A Mobile Learning Application for Self-Management of Health and Disease

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***Abstract*—Supporting self-management of patients is a highly challenging task, which needs to meaningfully exploit and interrelate approaches and technologies concerning interactive communication, personalized health and mobile learning. In line with these remarks, this paper reports on the development of an innovative clinical decision support platform for self-management of health and disease purposes. Work presented focuses on two basic components of the platform, namely a web-based collaboration support tool and a mobile application, both aiming to augment the interaction of all types of stakeholders with the platform. The functionality of the above components is sketched through a realistic use case.**

Keywords— self-management of health and disease; mobile application; collaboration support.

I. INTRODUCTION

It is broadly admitted that several clinical situations would be better monitored and managed, or even completely prevented, with the active participation of the patient himself or herself. Self-management of health and disease engages citizens and patients in activities that certainly promote and protect health; these include timely inspection and management of the symptoms and signs of illness, as well as close collaboration with a team of health care providers that enables them to make informed choices about their health status [1]. All these presuppose that the patients will engage in actively learning how to inspect and manage their situation. In the setting under consideration, mobile learning can also play a vital role; mobile health devices witness a large acceptance and use, they can integrate diverse medical monitoring functions, and they can be used from anywhere and at any time.

The facilitation and enhancement of the abovementioned activities are challenging tasks, which need to meaningfully exploit and interrelate approaches and technologies coming from the fields of interactive communication and collaboration, personalized health and mobile learning. This paper reports on the development of an innovative clinical decision support platform for self-management of health and disease purposes, which is in line with the above remarks. Specifically, it focuses on two basic components of the platform that aim to enable all types of stakeholders (i.e. patients, clinicians, healthcare professionals, etc.) to easily contribute, navigate through and exploit the related data and information. The first component is a web-based collaboration support tool with advanced argumentation, sense-making and decision making functionalities. The second one is a novel mobile application that augments the interaction of patients with the platform according to the envisaged self-management approach. These components offer both synchronous and asynchronous collaboration among stakeholders, enable the elicitation of tacit and explicit knowledge, and augment knowledge co-production and gaining of insights.

The foreseen solution is expected to leverage best practices by providing timely and actionable information that is based on well-documented expertise. It will fully cover the needs of all three stages of situational awareness in the context under consideration, namely *perception* (i.e. perceive the status, attributes, and dynamics of relevant elements in the setting under consideration), *comprehension* (i.e. perform a synthesis of disjointed elements of the previous stage through the processes of pattern recognition, interpretation, and evaluation), and *projection* (i.e. extrapolate information from previous stages to find out how it will affect future instances of the issue in hand).

Our overall objective is to increase the quality of health and disease self-management by encouraging citizens and patients to actively participate in their care through novel personalized technologies. At the same time, our approach aims to generate personalized and explanatory recommendations based on well-accepted clinical practice guidelines and treatment protocols, patient-specific data and consensus medical knowledge.

II. RELATED WORK

The raise of smartphones, i.e. devices that can support richer real-time and two-way communication than the conventional mobile phones whose technical functions basically included voice and short message services, paved the way for research and engineering in the domain of personal health care. An initial review presented in [2] examines the potential offered by the increasing processing and storage capabilities of smartphones as well as the additional functionality offered by their built-in devices such as fast internet connection, video capture and transmission, location determination, and - last but not least - connections via various types of protocols (e.g., Bluetooth with other external devices). The authors foresee a large and self-evident impact of smartphones on personal health-care, since they offer greater ease with which health professionals and patients can collect pieces of information and interact in a rich manner for purposes

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such as patient monitoring, sending of lab results, reminders, prescriptions and recommendations.

The work described in [3] examines the use of medical-related applications for both clinical and educational purposes. It reviews popular applications mainly for medication/drug reference, disease diagnosis/management and clinical scoring. Apart from the benefits associated with the rich connectivity offered by smartphones, it is interesting that the paper also examines negative consequences of the mobile applications in the health care environment, such as distracted doctoring, various security and privacy issues, as well as the potential for unprofessional behavior.

