Towards a Generic Platform for the Self-Management of Chronic Conditions

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Abstract—**Self-management is an approach to healthcare which aims to empower individuals to manage their own health conditions. This is of particular importance given the shifting demographics, increased prevalence of chronic conditions and financial austerity facing many countries. In this paper we present our current work on the development of a flexible, generic self-management platform which can be readily extended for specific chronic conditions. A Unified Modelling Language (UML) system class diagram is presented with the class design based upon functional requirements derived from literature and engagement with key stakeholders. We subsequently extend the UML class diagram to demonstrate how the design may be adapted for specific conditions.**

I. INTRODUCTION

As the demographics of many countries shift towards an ageing population it is predicted that the prevalence of chronic conditions such as Chronic Obstructive Pulmonary Disease (COPD), Dementia and Stroke will continually increase [1]. This incessant rise in prevalence will result in astringent socio-economic burdens including increased healthcare expenditure [2] and social disconnectedness amongst sufferers and their carers [3]. One emerging approach towards addressing these burdens is through a self-management paradigm in which a patient is empowered to manage their own healthcare conditions and associated facets. This empowerment may be facilitated by methods ranging from group-based education [4] to technological solutions, for example smartphone assistive applications which incorporate environmental and personal information [5].

In comparison to the traditional healthcare process there are two main advantages provided by enabling a patient to track and take control of their own healthcare conditions within a self-management paradigm. Firstly, a patient may have a higher level of motivation to adhere to medical advice when they are actively involved in the decision making process. One such example is participatory goal-setting whereby health-related targets are collaboratively chosen between a patient and a health-care professional [6]. Secondly, by utilizing machine learning methods on collected data self-management solutions may be predictive, thus empowering a patient to take evasive action when there is potential for a critical event such as a COPD exacerbation [7].

On one hand, the potential realisation of technological solutions facilitating self-management has been expedited by the rapid rise in the availability of Commercial-Off-The-Shelf (COTS) self-tracking devices capable of measuring health-related data, for example the Withings Smart Body Analyzer [8] which provides a user with weight measurements and body fat readings. Nevertheless, whilst such devices may promote the concept of the quantified self by providing real-time personalized health-data multiple technical challenges still remain in combining all available sensor based information into one consolidated resource in addition to managing proprietary data formats and interoperability issues.

There are a number of disease specific technological self-management solutions. The Aerial system [7] focuses on device management and questionnaires to predict COPD exacerbations. The Self-Management and Support Programme (EDGE) incorporates a daily symptoms diary, SP02 readings, personalized plans and educational materials for COPD [9]. In [10] Zheng *et al.* (2010) propose a self-management solution for stroke that enables a patient to set goals and monitor gross levels of activity in addition to containing a Decision Support System that detects lifestyle patterns and abnormal patterns of activities. A conceptualization of self-management intervention for people with early stage Dementia is presented in [11] where it is proposed that five key areas should be addressed: relationship with family, maintaining an active lifestyle, psychological wellbeing, techniques to deal with memory changes and information about dementia.

Within this paper we present the current technical design state of the Invest Northern Ireland funded Self-Management project (RD0513844). The project aims to develop a generic self-management platform which is readily extensible to accommodate a range of chronic conditions and will be validated on a cohort of approximately 50 patients across three conditions (COPD, Dementia and Stroke). There are two notable advantages with the approach in comparison to creating a bespoke solution for each condition. Firstly, from a financial perspective the cost of developing a solution is significantly reduced if it is based upon, and subsequently extends an existing application [12]. Secondly, by adopting a generic design, COTS sensors which adhere to implemented standards can be readily incorporated thus ensuring future extensibility and enabling the platform to update to contemporary devices.

The novelty of this paper lies in proposing a generic self-management architecture which may be readily extended to specific chronic conditions. The proposed solution incorporates requirements which are based upon literature best practice and includes functionality such as goal setting, self-reporting,

device measurement, social engagement and education. The remainder of this paper is structured as follows: in Section 2 we present the generic architecture. A discussion on the class attributes and methods follows in Section 3. Finally, brief conclusions and future work are presented in Section 4.

II. GENERIC ARCHITECTURE

Within this Section we present the current architectural design of a generic self-management platform. As an initial step towards identifying functional requirements the National Institute for Health and Care Excellence (NICE) guidelines on COPD management [13] and Stroke rehabilitation [14] were consulted. In comparison to COPD and Stroke the concept of self-management for Dementia is considered somewhat paradoxical as the mental deterioration suffered by a Person with Dementia (PwD) may eventually render them incapable of performing even basic Activities of Daily Living (ADLs). Therefore, the primary focus is on those with early stage Dementia/mild cognitive impairment to provide assistance with managing the PwD's life using, for example, reminding technology which specifically addresses the short-term memory impairments experienced by PwDs.

