# Modular HTML5 Health Kiosk

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# Abstract

As technology evolves, new areas of application emerge. One area that has been greatly influenced by technology is health. Technology underpins many of the advances on health, supporting health service providers to improve their processes and how they treat their patients. For example today health professionals can easily access detailed records on a patient's health, using a much wider scope of information than in the past. This enables them to provide much better diagnosis and treatments.

However, this evolution is not only supporting professionals, but is also empowering patients to have access to information and tools to better support them on different types of health related processes. With the development of user-friendly devices, non-professionals users can, for example, have access to information on their health without the need to leave their homes. However, in some cases, it is not possible for some people to have these devices at home. This has led to the creation of systems deployed in public locations and available to the general population. These systems, often denominated by health kiosks, serve multiple purposes, such as, for example: information center, telehealth kiosk, or even provide information about user's health - by having a set of medical devices attached to it.

In this dissertation we have designed an adaptable architecture and interface for a health kiosk. The goal is to support a flexible and component-based interface, which enables the support of multiple functions required by health kiosks. The proposed interface is based on Web technologies, and it can take advantage of technologies such as Web Real-Time Communication (WebRTC), which provides the ability to establish a connection between the user and a health care center in real-time, in case of any doubt by the user when using the platform or to obtain feedback on the produced results.

During this work, the proposed solution was implemented, creating a health kiosk, which was based on a previously version implemented using JavaFX. The proposed solution enabled the addition of several new modules, and intends to facilitate real-time communication with a health care center in the future. Given that new modules can easily be added to the solution, we can conclude that new functionality can be added to the system, which makes it extensible and capable of supporting other types of devices, data collection or communication elements with more ease.

# Resumo

À medida que a tecnologia evolui, novas áreas de aplicação surgem. Uma área que foi fortemente influenciada pela tecnologia foi a saúde. A tecnologia sustenta muitos dos avanços feitos na saúde, suportando as melhorias dos provedores de saúde nos seus processos e na forma como estes tratam os pacientes. Por exemplo, os profissionais de saúde de hoje em dia podem facilmente aceder a registos detalhados sobre a saúde dos seus pacientes, usando um espetro de informação mais amplo que no passado. Isto permite-lhes providenciar melhores diagnósticos e tratamentos.

No entanto, esta evolução não suporta somente profissionais, mas também dá poder aos pacientes para que estes tenham acesso a informação e a ferramentas que lhes deem um melhor suporte nos diferentes tipos de processos relacionados com saúde. Com o desenvolvimento de dispositivos *user-friendly*, utilizadores que não são profissionais podem, por exemplo, ter acesso a informação sobre a sua saúde sem a necessidade de sair de casa. No entanto, em alguns casos, não é possível para algumas pessoas ter estes dispositivos em casa. Isto levou à criação de sistemas implementados em locais públicos e acessíveis à população geral. Estes sistemas, normalmente denominados quiosques de saúde, servem múltiplos propósitos, tais como, por exemplo: centro de informação, quiosque de telemedicina, ou também para providenciar informação sobre a saúde do utilizador - tendo um conjunto de dispositivos médicos ligados a ele.

Nesta dissertação foi desenhada uma arquitetura adaptável e uma interface para um quiosque de saúde. O objetivo é suportar uma interface flexível, e baseada em componentes, que permita a utilização de múltiplas funções requeridas por quiosques de saúde. A interface proposta é baseada em tecnologias Web, e pode tirar vantagem de tecnologias como Web Real-Time Communication (WebRTC), que permite ter a capacidade de estabelecer uma conexão entre o utilizador e um centro de cuidados de saúde em tempo real, em caso de dúvidas por parte do utilizador de como utilizar a plataforma ou para obter feedback nos resultados produzidos.

Durante este trabalho, a solução proposta foi implementada, criando um quiosque de saúde, que foi baseado numa versão anterior implementada utilizando JavaFX. A solução proposta permite a adição de diferentes módulos, e tenciona no futuro facilitar a comunicação em tempo real com um centro de cuidados de saúde. Dado que novos módulos podem adicionados à solução proposta, podemos concluir que novas funcionalidades podem ser adicionadas ao sistema, tornando-o extensível e capaz de suportar outros tipos de dispositivos, recolha de dados, ou outros elementos de comunicação com maior facilidade.

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**Por ti, e para ti Silvana...**

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# Acronyms

**API** Application Programming Interface

**BLE** Bluetooth Low Energy

**BMI** Body Mass Index

**CSS** Cascading Style Sheets

**DOM** Document Object Model

**EHR** Electronic Health Record

**GUI** Graphical User Interface

**HTML** HyperText Markup Language

**IEEE** Institute of Electrical and Electronics Engineers

**JSON** JavaScript Object Notation

**IPC** Interprocess Communication

**OS** Operating System

**MAC** Media Access Control

**PHD** Personal Health Device

**RPC** Remote Procedure Call

**SpO2** Saturation of Peripheral Oxygen

**USB** Universal Serial Bus

**XML** Extensible Markup Language

**WebRTC** Web Real-Time Communication

# Chapter 1

# Introduction

When discussing the health of a person a number of parameters are taken into consideration. Most of the time these parameters are evaluated at a doctor's office, with a set of tools that allow him to collect information about the user, such as temperature, blood pressure, among other things. The evolution of technology allowed these devices to be commercially available, making it easier for the user to have knowledge about his health without resorting to a health professional.

Although it is easier now to have access to it, this is not globally true. There are limitations to the access of these types of devices, such as price, location, or even usability. Which leads to the creation of systems aim to offer these services to the population. These systems, usually called health kiosks, although this definition can be applied to different types of systems, could contain several medical devices alongside with instructions on how to use them. Throughout this dissertation, when referring to a health kiosk, the type of systems that are intended to be associated with this expression are the systems that contain some sort of medical devices capable of interaction from and to the user.

The idea of a health kiosk is to have a set of medical devices assembled together, alongside some kind of input and output in order to create a product that can be deployed with ease. The main goal is to have a system that doesn't require any previous information on how to use it, but instead to easily obtain the required skills by using the device, ultimately making it more usable by the population.

The demand for health diagnosis is high since health is an essential commodity, although not everyone in need has access to it, and also the type of service available varies a lot in different places. This fact is highly correlated with the difficulty that some populations have to access a health professional, or even health devices, being specially true in rural areas. Creating a health kiosk that can be transported and deployed in such areas and situations can improve health standards, by bringing medical services closer to the population.

Using technology with the purpose of improving patients health is not a new subject, the adaptation of technology to this field led to the development of new areas, like eHealth. These developments aim at integrating access to several health services and information through the

Internet and other similar technologies. Interacting with these devices does not only give the tools to users that live in remote areas, so they can evaluate their health state, but can also be used in other fields and situations, such as disease prevention, reducing time of consultations in hospitals, health information centers.

Medical resources are scarce in rural areas, and this prevents the population living in those areas to have access to basic health information. There is a need to adapt the existing resources to cope with this problem. This is not solely based on the insufficiency of resources in the area but also the difficulties of mobility from and to those areas. For example, not having an Internet connection in those places makes it challenging to provide and receive information from it.

Health centers, hospitals and other types of medical institutions, can also be improved. Consequently, they can be optimized by using new technologies. In current days, time is spent in making simple checking procedures, to have a summary of a patient's health status. All these procedures take time, leading to a longer consultation time, which at the end of the day means that the number of treated people is much lower than it could be.

Another use case for this type of tool is in elderly communities. There is an assumption that people living in these communities have a more debilitated health due to their age, sometimes combined with low mobility. The existence of a device that has the capabilities of evaluating elderly people's health will allow a more frequent control, and make it less of a burden to the patient. Furthermore, it also gives them some independence, and some sense of realization.

Home health-care exists, and it gives the possibility for anyone to have a system similar to a health kiosk in their homes. Usually this type of system is connected to several devices, and allows the user to make measurements whenever needed. Home health-care lacks the scalability that health kiosks aim. The benefit of these products is to provide a simple system that can be used anywhere with few or no maintenance. Privacy issues are not a main issue in home health-care, when addressing the fact that a product that is used inside the user's home, only accessed by the user or family members.

This chapter provides an introduction to the context of using health kiosks to evaluate the health of different types of users, providing a context to the usability of these systems, the problems they intend to solve and the motivation to implement them. It also provides a brief description of the tasks associated with this dissertation and what are the target goals.

## 1.1 Health Kiosks

Creating a health kiosk can have a positive impact in solving diverse problems, being the main problem it solves the patient's access to basic health monitoring resources, such as information, diagnosis, among others. The implementation of a health kiosk with the possibility of installing it and use it anywhere will reduce the population need to travel, and at the same time increase the access to health information. This information can improve people's health knowledge and, consequently, improving their lifestyle.

