring and care with timely detection of health issues, especially for children. In this paper, we propose a novel system for real-time personalized health advisory system for children in order to promote healthy habits and activities (including food, clothing, and activities). The system utilizes Electronic Child Record (ECR) that is continuously updated according to the captured measurements from biofeedback devices, and ontologies for vitamins/allergies, to provide personalized semantic-based recommendations. The preliminary evaluation demonstrated the potential of the proposed system to promote wellbeing of children and facilitate the communication among parties involved in the children care (parents, school staff, and health care staff).

***Index Terms*—** Decision Support System, Health Profile, Health Ontology, Biofeedback Technology

1. INTRODUCTION

Healthy children are the first natural step to a healthy adult population. Nowadays, it is becoming more difficult for parents to continuously monitor the health of their children, as they spend most of their day at school. Therefore, it is the responsibility of each member in the society (such as school staff and medical staff, in addition to parents) who has a major contribution towards children to collaborate to improve the quality of health, education and self-development services.

Furthermore, developing new children advisory systems that facilitate the communication among the involved parties in the children care has a direct impact on the quality of living for the children. In fact, there are several technologies that can be assistive to build children advisory systems. For instance, Decision Support System (DSS) is defined as supportive computer technology solutions that help in a complex decision- making procedure and facilitate the problem-solving process [1]. A DSS can be utilized to provide recommendations about children's food, clothing, and activities, in order to promote the well-being of both the physiology and psychology.

In order to adopt DSSs in children care systems, a trusted source of children information is needed. Health Profile (HP) is an optimal source for this information because it combines personal and medical information in one file. Most often, HP is generated based on Electronic Medical Record (EMR) and updated according to the most recent changes in the children health states [2]. A health profile that defines the specific needs and requirements for each child enables personalization of decision making, and thus improves the system performance efficiency. The child health state is captured via biofeedback sensors and the health profile is updated almost in real-time.

Furthermore, by referring to semantic metadata stored within a knowledge based system, the DSS would be able to suggest further options about the child's food, clothing, and activities, while taking into account different vitamin needs and potential allergies. To enable semantic-based decision making, ontologies are used to describe the related knowledge. Ontology can be defined as a collection of concepts, properties and relationship between these concepts in a specific domain that can be used for describing and reasoning about this domain [3]. In children care systems, ontologies can be built to maintain the most common allergies and their relationship to food and clothing, and to vitamins and their relationship with food and activities.

In children advisory systems that depend on DSSs, tracking all the changes in the child's physiology which affect the decision making process is essential. Biofeedback technique can be involved to capture these changes in real-time and unobtrusive manner. Biofeedback is a well-established domain concerned with evaluating measurable physical attributes of the human body such as heart rate and blood pressure and transferring results to a peripheral device to increases awareness and possibility of intentional control of those attributes [4].

In this paper, we proposed a personalized health advisory system for children based on real-time biofeedback sensors to provide accurate and up-to-date decisions about children's food, clothing, and activities using electronics child record, as the health profile for each child, and ontologies for both vitamins and allergies as knowledge base system to support the decision making. Three parties are involved with the system: the parents, the

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school staff, and the health care staff (such as family doctor).

The rest of this paper is arranged as follows: section I gives an introduction and the objectives of our work. In section II, a literature review on Decision Support Systems, Health Profile, Ontology Concept and Biofeedback Technology is presented. Section III describes the proposed system merits and how it works. The system implementation and preliminary results are presented in section IV. Finally, section V concludes the paper and provides perspectives for future work.

2. LITERATURE REVIEW

In this section, we present a brief review of the basic terminologies that we used through the development stages of the proposed system.

2.1. Decision Support Systems

DSSs and their applications are examples of computer technologies that have been improved effectively since their early start in the 1970s [1]. Their improvements embodied in the development of four potential tools which are data warehouses, data mining, OLAP and web-based DSS [1].

As a result, there are countless applications of the DSSs in different fields including medical, industrial, educational, political, environmental and business fields. For instance, many researchers work on the deployment of computerized Clinical Decision Support Systems (CDSSs) to enhance the decision-making process, evaluate the effect of this deployment in changing the medical performance and suggest successful deployment criteria such as researchers in [5][6][7]. Also, some researchers proposed DSSs to help in the treatment of some chronic diseases such as diabetes [8]. Regarding the adoption of DSSs in the industrial field, a researcher's effort in [9] is a good example where they designed a DSS for the selection of plastic die materials, which provided reasonable results.

