Interactive System Engineering 2
Medical Device
Portable pulse oxymeter
Connected to a cloud server

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***Abstract*- The following document deals with the implementation of the interactive system engineering project. In the beginning, the introduction explains the context of the project and what the product is about. Then the concept of the project will be explained following with the design of the concept. This includes the requirements, the use case, the state machine, and the associated diagrams. In the next step the hardware and critical-based parts of the system will be declared. Following that, the user interface will be introduced with it associated visualization. After that I will discuss, what the concept covers so far and if it solves the initial problem. Then I will point out what I improved because of and during the exercises. At the end of this paper, a conclusion is drawn to sum up the project and also looked ahead to the potential future of such products.**

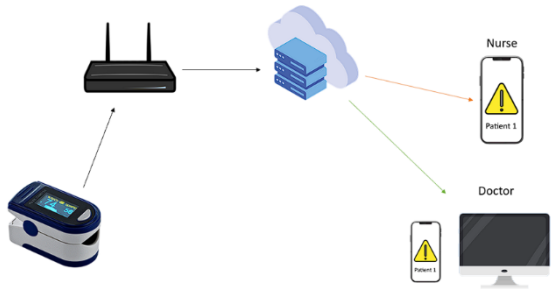
I. Introduction

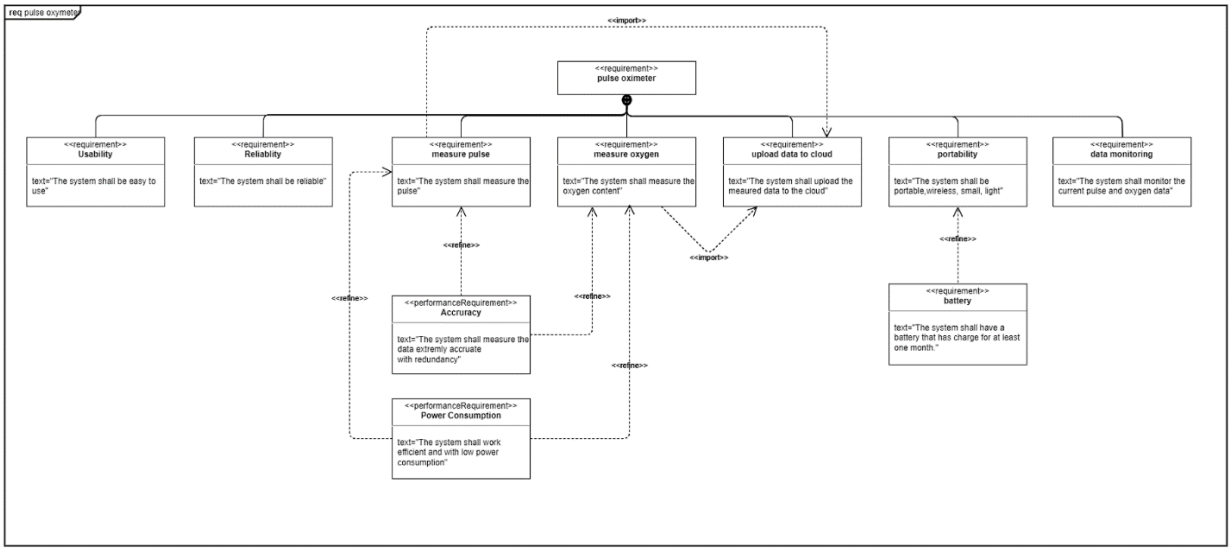
Pulse oxymeters are used heavily every day in hospitals and other medical facilities. They are particularly important because they can detect strokes, unconsciousness and much more. The pulse oxymeter that are in use today are wired and connected to a single monitoring device. This makes them only useful when the patient is in his room and not moving around. Portable pulse oxymeter exist, but these can be only monitored by the person who is wearing the device, who can already be unconscious or not familiar with the data that is displayed on the screen. Nurses are extremely stressed at work because they have long working hours, too many tasks for one person and most important too many patients to control. To that, hospitals do not have a lot of money and mostly do not have enough personal. Not every patient can be controlled and monitored at the same time, which is a big problem in today´s hospitals. There needs to be a product that reduces the amount of work that one nurse is doing on one day. It should be easy and painless to check the vital data while the patient is at various locations.

