Modular Health Kiosk based on Web Technologies

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Abstract: We describe a modular and easily reconfigurable Health Kiosk based on common, off-the-shelf Personal Health Devices and a computer with a touchscreen interface. The Kiosk is implemented in standard web technologies (JavaScript, HTML and CSS) on top of the Electron platform. It is intended to be used autonomously by the patients. It is highly modular, can easily be adapted and reconfigured by health professionals with little to no computer expertise, using a graphical interface, to adapt to different groups of patients and use cases. We document our findings, identifying problems faced throughout the development and solutions to those problems.

1 INTRODUCTION

With the increase of the population at a worldwide level, the expenses associated with health care are proportionally increasing. Despite that fact there are still some gaps that need to be fulfilled since the resources are mainly allocated in central areas that most of the time are not easily accessible to all the population. Moreover, due to that centralization of resources, the ratio of patients for each health professional is expected to increase, making it more difficult for them to proper assess all patients that use a medical facility.

There is a clear demand for alternatives to visiting a medical facility, due to the expenses associated with it, not only financial but also in terms of time. Due to the high demand and a low offer in terms of medical professionals available, there is a chance that when visiting a medical facility a patient may not be evaluated by a professional. This situation can lead to a delay in finding abnormal biometric values, causing a later treatment start.

Health has always been a field with a high-level of acceptance of innovation, and using technology with the intent of improving patients health is something that has been evolving over the time. This evolution allowed for the development of medical devices accessible not only to hospitals but also for personal use at home. (Suggs, 2006) There was an evolution from different types of devices that facilitated the access to health information. The phone acted as a way to solve simple questions for the patients, which, when the Internet access was globalized, was made easier through forums or e-mails.

A shortage of these types of devices or technologies in rural areas is visible and due to that fact, it should be a main goal of our society to try to reduce the discrepancy between these areas and others more developed. In rural areas where the offer in terms of medical services is low, the impact of a system that can make evaluation of the patients without taking time from the medical professionals can be extremely relevant. (Das and Padhy, 2014)

Creating a system such as the health kiosk would allow the patients, without the requirement of allocating human resources in these areas, hospitals or other possible locations, to obtain information on their health, ultimately saving time and resources to the user, and in the case of the hospital both to the patient and to the health professional that has access to the information without having to collect it.

Possible applications of this system are hospitals or health centers, but it is not limited to those as the system is being developed in order to adapt to the needs of the situation. This is accomplished by having a configuration that allows for modifications. With the right configuration it can be deployed in rural areas, based on the needs of those areas, or elderly communities in which its inhabitants require constant medical attention.

In this work, the possibilities of improving an existing health kiosk are analyzed, what modifications were made, what benefits those modifications bring to the table, as well as the difficulties faced on the

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development and milestones that are to be reached in order to have a fully functional system, capable of being deployed in different areas.

2 RELATED WORK

Using computers or other internet capable devices has always been of great help in health related developments, not only with respect to machines used, the type of devices available in hospitals but also in the way the general population has access to health information.

The evolution of technology made possible the adaptation of several of those developments to health areas, such as the phone, video, clarification of doubts via e-mail, medical websites, and the creation and usage of electronic health records. (Verma et al., 2008)

With the increase in the variety and offer of medical devices, it rose the idea of grouping a set of these devices associated with an application in order to create a system capable of taking measurements of its users to provide some feedback on their vital signs, which otherwise would not be possible if its users lacked the resources to acquire these devices or to make visits to health centers. Currently the health kiosk is a system capable of collecting data from a blood pressure monitor, a weighing scale and a pulse oximeter. Nonetheless, it is not limited solely to these devices as new ones can easily be added to the system.

The idea of a system capable of collecting biometric data from its users and show them the results is not new, as it can be seen in public locations, where most of the time static, offline systems with a small set of instructions provide the user valuable information. In parallel some other types of kiosks can be seen in some locations such as the information kiosks that serve the purpose of disseminating information throughout the population (Nicholas et al., 2003; Leeman-Castillo et al., 2010), they can be internet connected with the intent of remotely changing the available information.