The deployment of DSSs in an educational field is clearly illustrated in the DSSs designated for libraries to provide better services for readers as well as libraries staff [10], for selection of science research projects [11] and for teaching management [12]. Researchers' efforts in [13] and suggested applications for E-Government in [14] are suitable examples of deploying DSSs in the political field. The developed DSS in [15] to forecast flood and mapping risk is an instance of deploying DSSs to serve environmental issues. Also, using a DSS mentioned in [16] to select affordable housing locations illustrates how DSSs can be adopting in business field.

2.2. Health Profile

Health profile (HP) is the most important concept in Health Care area because it is the foundation of all decisions made by professionals in this field. Due to its crucial role for individuals as well as communities and countries, HP gained the attention of researchers and there are countless studies related to this concept.

In fact, we can classify HPs into two types based on researchers' efforts: individual HP and country HP and each of them have many sub-types. For instance, there are children, adolescent and disabilities HPs under individual HP whereas environmental and social HPs under country HP. World Health Organization (WHO) have specified the role and importance of country HP as a general indicator of the health at any country. Canada's [17] and England's [18] HPs are examples of country HP.

The individual or personal HP which is the subject of our research can be defined as a document which shows all the personal and up-to-date information about individual's health [19] and its generation requires collecting and summarizing the latest information from individual's Electronic Medical Record (EMR) [2].

In fact, many efforts have been done to form the standards and contents of personal HP to serve the various medical purposes. A famous example of such efforts is Nottingham Health Profile that is created to be a simple measure for individual's health in the physical, social and emotional areas and it has been defined as a standard and translated to several languages [20].

In addition, many tools have been developed to facilitate the creation and dealing with personal HPs. Child Health and Illness Profile (CHIP) is a suitable example of such tools that is used for evaluating adolescent health [21]. Also, the HP form made by the Duke University Health Center in USA [22] is an example of HP form for specific purpose.

2.3. Health-based Ontology

In general, there are two types of ontologies: generic such as WordNet and domain dependent ontologies [23]. Nowadays, domain dependent ontologies are involved in several applications to serve as a knowledge base of these application domains such as medical and business domains. For instance, researchers in [24] construct an emergency ontology based on emergency documents to assist the emergency decision support system in its task by reorganizing knowledge in these documents. They proved that building such ontology efficiently supports the knowledge reorganization and therefore the decision-making process.

Also, researcher's effort in [25] is another example of using ontology in medical domain. They adopted ontology technology for standardizing medical records and providing solutions for privacy issues. They ended by introducing an ontology-based Medical Record Information System (MRIS) that can be considered as a global standard.

Regarding the business domain ontologies, researchers work in [26] is a good example. They designed and developed a food recommending system to be used in planning menus of restaurants, hospitals or even at home and it has food ontology as one of its components.

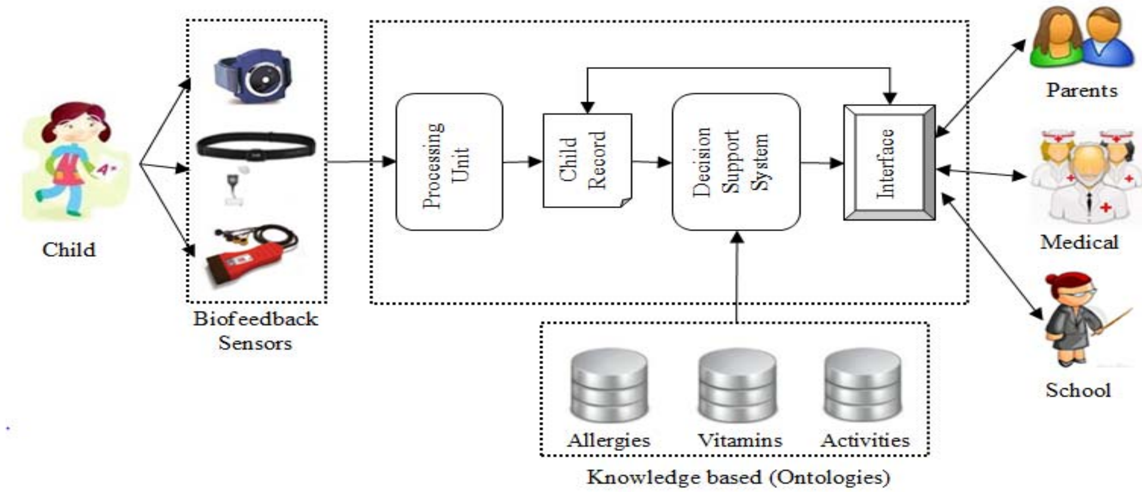

Fig. 1. System overview

Moreover, researchers in [23] suggested an effective novel approach of the automatic ontologies construction.

