COLLABORATIVE SYSTEM FOR PREVENTION OF INCREASED BLOOD SUGAR LEVEL

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ABSTRACT

Today there is a growing interest towards the adoption of novel technology in the field of medical monitoring and personal health care systems in general. In this paper we present algorithms that generate recommendations and suggestions for preventive intervention instead of emergency care and hospital admissions, used in the model of the collaborative health care system (Cohesy). Use of data sets from the health and physical activities history of users can be very important for improving the health of users because the history of the diagnoses can detect which physical activities contributed to the improvement of the health of the user. Step further, we use these data sets to generate recommendation for activity in cases where the user health has deteriorated.

I. INTRODUCTION

At a time when the volume and complexity of information exceeded the ability of health workers to function optimally without the support of tools for information management, information and communication technologies (ICTs) have become their indispensable tool. In the area of health research, the volume of new information is constantly increasing [1]. Thus, there is an urgent need for information and communication tools that can gather information from multiple sources and provide a new point of view of the human health, so that will give a clear picture on a system level.

The vision of new information and communication technologies, which involves continuous communication and access to information, has huge implications for health. Thereby providing systems that not only store health data, but offer continuous monitoring of health and communication with health centers is very important for users and medical workers [2]. Such systems can support decisions, searching through large amounts of health data and facts, identifying issues that directly relate to a given medical condition.

In this period of growing representation of information and communication technologies in health care, the term E-Health appears. The main principle of E-Health is that informatics and communication technologies should not be used only to improve the availability, efficiency, effectiveness and quality of any processes related to health care, medical centers and businesses. One of their applications is to allow citizens to be directly involved in their health care, providing information that will assist in making decisions about their own health [3]. Certainly, to achieve this, there is need of support of all stakeholders in health care management, facilitating the exchange of data among them all, support in decision making, and ultimately, shaping the health as a reflection of the whole community..

The recommendation algorithm, presented in this paper, is part of the Collaborative health care system model called COHESY [4]. This system model enables the user to contact other people with similar condition and exchange their experience. In that way Cohesy improves quality of care and life to its users, by offering freedom to enjoy life with the confidence that a medical professional is monitoring theirs health condition.

The purpose of recommendation algorithm is to give a recommendation for performing a specific activity that will improve user's health, based on his given health condition and set of knowledge derived from the history of the user and users like him. This recommendation algorithm is based on the dependence between the values of user's health parameters (e.g. heart rate, blood pressure, occurrence of arrhythmia) and his physical activities (e.g. walking, running, cycling). The aim of the recommendation algorithm is to discover which activities affect change in the value of each health parameter individually. Once revealed, algorithm can use that information in situations it recognizes as same or similar to previous health conditions of a same or another user with similar medical problems. If there is information, in users' history, that after execution of a physical activity, the health situation had already changed for the better, it can be concluded that this activity can help him or other users with similar health issues and improve their health condition..

II. RELATED WORK

There are many companies, researches, laboratory working on solutions for better health care of patients and systems that will help to have continuous monitor of the health of the patients. Pervasive and context-aware applications have been generally recognized as promising solutions for improving quality of life for the patients, which means integration of wireless sensor networks with pervasive computing devices in the creation of intelligent environment for providing unobtrusive monitoring, prompting or reminding of desirable activities and correcting or assisting the patients in their daily life [5].

MobiCare is a remote wireless patient monitoring system that provides better healthcare services [6]. It has three important building blocks: a body sensor network consisting of wearable sensors and actuators, a Body sensor network Manager (MobiCare client) that connects the network to a wide-area communication interface (using cellular wireless link) and back-end infrastructure support (MobiCare servers) at healthcare providers to implement necessary healthcare functionalities. This system enables healthcare personnels to be able to timely access, review, update and send patient information from wherever they are, whenever they want. Therefore, use of such mobile healthcare system can lead to significant economic benefits and cost savings for a patients as well as for the clinics.

