Toward a Generic Personalized Virtual Coach for Self-management: a Proposal for an Architecture

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***Abstract*—The shift toward prevention and self-management in health hinges upon a massive realization of behavior change, which involves the use of virtual coaches. Increasing availability of data from mobile devices and techniques for real time analysis provide new opportunities for personalizing virtual coaches. We propose an architecture that takes advantage of those developments. We identify the required knowledge and methods to develop a flexible ecosystem for rapid prototyping of personalized virtual coaches.**

Keywords–virtual coach; personalization; coaching strategy; data science; model based software development.

I. Introduction

Self-management is widely seen as a viable contribution to sustainable health-care as it allows to prevent health problems. Virtual coaches are important means to support self-management in order to maintain and increase health and well-being.

The wide availability of wearables and new techniques of data science to deal with big data provide many new opportunities for the persuasive design of virtual coaches [1]. The variety in health related data is increasing. While motion trackers have become common, other wearables are becoming available, such as stress sensors. Yet, many applications are still at a stage in which the data are simply presented as graphs. Mostly, data are merely used as input to a monitoring tool rather than as input for coaching strategies, let alone that the variety of data is combined in order to personalize the coaching strategy. While van Gemert-Pijnen et. al. and Siewiorek et. al. identify these opportunities [1][2], we propose an architecture for integrating big data in virtual coaches. The prototype described by Blaauw et al. combines the execution of ecological momentary assessments (EMA) with the collection of data from wearables [3]. In our proposal, we embed those two elements within a coaching strategy. Additionally, we enrich the notion of EMA by allowing for automatic execuction and personalization of EMAs. Albaina et al. illustrate the design process of a persuasive virtual coach for the very specific purpose of motivating elderly people to walk by using a pedometer and goalsetting [4].

This paper proposes an architecture for a generic personalized virtual coach. Section 1 introduces the main fields of knowledge that are required for developing a personalized virtual coach. Subsequently, we propose an architecture integrating knowledge of these disciplines. Section 3 elaborates on the required computer science techniques. The next section shortly describes the kind of process management that is required in order to take the concept of virtual coaching a step further. A discussion of future work finishes this paper.

II. Methodology

We define a virtual coach as a computational system that assists the user, either as stand in or merely as supplementary to a human coach, to support behavior that is desired by the user to improve health or well-being. This definition is wider than the definition of eCoaching by Lentferink [5], even if it is narrowed down with the adjective 'personalized' as defined below. Contrary to Lentferink's definition, which limits eCoaching to goalsetting, our definition is agnostic to the nature of the coaching strategy. As a result, we are able to distinguish between the generic nature of the virtual coach and a wide range of coaching strategies. Although the architecture as such does not exclude a wider application, it is developed within the context of eHealth. The intended applications range from the treatment of emotional eaters [6][7] to support for maintaining the social network by elderly people. As such, the virtual coach implements persuasive technology that attempts to influence the behavior of its users.

According to the behavior model of Fogg, behavior is most likely to be influenced when the motivation is high and the triggers to act are easy to execute [8]. Given the intrinsic difficulties of achieving enduring behavior change, our definition deliberately limits the virtual coach to changes that are desired by the user. According to Fogg's behavior model, triggers become easy to execute when they are adapted to the context of the user. Fogg's characterization of triggers straightforwardly translates into a crucial requirement for the virtual coach, namely that it must personalize its feedback to the user as well as the coaching strategies on which this feedback relies. A particular coaching strategy, or a different focus within a coaching strategy, might be more effective, depending on the dispositions, abilities, preferences, and lifestyle of the user.

The architecture proposed in the following section is based on the integration of three disciplines. The first one belongs to the therapeutical application of behavioural sciences, sociology or psychology, or a mix of them, depending on the nature of the intervention for which one implements the virtual coach. They provide an evidence based coaching strategy. For example, if an instantiation of the virtual coach needs to support the development of learning abilities of children, the coaching strategy will stem from theories about metacognition and the manner in which capabilities can be improved. In the case of emotional eaters, which comprises our first application of the virtual coach, the coaching strategy stems from existing face-

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to-face therapies [9].