A more approximated system to our proposal is the Multi-User Health Kiosk developed in a joint effort of the University of Pittsburgh and Carnegie Mellon University. (Courtney et al., 2013) Their findings provided helpful information on how to tackle the development of a health kiosk. Creating a modular architecture, to change in accordance to what is needed or providing helpful, step by step, instructions on how to use the devices, is information that, despite being simple, has a major impact on the usability of the system.

Since our aim with this system is to deploy it at communities, public locations or medical facilities, a multi-user approach must be made instead of creating a simple collection tool for a single user to use at home. This has to take into account that the system will be used by different users, with different characteristics and different health needs.

A specific application case of this type of system are elderly communities, as the need for attention on their vital signs is higher due to the increased fragility of human health over time. This type of deployment has proven to be very positive with a high-level of acceptance from its users. (Demiris et al., 2013)

The system is being developed making use of commercially available Personal Health Devices (PHDs). With the increased availability of these types of devices, the price is more accessible, reducing the total cost of assembling a system with these requirements. Some of the devices that are already working with this system, and possible new devices, communicate under a standardized form, which allows adding new devices in a simpler way since the communication module handles all the devices.

The ISO/IEEE 11073 Personal Health Data (PHD) Standards allow for the intended interoperability between some of the different devices that make up the system. This standard appeared as a merge of different standards such as ISO TC215, CEN TC251, IEEE 1073. (Nam et al., 2011) The Continua Health Alliance has a major impact both in the standard as well as in the health care industry, trying to standardize health devices in an orderly process, and also to make it easier for developers to work around with these devices.

Not having this standardization in some devices is a problem since it means that an individual approach must be made in order to interact with the devices. A way to establish the communication has to be created, as well as an interpretation of the messages sent by the devices, and if needed to the devices.

The objective of reducing consultation times, and keeping a more detailed patient's history is achieved by having access to these records. This implies that the health kiosk in the future must be able to add data to the patient's Electronic Health Record (EHR) this would improve the view the health professional has on the patient's history since the number of measurements taken outside a medical facility should be higher than inside one. Despite its benefits, it is not an easy task to converge the user's medical data of a user and make it available at all medical facilities that the user could visit. (Kalra, 2006) For now, a local database serves the purpose of giving the patients the possibility of saving and evaluating their history.

It is now possible, when using the health kiosk to make use of a smart card reader, this option makes it possible to extract data from the Portuguese Citizenship card. This function helps not only to avoid human error when inserting personal data, but also as a way of reducing usage time of the application. Further testing needs to be made in order to establish the true value of this feature. The data available for collection is public data that is visible in the physical card, no private data is accessible without a Personal Identification Number (PIN) that only the user has knowledge of, besides text data it is also possible to extract the picture of the user.

With the objective of being used in an autonomous way by the patients, the usability of the health kiosk is a concern. The current version of this system is an improvement to an existing version, which was assessed in respect of the usability of the application. The differences between the two versions will be address in the next section. (Soares et al., 2016) Little changes were made relative to the execution flow of the application in order to take advantage of the information that was collected regarding the usability. This evaluation of the application was based on observer-filled questionnaires alongside the option of keeping track of user clicks on the screen in order to evaluate the number and position of clicks per screen to see the changes to be made in the presented content.

3 OVERVIEW OF THE SYSTEM

An example of a health kiosk physical deployment is visible in Figure 1, which has three devices associated with it, a blood pressure monitor, a pulse oximeter and a weighing scale that is not visible in the figure. The interaction from the user is made through the use of the touchscreen, if the user chooses to, it can insert the citizenship card onto the smart card reader. After the exams are finished, the results are printed in the printer that is also visible in the figure.

Figure 1: Physical health kiosk.