Similar system, that facilitates the remote monitoring of the patients, is Personal Care Connect [7]. Personal Care Connect covers the connection and communication between the patient (with biomedical devices), data collection hub, medical server and medical personnel. Main advantage of Personal Care Connect is that it is a standard-based open (client and server) platform for interfacing to a wide variety of biomedical devices and sensors, collecting data from the devices and sensors, storing the data in a server repository, and making the data available to applications through a documented API, that allows Clinical-information system developers to have a uniform view of a wide variety of medical sensor data while have no need to know how to connect to each new device that comes on the market.

Jog Falls system [8] presented by Nachman et al., is an end to end system to manage diabetes that blends activity and energy expenditure monitoring, diet-logging, and analysis of health data for patients and physicians. This is an integrated system for diabetes management providing the patients with continuous awareness of their diet and exercise, automatic capture of physical activity and energy expenditure, simple interface for food logging, ability to set and monitor goals and reflects on longer term trends. Its interface gives physicians comprehensive and unbiased visibility into the patients' life styles with respect to activity and food intake, as well as enabling them to track their progress towards agreed goals. The main emphasis authors place on its novel method for fusing heart rate and accelerometer data that improves the accuracy of energy expenditure estimation (a key feature in enabling weight loss). The first tier in Jog Falls is consisting of the sensor devices responsible for collecting the physiological and activity data. The second tier consists of a smart phone, which is responsible for communicating with the sensors via bluetooth, aggregating and storing the sensor data, calculating the energy expenditure and intake, providing the user interface for logging, alarming and data review, and communicating with the third tier through GPRS. And the third tier in Jog Falls is consisting of a backend server that is responsible for aggregating and storing the data from all users, and providing the user interface for the physician.

Ivanovici et al. [9] proposed architecture of e-health system which can be used to monitor the health status of patients with diabetes and stroke. Their main objective is to design and implement a hardware and software prototype of a medical monitoring e-health system for primary healthcare and transmission of the acquired data to a processing and analyzing point capable to automatically send warnings towards the nearest medical unit. The proposed system is based on an intelligent application that process and analyze in real time the health status of the monitored individual. So, the application is able to assist and support the objectivity of the medical specialist decisions. Ivanovici et al. consider the possibility to simultaneously monitor both the audio and the video signals. This is important in order to monitor the comportment of the patient. By recording the movements and the vocal signals the system performs action recognition or recognition of the mimics and gestures for the non-verbal communication analysis. They believe that the action recognition of the individual is novelty of a high importance not only for patients not able to verbally communicate their state of health or to call emergency services, but also for detecting emergency situations.

These examples include detailed research of systems that cover only parts of our system model Cohesy. The main difference between the aforementioned examples and Cohesy is the social network, in which the recommendation algorithm that we present in this paper is implemented. Namely, linking different parts of Cohesy and their communication, broads their exchange of information which leads to more extensive data about various treatments, therapies and activities of patients with the same or similar diagnoses. Based on these data the recommendation algorithm generates recommendation for user to perform a specific activity that will improve his/her health. Meanwhile, the algorithm for recommendations bridges the gap between users, clinical staff and medical facilities, strengthening the trust between them and providing relevant data from a larger group of users, grouped on the basis of various indicators.

III. Collaborative Health Care System Model COHESY

The collaborative health care system model – Cohesy, gives a new dimension in the usage of novel technologies in the healthcare. This system model uses mobile, web and broadband technologies, so the citizens have ubiquity of support services wherever they may be, rather than becoming bound to their homes or health centers as pointed out by different authors [10].

A. System Overview

Cohesy is deployed over three basic usage layers. The first layer is consisting of the bionetwork (implemented from various body sensors) and mobile application that collects users' bio data during various physical activities (e.g. walking, running, cycling) and users health parameters (e.g. weight, blood pressure, blood-sugar level and heart rate). The second layer is presented by the social network implemented as a web portal which enables different collaboration within the end user community. The third layer enables interoperability with the primary/secondary health care information systems which can be implemented in the clinical centers and different policy maker institutions. Communication between the first and the second layer is defined by users' access to the social network where user can store their own data (e.g. personal records, healthcare records, bionetwork records, readings on physical activities). Social network allows communication between users based on collaborative filtering techniques, thus connecting the users with the same or similar diagnoses, sharing their results and exchanging their opinions about performed activities and received therapy. Users can also receive average results from the other patients that share same conditions in a form of recommendation or notifications. These notifications can vary from the average levels of certain bio data calculated for certain geographical region, age, sex to the recommendation for certain activity based on the activities of other user. Collaborative filtering can be used to achieve different recommendations in these contexts.

