An Innovative Platform for Person-Centric Health and Wellness Support

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Abstract. Modern digital technologies are paving the path to a revolutionary new concept of health and wellness care. Nowadays, many new solutions are being released and put at the reach of most consumers for promoting their health and wellness self-management. However, most of these applications are of very limited use, arguable accuracy and scarce interoperability with other similar systems. Accordingly, frameworks that may orchestrate, and intelligently leverage, all the data, information and knowledge generated through these systems are particularly required. This work introduces Mining Minds, an innovative framework that builds on some of the most prominent modern digital technologies, such as Big Data, Cloud Computing, and Internet of Things, to enable the provision of personalized healthcare and wellness support. This paper aims at describing the efficient and rational combination and interoperation of these technologies, as well as their integration with current and future personalized health and wellness services and business.

Keywords: Human behavior, Context-awareness, Big data, Big information, Big knowledge, Cloud computing, Quantified self, Digital health, Health devices, Social networks, User interface, User experience, Knowledge bases, Personalized recommendations.

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1 Introduction

A drastic change in the delivery of health and wellness services is envisioned for the forthcoming years. The current global socio-economic situation, with cuts in government spending, an increasing population of pensioners and a growing unemployment rate, has particularly fostered the need of more efficient health and wellness care models. These new models particularly build on the concepts of proactivity and prevention, which in simple words refer to avoiding as much as possible the need of care. In fact, it is well-known that most prevalent diseases are partly caused by lifestyle choices that people make during their daily living. Therefore, bringing these lifestyle diseases under control may have a great impact on healthcare and assistance spending, and certainly on people's health itself. To that end, empowerment, encouragement and engagement of people in their personal health care and wellbeing is especially required.

In this context, information and communication technologies appear as the main driver of change to support people empowerment, encouragement and engagement. Actually, an increasing number of applications and systems for personalized healthcare and wellness management have been developed during the last years. These solutions, mainly oriented to fitness purposes, are used for detecting very primitive user routines and behaviors, and are also utilized for providing track of progresses and simple motivational instructions. Withings Pulse [4], Jawbone Up [2] and Fitbit Flex [1] are some examples of instrumented bracelets and wristbands accompanied by mobile apps capable of providing some basic recommendations based on the measured taken steps and slept hours. More prominent health and wellness systems have been provided at the research level, yet they are fundamentally prototypes. Examples of these systems are [9] for detecting cardiovascular illnesses, [6] for alerting on physical conditions or [10] for tracking changes in physiological responses of patients with chronic diseases. These solutions have a very limited application scope, lack of interoperability with other similar systems and rarely personalize to the particular user needs and preferences. Therefore, to neatly support all health and wellness aspects of each particular user, comprehensive frameworks capable of tackling more complex and realistic scenarios are required. Although a few attempts have been very recently provided in this regard [8,7,5], most of them lack essential requirements of a person-centric framework for health and wellness support.

In this work we present Mining Minds [3], an innovative framework that builds on the core concepts of the digital health and wellness paradigm to enable the provision of personalized healthcare and wellness support. Mining Minds is further devised to intelligently exploit digital health and wellness data to generate new businesses and services, which are unquestionably called upon to change the actual healthcare and wellness panorama. The rest of the paper is organized as follows. The essential requirements devised for a framework supporting personalized healthcare and wellness services are shown in Section 2. Section 3 thoroughly describes the proposed Mining Minds Framework. A potential business model and service scenario that may be supported through Mining Minds is presented in Section 4. Finally, main conclusions and future directions are shown in Section 5.