The second discipline is that of data science. The wide spread use of mobile devices and recent developments in the field of big data and predictive analytics allows to achieve the required personalization by gathering, analyzing, and interpreting personal data. Analysis, both on the level of personal data (n=1) and of aggregated data, provides information to guide the coaching strategy in adapting its triggers to the specific circumstances of the individual user. Most importantly, streaming data, predictive analysis, and realtime data processing provide novel opportunities to achieve an appropriate timing of the triggers, which is key in the success of persuasive designs [8].

Finally, the third discipline comprises a subfield of software engineering called model driven software development (MDSD). The application of domain models, especially in the form of domain specific languages (DSL), entails the development of abstractions that capture the crucial elements of a domain, in our case coaching strategies [10]. For the purpose of the virtual coach, a DSL must be designed that allows for an straightforward implementation of coaching strategies. Such an implementation consists of a translation of (parts of) a coaching strategy into rules suitable for a computational system. The virtual coach executes these rules to provide feedback to the user depending on the outcomes of the analysis of data. Since there are many ways in which even a single coaching strategy can be implemented, considerable exploration and research must be carried out into the most effective ways of implementing coaching strategies. The application of MDSD ensures that the rules of a coaching strategy can be changed easily.

III. Architecture

We propose to combine a health data platform (HDP) with a platform for the implementation of coaching strategies (CSP) in order to establish an ecosystem for personalized virtual coaches (see Fig. 1).

A. *Health Data Platform*

One of the most important aspects of the required personalization of the triggers of a coaching strategy consists in the trigger's timing [8]. The real time analysis of personal data streams as well as the real time self-evaluation of the virtual coach itself provides new opportunities to establish an appropriate timing of the triggers.

The HDP employs techniques of data science to gather, store, query, analyze, classify, and predict health and lifestyle related data. We distinguish between direct and indirect data streams. The former stem from mobile devices, while the latter consist of data that is generated by the coaching strategy itself. The indirect data streams allow the virtual coach to consult the coaching history and adapt itself accordingly, for example to avoid coaching moves that have failed in the past.

B. *Coaching Strategy Platform*

The other part (CSP) implements the coaching strategy and consists of the following parts:

- user interaction;
- data processing unit to combine data generated by user interaction with the output of the health data platform;
- rule engine to provide the user with feedback by personalizing scheme's.

First of all, feedback may consist of advice to take educational modules to improve skills as required by the coaching strategy. It may also consist of the suggestion to set a certain goal. When accepted by the user, progress will be measured and visualized in such a way that it motivates the user to achieve this goal. A third important type of feedback consists of an EMA.

EMAs are often used in eHealth related research. They provide a convenient way to obtain structured real time information about the behavior and experiences of the user [11][12]. EMAs are used for research purposes as well as treatment. We propose a way of using EMAs within the virtual coach with two novel aspects:

- automatic execution;
- personalization.

Depending on the specific state of the individual, the coaching strategy might involve an EMA at certain stages of the coaching. Schematized EMAs can be used to personalize ecological momentary interventions, or EMIs. Coaching rules enable the automatic execution of EMIs that are tailored to individual situations.

Let us take a simple example to illustrate how this global architecture supports the implementation of a virtual coach. Suppose a wearable is used for tracking the movements of users. Let us take as a very simple coaching strategy that the virtual coach must be able to support existing good habits. Pattern detection and predictive analytics learns for example that a particular user A is usually running on each Friday morning. Let us assume that the user has entered his holidays via the user interface or that the virtual coach has access to this information by other means. and that he spends his Saturdays such that it is no option to improve movements. This extremely simplified coaching strategy can be implemented in the rule engine as follows:

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if running is predicted within 5 minutes,
remind the user unless he has a holiday
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The user will receive notice in accordance with her or his preferences (SMS, whatsapp, etc.). An improved version might take into account the weather and only remind the user when it has stopped raining.

