Hygehos Home: an innovative remote follow-up system for chronic patients

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Abstract. This paper describes an innovative architecture for the remote follow-up of the health of chronic patients, and its implementation which is called Hygehos Home. The main purpose of the system is to enhance the quality of the daily healthcare practice, by means of bringing both patient and medical professionals closer to each other and by empowering the patient in the healing process. On the one side, Hygehos Home is a platform which gives the patient access to a set of personalized e-Health services using different channels such as web or smartphone. The e-Health services currently provided are: a) health related questionnaires, b) vital sign delivery (weight, blood pressure, oxygen level in blood, temperature, etc.), c) pharmacologic treatment adherence follow-up, d) access to information about the disease, and e) direct communication with the care providers (physicians, nurses, etc.). On the other side, Hygehos Home is fully integrated in the Hospital Information System (HIS), so that the healthcare professionals can easily access all data registered by the patients, such as subjective feedback, vital signs, medication uptake, etc. In this way, the health professionals are able to conduct an efficient and continuous remote supervision of the evolution of the patient. Finally, the validation protocol being conducted is described.

Keywords. e-Health, remote follow-up, monitoring, medication adherence, chronic conditions, patient empowerment, healthcare sustainability.

1. Introduction

Life expectancy in modern societies and developing countries is growing rapidly. Worldwide, the population over 60 years is estimated to double its size, from 11% of the total population in 2006 to 22% in 2050. Such growing trend has a direct impact on the sustainability of healthcare systems, in terms of policy and public health budget [1].

Increased life expectancy, improvements in public healthcare and modern lifestyle have caused that the dominant epidemiological pattern is represented by chronic diseases. Such diseases are generally long-lasting and follow a slow progression. In

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addition, they *i*) involve a limitation on the quality of life of those affected and their caregivers, *ii*) cause a significant economic impact on families, communities and society at large, and *ii*) finally lead to mortality [2]. The most prevalent chronic diseases are cardiovascular diseases, cancer, respiratory diseases and diabetes, which together are the main cause of mortality in the world (63%) [3].

Additionally, not only the elderly people are affected by chronic conditions, but also adults and the youth. As an example, it can be mentioned that in Spain the 45.6% of the population over 16 suffer from at least one chronic condition (46.5 % of men and 55.8 % of women) and the 22% of the population suffer from more than two chronic conditions [4, 5]. As a result of this situation, one study [6] shows that the public and care dependency between 2005 and 2050, health spending will increase from 3.5 to 6.1 percent of GDP for all OECD countries.

Given that the main use of health resources is performed by patients with chronic diseases, there is an urgent necessity of developing innovative easy-to-use, unobtrusive, and reliable remote care and follow-up systems meeting the aforementioned challenges of chronicity. The widespread use of such systems can lead to an important reduction of relapses and preventable hospitalizations, improving the quality of life of the patients and increasing the sustainability of the health systems.

In this paper we present an innovative architecture for the remote follow-up of the health of chronic patients, and its implementation, called Hygehos Home. The main purpose of the system is to bring both patient and medical professionals closer to each other and to empower the patient in the healing process. On the one side, Hygehos Home is a platform which permits to any patient to access a set of personalized e-Health services using different channels such as web or smartphone. On the other side, Hygehos Home is fully integrated in the Hospital Information System (HIS), so that the healthcare professionals can easily access all data registered by the patients. Finally, the validation strategy which is being conducted is described.

This paper is structured as follows: Section 2 describes relevant State of the Art. Section 3 describes the main contribution of the project which is the architecture of an innovative remote follow-up system for chronic patients. Section 4 describes the Hygehos Home implementation of the architecture. Section 5 describes the validation methodology followed to validate the system, and finally, Section 6 contains the conclusions and future work.

2. State of the Art

In recent years increasing research is being conducted for the assessment of the benefits in quality of life and reduction of costs associated with the use of telemonitoring and self-management of chronic diseases, when compared to traditional methods [7, 8, 9, 10]. Results obtained so far point to the improvement in reduction of the number of hospitalizations and relapses.