Relative to the system architecture a representation is visible in Figure 2. The system has two possible types of devices, Continua Alliance Certified and Non Certified Devices, at the moment all the devices communicate via Bluetooth. Nonetheless, the development of a way to communicate with the devices takes one of two possible approaches, either the device is Continua Alliance certified and communicates with an Antidote IEEE 11073 PHD interface, or it is not certified and an individual approach must be made in order to communicate with that specific device. The process of creating a way of communicating with a non-certified device can be applied to other devices, creating a skeleton that is the base for the development. Consequently, reducing the time of development.

In the future we intend to have a connection to a central EHR system, in order to make the patient's data available in different health kiosks, as well as to health professionals. By sharing data along all different locations that the users visit the impact the collected information has is higher.

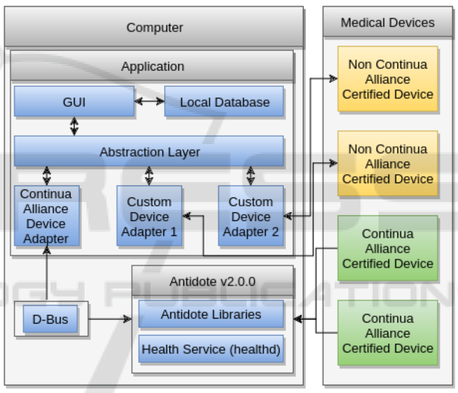

Figure 2: Overview of the System.

4 IMPLEMENTATION

The current development of the health kiosk has been based on a previous existing version that, despite already having a functional flow, did not have the tools for a proper continuous development. With that came the idea of developing a version of the health kiosk that used web technologies. The previous version was developed using JavaFX, where some challenges were found before the transition into the use of web technologies. This transition came as an alternative that could replace the existing version and at the same time take advantage of features that are available with the usage of this type of technologies, such as Web Real Time Communication (WebRTC).

The application was developed on top of Electron, a framework for building cross-platform applications based on JavaScript, HTML and CSS. The Electron[1] framework was selected because it makes it possible to communicate with the operating system directly using Node.js, while providing all the advantages of using web technologies (including the vast amount of JavaScript libraries for building web applications).

The previous version was already assessed in terms of usability (Soares et al., 2016). With that in mind, the development of the new interface was made trying to keep the same flow of interaction.

Some changes had to be made, either because of the advantages of using web technologies, or because the creation of new modules such as the smart card reader implied new screens that the user has to interact with. In the following subsections the adaptations made to the system will be addressed.

Regarding the usage of the application, there are several possible cases of use due to the modularity of the application. Figure 3 represents a full usage of the application, this includes language selection, authentication selection, performing exams and an end summary. Figure 4 represents a smaller application case, where no user data is collected, just the exams to be performed and a summary with respect to the collected data. These variations allow for different field applications since what is intended is to adapt the application to the users and/or scenario and not the other way around.

The flows visible in the figures goes through several steps, these steps being optional in some cases. By configuring the system to follow the flow visible in Figure 3 it gives the users the possibility of taking full advantage of all the features. Starting with the language selection, the user is presented flags representing all available languages. After selecting the language, all texts and voice instructions to be presented to the user are in the selected language. The user is presented now with the authentication method selection, if the user chooses to use the citizenship card all the necessary personal data is collected automatically. If not the user is presented with several screens in order to insert the data by himself. After having all the data, the user is presented with a screen showing all exams that are to be performed. Subsequently the user iterates over each exam, following a set of instructions, either by image or video, and evaluating the collected information on an intermediary results page. In the end a table is shown presenting the final results, and it is also visible in the screen a QR Code containing all the information of that table that is inserted as a calendar entry, all this is printed out to give out to the user. After that, the system restarts and is ready for a new user.