2 Requirements of a Person-Centric Digital Health and Wellness Framework

People health and wellness states can be represented through data of a very diverse nature, such as physical -sensory-, logical -personal profile and interests-, social -human cyber relations- and clinical -medical- data. Accordingly, one of the most important challenges posed to digital health and wellness systems refers to the intelligent and comprehensive collection, processing and organization of these data. For data collection, several modern systems such as wearable self-quantifiers, ambient sensors, SNS or advanced clinical systems, are increasingly available. Thus, a certain level of abstraction from heterogeneous resources is required to make their utilization transparent to the user. Moreover, data types are of a very diverse nature, ranging from structured - e.g., electronic health records -, semi-structured - e.g., multimedia - or unstructured - e.g., SNS -. Thus, an important requirement of person-centered digital health and wellness frameworks is to be capable of dealing with this new dimension of heterogeneous data. Not only data variety constitutes a key factor to be considered, but also data volume and velocity. Massive amounts of health and wellness-related data are generated over time on and around the subject at different paces. Therefore, these frameworks need to provide procedures to support the storage and real-time processing of such amounts of data. Similarly, mechanisms for load balancement and scalability are utterly required when dealing with several potential users and data collection mechanisms.

Determining a person's health and wellness state is a very challenging task that require more than simply collecting and persisting personal data. Thus, automatic intelligent mechanisms to process person-centered data, and extract interpretable information, are needed. Moreover, insights should be also gained not only from individual users but from the collectivity. To do so, advanced techniques to process people's health and wellness information in an anonymized form are particularly required. These insights can be leveraged by health and wellness care systems to extend, adapt and evolve the knowledge provided by human domain experts.

Mechanisms such as alerts, recommendations or guidelines, generally known as service enablers, are particularly used to catalyze both information and knowledge to be delivered in a human-understandable way to users and stakeholders in general. Not only should person-centered digital health and wellness frameworks provide these enablers, but also support mechanisms to customize them to each particular person needs and demands, for example, by mapping user needs to the best possible recommendations or personalizing the explanation of these recommendations.

Another important requirement of these frameworks refer to the presentation of health and wellness outcomes to the end-user. Since users of these systems may play a different role, the information needs to be presented in the most convenient way given their interest and expertise. For example, comprehensive user interfaces need to be prepared for clinical professionals, while more simplified and appealing presentations may be required by average users. Moreover, the analysis of the user interaction with the system is seen to be of great value. Users perceptions of system aspects such as utility and ease of use need to be fed back into the framework in order to provide the most personalized possible experience, as well as to help identify potential inconsistencies in the operation of the system.

Finally, all the aforementioned requirements need to be neatly accommodated to user security and privacy principles. Person-centered digital health and wellness frameworks deal with sensitive information, thus it is of utmost importance to adequate privacy, security, protection and risk management measures to all the processes involved in the treatment of this information.

3 Mining Minds Platform

In the light of the requirements presented in the previous section, a novel person-centric digital health and wellness framework is proposed here. Hereafter referred to as "Mining Minds", this framework consists of a collection of innovative services, tools, and techniques, working collaboratively to investigate on human's daily life data, generated from heterogeneous resources, for personalized health and wellness support. Mining Minds philosophy revolves around the concepts of data, information and service curation, which refer to the adequation, adaptation and evolution of both contents and mechanisms used for the provision of high quality health and wellness services. Motivated by these concepts, a multilayer architecture is particularly devised for Mining Minds. The architecture, depicted in Figure 1, is composed by three main layers, respectively, Data Curation Layer (DCL), Information Curation Layer (ICL) and Service Curation Layer (SCL), and an additional one, Supporting Layer (SL), to ensure the suitable operation of the former ones. In the following, the Mining Minds architecture layers are described.

3.1 Data Curation Layer

Data Curation Layer, DCL, is in charge of processing and persisting the data obtained from the Sensor Layer, which abstractly defines the possible sources of user health and wellness data, i.e., SNS, questionnaires, wearable biomedical devices or ambient intelligence systems, among others. The DCL is composed of Data Curation, Data Representation and Mapping, and Big Data Persistence components. Data Curation is responsible for the acquisition, labeling and analysis of the data obtained from the diverse sources, in both real-time and offline manners, as generic streams. The format of the acquired streams is based on the source devices, thus their specifications are hosted by device registry of the Data Curation component. To classify the data streams by device and usage,