IV. Computer Science Techniques

This section identifies the required techniques of the most innovative aspects of the proposed architecture.

A. *Data Science*

Widely available mobile devices provide diverse data streams that are useful for understanding, and possibly predicting, the behavior of the user. The nature of the virtual coach requires the analysis of these data streams to be automated. Patterns, features, and anomalies need to be discovered automatically (knowledge discovery). Knowledge discovery requires:

- the automation of the data analysis process;
- the handling of Big Data in combination with Analytics.

The automation of data analysis involves the preparation, transformation, and modeling of data in order to become in the position to discover 'knowledge', that is, useful information [13]. The diversity, realtime, and streaming nature of the data impose Big Data aspects [14] on the automation of data analysis [15]. Accordingly, the health data platform requires the latest techniques and frameworks to implement the storage and real time analysis of data streams, such as Apache Storm.

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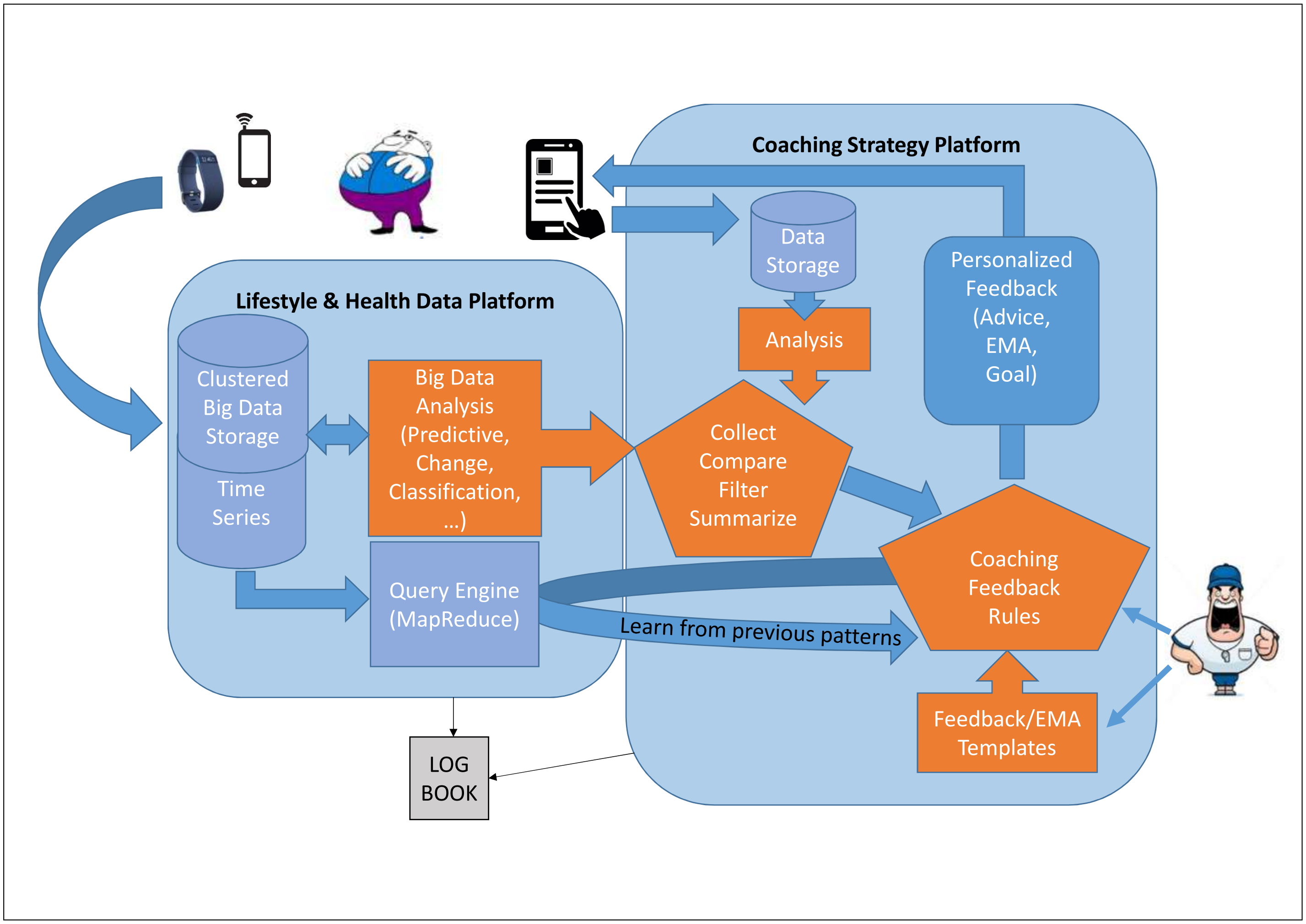