Communication between the first and the third layer is determined with the communication between patient and health care centers. The patient has 24 hour access to medical personnel and possibility of sending an emergency call. The medical personnel remotely monitors the patient's medical condition, reviewing the medical data (e.g. blood pressure, blood-sugar level, heart rate) and respond to the patient by suggesting most suitable therapy (if different from the one that is encoded in the mobile application) as well as sending him/her various notifications (e.g. tips and suggestions) regarding his/her health condition. The second and the third layer can exchange data and information regarding a larger group of patients group by any significant indicator (region, time period, sex, type of the activities) which can be later used for research, policy recommendations and medical campaign suggestions.

Cohesy creates the opportunity for increasing user health care within their homes by 24 hour monitoring on the one hand, and increasing medical capacity of health care institutions on the other hand. This results in reducing the overall costs for users and hospitals and improves the user's quality of life [11]. It provides a better health care allowing suggestions and recommendations based on knowledge from other users, cases and experience.

B. System architecture

The mobile technologies (devices and applications) in this system are used to support and enable collaboration. The installed mobile application, using various sensors (bionetwork), performs readings regarding users health during his physical activities (walking, running, cycling) and based on them, gives appropriate instructions, proposals and constraints of their execution, in order to improve his own health. In presented system model, mobile application attempts to categorize events by processing the collected data, from patient current state and patterns of the biologic and environmental sensors.

Using Cohesy the patients are not restricted in their movements or their location. By using installed mobile application they have access to the medical personnel at any time. The medical personnel can remotely monitors the patient's medical condition, reviewing the medical data (e.g. blood pressure, heart rate, glucose level, weight) arriving from the mobile application of the patient. At the same time, the patient individual data can be compared with average data obtained using different collaborative filtering techniques. In this way, medical personnel can quickly respond to the patient by suggesting most suitable therapy as well as when to receive it, focusing on activities that are necessary for his rehabilitation and maintenance of his health, sending him various tips and suggestions for improving his health. Even more important, the social network can learn from this recommendation and generate notifications and recommendation based on the most successful scenarios.

The installed mobile application has access to the social network (web portal) where it can store users' data and read average data readings on bio and physical activities of all users. Social network allows direct communication between users (if approved by the user and stored in the user profile) and sharing their results. This portal can provide interface and use data from a variety of medical databases and environmental databases (temperature, wind speed, humidity). In this way mobile application within the Cohesy system provides a tool for a complete personal healthcare.

Complex structure of data from a social network along with the data arriving from different clinical centers can be used by different medical databases for further analysis and research. The conclusions drawn from research data, while exploring medical databases, can routed back to the clinical centers. These data are used to individually analyze the condition of patients. Clinical centers have access to data on physical activities of patients collected by the application installed on their mobile device. Therapies and recommendation are drawn from the analysis of the overall data obtained by the clinical centers. Those therapies and recommendations now can be easily routed back to the patients' mobile devices.

Simultaneously, clinical centers can exchange data and information with a social network and thus have access to a larger group of patients that can share research, recommendation and suggestion of the medical personnel. Received therapies and recommendations can be used by the application to suggest to users when, where and what action to accomplished in order to improve their health. The social network has incorporated collaborative filtering that allows filtering large amounts of data on concrete condition. So, policy makers can get those data, make specific analysis of it and gave recommendations for national action by governments and non-government organizations, including programs and strategies.