As the early research studies presumed, the proliferation of smartphones for healthcare purposes has led more and more people to use mobile applications to facilitate healthcare management and share their personal healthcare information. Representative mobile applications for personal health care include the following:

- *Healow* [4] is a mobile app for communication between patients and doctors that allows patients to access their up-to-date medical records. Patients are also able to access their appointments, lab results, vitals, and manage medications.
- *WebMD* [5] is an application that helps users make decisions and health improvement efforts by providing mobile access to mobile-optimized health information and decision-support tools. The app also gives user access to first aid information without having to be online.
- *Arthritis 411* [6], addressed to people who suffer from osteoarthritis, can be used at home in order for users to learn more about arthritis pain and treatment options, even before consulting a medical professional. It is also a powerful tool for surgical specialists to help explaining knee and hip procedures during consultations with their patients.

A taxonomy incorporating the most significant security and privacy aspects of 38 top-rated Android and iOS healthcare applications is proposed in [7], helping to outline some of the problems related to creating and downloading such applications. The results of the evaluation suggest that having a unified mechanism to categorize mobile health applications with respect to security and privacy is important and can be beneficial.

As far as collaboration support for clinical decision making is concerned, many approaches and tools have been already proposed in the literature [8]. However, only a few of them aim to facilitate group decision-making processes by providing forums for expression of opinions, as well as qualitative and quantitative tools for aggregating proposals and evaluating their impact on the issue in hand (e.g. [9]). These exploit internet technologies to connect stakeholders in a way that encourages dialogue and stimulate the exchange of knowledge. They concentrate on the representation of knowledge, focusing on knowledge creation through interaction. In any case, such approaches do not meaningfully integrate and exploit information and signals from related mobile applications [10].

III. COLLABORATION SUPPORT

The collaboration support tool of our approach integrates a set of services that have been fully developed and thoroughly assessed in the context of the EU FP7 Dicode project [11]. The evaluation of these services was very promising (see details in [12]). The proposed tool enables stakeholders to share data and knowledge, as well as to map arguments and discourse about various issues of disease and health self-management, the ultimate aim being to jointly decide about which course of action to take and inform the patient accordingly. The tool facilitates the synchronous and asynchronous collaboration of stakeholders through user-friendly virtual workspaces, and reduces the data-intensiveness and complexity overload of the settings under consideration to a manageable level. In addition, it makes it easier for stakeholders to follow the evolution of an ongoing collaboration, comprehend it in its entirety, and meaningfully aggregate data in order to resolve the issue in hand.

Actually, the tool's workspaces enable the establishment of communication channels between patients, their health care professionals and associated researchers. They also enable the virtual monitoring and assistance of patients by health care professionals, allowing the latter to supervise and refine the recommendations generated for each patient, as well as monitor their actions and disease evolution. Moreover, these workspaces maintain chains of views and opinions, accompanied by the supporting data, which may reflect the current collective intelligence on the issue under consideration, and justify a particular decision made or action taken. It is noted that the tool provides alternative visualizations of an ongoing collaboration, which facilitates stakeholders to manage diverse information types and exploit the strengths of both human and machine reasoning to reach a decision (dedicated reasoning mechanisms are integrated). The above functionality attains and augments individual and collective sense-making, by exploiting the stakeholders' knowledge in informal argumentative discourses.

Our approach towards addressing collaboration needs brings together two paradigms: the Web 2.0 paradigm, which builds on flexible rules favoring ease-of-use and human interpretable semantics, and the traditional decision support paradigm, which requires rigid rules that reduce ease-of-use but render machine interpretable semantics. To achieve this, our approach builds on a conceptual framework, where formality and the level of knowledge structuring during collaboration is not considered as a predefined property, but rather as an adaptable aspect that can be modified to meet the needs of the tasks at hand. By the term formality, we refer to the rules enforced by the system, with which all user actions must comply. Allowing formality to vary within the collaboration space, *incremental formalization*, i.e. a stepwise and controlled evolution from a mere collection of individual ideas and resources to the production of highly contextualized and interrelated knowledge artifacts, can be achieved [13].