The motivations that led to the development of these systems was to provide a solution to the different discussed problems, creating a multi-user system that has the ability of easily adapting to different needs and situations. With this in mind, the goal of this system to create an easy configurable system capable of fulfill all the needs in terms of solving a series of problems related with the collection of health data. This is done with the idea in mind that the system has to adapt to the population that is using it and not the other way around.

Rural areas have always lacked the kind of health resources that can be found in cities [9]. This leads to the need of adapting existing resources in order to reach these rural areas. As sometimes there is no Internet connection in these areas and the communication is made with difficulties, an approach has to be made considering these facts. To surpass this, an off-line system, with the ability to accurately take measurements and give information to its users without the need of training the users would make a difference in these areas.

This lack of health resources is the main concern, and at the same time the main motivation, when creating a health kiosk, the ability to create a product that can be easily assembled and delivered to rural areas. In these areas the problem that patients face is the need to travel long distances in order to have access to a consultation, or even for small information that could easily be given by a health kiosk. Other benefit of this system is that it can be developed in order to produce correct and useful data without an Internet connection, as it has already been discussed some of these areas lack this resource. So, in the end, a product fully capable of giving correct information to its users would be implemented. Changes to the system would require a physical presence in the cases where there is no Internet connection.

Installing health kiosks in rural areas where it is known to exist an infectious disease could help in preventing its growth, or even prevent the existence of these types of diseases. Although this concept of information kiosk does not go along with the kiosk under current development, which the main objective is to collect data and act on the collected data. Some types of useful information and feedback can be given to its users in order to improve their lifestyles based on real collected information.

An also existing problem that can be solved by the use of a health kiosk is a pre-evaluation of patients in hospitals. This idea has been explored by Rajalaxmi Das and Himansu Mohan Padhy [2]. It consists in providing patients in the waiting rooms of hospitals, or medical centers, the possibility of using health kiosks. This system would evaluate parameters of the patient such as heart rate, blood pressure, temperature, Saturation of Peripheral Oxygen (SpO2), and when the patient enters the doctor's office it would have with him a paper with all the data collected and the doctor would also have access to it through a computer, this aim at simplifying the patients visit to the doctor and minimize the load that doctors accumulate during the day, with the purpose of attending more patients.

A lack of health professionals is also evident in developing countries, alongside with a high demand, and it also acts as a problem since it is a condition for the correct behavior of health services. An high ratio of patients by health professional can be an indicator of the health level in a region [9]. As having a high healthy state of the population is a factor with great importance in the development of a country, urges the need of solutions, preferably with a low cost, capable of providing health information to its users.

An application of the health kiosk system is also found in elder communities, where the average age is high and there is a presence of multiple chronic illness. All these factors require constant attention. It is not productive for each of these communities to develop a product capable of monitoring and keep track on their patient's collected data. So a solution that fits the needs of several of these communities would have a great impact on the everyday life of their residents.

Developing a health kiosk aims to provide all potential users, information on the different aspects of its health. Ultimately improving their own health and increasing the chance that in the future their behavior will improve based on feedback given by the health kiosk.

To build such systems, the possibility of using it having a single device or multiple devices must be present. Another relevant aspect is that from a single device that produces multiple parameters it must take into account which ones are relevant to the user and which ones can be hidden. This aspect will be discussed with more detail in Chapter 4.

The problem that this work aims to solve taking advantage of new technologies in order to improve the architecture of an existing health kiosk and the way it is being developed. An adaptation to its current development could provide the kiosk with the flexibility to adapt to different types of applications. Adapting the system to use Web based technologies, allows the creation of a modular application easily developed and maintained. This modularity would allow for changes in the application in a real-time basis, this is, if the person responsible for installing the health kiosk wants to change the exams that the kiosk is ready to perform then it should be easily adaptable to cope with the preferences of the maintainer.

## 1.2 Objectives of this Work

The base of this work is to consider a previous existing version of a health kiosk, although it currently works it is not a final version, and to redesign it using Web technologies in order to give a set of tools that these technologies provided. In the current project we aim at the creation of a flexible architecture that allows to support a more extensible health kiosk, which is a basic requirement to support new types of services and devices on the health kiosk. In the end it is expected to have a modular system, capable of supporting different types of instantiations.

The status of the original version is advanced since all the main aspects of it are developed. The users of the system can interact with it and in the end the results are given to them, this means that it is already an working version of the health kiosk. With this in mind, the idea is not to create a health kiosk from scratch, but instead to consider the existing version and adapt it in order to take full advantage of the Web technologies, and the benefits that they provide.

The usability of the older version of the health kiosk has been studied [11], so in this work the usability of the produced application will not be studied with high relevancy although some tests with a group of people will be made in order to evaluate if it is usable.

One of the aspects of higher importance in this work is creating a set of components that can be used by any type of measurement that is being made, and it generates a code that is proper to that measurement. By the use of components, code repetition can be avoided since a skeleton is created that can fulfill the needs of the code and generate a fully functional piece of code. Given the high modularity that is pretended from this health kiosk it is important that all the aspects relative to its development are taken in consideration since for a type of users an aspect can be important that is not relevant to other users.

Thinking ahead and creating a product that can easily adapt to different needs lowers the risk of creating a product that does not fit all the users needs. The product has to be able to change from a set of tests with, for instance, diabetes as the main focus, to a different one using different devices, for instance cardiac problems.

To fit all the needs that are required in this application the interface is going to be built using Web components, as they seem to provide suitable mechanisms to create an application that is modular. Which gives the ability to quickly adapt and create new components. It also has the benefit of reducing the amount of code needed to create the application since it allows reusing code in different instances.

In the specific case of health kiosks, the choice of Web components usage can be explained with the need to adapt the kiosk to the circumstances, not always the kiosk will have all the devices at the same time. In a case where the test that is being taken is to measure the Body Mass Index (BMI) of a population the kiosk only needs two devices, one to measure the height and other to measure the weight. Thinking in components, only two components are going to be used, one for each device.

The application of Web technologies and the reason for this choice will be addressed in Chapter 4 in more detail.

The final objective of this work is to have a system that fits all the described requirements. Making it adaptable to the different needs of the population, either by the type of exams or properties like language, voice instructions, among other functionalities. There are cases that require an identification number in order to associate the collected data with the user, but also cases where this aspect is not as important as the evaluation of a large number of people's health, in a disease screening.

It must provide improvements to the existing version in order to justify this change in technologies used, for that it must be implemented with a set of tools both to developers as well as to end-users. For the developers, the easiness of development comes as a great benefit, along with the potential for implementing new functionalities. For the users, being able to take advantage of this functionalities is certainly a factor to take into consideration. With the use of web technologies it is thought that there are aspects of these technologies that can be beneficial to the health kiosk and facilitate on reaching the modularity level that is pretended.

For all this it is necessary to understand what health kiosks are, the different types of components that can be used, what each one has to offer, and in what way those functions can help improve the way this health kiosk is used, and what it has to offer.

Given this, a goal of this work is to develop an architecture for providing an interface to the health kiosk and to develop ways to communicate with different medical devices. This communication is not currently entirely implemented in the application, using an external service to exchange messages, what is pretended is to also integrate this service that handles the communication into the application, rearranging the nodes in the architecture.

The health kiosk interface will have to be capable of a quick adaption to the needs of the circumstances, this is, it needs to be modular, composed of standardized components for easy construction on the application.

As a complementary objective of this work is the support of a Web component for the Web Real-Time Communication (WebRTC), in order to support communication with a health care center. This would allow the support of video and audio streaming and data sharing between the application of patient and a health care center. The main advantage for developers is that it can be used without the need to install plug-ins or third-party software.

## 1.3 Structure of the Dissertation

This thesis is organized as follows:

- Chapter 2 - *State-of-the-Art* - Different types of health kiosks are presented in detail, and an overview of their applications is given.
- Chapter 3 - *Health Kiosk - System Overview* - The status of the health kiosk on which this work is based, the current architecture and technologies it uses.
- Chapter 4 - *New Health Kiosk Architecture* - Describes the steps taken in the development of the new architecture.
- Chapter 5 - *Conclusion* - Conclusions taken upon the end of this dissertation and discussion of faced problems as well as decisions taken. It also presents future work that can be made in this area.

# Chapter 2

# State-of-the-Art

There are different types of health kiosks that provide information on the users health. Each system has its own specifications and implementation opportunities, depending on the requirements of the situation. The following sections provides an overview of the most relevant technologies used in health kiosks and what currently is being done in this area.