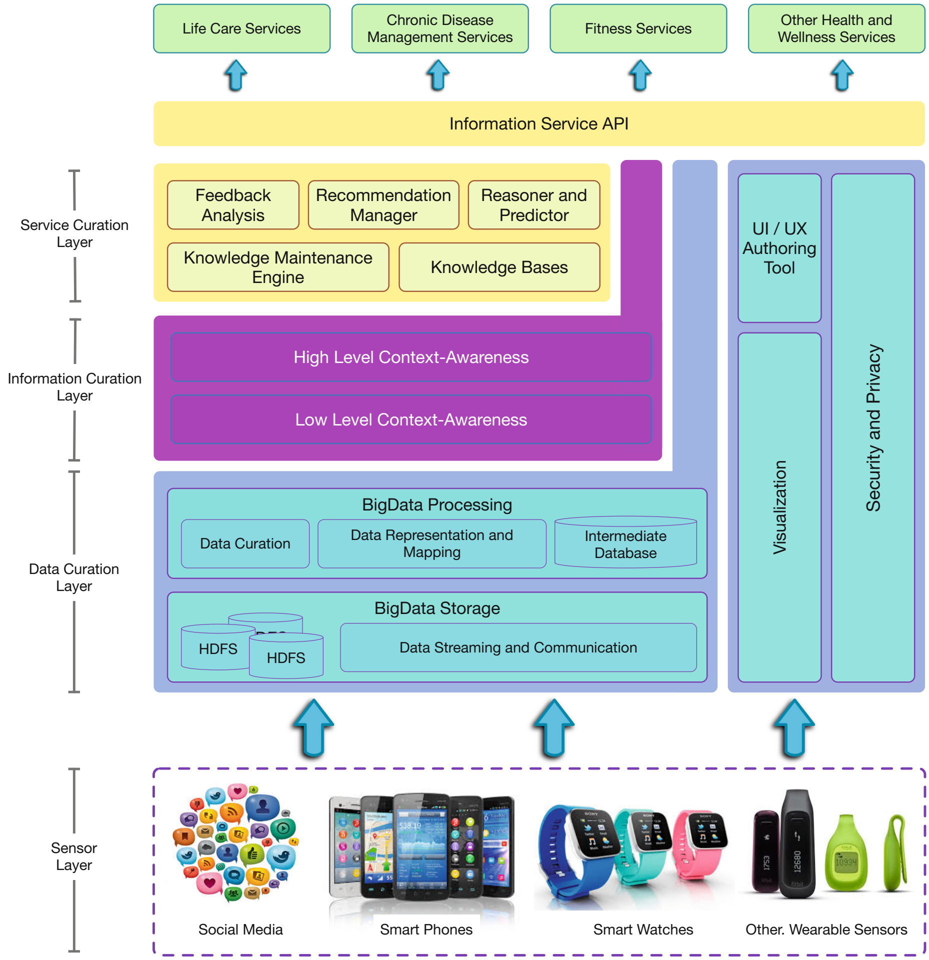

Fig. 1. Mining Minds Framework Architecture

the Data Curation component provides real-time data labeling, which converts the unstructured data into semi-structured format. As the volume of the data collected is large and type of this data is heterogeneous, the possibility of data noise and redundancy is high; therefore, the labeled data stream is forwarded for analysis where several data analysis filters are executed to ensure the reliability of data, keeping its comprehensiveness preserved. Apart from analysis of real-time data, the Data Curation also ensures the reliability of already preserved data with its provenance features. These features are executed as filters over offline data batch processes.

After analysis, data streams are forwarded to the Data Representation and Mapping component. The role of Data Representation and Mapping is to conform data according to a standard definition; such that, it is understandable and shareable among layers of the Mining Minds platform and also with third party components and applications. The conformance definition is based upon an ontology, where data from the labeled and analyzed stream is mapped to ontological resources, representing the data as resources with hierarchies. This conformed data model is forwarded to Big Data persistence for storage. The persisted data is made available to other Mining Minds layers through the so-called Intermediate Database. The Intermediate Database consists of a fast processing storage unit that temporarily hosts the data to be served in a rapid manner.