II. Concept

The solution to this problem is a portable pulse oxymeter with a that is connected to a cloud server. The pulse oxymeter measures the pulse and oxygen content in the patient´s blood and displayed it directly on to the pulse oxymeter´s screen. It also sends the vital data over a Wi-fi access point to a cloud server, where the data is stored and processed. The doctor or the nurses can access the data by any monitoring device that is connected to the server. They can see the past data and the current data in real time. The server can detect substantial changes in the data and if thresholds are exceeded. If this occurs, it

will send an alarm to the selected nurses and doctors, with the information which vital values are alarming and where the patient is at the moment.





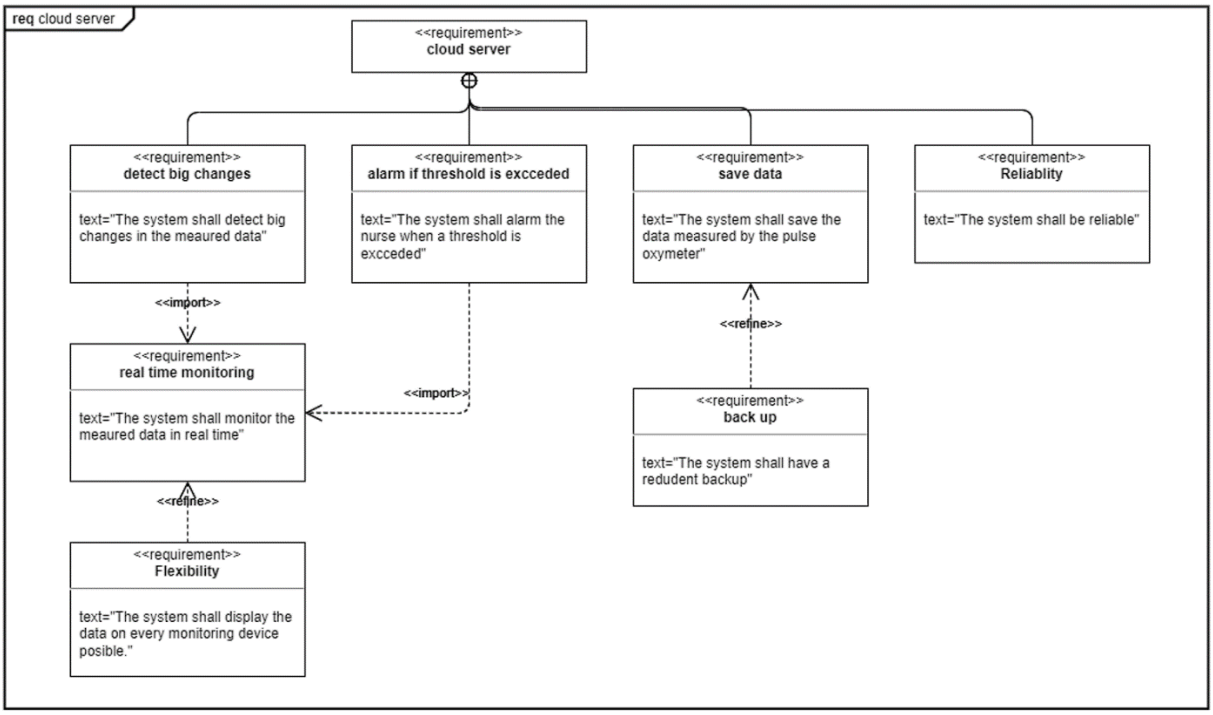
III. Design of the Concept

1. Requirements

One of the main requirements is that the pulse oxymeter is portable, with that comes that it requires a low power consumption and a powerful battery. It also needs a Wi-Fi connection and shall be packed in a small form factor, not bigger than a today´s pulse oxymeter. The current data shall be monitored directly on the pulse oxymeter which needs to be easy to use and reliable. The sensors shall be accurate and have a low power consumption.