## 2.1 Progress on Health Kiosks Technology

Using computers and other devices that can connect to the Internet in the field of health has the advantage of reaching a great number of people in an easy and quick way. This allows activities such as promotion and dissemination of health information and even to answer health questions as quickly as possible.

Efforts being made in the health communication field have as main focus the improvement of the patients lifestyle, for instance, improve the eating habits, reduce the intake of toxic substances, and also improve, through psychological support, the ability the patient has of taking decisions regarding his health. The fact that there has been some development which led to an enhancement on the communication level, this comparing with what it was 20 years ago, [12] leading to a simpler way of distributing information, made it easier for patients to reach health professionals, or just information, without the help of other people.

This progress also brought with it the possibility of adapting a number of technologies with the intent of using them in the health field, as phone, video, clarifying doubts over email, medical websites, electronic health records [13]. It also made it possible for the creation of more capable systems that group several of these technologies, such as information kiosks, and the so called health kiosks. They can be seen as a set of medical devices connected through a graphical interface that allows interaction with the user. The existence of a health kiosk is not solely based on the idea of a device that collects health data from an user, there are different types of health kiosks that will be addressed in the next sections.

## 2.2 Communication with Users

When transmitting the information to patients, there are different types of communication, computer based, Web based, phone based. These three groups represent the standard process of accessing health information.

- **Computer based communication** is implemented as the development of a personal or public station where it is possible to access health information, this information is stored locally, as it does not have an Internet connection. This type of device is visible mostly in public spaces with easy access from the population. The function of these stations can change, being their main objective to prevent and alert to the way some behaviors affect the patient's health. Often the implementation of these devices increases the knowledge of the general population, and has a positive effect in the reduction of health problems addressed by the device [4]. Usually these types of systems, although being called health kiosks, can be called information kiosks due to the fact of only having the sole purpose of informing the users. A limitation is the access to new information, as it does not have an Internet connection the content of these devices is static so there is no way to remotely change the content, each device has to be changed manually [12].

- **Web based communication** appears as a solution to computer based communication, with the possibility to instantly alter the content in all the devices connected to the network. This solution avoids costs both in time, as well as the need to update each device. By using a service as the Internet, which is available globally, it is the best and least costly way of reaching a higher percentage of the population. Initially, in the health field, the Internet appeared as a place where the users could find static information, in the present the evolution created the possibility for users to talk among themselves, share knowledge, learn procedures that can help them improve their health [12].

- **Phone based communication** appears allied to computer technologies with the purpose of sending and receiving information, this information can be collected through prerecorded questions, activated through the patient's voice. This type of communication works essentially as a mean to inform patients, and persuade them to improve their lifestyle, it can be used in different health fields as a mean to encourage patients to perform their exams and have knowledge about their current health status, among other things. The fact that an interaction between a health professional and the patient exists, even if it is not a direct conversation, increases the probabilities of a patient actually attend to a real consultation or take more care with their health [12].

## 2.3 Impact on the Population

The progress in the health field led to new areas of study, for example a personalized area, this personalization aims to consider users as individuals with unique characteristics and not as a group with similar characteristics. With this, the user has access to information, in textual, video or voice form that only fits him, such as health state, alterations, attitudes, family history, previous attempts of behavior alterations, efficiency. This type of information has great potential in areas like weight loss, help users on the process of reducing, and consequently stopping, the habit of smoking. This individualization increases the chance of success in the real value of message being delivered to the user.

Information kiosks are an example of these devices, as it was already referred their functions are not to collect data from the user, but to give information to the user about specific procedures that the user should follow in case of contact with a disease. A telehealth station grants the users means to communicate with health entities that possess the required skills to provide relevant information based on the user condition.

The interaction with these systems is simple since normally they are prepared to instruct the users on the process of interacting with them. From that it is possible to either obtain health information or to obtain a reading on different biometric readings.

There are implementations of health kiosks in pharmacies, these implementations, despite being a great help in monitoring some parameters of the user's health, do not provide the scalability desired from the health kiosks. Most of the time, they are static machines that receive input from the user, and providing them feedback. One failure point of these systems is the usability, sometimes an instruction is provided to the user, and if the user does not know how to use the system and fails to understand the instruction the result produced is not valid.

It is easily noticeable the association between the health status of a population and their development level, it is even possible to assess the level of development of a country from the health services they provide, due to the high correlation between health services and development. With this, it is expected that underdeveloped countries have scarcity in terms of medical services. Given this problem the introduction of health kiosks works as an alternative that could have an important role in the quotidian life of the population, possibly preventing the development of a disease as well as the relevant information on how to treat it.

Communicating information through phone is a resource well explored in developed countries, although this is not the case in underdeveloped countries, which could be an essential point in administrating and treating patients.

Creating these devices results of the constant search for more and better ways to improve the life of the human being, and how to extend it. As one of the main goals of this product is to provide medical services to rural zones that are not yet covered, or are reached with some difficulties, the low cost of production of these types of devices is a benefit, as opposed to creating a building, with personal specifically trained to do the same job.

At this point, ir can be found, without much difficulty, some types of health systems in shopping centers, pharmacies, or other public buildings. However, they lack some of the services that are objectives of the health kiosk on which this dissertation is based. The need for more information, and adaptation to specific groups, either in age or health reasons, serves as a way to differentiate it from the existing products.

Using as an example one application of a similar product [3], the use of a device that can evaluate the health status of a person in an elderly community can have a lot of benefits, they are provided with tools to monitor their health and a monthly report on the tests that were made. In this specific case, the users of that system had access to a health professional who they could reach in case they faced any problem. The study had as an objective to evaluate the acceptance of this kind of device in an elderly community, the results were very positive, and the acceptance level was high. The security was a concern for the experimenters, but it was revealed that security was not a big concern to most of the users.

The usage of these types of devices in an older age group comes up as a method highly used to evaluate the product due to the special needs in this specific group age, which requires higher level of attention to their health. The fact that the product was implemented in a closed environment lead to an easier implementation since it requires almost no security or when it does, it can easily be achieved by directly contacting the user. This will not be possible when considering the scalability of the system, by expanding the implementation of the product to different locations and increasing the number of users it would not be easy to give each user a card or a password, another solution has to be implemented. The use of a record system leads to storing sensitive data associated to each user, so the security ends up being a very import part of the implementation.

This product is not only applicable to monitor the health of the users whenever they want to, it can also be used as a way to reduce the consultation time, leading to an increase in the number of patients that are seen by a doctor at the end of the day. According to Das and Padhy [2], creating a device with minimal capacities of evaluating a patient's health like blood pressure, cardiac frequency, temperature, the level of oxygen in the blood, can directly affect the consultation time. This process involves creating a device to be used in hospitals and health centers, and used by patients before the consultation, this would give both the patient and the doctor's information right at the start of the consultation, which allows the doctor to more quickly reach a diagnosis. In the end a reduction in the consultation time is expected, which in rural areas is very important due to the lack in human resources. This could also lead to an increase the number of consultations.

As it was already said, health kiosks can serve as a base in which information can be collected, with this in mind, an experiment was made with the goal of improving the lifestyle of a Latino community [4]. The alimentary traditions in this community was not considered appropriate to a healthy development, possibly leading to health problems. Only collecting data about the community is not enough, it is necessary to train the population to improve their health habits. The health kiosk used in this study was created with that in mind, the device not only measures the users health, it also gives feedback on how they could improve their lifestyle. In the end this was in general an improvement to the community. The study also aimed to help users quit smoking, but the authors admitted that the procedure used in this specific task was not suitable to fully help users quit smoking since this task demands more personalized attention.

## 2.4 Advantages of a Health Kiosk

The advantages of using a health kiosk are diverse, from measuring health data of a certain person to the point of giving specific recommendations to the user in the way he could improve his lifestyle.

The need to diversify this product exists, currently, it does not exist a product that satisfies all the problems stated. Scalability of the product must be taken into account when thinking of developing a system with this purpose since, alongside all the details already addressed, the growth of the system is a major factor due to the need of implementing it no matter the conditions or the location.

There are, as it was already seen, several fields where this device was implemented, from a simple product, more accessible to the population, found normally in shopping centers and public facilities, to devices capable of storing the collected data and managing a health record.

When evaluating different kinds of diseases it is possible to create different groups that need the same kind of parameters evaluated. Each group has a set of devices that can be used to evaluate those parameters. For example, if a patient has diabetes it is important to evaluate the glucose level, height, weight and abdominal perimeter of the patient, among other attributes. If another patient has respiratory problems, the abdominal perimeter loses its importance. This leads to the need of a modular system, capable of adapting to the user needs, where each device should easily be added or removed. The proposal for this dissertation aims to create a framework capable of this modularity, re-designing an existing interface in order to use Web technologies that will help in this adaptation to the needs of the users.