[1] http://electron.atom.io/

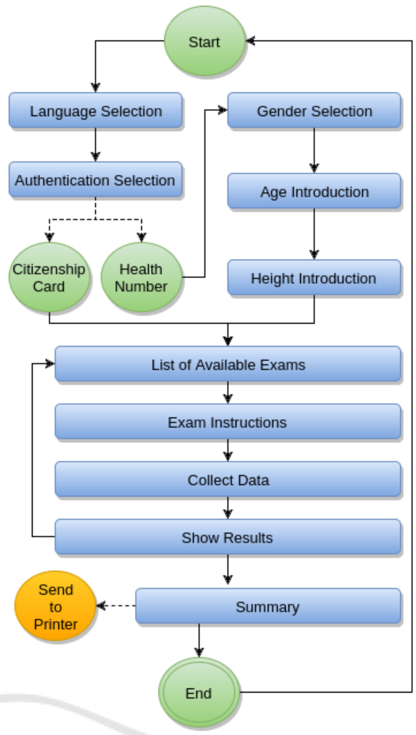

Figure 3: Example of the flow of execution.

What is intended with this system is not only to have the ability to collect data, process it and present the results, but to give the option to the responsible person to adapt the health kiosk in order to fulfill the needs of its users. There are different use cases to the health kiosk, some differences are related to the type of data that is intended to be collected, other to the necessity or not to collect user personal data, for that the health kiosk must be modular and easily adaptable to the circumstances.

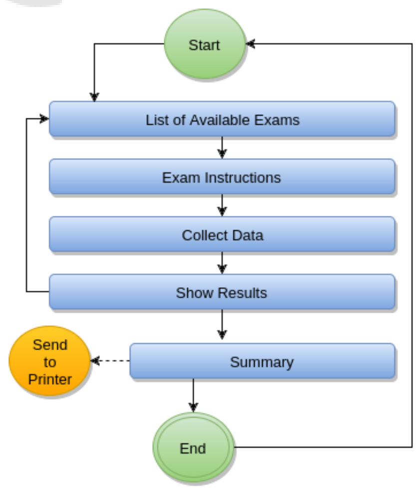

Figure 4: Example of a simpler flow of execution.

4.1 User Interface

The usage of this system can be divided upon three different stages, collecting personal data from the user, collecting data from the devices, presenting results to the user.

When the patient starts the process of using the health kiosk, it has the choice of either inserting a citizenship card, and the application itself collects relevant data from the card, or the user can himself insert its personal data, such as the national health identification number, gender, height and age.

After having all the user data collected, the next step is to go through all the defined exams, after each exam the user is presented with the results and a chronological chart with all the measurements taken with that device associated with the user. The collected measurements are displayed in a bar, colored green on what are considered default values for that measurement with a gradient to red as it increases the distance to those values. The intermediary results screen are visible in Figure 5, which represents what it looked like in the older version of the health kiosk, and Figure 6 represents the newer version of that screen.

The proposed changes included an usage of chronological graph, with the x axis being a time series, which means that the points take into consideration the distance between the presented dates; centering the next button and using a green color instead of blue.

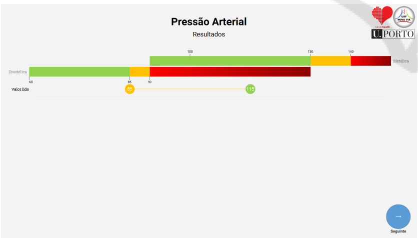

Figure 5: Blood Pressure Results on the previous version.

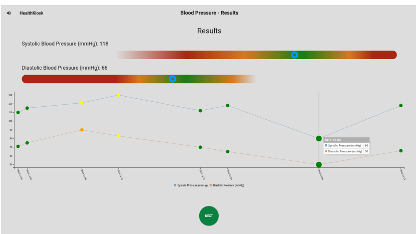

Figure 6: Blood Pressure Results on the new version.

In the final screen a table is presented with all collected data, as well as a QR Code that upon reading by a smartphone inserts in the default calendar app an entry with all the collected data.

A page is also printed containing the user personal data, the collected data and the QR Code. It also contains a logo on the top that can be configured to fit the needs of the situation.

The idea of using a QR Code to share data serves not only the purpose of saving the data in the users smartphones, but can also be used in the future as a way of transmitting data to a health kiosk smartphone application that if developed can act as a place where the user can evaluate at any moment their vital signs registry and even add other measurements that were not made in the health kiosk.