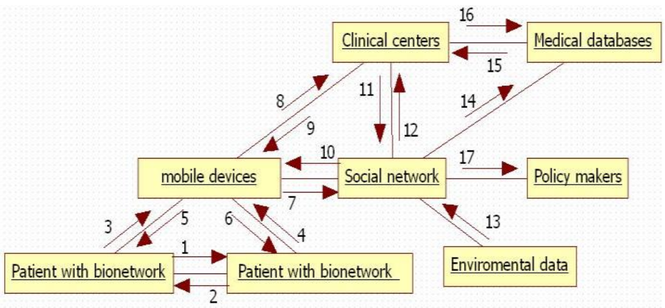

Figure 1: Data flow Diagram.

The flow and exchange of data information in this system is shown in the diagram on Figure 1.

IV. RECOMMENDATION ALGORITHM

There is a dependency between the change of the people's health parameters and the physical activities that they perform. Activities mainly contribute to health condition improvement. However, all activities do not have the same effect on the change of the health condition. That is why we need to classify the activities according to their characteristics. Furthermore, we need to find the connection between the type of activity which is performed and the type of change in the health parameters. We emphasize that every activity does not have the same influence for every person. For every person and at every moment, there is a set of feasible activities that could potentially improve his/her health condition. In this section we will explain an algorithm that can be used to find the set of feasible activities.

The algorithms for activity recommendation must be based on few main principles: (1) Except the physical activities, there are other factors that affect the change of the people's health condition (medicines, food and psychic condition) and the deficiency of this additional information brings to bigger inaccuracy in the recommendations; (2) People can be grouped according to their characteristics (diagnosis, place of living) and for each of these groups activities have specific effect on the parameters which is similar for people in same group, and is different for people in different groups; (3) For every person activities do not influence his/her health with the same intensity and in the same way. That is why we should find the individual dependency between the parameters and the activities.

Our algorithm recommends activities for given user u_* on the basis of the past activities and the past measurements of the health parameters. Here we include not only his past activities and measurements, but also those on the group in which he belongs. Thereby we get better recommendations and we eliminate the problem of "cold start" in the same time. The algorithm consists of seven steps and we will explain each of the steps in more details and we will give examples to make things more clear.

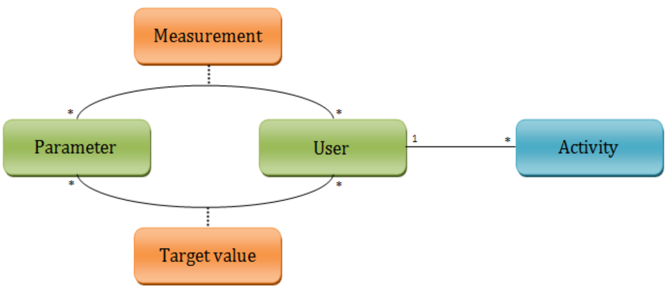

Figure 2: Simple diagram for the data needed by the recommendation algorithm

For each user and at each moment there is a health profile which can be defined as a combination of the values of his/her health parameters at some moment. Some of the profiles can be categorized as healthy person's profiles because the values of the health parameters belong to the normal range, but other profiles can be categorized as unhealthy person's profiles. Our application for healthy life aims to generate a transition of the user's health condition from profiles that indicate bad health towards profiles that indicate good health through. This is achieved through its advices for useful activities that can be performed by the user. The system will keep history of all health parameters' measurements, user's preferences and performed activities, and the recommendations will be generated according to these data.

STEP 1. Filter out users with a certain diagnosis

In this step we filter out users which have (had) the same health problem as user u_* (e.g. people with increased sugar level). We will denote this set as U'. All other users with diagnosis different than the diagnosis of the user u_* are ignored in the next steps of the algorithm. Here we can apply classification and clustering algorithms. We suggest that expert medical people should build classification rules and according to these rules we place users in classes. The rules can also be built indirectly by using techniques from data mining.

STEP 2. Find most similar users for the given user u_*

Here we use the momentary health profile for the user for which we want to generate recommendations and the history of profiles for the users in the set U'. We also need to examine other users' past profiles besides examining their momentary health profiles. The reason for this is that some of these users maybe had the health problem that the user u_* has at the moment and now the health condition of these users is better.