The NICE guidlines for COPD [13] and Stroke [14] and the conceptualization of self-management for early stage Dementia by Martin *et al.* (2012) [11] can be synthesised into the following functional requirements: activity planning which incorporates goal setting, schedule management and reminding technology; self-reporting which enables a patient to input symptoms and exercise performance; facilitation of social engagement; an education component which allows a user to interact with relevant resources such as instructional videos and measurement of progress which will be primarily via health-tracking devices.

In Figure 1 an overview of the primary system components are presented. Specifically, all remote based communication within the system is encrypted using Hypertext Transfer Protocol over Secure Socket Layer (HTTPS). Health-tracking devices may transmit measurements by pushing the data via Bluetooth to a listener on the Client device which is subsequently pushed to cloud-based storage. Alternatively, an emerging trend in data access is where the health-tracking device pushes data in a proprietary format to manufacturer's

Fig. 1: Overview of the primary system components highlighting the protocols used for communication.

cloud based storage; with available metrics accessible via a web-based API. The user client will be an Android application and responsive website which communicates with the Self-Management server using JavaScript Object Notation (JSON) over HTTPS and utilizing both push and pull data transfer models. The Self-Management server will provide cloud-based storage and perform applicable computation, for example aggregating data in response to queries. Additionally, the server will periodically pull data from the device manufacturer's storage using OAuth details provided by the user.

A high-level class diagram for the Self-Management platform is illustrated in Figure 2. To ensure conciseness we have omitted variables which are obvious, for example unique IDs. There are 10 primary classes which are aligned to the functional requirements: 'Reminder' and 'Goal' (activity planning), 'ReportedSymptoms' and 'ReportedExercisePerformance' (self-reporting), 'EducationalResources', 'Factoid' and 'Video' (education), 'Social' (facilitation of social engagement) and 'Device' and 'HostedHealthTracking' (device measurement). The classes will be instantiated and persisted on server-side hardware with the patients interacting with the system via an Android application or responsive website. These will utilize the Model-View-Controller (MVC) architecture with data represented as JSON and transmitted via HTTPS.

The central component of the platform is the 'Self-Management Storage and Inference Engine' which will form a subsystem; integrating the classes and inferring knowledge based upon, for example health-tracking data or self-reported symptoms. Knowledge in the form of condition and patient specific logic will be solicited from health-care professionals and used to influence the behaviour of the system such as adjusting a patient's daily targets in response to reported symptoms.

III. KEY CLASS ATTRIBUTES AND METHODS

Within this Section we provide an overview of the *key* attributes and methods utilized by the Self-Management platform as illustrated in Figure 2. Following our recent work on mobile-based reminding technologies for PwDs [15] two key attributes which will be captured are whether a reminder has been acknowledged and the type of the reminder which has been set. 'Acknowledged' will be an integer indicating whether the reminder was acknowledged, missed or missed due to the device being switched off. The type of the reminder will be an enum from a set of available categories. The primary motivation behind including these attributes is to facilitate the training of machine learning algorithms which, in conjunction with device hardware such as an accelerometer may be utilized to facilitate context-aware reminders that aim to maximize acknowledgement rates by determining an optimum dispatch time.

A fundamental workflow within a self-management paradigm is goal setting which enables a patient and a health-care professional to collaboratively choose life-goals, for example 'I would like to walk one mile in 30 minutes within a month'. There are nine main attributes that will be captured to represent each goal as described below. The status denotes the current state of the goal and indicates if the goal is active, cancelled or completed. The goal importance and self-efficacy
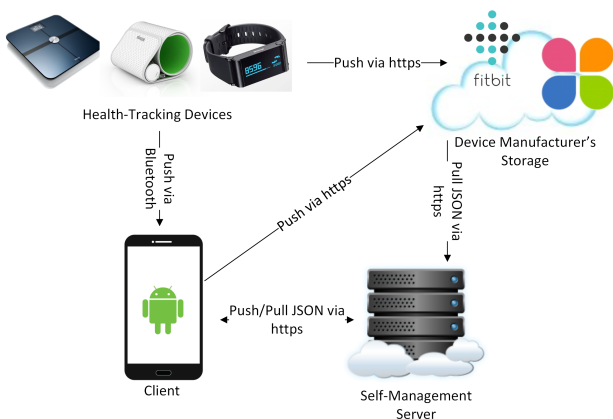
DementiaReminder