The ability of adapting to the problem is a benefit of these systems. Having a set of medical devices that normally are only used inside a medical facility is by itself a valuable benefit, this could be the type of device that takes the health care to areas that lack this type of service.

# Chapter 3

# Health Kiosk - System Overview

This chapter provides an overview on the architecture previous version of the health kiosk, which is extended in the context of this work. The different aspects of this system will be described in the following sections alongside with possible improvements that can be made in that area.

## 3.1 Current Health Kiosk Architecture Overview

The current version of the health kiosk allows full interaction with the end user, returning a set of results based on the parameters given by the devices connected to it. This means that the system is capable of accepting interaction from the user through an application. The application receives and processes data from connected devices and returns the processed data in a readable form to the user, both by presenting it on the screen and through a printer.

The Figure 3.1 represents the current system architecture, and also a separation between the hardware and software components that belong to this system.

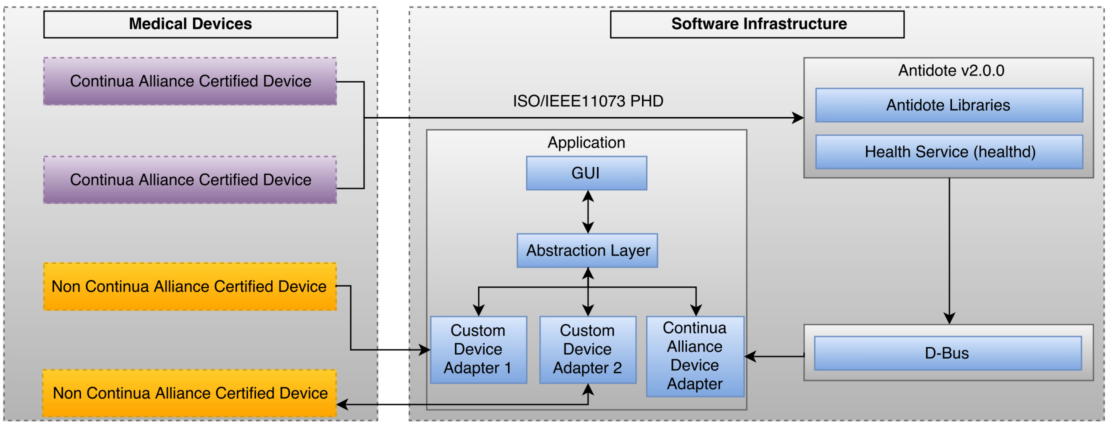


Figure 3.1: Health Kiosk Current Architecture

On the hardware side, two types of devices are represented, Continua Alliance certified and non-certified, these devices will be described in detail in this chapter. On the software side, the application and nodes that provide tools for the communication between the devices and the application are represented.

The hardware part of the system is composed by a touchscreen, connected to a PC that allows the connection of multiple medical devices, there is also the possibility of connecting a printer in order to give the users their results. The touchscreen allows the interaction with the users, in the Figure 3.2 the current flow of interaction is visible. As one of the goals of this work is to make the system modular, the flow will suffer some alterations.

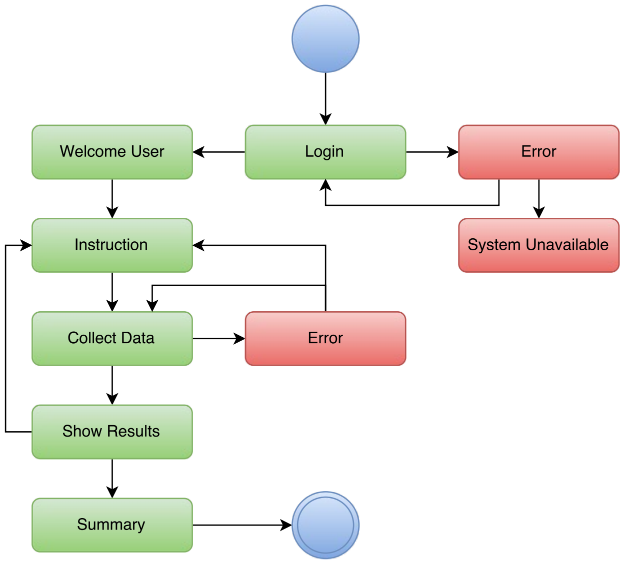


Figure 3.2: Flow of interaction with the user

## 3.2 Application Interface

Physical interactions between the user and the application are made through a touchscreen display. Although having the possibility of using a keyboard and a mouse, these are not available for the end-user in order to avoid incorrect utilization of the system.

The system is running an application with an interface developed using JavaFX [6]. This technology is composed of a set of graphics and media packages with the intent of providing tools for taking an application from the design phase to cross-platform deployment.

Being developed as a Java Application, it has the benefit of using other Application Programming Interface (API)s. Another aspect of this technology is the separation that is made between styling and implementing, making it possible for developers to focus in programming and designers to focus on the styling of the application that can be achieved using Cascading Style Sheets (CSS).

The information that was provided by the current developers of the health kiosk was that the styling of the application was not always as easy as it would be expected, sometimes causing problems in the outcome.

Despite being under development, the system already provides a fully functional platform. It is possible for any patient to start the procedure, interact with the devices, and in the end receive information through the screen and a paper on the data collected.

The following sections describe the core technologies used in the development of the health kiosk. Being core aspects of this system they have a lot in common with the new proposed architecture, although some changes have to be made on the approach to the technologies.

## 3.3 ISO/IEEE 11073

The standards family, Institute of Electrical and Electronics Engineers (IEEE) 11073, aim to allow Personal Health Device (PHD) to communicate with an external computer. It provides an interoperability between two systems, or components, allowing them to exchange information between them and use that information.

This information is exchanged from point to point, these points are described as an agent and a manager. The information is exchanged without the use of a specific transport protocol, being compatible with several of them such as Universal Serial Bus (USB), Bluetooth, ZigBee.

The agents in this exchange are the PHD that produces the data, and the managers are usually a computer or a smartphone with enough capabilities to allow it to communicate with the agents, collecting the data and to retrieve the relevant information from it.

In the current health kiosk application the communication with devices is based on Antidote [10] [5], a set of open source libraries that implement the IEEE 11073-20601 standard developed by Signove with the intent of improving the development of applications using this standard.

This set of libraries allows the communication of devices through different transport protocols, in the case of the health kiosk a Bluetooth connection with the devices is made. Antidote allows the use of the `healthd`, a manager application, which exports a D-Bus [8] service, discussed in more detail in the next section, in order to ensure API access from several major programming languages.

## 3.4 D-Bus Communication

In order to have information accessible to the application there must be a node in the system architecture that is responsible for exchanging messages between the devices and the application. This communication is based on the Antidote set of libraries, resorting specifically to the D-Bus API. D-Bus is a message bus system that facilitates communication between applications. This system simplifies the process of coding a reliable application or a daemon and consequently launching them when services are needed.

This system is an Interprocess Communication (IPC) mechanism, allowing for applications to talk to one another.

In its architecture it contains several layers: [7]

- A library, `libdbus`, allows for two applications to connect and exchange messages between them. This connection is a one-to-one connection, such as a network socket. The difference is that instead of byte streams, messages are sent. Messages with a header identifying the type of message, and a body with the data payload. It provides the abstraction of the transport used, and also handles the authentication.
- A message bus daemon executable, built into the `libdbus` library previously addressed, it has the feature of allowing multiple applications to connect to it. This daemon can forward messages between applications. This daemon provides the one-to-one connection to an application using `libdbus`. A node sends a message to the daemon, which in turn sends forward the message to of the connected applications.
- Wrapper libraries or bindings on particular application frameworks. There are also bindings at a programming language level such as Python. The wrapper libraries are a way of simplifying the process of programming with D-Bus. `libdbus` is used as being a low-level back-end for a higher level binding, most of the API is useful for binding implementation.

D-Bus has the purpose of fulfilling two different use cases, the communication between different desktop applications as long as they are running in the same desktop session associated with the logged user, and to allow communication between a desktop session and the operating system on which these sessions are running for events such as hardware detection.

It is visible on the architecture in the Figure 4.3 that the box representing the D-Bus communication is not integrated into the application since what the application does is an external call that handles this communication. The use of Web technologies imply the creation of a way to use this service, in the specific case of the new health kiosk architecture what is intended to be created is a Node.js module to handle the communication with the D-Bus service.