As mentioned above, the tool offers alternative visualizations of the collaboration space (called 'views'),

which comply with the incremental formalization concept. Each view provides the necessary mechanisms to support a particular level of formality. The more informal a view is, the greater easiness-of-use is implied. At the same time, the actions that users may perform are intuitive and not time consuming; however, the overall context is human (and not system) interpretable. On the other hand, the more formal a view is, the smaller easiness-of-use is rendered; the actions permitted are less and less intuitive and more time consuming. The overall context in this case is both human and system interpretable.

In the view shown in Figure 1, called 'mind-map view', users can upload and interrelate diverse types of collaboration items. This view deploys a spatial metaphor permitting the easy movement and arrangement of items on the collaboration space. The aim of this view is to support *information triage* [14], i.e. the process of sorting and organizing through numerous relevant materials. Exploiting the functionalities of the tool, stakeholders may organize their collaboration through dedicated item types such as 'ideas', 'notes', 'comments' and 'services'. Ideas stand for items that need further exploitation; they may correspond to an alternative solution to the issue under consideration and they usually trigger the evolution of the collaboration. Notes are items expressing one's knowledge about the overall issue, an already asserted idea or note. Comments are items that usually express less strong statements and are uploaded to express some explanatory text or point to some potentially useful information. Finally, service items enable the interoperation with and exploitation of external services; they permit users to configure, trigger and monitor the execution of web services from within a workspace, and allow the automatic upload of their results into it (as soon as the execution of the service is completed). Configuration and triggering of a service is performed through dedicated web interfaces, developed by the corresponding service's provider, which convey the necessary parameters for the execution of the service. Multimedia resources can be also uploaded into the mind-map view (the content of which can be displayed upon request or can be directly embedded in the workspace).

The collaboration support tool of our approach interoperates with a novel recommendation engine to provide custom-made recommendations based on well-accepted clinical practice guidelines and treatment protocols, patient-specific data and consensus medical knowledge (it is noted that a detailed description of the platform's recommendation engine goes beyond the scope of this paper). Through this interoperation, patients may receive actionable and informative recommendations, based on the monitoring and collective evaluation of their clinical conditions. Recommendations provided may concern: (i) proactive actions that a patient should undertake in order to improve (or avoid worsening) her/his clinical conditions, and (ii) predictions about future disease progress and chances of related comorbidities.

IV. Mobile App

In the development of the proposed platform, much attention is paid to the design of the mobile application component, in that it constitutes an integral part of the self-management and medical monitoring processes. The mobile application processes information from the collaboration support tool and translates it into actionable and informative recommendations and visualizations (exploiting the integrated recommendation engine). It works in two modes: (i) a free open-access mode that allows everybody to access the platform's features and obtain basic recommendations and related information, and (ii) a restricted mode for registered users, which offers detailed and precise predictions, as well as explanatory recommendations that intelligently process the clinical data of a specific patient.

The application is suitable for handheld devices such as tablets and mobile phones and enables a two-direction communication channel between patients and the proposed clinical decision support platform. On one hand, patients are able to provide data to the platform through the mobile application (both actively, with the user entering personal information to the device, and passively, with the device collecting personal data through its built-in sensors and antennas, associated wearables or shareable real time lifestyle data). On the other hand, the application receives data from the platform in the form of required/recommended actions, requests for the collection of additional data, or predictions of

