Interactive home healthcare system with integrated voice assistant

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Abstract—Voice assistants are making their way in home healthcare, improving patient care by increasing efficiency and presenting a new experience by offering a wide range of tools and capabilities. Patients can access medical information, monitor and analyze health issues and communicate with ease with the help of useful applications and services. This is especially beneficial for the elderly patients. This paper showcases the patient-focused voice and web services developed for Amazons Alexa and Google Assistant and pinpoint the benefits of this technology in healthcare in the comfort of the patients home.

Index Terms—Voice assistant, voice application, healthcare, medical services, heart monitoring system

I. INTRODUCTION

Technology is disrupting industries wide across the whole spectre and these advancements are happening at such a pace, which makes it hard for the humans to adapt to it. The healthcare is no exception to this, now spreading into the homes of the patients. For example, with heart sensors that allow 24/7 monitoring of the heart condition. But technology is an obstacle, as well as a helping hand, to the elderly people, which are most in need of heart related treatments. They are unable to use the web and mobile applications and furthermore, with their deteriorating memory and lack of medical knowledge, they are led to isolation, in this aspect. This is where voice applications, come offering a well known interface.

Voice is gaining on popularity with the adults in the U.S, in fact according to a statistical research [1], 46% of U.S. adults are already using voice assistants at home and the number is only expected to increase in the coming years. In a survey conducted by Google [2], 41% of people, who own a voice-activated speaker say it feels like talking to another person. Aside from convenience, voice assistants offer a number of advantages in healthcare, for an example its hands-free interaction, 55% of surveyed users [1] stated that one of the major reasons they use these applications is to interact with their devices without using their hands, also there are projections that 50% of all searches will be voice made, by 2020 [3]. This is especially beneficial for people with disabilities who may have difficulty typing on a smartphone or a keyboard. Voice assistants have the potential to remove barriers and give these patients more control over their health, adding value to patient engagement. Whether by optimizing communication or providing critical new features, voice assistants are becoming an essential part of the healthcare industry shift towards patient-centricity. This paper is a proof-of-concept for voice enabled healthcare system, that contributes informing the patients heart conditions.

The paper is organized as follows. Related work of similar applications and enabling technologies voice operated healthcare are described in great detail in Section II. Section III describes the architecture of the voice enabled healthcare system. Section IV describes the healthcare services implemented in our voice applications. A voice assisted heart healthcare use case is described in Section V. The conclusion is presented in Section VI. In Section VII the authors discuss the results. Future work is presented in Section VIII. The conclusions are presented in Section IX.

II. RELATED WORK AND ENABLING TECHNOLOGY

A. Related work

Up to the point of writing the paper, the authors found two startups operating in the home healthcare field by integrating voice enabled platforms. CardioCube [4] is a voice enabled artificial intelligence application that runs on an Amazon Alexa enabled device. Its main feature is to communicate with the patient about their hearth failure decease in the comfort of their home, asking questions that any cardiologist would. With the retrieved information, CardioCube updates the patients EHRs hosted on the hospital's server for better and faster decisions. This solution is in the same field, covering voice enabled home healthcare, but it differs in that it represents a cardiac therapist.

Pillo [5] is a voice enabled home health device that manages and personalizes the patients healthcare regimen. It stores, dispenses and orders refills for the patients medication. Due to its voice enabled features, patients can interact with it and Pillo will provide answers to health-related questions. Voice and facial recognition help Pillo ensure the right person gets the scheduled medication. Also it can send alerts of an medication issue to the patients caretaker. This product covers the voice
enabled home healthcare segment, but it differs in that is only a medication organiser.

**B. Medical cloud**

Tasic et al. [6] propose a solution to deal with the challenges of building a medical cloud. Its functionality goes beyond storing data, namely elasticity and scalability, quality of service, security and privacy, availability and disaster recoverability being the strong points of the medical cloud. The medical cloud collects streaming raw data, extracts important features by processing it and stores it neatly in the patients EHRs.

EHRs provide invaluable data to clinical researchers, who advance medical knowledge and the development of new treatments for common health problems. Making EHRs available through applications makes patients more and more engaged in their healthcare, giving the ability to manage their conditions. By helping the patient take control of their disease management, it is creating a greater sense of patient empowerment.

**C. Wearable Sensors - Savvy**

Wearables in recent years are gaining a momentum in healthcare. In the past, wearable technology has been too bulky or unwieldy to be useful, but the proliferation of smaller, more compact, more powerful devices and the resulting improvements in computational power have made wearables more convenient. It is giving new opportunities for both patients and clinicians to monitor chronic conditions in ways that were once impossible. This new tech could help transform the focus of healthcare from reactive chronic-disease treatment to one that proactively treats these conditions and helps prevent such exacerbations. Analysts view wearable computing as an industry primed for explosive growth in the near future. For instance, Tractica reports [7] that worldwide medical wearables shipments constituted 2.5 million units in 2016.