In parallel, new remote follow-up solutions are emerging. LifeWatch [11] makes home monitoring of patients vital signs. The system uses mobile phones, smartphones and computers for sending data and communication between the patient and the doctor. The system is completed with a control centre and medical alarm monitoring, which is responsible for monitoring risk patients. Tunstall [12] also offers a telemedicine solution, called Mymedic, designed to provide continuous care for people with chronic diseases through remote monitoring of various vital signs, reading and interpreting

them by health professionals. The Mymedic device can be configured according to the needs of each user and the physician performing monitoring. There are different packages targeting different chronic diseases (COPD, diabetes, blood clotting, heart failure and others). Saludnova [13] sells two telemonitoring systems. Careline Home allows comprehensive monitoring of patient's vital signs and sends an automatic alarm signal via mobile phone or e- mail to the corresponding physician if the application detects abnormal vital signs. Careline Pro enables the doctor or nurse to manage multiple patients simultaneously and works as a tool for monitoring and control of the patient in real time. Bidea Avant sells Medical Guard [14], which is a platform for telemonitoring chronic patients, allowing the collection of different parameters related to each specific disease, also allowing instant messaging for secure patient-physician communication and alarm generation over certain thresholds.

However, all the aforementioned previous solutions suffer from several important limitations, which hinder them to fulfil the needs of most care providers. One of these main limitations is the fact that these solutions are not integrated in the hospitals' or medical centres' Electronic Health Records (EHR), creating islands of information in the healthcare systems, decreasing the productivity of the health workers who had to switch between several applications in order to view the complete information of the patient.

A second important drawback of previous solutions is the fact that many of them are "disease oriented" rather than "patient oriented". It is common that patients suffer from chronic comorbidities; hence, seamless solutions that can be personalized to each patient are needed.

Finally, the heterogeneity of the patients imposes requirements that most current products don't meet. Age range of the users, technical skills, economical status, sensorial and cognitive disabilities, and different life styles require that telemonitoring systems excel in usability, accessibility, and, especially, in simplicity.

In this paper, we report a solution which tackles the aforementioned limitations of current products, such as the lack of complete integration with the EHR, and the customization to any patient, including those with multiple chronic conditions.

3. Proposed architecture

We propose an innovative solution for the remote follow-up of chronic patients. Differently from most current products available on the market, the proposed architecture has been designed from the very beginning to meet the following main requirements:

- Full integration in the Electronic Healthcare Record (EHR) and in the Hospital Information System (HIS).
- Easy customization to each patient (including people with comorbidities).
- Multichannel deployment by integrating current mainstream communication devices such as personal computers, smartphones, tablets and smart TVs.
- Maximization of the usability and accessibility in the user interfaces.

Figure 1 shows the proposed architecture. It consists of 3 layers: *Data Layer*, *Application Layer* and *Multimodal User Interface Layer*. Additionally, each layer is

divided in two sides: *Health Professionals' Side* and *Patients' Side*. This architecture defines a new communication paradigm between care providers and chronic patients. This communication is carried out through the Hospital Information System (HIS), which is extended with personal health information provided directly by the patients by means of personalized e-Health services delivered through several channels (such as tablets, smartphones or personal computers). By means of these services the care providers inquire the patient about different health parameters such as vital signs measurements, subjective health status and confirmation of the treatment follow-up. Next, each layer will be described.

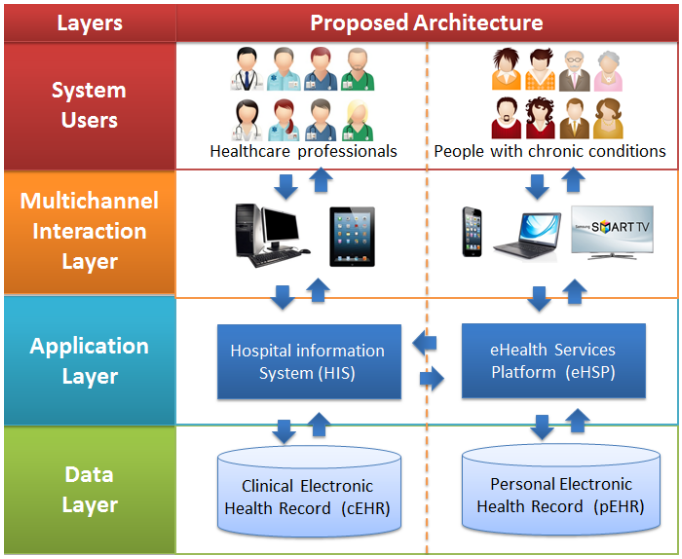

Figure 1. Proposed architecture for the remote follow-up of chronic patients.