The printing of the results, as well as the generation of a QR Code are optional functions that can be disabled by the person responsible for the configuration. This goes along with the idea of creating a system that is highly configurable and capable of dealing with the needs of its users.

4.2 Application Modularity

From the beginning one of principles of the development of this health kiosk was the idea of modularity. By creating a system that is based on this idea, adding or removing elements, changing their order or using the system with different configurations is a goal easier to achieve.

With that in mind, one of the main focus when developing this application is the possible configurations that the application should have. The use cases can increase by creating a modular application. As such, a configuration file was created, in which all the possible options of the system are inserted. The configuration file allows for the definition of which screens to show, which exams are to be performed and in which order to show them.

When having the possibility of choosing which screens to be used, or which exams to perform, the system is easily adapted to different use cases, from a situation where no user data is needed such as a specific event where only a specific parameter is being evaluated in a population to detect anomalies, to cases where the system is deployed in a local place where all the population can access it, and a record specific to each user has more meaning.

A approach was made, when the system was being developed, to try and simplify the process of adding new exams or devices. A skeleton, based on web components, is created for adding new exams to the application, and if the device is certified, it can easily be added to the system, needing only specific codes for the parameters being read from the device.

Figure 7 represents an exam component, this component can be reused in different cases, the compo-

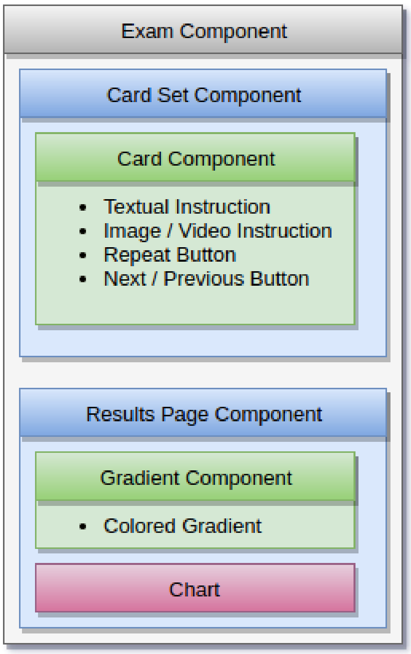

Figure 7: Representation of an Exam Component.

nent itself contains two different components, the card set that is shown to the user with the instructions, and the results component that is shown after the user has passed through all the instruction cards. This approach was made throughout all the application in order to facilitate adding new screens or elements to existing ones.

4.3 Internationalization

Although at the moment the smart card component collects only data from Portuguese Citizenship cards, and the national health identification number asked is also the Portuguese one, this will not always be the case, and the wide range of possible users of the health kiosk must be taken into consideration. With that in mind, we implemented in the system the possibility of using different languages, making use of an internationalization framework[2].

Having each text component associated with an id, and for each language a set of ids with the respective text values, the process of making the application available in new different languages was made easy. As for adding a new language the development process passes only through creating a file with all the id and values pairs and the system is capable of dealing with that information.

Although the previous version of the health kiosk already had voice instructions, these were recorded by a person. This has some limitations in terms of development. This initial approach made possible a first development and evaluation on how sound instructions can help the user take the available exams. However, it has several problems associated with it, for perfect instructions no noise in the sound would be preferable and this is not possible to achieve with low cost recording devices. Another fact to take into account is that even small changes to the audio instructions imply that a new recording session has to be made.

To tackle these issues, we added digital voice instructions to the application. These voice instructions are generated making use of the text-to-speech technology and saved into files to ensure that the produced speech is the same across all systems. The process of creating these instructions is the same as for the text instructions, a set of values associated with an Id have to be created, and then all these values are read and a file for each available language is generated. Since the voice's used are the available ones on the operative system, and new ones can be added, it is easily possible to add voice instructions in different languages.