2.4. Biofeedback Technology

Due to its capability of providing critical information about individual's physiological and psychological conditions, biofeedback technology has been involved in many applications for medical and non-medical purposes. In general, biofeedback procedure achieved by the deployment of different types of sensors that represent the information source and guarantee the real-time feature of biofeedback process.

Researchers in [27] presented a Heart Rate Variability biofeedback training to assist patients in controlling their sympathetic activities, which are correlated with different emotional moods such as stress or anger based on ECG usage. Also, researchers in [28] designed a portable biofeedback device for rehabilitating children who suffer from scoliosis and correcting their posture. It is a non-medical device to warn the child to correct his/her posture and designed for children between 3 and 10 years old. A similar work has been done in [29] but it aims to correct computer user's neck posture by using a biofeedback system that based on a real time single accelerometer.

The breathing biofeedback system proposed in [4] is capable to guide the user to take a deep breath slowly to enable the cardiovascular system function effectively. It is designed as a smartphone based system and uses a Bluetooth technology. A similar effort has been done in [30] but it aims to decrease the high blood pressure using a respiratory system. They system isolates the patient from the outside world by using headphones which instruct him/her to breath in a specific way that leads to the decrease or maintain of blood pressure. Also, researchers in [31] developed a wearable respiratory biofeedback system using body sensor networks.

3. THE PROPOSED SYSTEM

The proposed system consists of four main parts, which are: Biofeedback Sensors, Decision Support Components, Graphical User Interface (GUI), and Semantic Data store. Figure 1 illustrates these components.

In this system, biofeedback sensors such as ECG, humidity and temperature sensors are attached to child body using special materials that guarantee the child comfort and connected wirelessly to a processing unit that may locates in the same place such as principal's office in the school or in a different place for example, in a family doctor clinic. The wireless connection can be accomplished by using Wi-Fi or Bluetooth technology. The processing unit is responsible about receiving signals sent by these sensors and updating child's health profile on real-time basis and this is the key feature of the proposed system.

The Decision Support System, which represents the core component of this system, is fed by information retrieved from the child's health profile and semantic data store in order to make a suitable decision in a suitable time. Note that in the proposed system, Child's health profile contains three main parts, which are personal information, vitamins information and allergies information.

Semantic data store consists of three different ontologies that are vitamins, allergies and activities ontologies. Vitamins ontology contains information about the recommended vitamins to promote child health with the most common nutrition sources for these vitamins. Table 1 shows these vitamins with their nutritional sources [32]. Note that for each vitamin, food is mentioned in an ordered list starting by the richest food of this vitamin. The most popular types of children allergies are collected in the allergies ontology and combined with the prohibited food for each type. Table 2 illustrates these types of allergy and the food that must be avoided [33-34]. The third ontology consists of many children activities that can be used to recommend a specific activity for the child in a specific situation.

Table 1. The rich nutritional sources of recommended vitamins for children

Vitamins	Source Type	Food
A	Animal	Liver, Beef, Chicken, Milk, Cheese, Egg
A	Plants	Carrots, Spinach, Cantaloupe, Apricots, Papaya, Mango, Oatmeal, Peas, Peaches, Pepper
B6	Animal	Beef liver, Tuna, Salmon, Chicken Breast, Turkey, Ground beef, Cottage cheese
B6	Plants	Chickpeas, Breakfast cereals, Potatoes, Banana, Waffles, Nuts
B12	Animal	Liver, Beef, Clams, Salmon, Tuna, Milk, Yogurt, Egg, Chicken, Haddock
B12	Plants	Breakfast cereals
C	Plants	Red pepper, Orange, Grapefruit, Kiwi, Broccoli, Strawberries, Potato
D	Animal	Cod liver oil, Salmon, Tuna, Milk, Yogurt, Margarine, Liver, Beef, Sardines, Egg, Cheese
D	Plants	Orange juice, Ready-to-eat cereal
E	Plants	Sunflower seeds, Almonds, Sunflower oil, Hazelnuts, Peanut butter, Peanuts, Corn oil, Spinach
K	Plants	Kale, Spinach, Parsley, Mustard, Lettuce, Broccoli