For the system to work every room and every park in a hospital shall be equipped with a Wi-Fi access point which is directly connected to the hospital's own server.

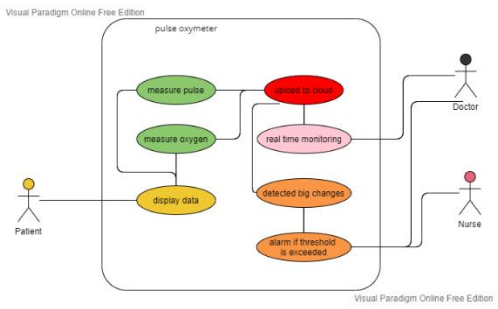
The data which the pulse oxymeter sends to the server, needs to be saved and compared with old data in order to see if the current data exceeds any thresholds or any substantial changes occurred. If this is the case, an alarm shall be sent out to every monitoring device that is responsible for the specific patient. Also, the current and past data needs to be monitored in real time at any monitoring device that the nurse or doctor uses, which includes for example hospital PCs or smartphone. The server needs to be reliable and flexible.



2. Models

A. Use case

The pulse oxymeter measurers pulse and oxygen content inside the patient blood, displays the measured data directly onto the pulse oxymeter´s screen. It also sends the measured data to the cloud server where the doctor and the nurses can monitor the patient´s data in real time. The server detects substantial changes and if a threshold I exceeded. If so, it sends an alarm to the doctor and nurses.

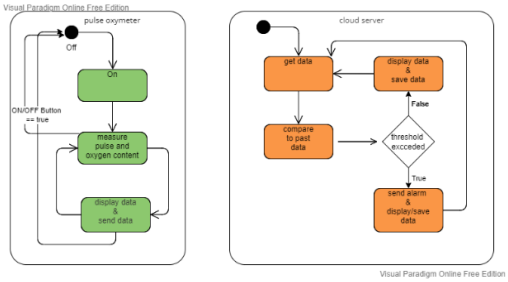


B. State machine

The pulse oxymeter starts with the “Off” state which switches to the “On” state with the press of the ON/OFF button. When the “On” state is activated, it switches directly into the state where it measures the pulse and oxygen content of the patient´s blood. After measuring, it sends the data to the cloud server. When the ON/OFF button is not pressed it keeps on switching between measuring the vital data and sending it to the server. When the ON/OFF button is pressed the pulse oxymeter switches off.

The cloud server is always on, so it does not have an “OFF” state. It starts with getting the data form the pulse oxymeter. Then it compares the current data to the data that is already stored. If it exceeds any thresholds, it sends an alarm to the monitoring devices, displays the values, and saves the current data. If it does not exceed any thresholds, it

displays the values at the monitoring devices and saves the current data to the cloud server. Then it goes back to the beginning state where it gets the data from the pulse oxymeter.



3. Hardware

The pulse oxymeter will be equipped with two pulse and oxygen sensors, to create a redundant system. The processing and the connection to the server is managed by a single core, Wi-Fi capable microcontroller with a low power consumption. The pulse oxymeter should have a battery which at least lasts for one month or longer.

The cloud server should be an enterprise model with a 2.5 gigabit connection to every Wi-Fi access point and wired monitoring device. The storage needs to be big enough that it can be used for ten years without the need for upgrading. This could be for example a five-petabyte hard drive server equipped with twenty terabytes of solid-state drive as cache. The cache is needed because the information gathered by the pulse oxymeter needs to be processed fast. After processing the data can be stored in the slower and more cost-efficient hard drives.

The monitoring devices for the nurses and doctors can be any device that has a connection to the server and a screen. For example, a desktop PC, smartphone, or tablet would be perfect for this task.

4. Critical-based parts of the system

The pulse oxymeter needs to be redundant in terms of sensors. There needs to be at least two sensors of each kind inside the system. The sensors need to control the ones of the same kind, to create an accurate picture of the patient´s vital data. This is especially important because if the system sends a false alert, the time of the nurses will be wasted, and in case the system does not detect bad vital data because of a miss read, the patient can be in life-threatening danger.