## 3.5 Device's Properties

As an objective of the health kiosk is its easy development and deployment, the selection of devices to use in this system must be taken into account. What this means is that standardized devices are preferred over proprietary ones. This is due to the fact that standardized devices communicate in the same manner regardless of the device being used. The compatibility of new devices with the system is easily assured by having this possibility, if one device is already supported, the process of adding a new device is as easy as knowing the codes of the messages produced by the device and repeat the process for those codes.

In this health kiosk the selection falls mainly over devices under the Continua Alliance standardization. This association aims to promote the standardization of PHD, the benefits would include affordable and readily connectable sensors. This is a goal that fits the needs of a system such as the health kiosk that aims to reach rural populations with a low-cost set of devices. By having low-cost devices the easiness on how systems are deployed increases.

As it was stated in Section 3.3 there is an agent and a manager under this standard, a Continua-Compliant manager has guaranteed compatibility to every Continua-Certified device. [5]

There are cases on which the the communication is not made under Antidote, visible in Figure 4.3 is a node denominated "Non Continua Alliance Certified Device" which can be, for example a Bluetooth Low Energy (BLE) device. Due to being a non-certified device, the tools to retrieve data differ.

Currently, a Nonin 3320 Oximeter is available in the health kiosk, this device does not fall under the standardization, to collect data from this device `gatttool` is used. This tool allows the access to the services that are running on the device. This tool allows the exploration of the device's services, but it also allows for the definition of variables in the device with the intent of making data available for the application.

## 3.6 Usability of the System

The usability of the health kiosk has already been evaluated [11]. It was verified that there were some points which needed some improvement. Nonetheless, the results were very positive. The evaluation of the usability is a continuous process, besides having potential users evaluating it, this evaluation has to also be made by health care professionals in order to have information on the provided instructions to assure the correct assessment of the parameters.

There are some aspects in the current version of the health kiosk that improve the usability of this system increasing the potential it has in reaching the maximum number of people.

The ability to generate data in a printable format, makes it possible to deliver the user the collected data. This increases the chances of the user to recall the given information, and with that in mind, the chances of the user improving his health habits increase.

With the use of audio and video instructions the usability of the health kiosk is increased. Only having textual instructions could lead to incorrect usage of the application. Providing not only textual instructions but also video and audio instructions, and since the goal of this system is to reach the largest number of possible users, the changes for a correct usage of the application increase.

## 3.7 Conclusion

This chapter addressed the main components of the current health kiosk which in some cases will be part of the new architecture.

What exists at the moment is a system that is correctly working, making it possible for it to be used in some application cases. As the development of new functionalities is not as easy at it was expected, a solution was proposed that a new version of the health kiosk made use of Web technologies. This not only makes it simpler for the development of the interface as well as it makes it possible for the use of all the possibilities that Web technologies allow.

The communication with the devices will be done in similar form on the new architecture, what differs is the use of [1]`Node.js` to handle the communication. Modules for communicating with each type of devices have to be created.

Continually testing the usability of the system can be a point of differentiation from other similar systems. Having feedback from potential users as well as taking into consideration the need to have information from medical professionals on how to correctly instruct the users the health kiosk can directly affect the acceptance of this system.

The next chapter addresses the work done, the steps taken when developing the new architecture. There were some choices made along the development of this system, as well as some new implemented ideas that take advantage of the use of Web technologies.

[1] https://nodejs.org/en/

# Chapter 4

# New Health Kiosk Architecture

This chapter provides a detailed overview on all the design decisions and developments on the course of this project. On the different sections the choices made are described and how they differ from the previous version of the health kiosk. Furthermore, it is also detailed the new elements added to the architecture.

The overall architecture of the health kiosk was already depicted in Figure 3.1. The first section of this chapter provides a global view on existing architecture and all the proposed changes, to be implemented in this new system architecture, especially the use of Web technologies, which provides multiple advantages. These advantages are addressed in the following sections as well the possible applications the new architecture enables.

## 4.1 Proposed Changes to Architecture

In this section several alternatives to the architecture will be described, which were taken into account when making decisions on what technologies to use. Some considerations on how these technologies could improve the efficiency of the health kiosk will also be addressed.

### 4.1.1 Web Components

This work aims to provide a new interface to the existing project. This means that an alternative to JavaFX is needed. Upon research the idea of using Web technologies seemed logic, and with it the use of Web components to address the modularity needed in the application. It will allow for the creation of custom elements adaptable to the needs of the interface.

This modularity is possible due to the fact that when using Web components a skeleton is built, which can be easily used as many times as needed, with different types of input, and different data.

A component is an empty structure that needs data to fill the attributes, and with different data, different components can be created using the same skeleton. The advantage for the user is that he does not have to rewrite the code for the skeleton each time he has to build a new component.

A practical example of this usage is for example a phone book, each contact can be defined as a component, the structure of that contact contains several attributes, a photo, the name, number, address, etc. It would take some time, and extra space to write code for 50 contacts, using Web components that problem can be reduced, as the person that is developing the application has only to write the code for the component once, and then invoke it with the attributes the number of times that it needs.

In the case of this project, this is useful due to the fact that the application that is being built has to serve different types of users, from users, that check their weight, and blood pressure, to more specific users as diabetics that need a different set of medical devices. This modularity is needed due to the fact that the application is not static and it must adapt to needs of the situation that is going to be used on.

The different situations in which the health kiosk can be applied require different medical devices, this modularity is achieved by having the exams easily added and removed from the execution flow of the health kiosk. The use of Web components also allows for an easier implementation of a new device, since the components are already created only having to be filled and the communication with the medical device assured.

### 4.1.2 Libraries

There are two main choices when trying to use a library that wraps Web components, Polymer and X-Tag. These libraries are used in a way of closing the Web components gaps, allowing them to be more compatible with all browsers, for that they use polyfills. Polyfills being pieces of code that the developer expects the browser would provide natively, for instance, the support of Canvas in older browsers. Polymer and X-Tag are different, but not too different, they both work with the same objective.

Web components have four specifications, Custom Elements, HyperText Markup Language (HTML) Imports, Templates and Shadow Document Object Model (DOM). Polymer makes use of all four as opposed to X-Tag that uses only Custom Elements and gives the developer the option to include Shadow DOM.

A X-tag element is represented in the listing 4.1. A Polymer element, and the way it is imported is represented in listing 4.2.

As it was already stated, X-Tag uses only custom elements Application Programming Interface (API) to build components, in the listings above it is possible to observe the differences when creating the same element both with Polymer and X-Tag. Both libraries would be appropriate to use in the development of the applications, Polymer was chosen to develop this

```
xtag.register('example-element', {
  content: '<p>This is an example-element.</p>'
});
```

Listing 4.1: X-Tag Element

```
<!-- Creation -->
<polymer-element name="example-element" noscript>
  <template>
    <p>This is an example-element.</p>
  </template>
</polymer-element>

<!-- Import -->
<link rel="import" href="path/to/example-element.html">
```

Listing 4.2: Polymer Element

application. It comes with a set of polyfills, which guarantee the compatibility with all modern browsers. The use of Polymer implies the use of Shadow DOM which produces a more isolated, and better packed API, being consistent with the goal of the application, which is having an application that consists of several components that can easily be assembled to fulfill the needs of the situation.

### 4.1.3 Web Application vs Desktop Web Application

The intention to build an application lead to the question of whether to build a browser application or a desktop application since in both ways it is possible to implement the idea of using Web technologies. In this section, a comparison will be made, with the intention of having all the advantages and disadvantages of each one to reach a decision of which is going to be used in this dissertation project. It is also visible in Figure 4.1 the differences between these two types of applications when addressing the health kiosk architecture.

The use of Web technologies to develop a browser application is now more common than a few years ago, the possibilities increased, as it is now possible to access the camera, the microphone and the file system among other things. As such, the development of the health kiosk as a Web application was an option that was not immediately discarded because it could reach the same goal as a desktop application although the process inherent to it would differ.

One of the advantages of using a desktop application, rather than a Web application, is the direct access to the device in which the application is running, by using a Web application that access would be limited to requests to a server, and this server would be the one that would send and receive messages through the D-Bus daemon.