Table 2. The most common types of allergies with prohibited food for children

Allergy Type	Food
Peanut	Mixed nuts, Ground nuts, Artificial nuts, Peanut oil, Nut meat, Peanut butter, Peanut flour, Peanut protein
Shellfish	Crab, Lobster, Crawfish, Shrimp
Egg	Egg, Mayonnaise, Surimi, Meringue
Soy	Soybean, Soy protein, Soy sauce, Tofu, Tamari
Milk	All types of milk, Butter products, Cheese, Cream, Lactose, Whey, Yogurt, Backed goods
Tree Nut	Almond, Beechnut, Butternut, Cashew, Coconut, Hazelnut, Macadamia, Nut paste
Fish	Bass, Flounder, Cod
Wheat	Bread, Cereal, Cracker meal, Flour, Pasta, Wheat oil, Wheat grass, Wheat gluten

In addition, a user-friendly Graphical User Interface (GUI) is used as a real-time communication medium with parents/guardians; school staff or medical staff what provides them with food and activity recommendations for the child. Also, they can interact directly with child's health profile and receive updated information about child's health status at any time.

4. IMPLEMENTATION AND PRELIMINARY RESULTS

This section introduces the graphical user interface (GUI) design of the proposed system as well as an example walkthrough. Figure 2 shows the welcome page of the interface with three parties involved: parents, school staff, and medical staff. The current implementation is focused on the role of the parents and thus will show the parents-related GUIs. The three parties are then presented with a login page to provide secure access to the children health information.

Fig. 2. Welcome page of the GUI of the system.

Once the parent is authenticated, she selects one of her children and be presented with the main parent page, shown in Figure 3. Five icons are presented in Figure 3: Food, Clothing, Activities, Feedback, and Display Health Profile. The Food icon provides recommendations about the food that should be, for example, send with the child to the school (or the meal for the child), taking into consideration the Vitamin needs and allergies. The clothing icon provides recommendations about what to dress the child (according to allergies, weather, and activities involved). The Activities icon suggests exercises such as sports, reading, or socializing. The Feedback icon enables the parent to give her opinion and feedback into the system (such as to confirm giving food, or activity of the child). Finally, the system enables the parent to view, in real-time, the health status of the child using the Display Health Profile icon.

Figure 4 presents an example scenario of the system workflow: Consider a child named Ali who suffers from fish allergy and reduction in vitamins A, B6 and D. One day, Ali's mother decides to add meat to his dinner. She send a request to the system through the GUI in order to get a list of meat types that are rich in vitamins that he needs specially vitamin D and in the same time do not cause any allergic reaction for him. After sending the request, DSS utilizes Ali's health record (updated via sensors attached to Ali's body while he is at school) and the vitamins and allergies ontologies of food types and allergies. Thus, the system displays a list of meat types (for example liver and beef). Finally, the mother selects one of the proposed items, and update Ali's health record by decreasing the required amount of vitamins A, B6 and D.

Fig. 3. Main page for the parents.

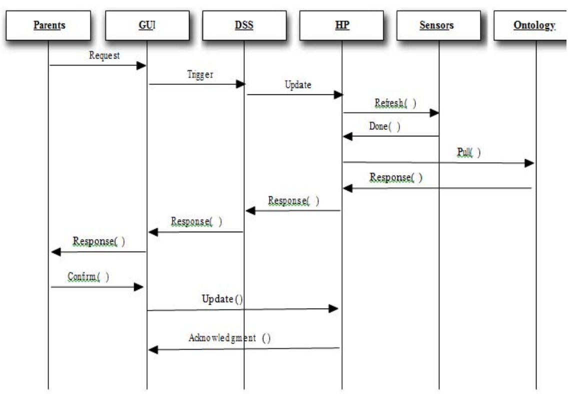

Fig. 4. Generic view of system workflow.

Sixteen (16) parents took part of the usability study of the proposed system (8 mothers and 8 fathers). All the subjects agreed that the system would facilitate their children's life. Furthermore, 90% of the subjects anticipate that biofeedback systems will be deployed in the near future. However, 10% of the subjects disagreed to attach biofeedback sensors to their children's bodies. Finally, when ask to rate the system over 100, the average rating for the system was 84%.

5. CONCLUSION

In this paper, we have proposed a personalized health advisory system for children care. We have described the system architecture and implemented the knowledge base (ontologies for children health) and the user interface. The preliminary evaluation with parents showed the potential of the system to track, in real-time, the children health and provide a useful means to adjust the children life-style for better health and wellbeing.

As per future work, we plan to integrate biofeedback sensors into the system and test the real-time operation. Furthermore, we will investigate the possibility of adding contextual information about the children's environment in order to provide more accurate recommendations. Finally, a comprehensive usability study is necessary to approve the feasibility of the system with all the three parties involved with the system (parents, medical staff, and school staff).

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