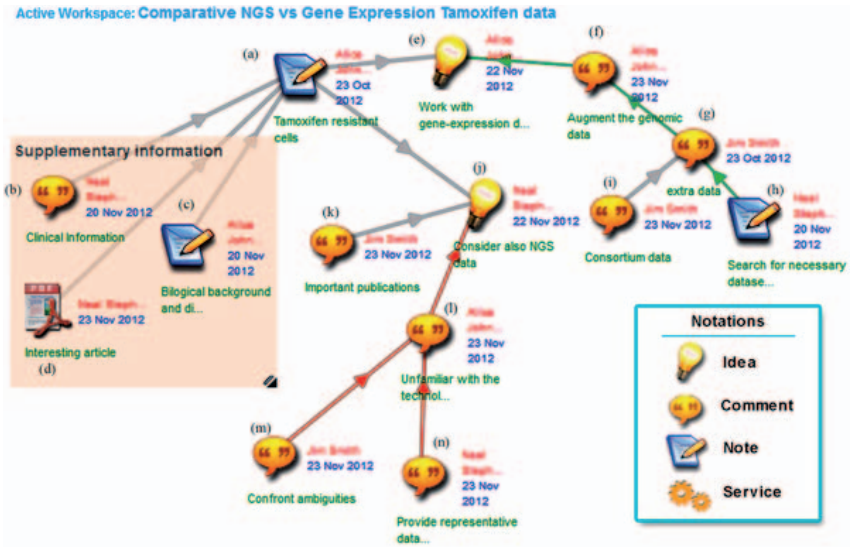

Fig. 1. An instance of the collaboration support tool.

the patient's own status. The mobile application takes care of processing the received packets of information from the platform and translating them into patient-readable documents.

Despite the capabilities currently provided by the state-of-the-art solutions in mobile applications and mobile telecommunications, such as high processing speeds, memory capacities, ultra-high networking data-rates as well as support of rich APIs (either standardized or not) for various purposes, there are several major technical challenges that the design of the mobile application should bear with. These challenges are tightly related to the fact that medical services should be handled with high sensitivity in several different aspects [15]:

- **Interoperability**: It is a major requirement that can be applied in many ways since the mobile application will interact with various medical devices in order to exchange operating instructions or medical data. Since the connection of medical devices from different manufacturers has faced similar problems, the European Standards for Medical Device Intercommunication propose open standards for such communication types.
- **Portability**: It is important that the user can use his/her own device and that the mobile application is designed in a way that it does not have special requirements in terms of user equipment. The most efficient way to achieve portability is to develop a web-based application. The state-of-the- art in web technologies provides the web browsers, even the mobile ones, with extreme capabilities, including access to the various built-in modules (such as cameras, sensors, etc.). Almost all modern mobile browsers support these web standards and therefore portability is assured. Thus, there is no need to install native applications.
- **Data Integrity**: The design of the mobile application has been made under the assumption that all the data are kept "centrally" in the core of the platform. The term "centrally" does not mean that there is a single entity keeping the information, since it can be a cluster of nodes handled by an algorithm for distribution.
- **Privacy**: Privacy will be assured by applying security in the platform at all levels. First, the information will be exchanged over secure protocols such as SSL. Second, strict security policies will be applied at the platform, where all the collected data will be aggregated. Last but not least, appropriate authorization will be assured through the application of access control throughout the platform and typical data isolation techniques.
- **Performance**: Performance is certainly boosted by the extreme capabilities of the current mobile devices and network speeds. In any case, the design of the proposed mobile application also considers: (i) creating a lightweight application that does not require high processing capabilities nor high memory capacity, and (ii) limiting the need for data exchange. Information over the network will be exchanged only when this is necessary, thus avoiding frequent and unnecessary data exchange and restricting the inevitable dependency on the network connectivity.
- **Usability and user-friendliness**: In order to engage users, the application should achieve high levels of usability and user-friendliness. Apart from appealing layout and intuitive interaction functionality, the design takes under serious consideration the target end-users of the application. Therefore, given that it mainly addresses needs of elderly people that are possibly not familiarized with the latest technology advances, the design proposes a simple and clear layout that provides end-users with straightforward and consistent ways for inserting their input as well as for receiving any potential feedback in an unambiguous manner.

V. AN INDICATIVE USE CASE

To better demonstrate the functionality of our approach, we sketch in this section an indicative realistic scenario of its use (see Figure 2). Patient A finds some vague information about an alternative treatment for his disease. He uses the app in his mobile device to create a new workspace in the collaboration support tool and share his findings with other stakeholders (researchers, physicians, other healthcare professionals, interested patients and other interested parties), aiming to hopefully get additional information on this treatment.

Researchers that are familiar with this treatment provide more information about it, and upload relative research results. Clinical doctors that have adopted this treatment provide clinical results and offer useful insights. The participants, using their apps and the collaboration support tool, discuss the related issues, and express opinions and arguments in favor and against the alternative treatments. For example, they may discuss the type of the disease the treatment is useful for, the type of patients that might benefit from it (and the types that will not), if and how it is better than other treatments, the possible side-effects and negative reactions, etc. The collaboration tool's functionality is exploited to visualize the discussion and the associated data coming from different perspectives in order to get concise views of the issue being elaborated and make better sense of the data uploaded, as well as the opinions and the supporting arguments expressed, the ultimate aim being to conclude the issue under consideration.