Savvy ECG [8] is a wearable medical sensor that constantly measures ECG signals. Savvy placed its emphasis on elegance and simplicity of design, both in its outward appearance and its underlying technology. It is fixed on two standard ECG electrodes and can be easily attached/detached to the body of the patient. Its lightweight, has a long-lasting battery and is IP54 certified, which means it has limited protection from dust and water spray from any direction. Savvy uses Bluetooth to communicate with a mobile device streaming data in 30 second intervals, further on communicating via Wi-Fi or 3G/4G mobile operator network with the medical cloud, where the data is analyzed and processed. As an alternative to the mobile device, Savvy can communicate to the local computer by connecting it with the appropriate cable [9].

**D. Voice assistants**

Amazon and Google are leading the voice search trend with their branded hardware. With the progression of Artificial Intelligence, innovative decision makers are beginning to explore new opportunities to leverage voice technology beyond commonplace routine. Being part of the Internet of things, which is taking popularity in every household and is integrated in people’s everyday life. For example, Ilievski et al. [10] in their paper demonstrated how a voice assistant can be integrated with a home Air Quality Index measuring station.

Alexa is the voice controlled assistant developed by Amazon, which serves users via an Echo device, which has internet access. Amazon hosts a natural language processing system on the cloud to understand users requests and integrated very sensitive microphones that let the Alexa assistant to listen and give back a quick response through the speaker. But, the device streams you voice only when you ask it to do something. The default wake up word is Alexa. Once you have its attention, the microphone streams everything you say to Amazons cloud for further analysis. Alexa uses skills [11], voice application, to enable new abilities. They can be stock Amazon or developed by a third party developers. Each skill has a special invocation name that makes it unique from other skills. It is composed of actions that fulfill a users request, called intents and each intent can be activated by likely spoken phrases called utterances.

Parallel to the Alexa Skills, in the Google environment we have the Google Actions [12]. Using these the developers extend the functionality of the Google Assistant enabled devices, which include Google Home devices and Android smartphones with versions of 5.1.1 and up. The Google Actions consist of three important components. The first one is the intent. This describes the need or aim that the user wants to achieve by using the Google Assistant. Each intent, has its own unique identifier and it is recognized by Speech-to-text translation of the voice command of the user. Then comes the Action, that can serve several specific intents of the user. There are two types of Actions, Smart home Actions, which can be used to control your IoT devices in your home, and Conversational Actions that can have a variety of applications such as buying things online. Finally, each Action has its own fulfillment, the code that is used to handle the intent and process the queries from the user. Such Conversational Action and Alexa Skill have been developed, to support the medical services. Each of these medical services are described in full detail in the following section.

**III. Architecture**

The workflow starts with the wearable ECG sensor (section II, C) registering the ECG scans (Fig. 1). The mobile application [9] communicates with the wearable ECG sensor via Bluetooth worn on the patients body, monitors the scans and stores them on local storage and on the medical cloud. The ECG data sent to the cloud is analyzed and stored on the server. Patients can monitor and access the data sent from the sensor and receive alerts for abnormal heart functionality. The web application [9] enables registered doctors to monitor patients heart condition and retrieve data files of ECG scans. The medical cloud [6] has a crucial role in providing more personalized healthcare and information-based services. It collects the raw data from the sensors, processes the data to reveal relevant information, stores the information in EHRs which are easily accessible for all authorized applications and users.
The voice application takes the system's functionality one step further. It receives voice commands and information from the patient, which then communicates with the developed web service for the requested service or information. The featured voice-enabled services are: heart condition checker, sending a report of the patient's heart condition, scheduling appointments, and a therapy reminder. The voice application is developed for the Google Assistant devices and Amazon Alexa-enabled devices. More about these services in the next section.

As an addition to the architecture, the authors developed a special web service that serves incoming requests from the voice applications. When the voice application requests heart condition, the web service sends back processed heart condition information from the patient's EHRs stored in the medical cloud. If there is something noted in the reading, the patient can forward a file of the reading through the web service to the doctor. As part of this web service, the authors developed a custom voice management system that schedules appointments through a voice interaction with the patient. Also, the web service keeps in order the patient's schedule of his therapy, by sending notifications through the voice application.

IV. MEDICAL BACKGROUND

A heart attack is a serious medical emergency within the cardiovascular diseases. Statistics provided by the World Health Organization on heart diseases [13], have revealed that different types of a heart attack are the cause of nearly one-third of deaths in the World. However, a timely medical attention may save the patient of premature death, and drastically reduce the risk of serious damage to the heart [14]. Interestingly, studies show that a heart attack may be predicted a couple of hours before its onset by detecting changes in the Electrocardiogram (ECG) of the patient [15].

In this project the authors aim at detecting three types of arrhythmia’s: Ventricular fibrillation, infrequent Atrial fibrillation, and frequent Atrial fibrillation. Each type of arrhythmia is mapped to a severity level value. Depending on the type of the irregular heartbeat, the web service by request of the voice application retrieves the types of occurred arrhythmia’s and returns a value of severity. The value of severity then is used to respond with a message to the patient. Ventricular fibrillation is severity level 1, which means that the patient's heart condition is fine and no further actions are needed. Atrial fibrillation on the other hand, if this type of arrhythmia occurs infrequently, the voice applications suggest the patient to seek that doctor in the next week or so. If Atrial fibrillation is frequent, then the voice application suggests the patient to see a doctor and continues on scheduling an appointment.