3.2 Information Curation Layer

Information Curation Layer, ICL, represents the Mining Minds core for the inference and modeling of the user context and behavior. It is composed by two sublayers, namely, Low Level Context Awareness (LLCA) and High Level Context Awareness (HLCA). The LLCA is in charge of converting the wide-spectrum of data obtained from the user interaction with the real and cyber-world, into abstract concepts or categories, such as physical activities, emotional states, locations and social patterns. These categories are intelligently combined and processed at the HLCA in order to determine and track the normal behavior of the user.

The LLCA consists of functionalities for SNS analysis, activity recognition, emotion recognition and location detection. The SNS analysis relates to the processing of the data generated by the user during their interactions in regular social networks such as 'Facebook' or 'Twitter'. This comprises from posts or tweets generated by the user themselves, user mentions, user traces and even global social trends, in the form of both text and multimedia data. From here, personal and general people interests, needs, conducts and states may be determined. The activity recognition process refers to the identification of primitive physical actions performed by the user, such as, 'standing', 'walking' or 'jogging'. This process may build on several sensing modalities, as they happen to be available to the user. Examples of these modalities are wearable inertial sensors, video and audio. The emotion recognition process is defined to infer user emotional states, such as 'happiness' or 'anxiety', by using sensor data similar to the aforementioned, as well as more sophisticated sources exploring human physiological variations and responses. In order to determine the user situation, it is of extreme importance to track the user ambulation. This is the role of the location detection functionality, which essentially builds on the data collected through indoor and outdoor positioning sensors, such as video and GPS, to specify the exact location or direction of the user. The information generated on top of the LLCA is unified and delivered to the DCL, in order to make it accessible to not only the HLCA, but other Mining Minds components and applications.

The diverse categories identified through the LLCA are used by the HLCA to define a more comprehensive representation of the user context and behavior. Two main functionalities are considered to that end. The first one corresponds to the context awareness and modeling, which enables the interpretation and representation of the user context. The modeling of the context is performed through ontologies, which have been adopted in the past as a unified conceptual backbone for modeling, representing and inferring context, while its interpretation is done through a rule-based reasoning process. Thus for example, based on the actual time (e.g., midday), location (e.g., restaurant) and inferred activities (e.g., sitting), this functionality can determine the precise user context (e.g., lunch). The context awareness and modeling is also used to populate the LifeLog Repository. This repository is used to store the contexts determined for the person during the use of the Mining Minds system. This information can be served to other Mining Minds components and applications, although it is primarily devised as input to the second essential HLCA functionality, so-called behavior modeling and analysis, which is devised to identify the user behavior patterns and routines. For example, if it has been identified that the user normally goes for lunch during a specific time span in work days, it can be determined as a personal behavior pattern or routine of this particular user. LLCA and HLCA information is regularly stored in the Intermediate Database, making it accessible to the SCL and other potential parties.

3.3 Service Curation Layer

Service Curation Layer, SCL, provides the means to transform the data and information generated by DCL and ICL into actual services. To do so, SCL supports automatic and expert-based knowledge creation and maintenance, personalized recommendations and predictions, and users feedback analysis. The knowledge creation capability is activated either by the domain expert or knowledge engineer, by using data driven, knowledge driven or hybrid approaches. The created knowledge, which is persisted in the Knowledge Bases of SCL, has various levels of granularity, which range from abstract or general to personalized or user-specific knowledge. The knowledge managed by SCL is used to generate personalized health and wellness recommendations. First, the Reasoner component uses the abstract level knowledge for generating general recommendations, that are further personalized by the Recommendation Manager. Then, the Recommendation Manager makes use of the personalized knowledge, which encodes user preferences and contextual information. Once the personalized recommendations are delivered to the user, feedback can be obtained from their acceptance - i.e., recommendation is followed - or rejection - i.e., recommendation is not followed -. This feedback is analyzed through the Feedback Analysis component, which converts it into information interpretable by the Knowledge Maintenance Engine component. This valuable information is then used by the Knowledge Maintenance Engine to update and evolve the user-based knowledge, in order to ensure a more personalized and adequate health and wellness support.