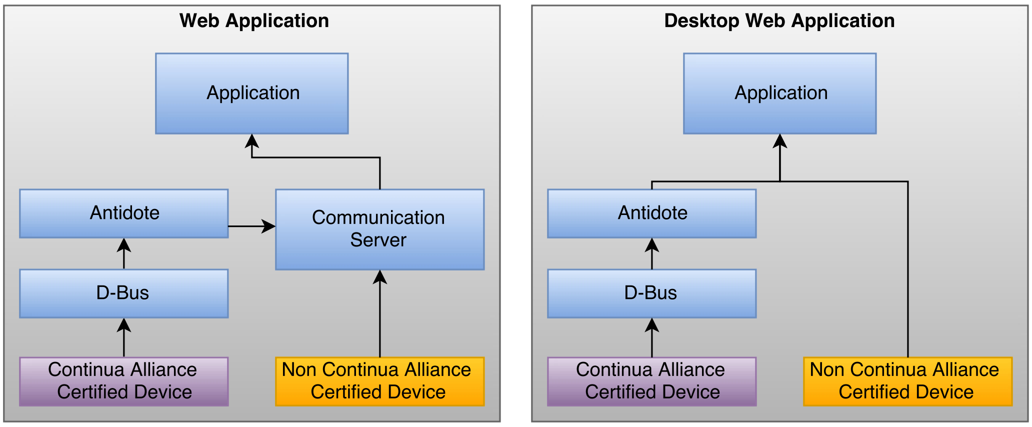


Figure 4.1: Web Application vs Desktop Web Application

The fact that using a desktop application would remove this need for an external server to communicate with the devices is a disadvantage face to the solution that can be reached by using a Desktop Web Application.

When thinking of a desktop application, Electron comes up as a global solution that includes all the technologies needed. It comes as an alternative to the use of JavaFX to build the application.

Electron provides the ability to use Web technologies such as HTML, Cascading Style Sheets (CSS) and JavaScript, it is based on Chromium and can be used with Node.js. It is open source, which is a benefit to the project since the main goal is to produce a low-cost system, and is cross-platform, it works on Mac, Windows and Linux. These three points serve already as a way to match the same possibilities as a browser application.

It surpasses a browser application due to the possibility that Electron has of allowing the interaction of the application with the operating system on which it is working. The process of the application can access Node.js modules, which is an advantage since it allows a better interaction with the system.

This was the advantage that ended the decision between desktop applications and Web applications. The fact that the health kiosk needs access to the device in which it is running to get information from the health devices increased the chance of choosing a desktop application.

It could be accomplished with a Web application, resourcing to an implementation of a communication server responsible for exchanging messages between the application and the devices through the D-Bus API. However, to use that approach a new node in the system would have to be created, possible creating a point of failure.

The application is started from a script that at the same time invokes `healthd` and executes electron with a JavaScript file as a parameter, this generates a main process that interacts with a BrowserWindow module, this module runs a rendered process that receives as input a HTML file with all his reference files, CSS, JavaScript, and other files, proceeding to the rendering of the page. This process is visible in Figure 4.2.

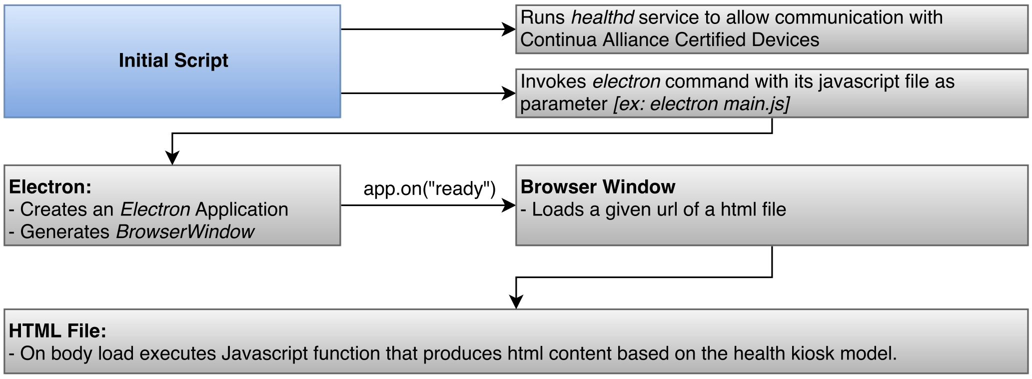


Figure 4.2: Electron flow of execution

### 4.1.4 Web Real-Time Communication (WebRTC)

Although developing a Web component for communicating with the back-office using WebRTC [1] was not the main focus of this work, but an additional task to be done if there was time available, in this section there will be an introduction to its principles and what advantages it could bring to the project.

WebRTC is developed in a way that gives the browsers and applications the ability of using real-time communications, using its API. The protocols are already implemented, and the developers have at their reach a set of tools that allow communication between different devices.

The fact that it allows not only real time communication but also data and file sharing with no need to install additional plug-ins makes it an interesting extension to a health kiosk application since it gives the possibility for the user to be connected to a health professional, and have any doubts about the service or its current health state explained.

A compatibility between both a Web application and a desktop application ensures that it would work in both cases since the only need is a WebRTC compatible browser. Using Electron assures compatibility with this technology since it runs using Chromium browser.

Being a peer-to-peer system the connection would be made from the user's browser to the health professional browser. At the moment there is no functionality in the health kiosk that could use the fact that when sending files with WebRTC the files would go directly from the user to a doctor or vice-versa, this function could help reducing consultation time, as described by Das and Padhy [2].

The idea of using WebRTC in this project goes along with the idea of having a health care center with the qualifications to give support not only in terms on how to use the health kiosk but also by giving feedback based on the measured data. When using the health kiosk, the user would have an option at any moment to connect to a back-office, which was composed with several health professionals, a request would be made to all of them until one would accept the connection. After establishing the connection the user would have audio, and video if necessary, from and to the health professional. The health professional could receive in real-time information on the user, such as the measurements he already made, identification, and the current status of the health kiosk.

As it was already seen the development of a WebRTC component does not require additional plug-ins, frameworks or applications, so the implementation along with this project is expected, and it will certainly be a point of differentiation from other health kiosks.

## 4.2 Interface Development

The work made on the application's interface was the core of this dissertation. The structure of the application has to be modular, which means that from the start of the application to the end the screens to be shown or not and the options available are defined programmatically. This option goes along with the different needs of the target instantiations, as one use case can have different needs than other.

What this means to the person installing the system, or maintaining it, is that he will have access to a file with the specifications of the health kiosk and can edit it in order to adapt the health kiosk to his current needs.

In Section 5.2 a possible graphic interface will be addressed, this interface intends to replace the need of editing a file, making changes in the health kiosk simpler, and reducing a possible point of failure.

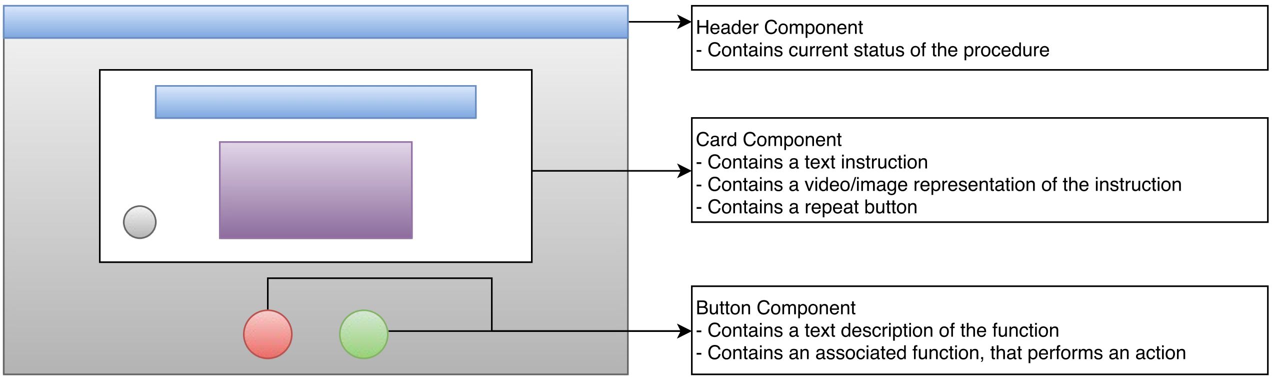


Figure 4.3: Screen with different components

In this figure 4.3 different components are visible, all inside one component which is the current screen being shown.

The first component is the top bar, which contains a title. Each screen shown during the use of the system has a top bar. The title describes the current shown screen. The next component is a card, the meaning of card is that it provides instructions to the user as if it was an actual physical card. Each card contains a title with a phrase that is the instruction to that card, an image or video that shows the representation of the instruction given and a button with the ability to repeat the video and an audio instruction that was given when the card was presented to the user.

## 4.3 Health Kiosk Configuration Model

This model defined in a JavaScript Object Notation (JSON) format is visible in the listing 4.3. It provides the basis on which the health kiosk will be generated. A value of true or false defines if the screen is to be shown or if a function is to be integrated in that case.

For instance, when there is no printer available, the person responsible for maintaining the health kiosk could simply define the value of the variable ***print_results*** as *false*.