3.1. Data Layer

This layer contains two different Electronic Health Records (EHR). The first one is the clinical Electronic Health Record (cEHR), which contains common clinical health information entered by the clinicians. The second one is the personal Electronic Health Record (pEHR), which contains health information registered by the patients themselves. Both EHRs are kept separated due to legal issues, but the information they contain can be matched to the corresponding patient by means of unique personal identifiers used at both sides.

3.2. Application Layer

This layer contains two main applications: the extended Hospital Information System (eHIS) and the e-Health Services Platform (eHSP). The eHIS is an extended Hospital Information System which provides access to the health professionals to both cEHR and pEHR. Besides, the eHIS provides access to the eHSP so that the care providers can personalize the e-Health services to deliver to each patient.

3.3. Multichannel User Interaction Layer

This layer contains the user interfaces that the health professionals and the patients will use to access the system. The care providers will use the workstation or the tablets in order to access the eHIS application. The patients will use the tablets, smartphones, smartTVs or their personal computers to access the e-Health services assigned to them by the care providers.

4. Architecture implementation

The proposed architecture has been successfully implemented and it is already available in the market as a commercial product called Hygehos Home [2]. The implementation details are described in the next.

4.1. Data Layer

First of all, the cEHR has been selected for the system. For this task, a commercially available Electronic Health Record called Hygehos EHR[3] has been used. Next, the pEHR has been developed using SQL database technology.

4.2. Application Layer

Next, the applications comprised in the Application Layer are described.

4.2.1. Extended Hospital Information System (eHIS)

Analogously to the Data Layer, the Hygehos HIS[3] has been selected. Hygehos HIS is integrated with the Hygehos EHR (cEHR) and it has been extended in order to access both pEHR and eHSP.

4.2.2. E-Health Services Platform (eHSP)

A web services facade has been developed using the ASP.NET framework. The developed web services use SOAP and RESTful protocols (via HTTP POST and GET methods) and SSL has been implemented to provide safe communication.

The e-Health services that have been implemented are:

1. Personal health questionnaires,
2. Personal vital signs delivery (weight, blood pressure, oxygen level in blood, temperature, etc.) and evolution chart,
3. Daily pharmacological treatment prescription and uptake confirmation,
4. Frequently asked information about the personal disease of the patient, and
5. Contact information (telephone, SMS, email, etc.) with the corresponding healthcare professionals (doctor, nurse, assistant, etc.) of the patient.

[2] Hygehos Home: http://www.hygehos.com/hygehos-home/
[3] Hygehos: http://www.hygehos.com/

Additionally, the health information retrieved by the web services is stored in the pEHR. Hence, corresponding SQL commands have been implemented.

4.3. Multichannel User Interaction Layer

Several user interfaces have been developed in order to adapt to the needs of the health professionals and the patients. These user interfaces are described next.

4.3.1. Graphical User Interfaces for the eHIS

Dedicated Graphical User Interfaces (GUIs) have been developed and integrated in the eHIS in order to provide the health professionals with appropriate access to configure and personalize the e-Health services to be delivered to each patient. Similarly, dedicated GUIs have been developed in order to provide the clinicians with access to the feedback of the users. Besides, in order to achieve a close-to-zero learning curve for the health professionals, the implemented GUIs follow the same look-and-feel of the original Hygehos HIS GUIs.

4.3.2. Patient Android application

A dedicated Android application has been developed which consumes the web services provided by the eHSP. The Android Software Development Kit (SDK) has been used to develop the application. More in detail, the Eclipse Integrated Development Environment (IDE) has been used along with the Android Development Tools (ADT) plugin. In Figure 2 several screenshots are shown.

