

Elderly Patient Monitoring System

Final Report

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Elderly Patient Monitoring System

Final Report

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Department of Information Technology

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October 2017

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Signature:

Chathurangi W.A.S.

Signature:

Ranathunga R.M.K.V.

Signature:

Date:

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Supervisor's Signature:

Date:.....

Mr.Yashas Mallawarachchi

ABSTRACT

Declining birth rates and longer living people are major reasons to increase ageing population. Since they need more concerns and treatments on health, it is becoming a problematic scenario to look after them regularly. Most of the elder people are getting affected by respiratory disorders and monitoring of their health conditions has become a must. The purpose of a patient monitoring system is to implement an inexpensive system which can monitor multiple necessary facts about the patient's health along with the observation in patient's behaviors, emotions and respiratory sounds. Computer vision and IOT based approaches are proposed to monitor the patient, identify the anomalies in the patient and finally alert the responsible person with an appropriate alerting system. Process of patient monitoring at the domestic level is hardly been implemented via a proper technological solution, hence the system implemented as the result of this research can be effectively used for the monitoring of the patient.

Keywords: Patient Monitoring, Respiratory Disorders, Behaviors, Emotions, Heart Rate, SpO₂, Respiratory Sound Analysis

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LIST OF ABBREVIATIONS

ELPS	Elderly Patient Monitoring System
OS	Operating System
PC	Personal Computer
RAM	Random Access Memory
IT	Information Technology

1 INTRODUCTION

1.1 Background & Literature Survey

Background

One of the major challenge for future is the ageing of the population, and how the health of old people can be preserved. Since the rate of the growth in ageing population is too high, there should be different ways to tackle the problem. Approximately percentage of older people is projected to be more than double the worldwide over the next half century [1]. With the ageing, older people are restricted to bed due to various kinds of diseases and eventually they are becoming bedridden patients. Majority of the elderly patient are getting directly affected by the air pollution in the domestic environment due to limited outdoor activities. Since the respiratory disorder for elderly people are common, they have been untreated to some extent [2]. Elderly patients who are getting treatments under their own roof need a help of a caregiver to get the attention, care and monitoring. Caregiver's role is to help patients by preventing occurrences of breathing problems. At the same time caregiver need to report the identified problems to doctor in order to ensure the correct directions for the treatments are followed [3]. Caregiver has to monitor elderly patient in few different ways to identify the anomalies in an appropriate manner. Heart rate or the pulse is a parameter to check the health of a person regardless of age or gender. Monitoring such thing in patients who are having respiratory issues is as much as important due to frequent changes in heart rate. Very low heart rates, frequent fast heart rates or irregularity in heart rate are mostly due to abnormality of the patient's body and caregiver should inform the doctor in case of such incident. Blood oxygen saturation level (SpO₂) or the percentage of the oxygen amount in the blood is another health parameter which can be advantageous in monitoring the patients with respiratory issues. It is a must to identify the normal SpO₂ level of such patient with the help of a doctor and keep monitoring it to avoid adverse events. Patients with respiratory problems are lacking the ability to take oxygen in to their bodies easily and they are putting extra effort in breathing to gain more oxygen. Therefore tool such as SpO₂ can be used to monitor how effectively the body is taking oxygen [4]. Not only the health parameters, but the tracking the behaviors of those patients has significant impact on the monitoring part. Patients with respiratory issues are having