3.4 Supporting Layer

The role of the Supporting Layer, SL, is to enrich the overall Mining Minds functionalities through advanced visualization, interactive and personalized UI/UX and adequate procedures to ensure privacy and security in all aspects. The main role of the Visualization component is to adjust the style of the information delivered to the users based on their expertise and role. On the one hand, for example, average users may receive certain recommendations related to their daily life activities in the form of comprehensive textual or audiovisual instructions. More complex analytics may be displayed to human experts in relation to users health and wellness data, information and knowledge.

UI/UX is a major supportive component aimed to engage the end-user with the Mining Minds system in an intuitive fashion. Considering user preferences, habits, attitude and mood, the UI/UX component enables the end-user applications interface to adapt accordingly. This adaptation is required to fine tune the human-computer interaction experience with respect to font size, color, theme, or audio levels, among other characteristics.

Considering the sensitivity and associated concerns of the collected personalized information, the Mining Minds system need to assure and exhibit adequate privacy and security, not only at a storage level, but also during processing and delivery of services. Mining Minds employs state of the art existing cryptographic primitives along with indigenous protocols to exhibit more control over possible states of data. For secure storage, AES standard is considered, whereas for oblivious processing homomorphic encryption and private matching is used. Taking into account the intensive data flow between end-users applications and systems and the Mining Mind platform, randomization techniques are considered. These procedures ensure a high entropy for minimal leakage of information. For sharing personalized information and recommendations with the users, an authorized model ensures the legitimate disclosure. Slow processing of information is an effect caused by the encryption; however, to assist partial swiftness to Mining Minds, sensitive and non-sensitive information is decoupled where required.

4 Business Model and Service Scenario

A potential business model for Mining Minds consists of enhancing the relationship between health insurance companies and their customers. A healthier customer is beneficial for an insurance company as it can help reduce medical and assistance costs, ultimately resulting in higher profits. Likewise, customers can benefit from managing their health and wellness by improving their health conditions and also receiving rewards in the form of cheaper health insurances, lower co-pays, deductibles and out-of-pocket health expenses.

The management of people's health and wellness through Mining Minds requires defining diverse service scenarios. These services should particularly relate to the user's daily life activities, covering those aspects of their lifestyle that may have a direct or indirect impact on their health and wellness status. One of the simplest but at the same time most challenging case application scenario refers to the weight management of a person. The determinants of abnormal weight have been deeply explored in the past; however, practical mechanisms to encourage and guide users to lose or gain weight are very primitive and of limited success. Mining Minds aims at tackling this problem from an holistic perspective, supporting diverse key services necessary for an efficient weight management, such as healthy diet menu management, restaurant recommendations, convenient food store suggestion and exercise encouragement, among others. These services are not only seen to serve as pillars to empower users and promote a healthy weight management, but also open a new branch of potential third party businesses. Other envisioned case study scenarios that are in the scope of Mining Minds include, but are not limited to, health management of chronic disease patients, anti-aging habits promotion, pregnancy management and infant care assessment.

5 Conclusions

This work introduced Mining Minds, an innovative digital health framework for personalized healthcare and wellness support. The framework has been neatly designed taking into account crucial requirements of technologies and applications of the digital health and wellness domain. As a result, a multilayered architecture defined to provide the necessary functionality to enable a broad range of services for personalized healthcare and wellness has been presented. The proposed architecture, being the result of both technical and business-oriented research, could enable a new marketplace and the creation of a new business ecosystem around healthcare, wellness and other related domains.

This paper also showed the feasibility of the Mining Minds concept as well as an initial realization of the key architectural components. Future work includes the enhancement of the existing components as well as an evaluation of the presented architecture and its services on a large scale testbed, which is currently under construction.

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