Figure 1. Architecture Personalized Virtual Coach

B. Model Driven Software Engineering

The implementation of a coaching strategy requires at least some techniques that are developed under the label of artificial intelligence (AI). A common distinction between two approaches in AI is that between rule based expert systems and data based machine learning systems. Currently the latter is quite popular, because of success in applying this approach to previously unsuccessful cases, such as machine translation and computer vision. To a large extent, this success is the result of the availability of a lot of data of sufficient quality, such as labeled images for computer vision.

Unfortunately, in the case of coaching strategies, this data is hardly available (or not in the language of the intended users) and is not likely to become available in the foreseeable future. Moreover, experts on coaching strategies aim at improvements, which requires a conceptualization of psychological and/or social processes. In the case of machine learning, however, correctly labeled data is used to produce rules for computation indirectly. These automatically produced rules not only remain implicit, but also remain almost incomprehensible for human cognition. Thus, a machine learning solution to the coaching strategy as a whole tends to obfuscate an understanding of these processes, which is precisely what domain experts aim to unravel. Although machine learning is invaluable to analyze the data streams, and can be used in several other parts, such as natural language processing, we do not regard it as the first choice for implementing the coaching strategy as a whole. Nevertheless, once sufficient virtual coaches, using sufficiently rich data sets, have operated for some time, their data might be useful to train machine learning modules to improve the virtual coaches. Currently, however, we are not yet at this stage, but have to start by implementing coaching strategies as understood by domain experts.

The field of MDSD provides convenient means, such as the concept of a DSL, to implement a rule based system. Such a DSL based system allows to formulate the coaching strategy in terms that are close to the coaching domain. In the case of dialectical behavior therapy for emotional eaters, a simple example of such a rule could be [9]:

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if Anger or Fear dominates
follow Dialectical Coaching Strategy
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Obviously, such a rule presupposes several software modules, such as modules that allow to determine the dominating emotions, for example by means of EMAs, a stress sensor, or the analysis of expressions in natural language. The DSL

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provides an abstraction level that does not require knowledge about the way these software modules and the analysis of data are realized.

V. Development process

Nowadays, agile approaches dominate the development of software. These approaches ensure a crucial role for all stakeholders at each stage of the development. An agile approach, especially in the form of scrum, is particularly suitable for a development process that requires the integration of quite diverse disciplines. By means of an, preferably daily, participation in the scrum process, the expert on coaching strategies is immediately confronted with the the (im)possibilities of engineering techniques Conversely, the engineers get immediate feedback on their interpretation of the coaching strategy. In addition, the agile approach prepares the virtual coach for adoption by users and the healthcare sector [16].

VI. Conclusion

We have identified how knowledge of diverse disciplines should be integrated, and proposed an architecture for a generic personalized virtual coach that utilizes recent developments in wearables and data science. Focusing on the implementation of the coaching strategy required by the treatment of emotional eaters, several software modules for both the HDP and CSP are currently under development. Future work will consist of the integration of the software modules to show the viability of our architecture, including the design of an appropriate DSL for implementing coaching strategies. Planned expansions to other coaching cases will warrant and demonstrate the generic nature of our solution.

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