+rephrase(in type:enum, description:String):String
+verifyCompliance (in type:enum) :boolean

Goal

-status:int
-importance:int
-efficacy:int
-currentValue:double
-goalValue:double
-startDate:date/time
-endDate:date/time
-frequency:enum
-metricType:enum

User

-condition:enum

ReportedSymptom

-symptomID:int
-value:int

ReportedExercisePerformance

-exerciseID:int
-numberOfReps:int
-difficultyExperienced:int
-weight:double
-duration:time

Reminder

-acknowledged:int
-type:enum

EducationalResources

-condition:enum
-source:URI

Self-Management Storage and Inference Engine

Social

-uri:URI
-lastOpened:date/time

Device

-metric:enum

EnvironmentalSensor

-type:enum
-location:enum
-state:boolean
-lastActivitated:date/time

Factoid

-fact:String
-suggestion:String
-lastPushed:date/time

Video

-guideType:enum
-typeID:int

HostedHealthTracking

-uri:URI
-oAuth:OAuth
+getMeasurements(in startDate:date/time, endDate:date/time): String

——— = Association ---▷ = Specialization

ClassName | = Class
variables
methods

ClassName | = Class Specialization for Dementia
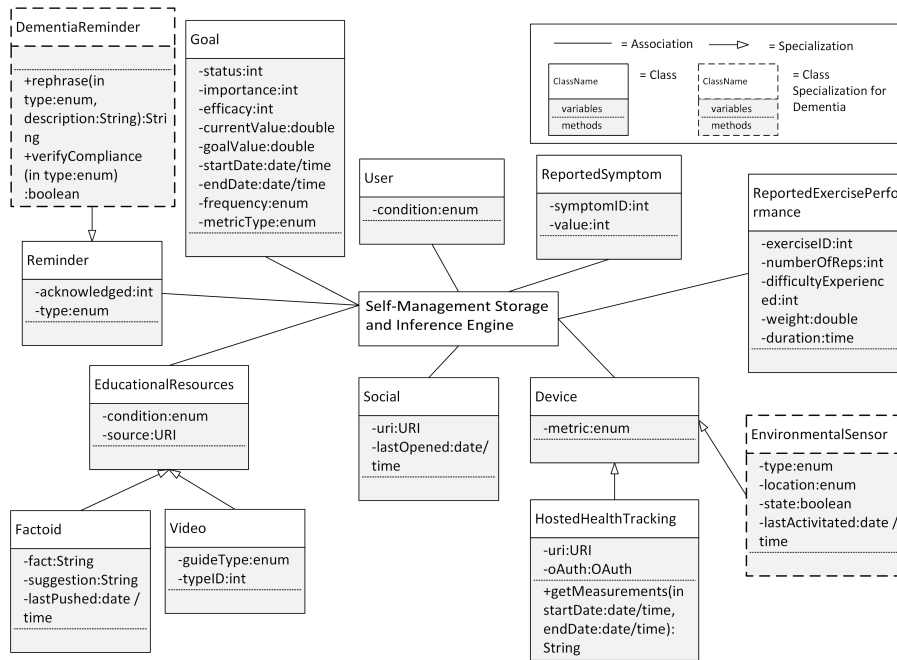variables
methods

Fig. 2: High-level class diagram outlining a subset of attributes which will be utilized by the Self-Management platform.

assigned by the patient will be used by the Self-Management platform when autonomously setting daily targets in response to long-term goals. For example, goals which are assigned a low self-efficacy by the patient may initially have modest targets to inspire confidence. A goal's current and target value refer to the current and target measurements respectively and will be utilized in conjunction with start date, end date and frequency to determine targets. The attribute 'metricType' will be used to relate a specific goal to a health-tracking device such as a Fitbit Flex or self-reported metric, for example stress level or number of repetitions for a range-of-motion exercise. The main attribute of the User class is 'condition' which will be initially selected from the set, {'COPD','Dementia','Stroke'}.

There are two classes relating to self-reported metrics: symptoms and exercise performance. The main attributes for reported symptoms are the reported value, for example the level of fatigue and 'symptomID'. The 'symptomID' enables the reported values to be linked to a predefined symptom which will be entered by a health-care professional and contain attributes such as 'description', for example 'fatigue' and type, for example scale or numeric. Similarly, the 'exerciseID' will be included in the 'ReportedExercisePerformance' class to enable linking with a predefined exercise. Additional attributes pertinent to reporting specific exercise performance are the number of repetitions, difficulty experienced, the weight used (if appropriate) and exercise duration.