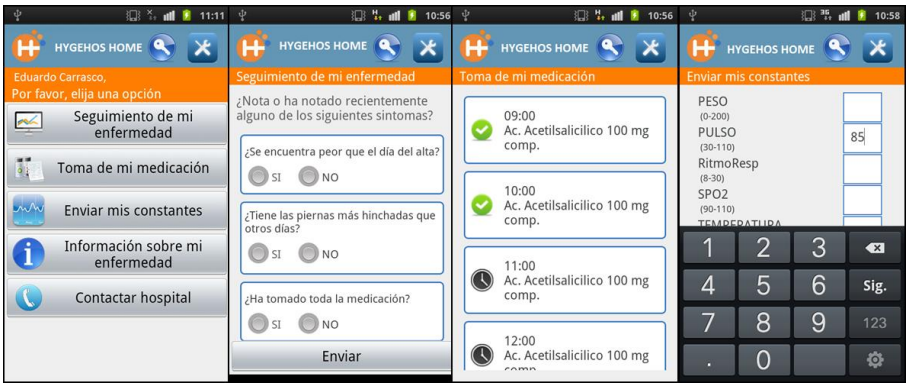

Figure 2. Screenshots of the Android application developed for the chronic patients.

4.3.3. Patient website

Similarly to the Android application, a web user interface has been developed which consumes the web services available at the eHSP. User website has been developed using ASP.NET framework. Figure 3 shows a screenshot of the user website.

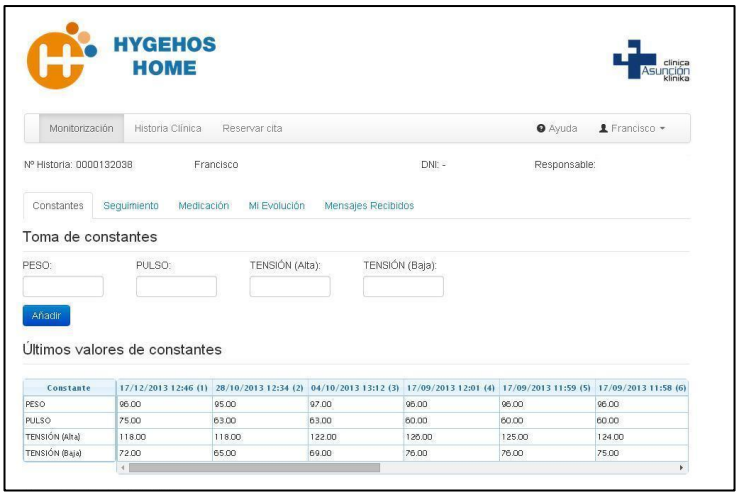

Figure 3. Screenshot of the patient web user interface.

5. Validation methodology

A pilot study has been designed to validate Hygehos Home. The duration of the pilot is 3 months in which a small sample of patients and health professionals will be asked to use the system in a regular basis. After this test period, both patients and health professionals will be asked about the usability and their satisfaction with the system. This pilot study is being conducted at the present moment, and the results will be published in a later publication. The main specifications of the study are described next.

5.1. User recruitment, tests conductor & ethical issues

A group of 15 patients with several chronic conditions (mainly cardiovascular diseases, obstructive pulmonary disease and diabetes) and a team of 6 primary care physicians will be involved in the tests. User recruitment and piloting will be conducted by Clínica de la Asunción, at Tolosa (Spain). Primary Care of Gipuzkoa, of the Basque Health Service, OSAKIDETZA, will participate in the piloting as well.

The pilot study has been approved by the Ethics Committee of the Basque Country. Corresponding documentation has been already developed which includes information forms and informed consent form to be signed by all participants in the study.

5.2. Test procedure for chronic patients

Chronic patients will be offered both a Smartphone with the Hygehos Home app and the web address of the Hygehos Home website to access the system from their PCs. The patients will have to use the system by themselves (or by an authorized caregiver or relative). Training on the system is not planned since both app and website are considered to be simple enough to be used by the participants in the study. Furthermore, a user manual and a hot-line service will be available.

The patients will be requested to perform the following set of tasks:

- Answer to personalized questionnaires according to the periodicity prescribed by corresponding physician.
- Enter vital signs according to the periodicity prescribed by their physician, such as weight, pulse, temperature, etc.
- Adhere to prescribed pharmacological treatment prescribed by corresponding physician and enter in the system the confirmation of the medication intake. The patient will receive alarms to support the user in the medication intake.
- Access frequently asked questions about the disease of each patient. This summary includes general information about the disease and related recommendations of your doctor about diet and other habits.
- In case of any specific issue, contact their corresponding health professionals (physician, nurse, etc.) by any of the channels provided in the system (telephone, SMS or e-mail).