If the pulse oxymeter has low battery or when it gets damaged it will send a notice to the nurse with the information which patient is affected and what the last location was.

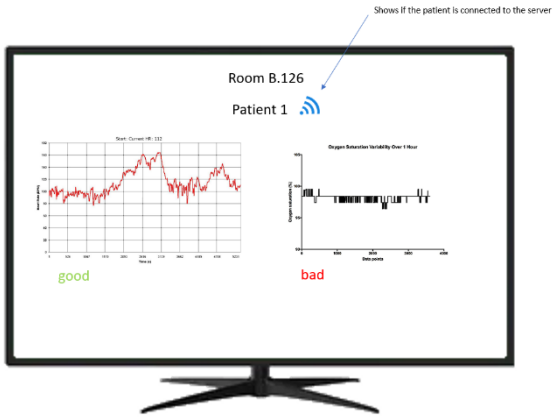
5. User interface

The user interface is divided into two parts. The first part is for the patient and the pulse oxymeter itself and the second part is for the nurses and doctors.

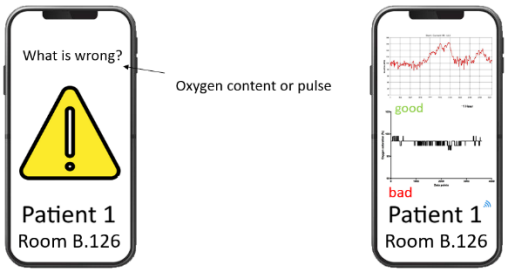
The user interface for the patient is directly on the pulse oxymeter and is fairly easy to use. It shows the current pulse rate bar graph, the average pulse rate and blood oxygen saturation level. It also has a simple ON/OFF button and an indicator if the device is connected to the server.

The user interface for the doctors and nurses can be monitored on any device that is connected to the server. It shows the history of the data and the current data in a real time graph. Pulse and oxygen values have a different graph for their values. Also it is shown, if the values are good or bad, depending on the data of the patient. In the top of the screens it shows which patient the nurse or doctor is looking at and in which

room the patient is staying in real time. Also it shows if the patient is connected to the server.



If the patient is not feeling well and thresholds are exceeded, an alarm will be send to the nurses and doctors where it says which patient is in danger and where he is at the moment. It also shows why the patient is not feeling well. The three options are, pulse bad, oxygen stauration bad and both bad.



IV. Discussion

The Concept covers so far the main initial problem. It sends the vital data to a cloud where every nurse and every doctor can have a look at the past and current data. It also detects big changes in the vital data or exceeded thresholds on it own, and if so it alarms the availble nurses. What it does not cover is the infrastructur around the system. Every room needs an Wi-fi access point and a Ethernet connection to the server. This also includes the maintenance of the server, pulse oxymeter and the access points. It also does not cover what happens when the patient is wearing the device wrong or not at all.

The initial problem, that it should be easy and painless to check the vital data while the patient is at various locations, is solved with this system. The nurses can check whenever and wherever they want the vital data of a selected patient and see how their pulse and oxygen content is. It alarms the nurse automatically if the patient has bad blood pressure or bad oxygen saturation. This takes tremendous amount of work from the nurses and should reduce their stress level by a huge amount.

The lectures and the exercises were extremely helpful for the evolution of this document. Every diagram got feedback and was improved during and after the exercises. This also implies to the user interface concept as well to the overall concept.

V. Conclusion and future work

The project deals and solves a big problem in today´s health care, the stress that the nurses have to deal with every day. It reduces the workload and makes it painless and easy to check the vital data at any given moment and any given location. The alarm system will be helpful to save lives at the right moment when no one could have taken a constant look at the patient. It takes an already useful product like the normal pulse oxymeter and makes it smarter and more up to date.

In the future, the product could be used in different facilities apart from the hospital. For example, in retirements home or for elderly people at their own home. The system could also adopt other monitoring devices with different sensors for different purposes.

Overall, the system is extremely helpful for the medical industry and will continue being developed and improved.