The 'Device' class models attributes that pertain to a single health-tracking device which does not have manufacturer provided online data storage and associated web based API. The 'metric' refers to the measurement which the device can capture, for example Oxygen Saturation. This class is extended by 'HostedHealthTracking' which contains attributes including; encrypted user OAuth details which will be used when authenticating data requests between the Self-Management server and device manufacturer's storage. The attribute 'uri' is a Uniform Resource Identifier (URI) containing the scheme, authority and path (where appropriate) of the hosted data. Functionality to pull data from a device manufacturer's server will be provided by the 'getMeasurements' function which will accept a date range as input to be appended to the URI and returns a JSON string containing the relevant measurements.

The 'Social' class enables a specific online social resource such as Facebook or an online forum to be represented by the system and will contain a URI. It is envisaged that shortcuts to social media resources will be displayed within the Self-Management client application thus enabling the date and time of the last launch to be captured. This will be persisted in storage subsequently enabling a usage profile to be generated. Whilst this metric may be indicative of user engagement with social media, the time spent interacting with such resources is not captured. Thus, in future versions it may be desirable to develop bespoke social-media interfaces, for example EasiSocial [16] which assist users when engaging with such platforms and enable the interaction time to be captured.

The class 'EducationalResource' models a resource such as reliable websites or ebooks that a user may engage with. Key attributes include the source URI and registered condition. This class is extended for factoids which are concise fact and suggestion pairs that are periodically pushed to a patient's device [17]. The user can tap the factoid to view further information such as the literature source. The class 'Video' extends 'EducationalResource' and is primarily intended to model instructional video resources such as exercise videos or device measurement guides. As such, key attributes are the 'guideType', for example 'exercise' or 'device' and the 'typeID' which can be used in conjunction with 'guideType' to infer the specific exercise or device that a video refers to.

A. Specialization for Dementia

In Figure 2 we highlight the extensibility of the generic system design by illustrating the class specialization required to adapt the system for a PwD. As the class design is based upon common functional requirements there are only two specializations required: 'DementiaReminders' and 'EnvironmentalSensor'. It is, however, useful to note that the majority of generic classes would be instantiated and populated with Dementia specific content such as educational material, for example mental exercise guides.

A common trait amongst people with early stage Dementia is that they may not be willing to acknowledge their short term memory loss or cognitive decline [18] and may therefore become agitated with a system that seeks to provide reminding functionality. Thus, it is proposed that a reminder would be rephrased into a question as opposed to presenting the user with a statement. For example, instead of issuing a reminder stating, "Remember to take your medication" the text of the reminder would be rephrased to read, "Did you remember to take your medication?" This functionality will be incorporated in the 'DementiaReminder' class with a rephrase method accepting the type and description and returning a String.

The 'verifyCompliance' method will accept the type of reminder as an input thus enabling specific environmental sensors to be queried and will initially return a boolean indicating if the action was performed or not. This method will utilize the 'EnvironmentalSensor' class which extends the device class subsequently modelling an environmental sensor which does not have online storage provided by the manufacturer. The 'EnvironmentalSensor' class will contain type, for example contact switch and location, for example 'medicine cupboard door'. The location is an enum which will be populated with a predefined list of locations within a patient's home. The inherited attribute 'metric' will be used to store a reminder type which will be used in conjunction with the location to verify compliance. Additionally, the 'EnvironmentalSensor' class will contain, state, for example closed and last activated.

IV. CONCLUSIONS AND FUTURE WORK

In this paper we have presented the details of a generic self-management platform which is based upon functional requirements obtained from literature. The proposed platform is readily extensible to support a range of long term chronic conditions by populating appropriate class instantiations with condition specific data and by incorporating relevant classes, for example Dementia reminders. The main focus of future work will lie in implementing the presented design and subsequently performing a longitudinal evaluation with a cohort of approximately 50 patients, each with a single chronic condition, i.e. COPD, Stroke or Dementia.

V. ACKNOWLEDGEMENTS

REFERENCES

[1] D.E. Bloom, E.T. Cafiero, E. Jane-Llopis, S. Abrahams-Gessel, L.R. Bloom, S. Fathima, A.B. Feigl, T. Gaziano, M. Mowafi, A. Pandya, K. Prettner, L. Rosenbert, B. Seligman, A.Z. Stein, and C. Weinstien. The Global Economic Burden of Non-communicable Diseases. Technical report, World Economic Forum, Geneva, 2011.