4.4 Hardware

Currently the prototype of the health kiosk is deployed in an all-in-one PC with a 22" touchscreen. This prototype is capable of collecting from any possible combination of a blood pressure monitor, a weighing scale, and a pulse oximeter. This system has connected to it a printer in order to handout the results to its users and a smart card reader to extract data from the citizenship card.

The current supported and tested devices in the system are two Continua Alliance Certified devices, a blood pressure monitor (AND A&D Medical UA-767 Plus BT-Ci) and a weighing scale (AND A&D Medical UC-351PBT-Ci), and a non-certified device, a pulse oximeter (Nonin 3230), this device communicates via Bluetooth Low Energy (BLE). Although Nonin has a Continua Alliance compliant device we used this one to develop and test the integration of non Continua devices. Moreover, we also experimented with the differences for a BLE device.

4.4.1 Device Communication

During the development of the new version, we created modules to communicate with the devices. By using Electron to develop the application, Node.js can be used in order to access the operating system directly, which would not be possible if a browser application were to be developed.

[2] See http://i18next.com/.

Using a Node.js module (`node-dbus`), made it possible to develop a new module capable of communicating with the existing Continua Alliance certified devices, and to easily add new devices as long as information about the devices is previously given to the developers in order to properly extract relevant information produced by the device.

Continua Alliance certified devices, generate data in eXtensible Markup Language (XML) format, having the relevant medical data associated with a specific Id for the parameter, it also provides information relative to the date of the measurement. It also contains parameters that can hold information about the physical device.

Since the objective of the application is to adapt to the users and not the other way around a decision had to be made in order to support non certified devices since there is a possibility of these types of devices being cheaper for some possible use cases. This decision goes along with the idea of creating an adaptive system that is not closed in terms of compatible devices.

For the case of the Nonin Oximeter 3230, as it is not a Continua Alliance certified device a different approach had to be made. Since this device communicates via BLE it was decided that taking advantage of a Node.js modules (`Noble`) was an appropriate way to develop the means to communicate with these types of devices. For that a module was created that takes the MAC Address of a device, starts scanning until the device is found, after connecting to the device it has to activate the characteristic of the device responsible for sending data via Bluetooth, when that is done a stream of continuous data is received by the application, being decided that upon a number of repetitions that value was to be considered and the stream stopped.

The development of these new modules will allow a simpler development in the future since the base of the communication is already implemented and what is required is to adapt it to the new devices is an evaluation of the device in order to proper assess what messages it sends, how it sends them and what is the best way to extract information from them.

4.5 Usability

Being an application that evolved from an existing one, and since the previous version had an usability evaluation, what was made when developing this application was to follow the flow of interaction provided in that application. The usability of the previous version was studied in different scenarios, at the university open days (by 195 users), at a health day in one of the university schools (46 users), during a week at a local city hall (127 users) and for thirteen days in thirteen different villages in Brazil (465 users). This covered different age groups, and usage information was retrieved not only from the application but also from the evaluation on how people used the system. The evaluation used observer-filled questionnaires and user click tracking. The evaluation did not use the standard user questionnaires as we perceived them as either too long or less appropriate than a researcher observing the usage. More details can be seen in (Soares et al., 2016).

At the moment the usability of the current system has not been tested by a large population. The tools for assessing time spent on each screen and where the user has clicked throughout the usage are developed and will soon be tested. This will allow us to evaluate if the interface is easily usable, if the user has the ability to use the application from start to finish without any assistance, or if so which screens are taking more time from the flow of interaction.

The collection of time spent on each screen can help us determine if the instructions on the screen are easy to understand, and for instance, if having the ability to use a citizenship card is quicker and more adopted than introducing the data manually.

By also collecting the coordinates of the clicks and group all clicks made in a single screen presenting them on top of a screen representation it is possible to determinate if the screen is usable, and if it is being used in the most correct way. If a large group of people click somewhere in the screen that is not intended to be clicked then something is not right about that screen and must be evaluated.