5.3. Test procedure for physicians

Physicians will access to a new functionality inside the Hygehos HIS which is called "home monitoring". No training is expected to be necessary, since the new functionality follows the same look-and-feel of the Hygehos HIS, which is already mastered by the physicians participating in this study. Additionally, a user manual and a technical hot-line are provided. By means of this system, the physicians will be requested to perform the following tasks:

- Define personalized questions for the patients in the study with the goal of retrieving most valuable subjective information, symptoms, etc. Establish the periodicity in which these questionnaires have to be filled out.
- Define the vital signs to be provided by the patients in the study, such as weight, pulse, temperature, etc. and the periodicity in which these values have to be delivered. Physicians will have to make sure that valid point-of-care devices will be used.
- Supervise the correct adherence to prescribed pharmacological treatment by checking the confirmations delivered by patients. In case medication prescribed is not followed, patient will be contacted.
- Select the frequently asked questions about the disease of each patient. This summary includes general information about the disease and related recommendations on diet and other habits.
- Provide contact data (telephone, SMS or e-mail) and availability in order to be contacted by their corresponding patients in case it's needed.

5.4. Variables to measure and data collecting process

After the three-month-long pilot usability of the system and the satisfaction of the users with it will be measured. One-to-one interviews with the patients and questionnaires will be used to collect the information.

Regarding usability, the questionnaires will follow the System Usability Scale (SUS) [15]. This scale provides 10 predefined questions, which have to be answered with a 1 to 5 Likert scale. In this scale answers may vary from 1 that means strongly disagree to 5 that means strongly agree.

Regarding user satisfaction it will be collected by means of dedicated questionnaires based on the QUEST 2.0 scale [16]. Answers will be collected using a 1 to 5 Likers scale, in which answers may vary from 1 that means not at all satisfied to 5 that means very satisfied.

The questions of the satisfaction questionnaire are shown next:

1. How satisfied are you with the service of personal health questionnaire?
2. How satisfied are you with the service medicine intake?
3. How satisfied are you with the reminders for the medicine intake?
4. How satisfied are you with the service of delivering personal vital signs?
5. How satisfied are you with the chart of the evolution of the vital signs?
6. How satisfied are you with the service of information about my illness?
7. How satisfied are you with the contact your health professionals service?
8. How satisfied are you with the overall system HYGEHOS HOME?

Validation of the system by physicians is also considered, for which one focus group meeting will be conducted with the physicians participating in the study. In this focus group meeting both usability and satisfaction with the system will be measured and the same questionnaires will be used.

5.5. Data Analysis

Regarding usability, the answers collected will be processed according to the SUS scale and the SUS score will be obtained, which ranks from 0 (system not usable at all) to 100 (system fully usable). Next, both usability scores and satisfaction answers will be analysed and results segmentation for the different user groups involved (depending on age, chronic conditions, etc.) will be carried out.

6. Conclusions and future work

In this paper an innovative architecture for the remote follow-up system for chronic patients is presented and its first implementation called Hygehos Home is described. The system seeks to enhance the quality of the daily healthcare practice, by means of bringing both patient and medical professionals closer and by empowering the patient in the healing process. The main innovations of the system are (*i*) that it is fully integrated in a Hospital Information System, and (*ii*) that is not restricted to certain pathologies, but it is easily customizable to any patient or chronic condition.

Additionally, the methodology that is being used in a pilot study that is running to validate the system is also described. In the pilot study, 15 chronic patients and 6 physicians will use the system. The piloting will last three months and aims to validate its effectiveness for improving health care, before its general commercialization and

deployment in primary care of several regions in Spain. The results of this piloting will be published in a later paper.

Finally, further clinical research is envisaged in order to measure the contribution of Hygehos Home to the improvement of patients' quality of life, as well as the reduction of relapses, unnecessary medical appointments, waiting times, and the improvement of the sustainability of the healthcare systems.

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