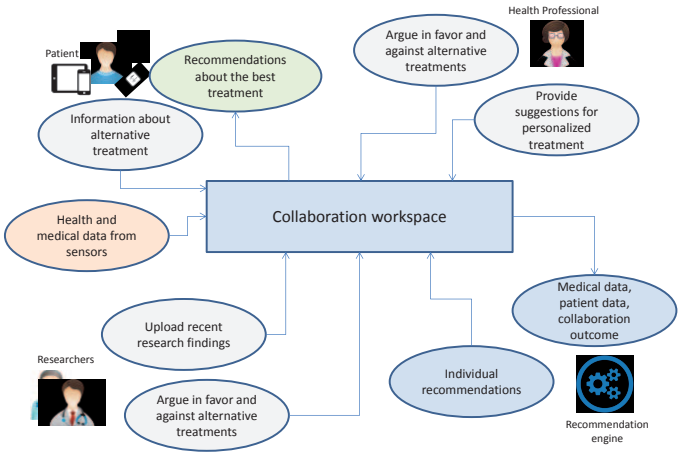

Fig. 2. Use case diagram for an indicative scenario.

Patient B, in a similar medical condition to that of Patient A, is highly interested in the issue and provides additional information on her own condition. Meanwhile, the mobile app of both patients gathers medical data from associated sensors and updates the relevant parts of the platform's database. The recommendation engine uses the patients' data from the database, and the information that have been brought up on the collaboration support tool, and suggests to patient A to avoid this treatment as it is not suitable for him, and to patient B to follow this treatment as for her it is better than the one used.

A health care professional notices the recommendations and uploads some additional information suggesting that this treatment is better to be followed in conjunction with another medical protocol. The recommendation engine modifies its suggestion accordingly. Finally, patient's B attending physician agrees with the recommendation and modifies the patient's treatment. The mobile app retrieves the information and modifies the medication schedule of patient B, in order to alert her when needed. As a result, both patients are better informed about their medical status and the treatments that better suit to their cases.

VI. CONCLUSIONS

Compared to existing clinical decision support approaches, the work described in this paper follows a novel approach aiming to meaningfully integrate a set of tools for helping the patient efficiently and effectively manage their own health conditions. This direction is in accordance with recent developments in the area, e.g. various systems presented at the 2015 Summit on Translational Bioinformatics and Clinical Research Informatics of AMIA (American Medical Informatics Association), which suggest the idea of helping the process of decision making by facilitating access and integration of information coming from different sources rather than providing specific diagnostic advice.

Our approach can be viewed as a fundamental transformation of the traditional patient/healthcare professional relationship into a collaborative partnership, through which patients become learners that are informed about their health status and take an active role in their treatment applying the knowledge they continuously gain. By providing informative and actionable recommendations to citizens and patients, our approach contributes to the realization of proactive, predictive, preventive, and participatory ('4Ps') approach in medicine.

The major anticipated outcomes of the proposed platform are:

- *Improving the participation of the patient in the health care process:* Patients will learn to manage their own conditions, access significant new information about their disease and manage related comorbidities. This is expected to thoroughly improve early detection and diagnosis of diseases and significantly reduce the number of severe clinical episodes and complications.
- *Boosting the development of mobile applications for self-management of health and disease:* Our work shapes an innovative healthcare support environment that fosters and promotes the use of mobile applications and associated personal devices, which facilitate a unified exploitation of diverse data sources and stakeholders' knowledge. Such applications enable patients to exploit a well-informed scientific workflow in a timely and effective manner. In addition, they offer advanced argumentation-based reasoning and predictive modelling mechanisms, adopt a knowledge-based decision-making view, and build on the synergy of human and machine reasoning to provide actionable and informative recommendations.

Future work directions include the full integration of the proposed platform's components and its pilot operation and assessment in a specific medical decision making context (concerning the Chronic Obstructive Pulmonary Disease and related comorbidities).

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