More consideration has to be made in order to proper evaluate the usability by using these methods, such as the elimination of outliers that could affect the visualization of the problems on the screen. A small amount of users could make excessive clicks in wrong places or spent too much time in certain screens and with that alert for a non existing problem.

The usability of a previous version of the health kiosk has been tested (Soares et al., 2016) with the same idea of representing clicks on a screen representation, which is visible on Figure 8.

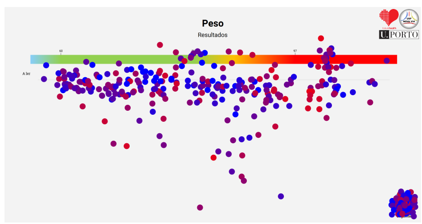

Figure 8: Weight measurement result screen usage pattern.

In Figure 8 it is possible to evaluate that users try to interact with the color gradient before clicking on the button to show the new screen. This type of information allow us to consider what steps to take to make the application more fluid, with quicker and better responses from the users.

4.6 Configuration Tool

Both on the previous version as well as in the new version there was a unique point in the system that was responsible for the configuration of the system.

The configuration file is currently responsible to allow for the definition of which screens to be shown or wich personal data to collect, if features such as QR Code, printing, voice instructions should be used or not in the application among other different options.

For easier configuration, all possible configurable values must be in this file. At this moment it is under development a tool that will allow for non-technical users to configure the health kiosk. A preview of the application interface is visible in Figure 9, this application will be divided in several blocks of configuration grouped by what is being configured, such as available languages, what type of authentication is to be used, what exams are to be performed. The development of this tool is not only important to make the health kiosk configurable without technical help but also to evaluate what truly is configurable in this system.

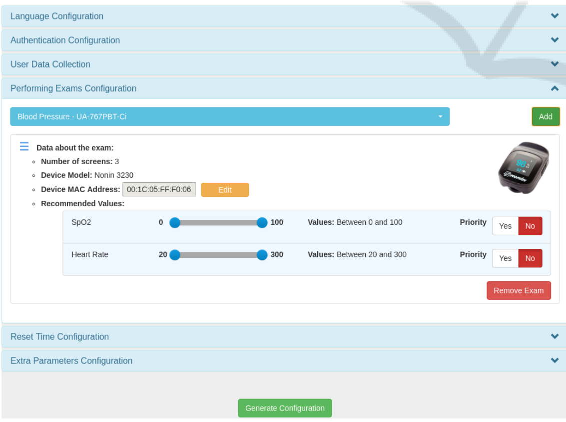

Figure 9: Current status of the Configuration Tool.

5 CONCLUSIONS

A system such as the health kiosk could have a major impact in different possible scenarios, such as rural areas lacking medical resources or health centers with higher attendance than the one they can process. Deploying this system in these locations, makes it possible for the population to, by themselves, measure their vital signs.

The current prototype makes use of a simple weighing scale, a portable blood pressure monitor and pulse oximeter, an evaluation of possible changes to this setup is undergoing, with the idea in mind of having devices simpler to use and that possibly collect more data. One example is going from a normal blood pressure monitor that the user has to set up and adjust, to one where the user simple introduces the arm in the fixed device and waits for the results. Also, weighing scales capable of evaluating body fat are also an alternative to the current existing ones. One point that has to be considered is relative to the powering of the devices, presently all the devices are battery powered, which is not feasible in large scale.

At it was already referred, the configuration of the health kiosk is made by editing an existing configuration file with the desired values, but a Graphical User Interface (GUI) is being integrated into the health kiosk system soon that will allow for anyone responsible for the health kiosk to edit the configuration without knowledge of the technical details.

It is also being developed under a master's thesis project a module that will allow the establishment of a video conference, using WebRTC, in which the patient can get help on how to use the device or ask for a medical opinion on the collected data. Due to the possibilities of WebRTC, the health professional is not only able to establish a video conference, but it is also able to have access to data from the application, and to send data to the application. This creates the possibility of having remote instructions that can change the status of the application.

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