V. VOICE ASSISTED MEDICAL SERVICES

The future of voice-assisted healthcare, and the system presented in this paper as a proof-of-concept (for heart care) first, need to provide the user with time-efficiency in taking care of their health, by encompassing different services and functionalities into one single application. The voice applications developed for this paper, both for the Google Assistant and Alexa Devices, have been made with this aim. As mentioned previously they are communicating with our Web Service, that acts as a layer communicating with the medical cloud and other needed services.

The authors have developed 4 different functionalities for the Voice applications (skills), implemented as a proof-of-concept. First, it is enabled for the user to easily and instantaneously get advice about the readings made by the previously mentioned Savvy sensor. When prompted, the assistants tell information about the readings since the last time such a question has been asked. Depending on the results, there are three types of replies, no action to be taken, recommendation of an appointment to be scheduled in a couple of weeks, and immediate appointment scheduling. In order to make it more convenient for the doctor, a PDF of the readings can be sent to the doctor in advance of the appointment.
This brings us to the second functionality, that is appointment scheduling (Fig. 3). Through the web service the user can schedule the nearest appointment or one on a specific date, by talking to the Voice assistants. A typical use case is as follows, first the user makes the query I want to schedule an appointment., the assistant asks for what time and day, and after the user answers the question, a final confirmation is requested, after which the appointment is scheduled.

After the appointment, the user may have received a certain therapy to follow and again the responsibility for the therapy schedule can be handed over to the voice assistant skills developed by the authors. That is, for each user apart from the readings and EHR information on the web service, a therapy information is stored that the user can save. The user can input several medications and their specific schedules, one medicine at a time. After prompting the assistant to insert new therapy, the user can insert the new medicine according to the pattern: “Medicine, X times a day, starting at hour.” This can be repeated for all needed medicines. The therapy service flowchart is show in Fig. 4. The assistants, in addition, remind the users about their therapy and appointments, by notifying them if they use the assistants within 30 minutes of some of the two types of events.

VI. VOICE ASSISTED HEART HEALTHCARE USE CASE

In this section we will go through a use case where the user checks his heart condition (Fig. 2). The functionality loop starts with the patient asking the voice assistant, at any moment, to check the readings from the sensor, example phrases: “How are the ECG scans?”; “Is everything alright with the readings?”. This will return the readings since last time the patient checked the condition of his heart. Depending on the severity of the readings, the voice assistant will respond with different sentences, some requiring further actions. If everything is alright, the voice assistant would notify the patient by saying: “Everything seems fine”. If the readings show a slight appearance of abnormal heart activity, the voice assistant will notify the patient by saying: “I suggest seeing a doctor in one or two weeks time?”. If the medical cloud detects abnormal heart activity, it will notify the patient with the sentence: “Detected severe arrhythmia, I am appointing you to the doctor on date”. In the last example, the communication continues with arranging an appointment with the patients doctor by suggesting a date by checking previously with the appointment management system. The patient can accept the appointment or suggest another an optimal date.

VII. RESULTS

For these proof-of-concept voice skills, 4 functionalities have been developed for the future of home care voice assistants. The ECG readings check, appointment scheduling, therapy record and sending a pdf to the doctor’s email. All necessary functions that encompass a complete home care solution. A demo video of these can be seen on the following link: https://bit.ly/2V2iFg7. The demo has been done using the Amazon Alexa Echo dot.
VIII. Future Work

This paper presents Alexa and Google Assistant applications, with the intention to serve the patient and help him with the monitoring of his vital signs in the comfort of his own home. Furthermore, giving the patient options to schedule a doctors appointment, save his therapy and medications guidelines so that the assistant can notify him and remind him when an action is needed and finally. Further functionalities might be a first aid help in emergency situations. The Assistant could look for the optimal hospital, depending on the traffic and frequency of visitors information and book a taxi ride or simply call a First-Aid ambulance, depending on the severity of the symptoms. In addition, voice assistants can advance its helpfulness by having the functionality of a symptom checker. The user at home lists the symptoms to the assistant, and the assistant based on probability could inform him of the most probable issue. Furthermore, it can find its use in first-aid ambulances, where a quick important medical information is needed, such as patients health record, blood type, allergies and so on.

IX. Conclusion

This paper focuses on solving the obstacles patients face when using wearable health sensors in their home environment. Such as lack of convenient tracking of readings, as well as misunderstanding of sensor readings, by handling the responsibility to the Amazon and Google voice assistants. Furthermore, the voice assistants can make suggestions and even schedule a doctors appointment, make reminders of the actions needed in the prescribed therapy and before appointments. Such use case of home health monitoring is the Savvy ECG sensor with voice assistant interaction, which is briefly described and it presents an easier way to understand and act on the readings. The authors hope that this paper will convey the benefits of voice interaction in the domain of home healthcare.

REFERENCES