Relative to the exams, each one is composed by the Media Access Control (MAC) address of the device that is associated with that exam when the device is not continua alliance certified. The priority is a parameter that it not yet used, but will serve the purpose of defining which measurement is to be shown in case of several devices measuring the same parameter, such as a blood pressure monitor and an oximeter, both measure the beats per minute. The rest of the parameters are self-explanatory.

The modularity intended with this system is achievable through the parameters defined in the model. Each application case has different requirements, with that in mind several options are available to the maintainer of the system, at any time the flow can be changed by defining a parameter as true or false.

## 4.4 Local Database

The future of the health kiosk will most likely pass through the use of an Electronic Health Record (EHR) in order to have at all times and locations access to all the records that a patient has created.

In a deployment case where there is no Internet connection the access to an online database will not be possible, for that a local database would be used with the intent of at least allowing the patient to retrieve the measurements he made in that system.

Given that, a way of saving and retrieving information was created using a JSON format. The saved data would include personal data about the patient, and the measurements he made, with the respective date.

An example of this database can be seen in the listing 4.4. Two exams are visible in this listing, *weight_continua* a continua alliance certified weight scale and *oximeter_nonim* a oximeter reader that is not continua alliance certified.

```
{
  "Healthkiosk": {
     "language_screen": true,
     "login_screen": true,
     "gender_selection": true,
     "height_selection": true,
     "age_selection": true,
     "exams": {
        "oximeter_nonin": {
           "mac_address": "XX:XX:XX:XX:XX:XX",
           "priority": 0,
           "title": "Oximetry",
           "img": "resources/exams/oximeter_nonim/oximeter.png"
        }
     },
     "qr_code_support": true,
     "final_results": true,
     "print_results": true
  }
}
```

Listing 4.3: JSON Health Kiosk model configuration

## 4.5 Multi-language Support

Turning the health kiosk into a system capable of reaching the maximum amount of users, requires some adaption. The ability of having a system fully functional in different languages is a requirement if it is expected to expand the deployment of this system to more than one country.

The internationalization of the system would improve its usability. A restriction would be made, if the system was available only to the developed language. To avoid restrictions in the usage of the health kiosk, English and Portuguese languages were selected to be available in the system developed during this dissertation.

The tool used to make this possible was [1]`i18next` , an internationalization framework. The way this framework works is that given an id and the language identification it searches for the value of that identification in the corresponding file. Providing all strings used in the system alongside a unique identification to that string makes it is possible at any moment to obtain the different values for an id in different languages. This framework is available as a module usable by Node.js.

[1]http://i18next.com/

```
{
   "users": {
      "999999999": {
         "gender": "m",
         "height": 180,
         "age": 27,
         "measurements": {
            "weight_continua": {
               "1": {
                  "date": "2016-06-15T19:15:49.286Z",
                  "weight": 68
               }
            },
            "oximeter_nonin": {
               "1": {
                  "date": "2016-06-15T19:18:02.065Z",
                  "spo2": 98,
                  "bpm": 59
               }
            }
         }
      }
   }
}
```

Listing 4.4: JSON Health Kiosk database

### 4.5.1 Text-to-Speech

The existing audio instructions were recorded by an actual person, using a recorder. This approach brought some limitations to what could be done. If an instruction had to be slightly changed it would imply a new session to record the file, also there is always some noise interference when recording using a microphone.

As a way to avoid the work of recording each voice instruction in order to increase the usability of the application the idea of using text to speech was considered.

Initially the goal was to use Web Speech API that was directly implemented in the Electron browser. Due to the limitations in terms of available voices in the used Operating System (OS), an alternative approach was thought. Using OS X installed voices made it possible to generate files from some text that was previously provided. Keeping all strings in different files for each implemented languages with an id for each one of the phrases, these files could be parsed and served as input to a Node.js modules, [2]`Say.js` , that produces files with audio from text, and it allows the developer to choose the system voice to use. The process is visible in listing 4.5 that makes use of the JSON content found in listing 4.6.

[2]https://github.com/marak/say.js/

```
var say = require('say'), jsonfile = require('jsonfile');

var data_en = jsonfile.readFileSync('./en.json');
var objects_en = Object.keys(data_en);

produceFiles("Ava","en",data_en,objects_en);

function produceFiles(voice,folder,data,objects) {
    for (var index=0; index<objects.length; index++) {
        say.export(data[objects[index]], voice, 1,
            ('./sounds/'+folder+'/'+objects[index]+".wav"), function(err) {
            if (err) {
                return console.error(err);
            }
        });
    }
}
```

Listing 4.5: Module for producing instruction files from text

```
{
  "age": "Age",
  "height": "Height",
  "resultRead_only": "Result Read",
  "resultRead": "Result Read. Remove the device",
  "startIndicator": "Click next to perform the measurement",
  "thanks": "Thank you for your participation"
}
```

Listing 4.6: JSON file containing text to produce audio instructions

## 4.6 QR Code Integration

The QR Code was an idea developed in the course of this work, it appeared as a solution to cases where it is not viable to have a printer in the system but the users are in possession of a smartphone. The main objective of using a QR Code is to allow the users to directly save the measurements in their smartphones. The use of an application to read the produced QR Codes produces a request to add a calendar entry. The entry will have all the collected data automatically inserted in the description, and the time the QR Code was produced.

One of the possible uses of the health kiosk is in rural areas, where sometimes there is a lack of resources that would not allow for the users to have a smartphone and consequently not taking advantage of this functionality. Nevertheless there are deployment locations that are more expected to have users with access to a device capable of using this technology, such as shopping centers, or city halls.

Figure 4.4: QR Code Image containing measured data

This is therefore a functionality that has value if some requirements are fulfilled. It has the potential to be very useful, as it will be discussed in Section 5.2.1. A practical example can be tested in Figure 4.4.

## 4.7 Device Communication

The device communication is currently made under two processes.

Devices that are Continua Alliance certified, communicate through the use of the Antidote set of libraries, exchanging messages through the use of the D-Bus API.

The devices that are not Continua Alliance certified communicate differently due to the lack of standardization, so it is not possible to create a function capable of handling all of these devices. In this project the device that fitted this requirement was a Nonin Oximeter, with the goal of measuring Oxygen level and heart rate. A module to handle communication with this device was created and part of his implementation is represented in Listing 4.8.

In the next subsections a description on how these communications behave is made.

### 4.7.1 Continua Alliance Certified Devices

For the communication with the devices a Node.js module was created, visible in part at the listing 4.7, establishing the communication and receives data from the devices.

Creating this module allows for a paired device that is Continua Alliance certified, upon communication, the application receives the data produced by the device. The Continua Alliance certified devices produce an XML when a measurement is made, parsing is required in order to retrieve the important information from the produced XML. Each retrievable parameter is associated with a code making it easier to collect the pretended data.

In the Listing 4.7 some information is missing, a more complete version is available at https://github.com/joaopgsilva/Continua-Health-Devices-Reader/blob/master/health_app.js, but essentially what is done in this module is establishing a manager for different agents, in this case it is expected a connection from a weight scale, with the code 0x100f, and in the Extensible Markup Language (XML) produced from the collected data it is possible to know the measured weight with the code 57664.

```
...
var EXPECTED_DEVICES = [0x100f], MDC_MASS_BODY_ACTUAL = 57664
var dbus = new DBus(), bus = dbus.getBus("system");

bus.getInterface("com.signove.health", "/com/signove/health",
    "com.signove.health.manager",
    function(err,iface) {
        var service = dbus.registerService("system","org.health.app"),
            objectName = '/com/signove/health/agent/' + process.pid, obj =
            service.createObject(objectName), iface1 =
            obj.createInterface('com.signove.health.agent');
        ...
        iface1.addMethod("MeasurementData",{in :
            [DBus.Define(String),DBus.Define(String)]},
            function(device, xmldata) {
                console.log("MeasurementData: \nFrom " + device + "\n");
                console.log(xmldata + "\n");

                var doc = new dom().parseFromString(xmldata);
                var weight  = parseFloat(xpath.select("//meta-data[meta='" +
                    57664 + "']/../simple/value/text()", doc));

                console.log('Measured weight is: ' + weight);
            }
        );
        ...
    try {
        iface.ConfigurePassive(objectName,EXPECTED_DEVICES);
    } catch (err) {
        console.log('Please run healthd process first...');
        process.exit(1);
    }
});
```

Listing 4.7: Module for communication with Continua-certified Devices

### 4.7.2 Other devices

For other devices, as it was already referred, the approach is different since it must be taken into consideration the process on which the device communicates.