[2] D. A Mayer-foulkes. A Survey of Macro Damages from Non-Communicable Chronic Diseases : Another Challenge for Global Governance. *Global Economy Journal*, 11(1), 2011.

[3] E. Y. Cornwell and L. J. Waite. Social Disconnectedness, Perceived Isolation, and Health among Older Adults. *Journal of Health and Social Behavior*, 50(1):31–48, March 2009.

[4] K. Khunti, L. J. Gray, T. Skinner, M. E. Carey, K. Realf, H. Dallosso, H. Fisher, M. Campbell, S. Heller, and M. J. Davies. Effectiveness of a diabetes education and self management programme (DESMOND) for people with newly diagnosed type 2 diabetes mellitus: three year follow-up of a cluster randomised controlled trial in primary care. *BMJ*, 344(apr26 2):e2333, April 2012.

[5] M. Beattie, H. Zheng, C. Nugent, and P. McCullagh. Self-Management of COPD: A Technology Driven Paradigm. In *Proceedings of the 8th International Conference on Ubiquitous Information Management and Communication*, Siem Reap, Cambodia, 2014. ACM.

[6] M. Heisler, R. R. Bouknight, R. Hayward, D. M. Smith, and E. Kerr. The relative importance of physician communication, participatory decision making, and patient understanding in diabetes self-management. *Journal of general internal medicine*, 17(4):243–52, April 2002.

[7] M. van der Heijden, P. J. F. Lucas, B. Lijnse, Y. F. Heijdra, and T. R. J. Schermer. An autonomous mobile system for the management of COPD. *Journal of biomedical informatics*, 46(3):458–69, June 2013.

[8] Withings. Withings Smart Body Analyzer, Accessed Sept. 2014. Online, www.withings.com/us/smart-body-analyzer.html.

[9] A. Farmer, C. Toms, M. Hardinge, V. Williams, H. Rutter, and L. Tarassenko. Self-management support using an Internet-linked tablet computer (the EDGE platform)-based intervention in chronic obstructive pulmonary disease: protocol for the EDGE-COPD randomised controlled trial. *BMJ open*, 4(1):e004437, January 2014.

[10] H. Zheng, C. Nugent, P. McCullagh, S. Huang, Y.and Zhang, W. Burns, R. Davies, N. Black, P. Wright, S. Mawson, C. Eccleston, M. Hawley, and G. Mountain. Smart self management: assistive technology to support people with chronic disease. *Journal of Telemedicine and Telecare*, 16(4):224–227, 2010.

[11] F. Martin, A. Turner, L. M. Wallace, and N. Bradbury. Conceptualisation of self-management intervention for people with early stage dementia. *European Journal of Ageing*, 10(2):75–87, November 2012.

[12] L. Chen, H. Yu, H. Li, and Y. Wang. An architecture model for multiple disease management information systems. *Journal of Medical Systems*, 37(2), 2013.

[13] National Institute for Clinical Excellence (NICE). Chronic Obstructive Pulmonary Disease Management of Chronic Obstructive Pulmonary Disease in Adults in Primary and Secondary Care. Technical Report April 2007, NICE, 2010.

[14] National Institute for Clinical Excellence (NICE). Stroke Rehabilitation Long-Term Rehabilitation after Stroke. Technical Report April 2007, NICE, 2013.

[15] P. J. Hartin, C. D. Nugent, S. I. Mcclean, I. Cleland, M. C Norton, C. Sanders, and J. T. Tschanz. A smartphone application to evaluate technology adoption and usage in persons with dementia. In *36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pages 5389–5392, Chicago, USA, 2014. IEEE.

[16] K. Boyd, C. Nugent, M. Donnelly, R. Sterritt, R. Bond, and L. Lavery-bowen. EasiSocial : An innovative way of increasing adoption of Social Media in older people EasiSocial. In *ICOST 12th International Conference on Smart Homes and Health Telematics*, Denver, Colorado, 2014. Springer.

[17] P. J. Hartin, C. D. Nugent, S. I. Mcclean, J. Cleland, I.and Tschanz, C. Clark, and M. C. Norton. Encouraging behavioral change via everyday technologies to reduce risk of developing Alzheimer's disease (Accepted). In *International Workconference on Ambient Assisted Living*, Belfast, Northern Ireland, 2014. Springer.

[18] Peter V Rabins and Betty S Black. Measuring quality of life in dementia: purposes, goals, challenges and progress. *International psychogeriatrics*, 19(3):401–7, June 2007.