Similarity between two profiles can be found by using Euclid distance. We note that firstly the parameters' values need to be normalized. In the similarity formula different weights should be given for each of the health parameters according to the importance of those parameters in people's health.

STEP 3. Filter all activities which could harm the user or which do not have a good effect on the user

What we want to get in this step is a set of activities A' that would not cause additional worsening of the health condition of the user for which we want to generate recommendations. There is some subset of parameters that are more significant than the others and according to which we make this type of filtering. Here we use the history of performed activities and measurements. All activities for which we have discovered that they worsen the parameters' values are removed. For example, if the user is fatigued quickly after starting some type of activities, these activities should not be recommended for him.

STEP 4. Find the benefits of performing activities

User for which we want to generate recommendations has (possibly) different degree of disorder for each parameter. The algorithm should recommend activities that would decrease the total degree of disorder for all parameters. From the history of activities and measurements we take all triples $(measurement1, activity, measurement2)$ for which

$$t_{measurement1} < t_{activity} < t_{measurement2}$$

$$t_{activity} - t_{measurement1} < threshold \quad (1)$$

$$t_{measurement2} - t_{activity} < threshold$$

Then, for each activity we determine the intensity with which it increases or decreases the value of some parameter. Benefit of performing some activity by user u to improve the value of some parameter ($V_{u,a,p}$) is defined as improvement of the parameter's value for the user (increase if it is under the normal range or decrease in the other case) that would be achieved if this value changes in the same way as in the past while performing the same activity.

STEP 5. Make matrix of useful activities per user

In this step we calculate the overall benefit of performing some activity for each user. The overall benefit of some activity for user u (2) can be defined as improvement of the health condition for the user that would be achieved if his parameters' values change on the same way as in the past while performing the same activity.

$$V_{u,a} = \sum_{u} V_{u,a,p} \tag{2}$$

The matrix of useful activities gives the overall benefit of performing each activity by each user from the set of similar users (also in this set we include the user for which we want to generate recommendations).

STEP 6. For each user we take the most useful activity

This is done by finding the activity with maximum overall benefit for each user.

STEP 7. The activity that has the biggest usefulness for the most of the similar users is selected and recommended to the monitored user u_*.

Determination of the activity that should be recommended can be made in other way. We can calculate sums of the overall benefits per activity and we can find the activity with biggest sum of overall benefits. This is the activity that will be recommended to the user in the other way.

V. Conclusion and Future Work

In this paper we present a recommendation algorithm as a part of collaborative health care system model - Cohesy. The main purpose of this algorithm is to find the dependency of the users' health condition and physical activities he/she perform. To achieve this we consider datasets from the health and physical activities history of users and use classification algorithm on these datasets for grouping the users based on their similarity.

Recommendation algorithm gives to the user recommendation for performing a specific activity that will improve user's health. This recommendation is based on his/her given health condition and set of knowledge derived from the health and physical activities history of the user and users like him/her.

Use of this recommendations allows the user to adapt and align his/her physical activities while improving his/her health condition and overall way of rehabilitation, meaning to be fully able to take self care and professional concern about his/her health.

We must mention that we are currently in the implementation phase and therefore we have not presented any experimental work yet. Till now, communication between the first and second level of Cohesy is implemented within the framework of SportyPal mobile collaborative system [152]. It has approximately 450000 active users that are connected to its dedicated social network. SportyPal system, using mobile application, is capable of reading parameters for a particular activity, such as path length, speed, time interval, consumed calories. By using an additional device that connects with the application, it can read health parameters of the user (e.g. blood pressure, blood-sugar level, weight and currently heart rate). Active social network at SportyPal.com additionally allows users to analyze their results, to compare them with the results of other users or to comment all results.

We are convinced that in our further work, we will be able to implement the module for generating recommendations based on the recommendation algorithm that we have proposed, and will succeed to evaluate its functionality and benefits through the SportyPal system.

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