When communicating with a non-standard device, in this case an Nonin Oximeter the use of a Bluetooth tool was adopted, in this case `gatttol`.

In the process of establishing the connection and receiving data the `gatttol` command is invoked with the necessary flags along with the MAC address of the Nonin Oximeter, then it listens for incoming data. Since this device produces a stream of data, it was defined that the result will be determined as corrected when it receives the same value five times. After that, it is returned to the application as the final result.

In the Listing 4.8 is visible how this process is made, first a MAC address is provided, then the `gatttol` command is invoked with certain flags, after that the module listens for incoming data. If an error occurs, such as a timeout, a message is provided to the user and the program restarts, trying to set a new listener for the device. A complete version is available at https://github.com/joaopgsilva/BLE-Oximeter-Reader/blob/master/nonin_3230_reader.js.

```
var spawn = require('child_process').spawn;

var mac_address = "XX:XX:XX:XX:XX:XX", child, flag="0x00";

function start() {
    child = spawn('gatttool', ['-b', mac_address,'--char-write-req','-a',
        flag,'-n', '0100','--listen']);

    child.stdout.on('data', function (chunk) {
        var message = chunk.toString();
        // Some processing of the variable message has to be made
        // to retrieve the desired parameteres.
    });
};
```

Listing 4.8: Skeleton of a module for communication with a Non-Continua-certified Device

## 4.8 Web Real-Time Communication (WebRTC)

Initially WebRTC was proposed as a complementary implementation, due to possible time limitations. Nevertheless a simple implementation of this service was made, it allows for the health kiosk users to connect to the health care center, and to possibly start a video-conference.

The limitations of this implementation are due to the fact that currently they only work in a local network. Although serving the purpose of a demonstration on how this feature could be used in a future implementation, lacks the scalability desired, and is in fact a subject that must be taken into account in future work. More will be discussed in the section 5.2.2.

## 4.9 Application Usability

The present work mostly focused on the development of a modular architecture for health kiosks, which is based on Web components. Nevertheless, on the course of the project several small usability experiments were made with different people (with different backgrounds - e.g.: people with technical background, people without technical background, and people with different ages). Although these tests were not extensive, they have shown that the proposed extensions and implementation enabled the different people (and possible users of a health kiosk) to accomplish the different tasks available on the kiosk. Namely, users were able to perform the end-to-end flows of activities supported by the health kiosk.

# Chapter 5

# Conclusion

This chapter provides conclusions and possible directions of future work, namely indications on possible implementations and extensions on the proposed health kiosk.

## 5.1 Conclusions

As it was intended, a modular system was created, with the ability of adapting to different circumstances. This modularity was achieved with resource to Web technologies, such as Web components that helped on creating components that could be reused in different circumstances. There are several types of components, such as the different screens that are shown, the keyboards, an exam, and the cards that are shown in the each exam are all examples on how components can be implemented in order to reduce code needed to program the applications. It also makes it easier to rearrange the applications, as it is simpler to move the code in the application.

The idea of creating the application based on components, makes it simpler to develop the application and for non-developers to understand how the system was implemented. Since the creation of custom-elements with given parameters makes it easier to replicate components.

Besides creating the graphic interface some other options appeared during the development, such as internationalization of the application. This would make it possible for the application to be used in different languages, to demonstrate this possibility it was defined that the languages to be implemented were English and Portuguese. Through the use of a framework, the process was simplified, by creating Id and Text pairs for each language, it is easy to access its contents in any language.

Besides the textual interface internationalization, and since audio instructions are provided, the need to a simpler process of producing audio instructions other than recording was needed. So, the idea of using Text-to-Speech appeared, having two forms of implementing this function, one via the Web Speech Application Programming Interface (API) included in the browser, other via prerecording the instructions with resource to voices existing in OS X. The latter one was chosen to be used since the first one did not fulfill all the requirements to be implemented.

Other functionalities such as the QR Code were implemented since they provided a way of increasing the usability for the end-users. Since a goal of health kiosk is to reach the maximum number of people, increasing the number of features will act as a way of differentiating this health kiosk from other possible implementations.

There is space for improvements in the health kiosk as it will be described in section 5.2 and due to time limitations it was not possible to implement them. Nevertheless the system that was created is capable of assessing several parameters of a user, save his information for future usages, moreover it is capable of adapting itself to different situations.

This adaptation is not only with respect to exams made but also to on which screens to use. The possibility of selecting language, having a screen to enter an identification number. Keeping in mind that the use of a screen is configured by the person is managing the health kiosks, should he consider not to use a screen, it must not affect the rest of the application.

Although being a complementary task, the implementation of Web Real-Time Communication (WebRTC) in the health kiosk was made, even though in a simple manner due to time constraints. The idea of using WebRTC to allow for the users to interact with a health care center is definitely a way of differentiating an application, and could be very useful in locations with access to the Internet, but that lack the medical staff that are capable of answering those doubts. Future implementations can integrate the exchange of information from the user to the health care center that allows for the health professional to easily assess the health condition of the user.

In conclusion, although having some points that can be improved in the future, a system was created that aims to satisfy the need of health systems, with low production price and easily deployed, in rural areas. The usage of this system is not solely restricted to those areas and due to its modularity it can be applied in many different manners in order to fulfill the population needs.

## 5.2 Future Work

In this section some possible improvements to the existing version will be addressed, and in how do they could help enhancing the efficiency of the system, and promoting its use.

### 5.2.1 QR Code

The usage of QR Code in the health kiosk system was implemented with the purpose of giving the user another method of saving his collected data. One idea to take more advantage of the use of QR Codes would be the development of a smartphone application since the use the QR Code already establishes the possession of a smartphone by the user.

This application could be an improvement to the storage of data directly in the user's calendar. The idea behind the application could be the directly integration of a QR Code reader that when data is collected then it would be processed by the application creating a local database. Through the collected data it is possible to create a set of tools to make use of the collected data such as temporal graphics that describe the evolution of the user over the health kiosk usage.

In the beginning of the implementation of this application if there is no way of integrating a synchronization process that makes the data accessible in all the user's devices, at least the ability to backup and restore data should be provided. Thinking about a user that has more than one device this must be taken into consideration. There must be also the hypothesis of inserting data manually, by the user. This would allow for when the user assesses his conditions at a hospital, for example, to insert the collected data in the application.

### 5.2.2 WebRTC

Since the implementation of WebRTC was just as a demonstration of the potential it could bring to the health kiosk. In the future it is expected to have this function fully functional, this would allow for the back-office to have access to current status of the health kiosk.

The idea of a health care center is to have a number of capable people, preferably health professionals that know how the health kiosk is operated. The knowledge in health would provide the user feedback on the evaluated parameters in order to increase the knowledge on the parameters and how to improve the users health.

### 5.2.3 Electronic Health Record (EHR)

An EHR, allows the user to save data in an online record accessible from any health kiosk.

Storing the health records relative to a patient online, would make it possible for health professionals to access all of a patient records. If a patient often uses the health kiosk, and this has the ability to save his data in a EHR this could help on a better diagnostic from a health professional since different parameters are available to him, and he can assess the evolution of said parameters.

### 5.2.4 Identification Card Reader

Having a card reader that collects data from an identification card makes it possible to collect the personal information, needed for the correct behavior of the system, about the user. Having the ability to avoid manually inserting data by the user could save time, and possible avoid user-made errors. This functionality has to be able collect information on the user, such as gender, height and his personal national health system number.

The safety is a concern when dealing with personal data, so this idea must be debated since its use implies the collection of what is considered personal data since an identification card contains more information than what is asked for the user to manually introduce.

### 5.2.5 Graphical User Interface (GUI) for Generating Health Kiosk Model

The current process for the adaptation of the health kiosk implies configuration of a JavaScript Object Notation (JSON) file to the specific needs of the health kiosk. Since after its deployment it is not expected that the person responsible for the maintenance of the system to have the ability to directly change the configuration files.

What is pretended with the creation of a GUI is to simplify this configuration that provides all options for the user to easily configure the system, from what exams to have accessible and the order they are executed to having functionalities such as QR Code or printing the results.

### 5.2.6 Tools to Assess Usability

The usability was not given a great amount of importance in this implementation since the goal was to create the basic architecture of the system. It will certainly be one of the next steps in the development of this system since the system must be fully usable by different types of people, from people with little experience in using computers and medical devices to most experienced ones.

In this application some possible implementations would be tracking the clicks that each user makes in each screen. Having access to a log that compiles the touches and associates them with the screens, makes it possible to retrieve some information from that data. Either the collected data provides information that the users are clicking the correct buttons, or it provides information on where the users are failing to understand the procedure needed to advance in the use of the health kiosk.

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