restlessness in case of a situation where they need more oxygen. Restless patients tend to change their position in the bed to gain more oxygen in to the body. Even the pose can be changed with amount of the oxygen that the patient require at the given time. Clarifying the normal behaviors and the abnormal behaviors of the patient respective to the time is a responsibility of a caregiver. Unknown observations should be identified as an abnormal behavior. It is so much tough to find a disease for which emotions are not playing any significant role in identifying abnormalities of the patient. Emotions have a huge impact on understanding the mental status of the patient in order to give more attention and special care. Emotions can state the stress level, anger, sadness and many other feelings which should be classified as normal and abnormal. Therefore caregiver should have the responsibility of focusing on the emotions of the patients in every possible second. Auscultation or the listening to the internal sounds using a stethoscope is an effective way of diagnosing the respiratory sounds and identify related diseases in the respiratory system [5]. But identification of respiratory sounds and separate them as normal and abnormal is not an easy task to perform. It requires a skill level of a well-trained physician to listen and understand the sound for classification. Elderly patients should not be treated with the wrong drugs irrespective of any disease. It will affects the health level of the elderly patient immensely. Caregiver has a high responsibility on his/her shoulders where sometimes he/she may forget to give the drugs of the patient in time with the right amount of dose. Therefore caregiver should be aware of the drug taking of the patient and should adjust his/her schedule according that.

Developing a system with cost-saving health technologies and bringing it to the market will be helpful to improve prevention, diagnosis, and treatment of disease. Even the promotion process will be easier with the cost-effectiveness of such system. Finally the product can be targeted to different markets which are in need of such a product. People who are having bedridden patients in their home will be directly benefited with the proposed system. Elder's homes and Elder care agencies will be assisted by the suggested patient monitoring system.

Literature Survey

Electronic Health has been with the people for many years and has been defined as use of Information and Communication Technology. With the arrival of many technologies, concept of the patient monitoring system has emerged. Comparison of existing patient monitoring systems is a must prior to propose a solution for an identified problem.

Most of the provided solutions in this domain regardless of respiratory patients have mainly targeted on taking major health parameters of the patient such as heart rate, SpO₂, respiratory rate etc. But the requirement of monitoring emotions, behaviors and the inner sounds of the patients have hardly been addressed. Even a proper solution for patients who are having respiratory issues have not been implemented. Therefore identification of the solutions for the main components separately will optimize the performance of the system with the newest technologies.

Table 1.1 Comparison of Existing Systems

SYSTEM	RESPIRATORY SOUND ANALYSIS	SENSOR CONFIGURATIO N & ANOMALY DETECTION VIA SENSOR INPUTS	ABNORMALITY DETECTION OF BEHAVIOURS	ABNORMALY DETECTION IN EMOTIONS	ALERTING CAREGIVER
PROPOSED SYSTEM	✓	✓	✓	✓	✓
JAWBONE	✗	✗	✓	✗	✗
PREVENTICE SOLUTIONS	✓	✓	✗	✗	✓
GREATCALL	✗	✓	✗	✗	✓
ALARM.COM	✗	✓	✓	✗	✓

Variety of respiratory problems have been taken in to considering in the existing solutions. Most of the systems are having one specific disease regarding respiration and implemented a solution to get rid of it. But it is necessary to be focused on more respiratory problems rather than two or three. Elderly patients are having various kinds of problems in respiration. Therefore considering on more issues related to respiration will be reliable from the perspective of the patient.

1.2 Research Gap

There are several computerized monitoring systems available to date, but which are lack of many mandatory features worth to their extreme cost. None of the solutions provided up to today, do not cover a large area compared to our proposed system. We identify the several issues and try to come up with proper solutions for those. Most of the current solutions mainly consider on monitoring health parameters such as heart rate, spO2 and respiratory rate of the patient. But our proposed system will monitor the heart rate to in order to check the irregularity or arrhythmia. Because only displaying the heart rate of a given time will not provide any benefits for the patient or the caregiver. Derivation of the SpO2 with respective to time is way better than showing only the SpO2 level .Continuous monitoring of the emotions and the behaviors of the patients as important as monitoring the major health parameters. But the proposed solutions are lacking the features of the detecting anomalies in emotions and detecting anomalies of the behaviors. Proposed system will monitor the emotions and the behaviors of the patient in every single second to capture any abnormality or an unknown observation. Additionally a component to analyze the respiratory sounds of the patient is effective in many ways. Even the majority of the systems related to respiratory issues are only focusing on getting the respiratory rate of the patient. But the analysis of the respiratory sounds has been experimented as a separate component and few experiments are having much higher success rate comparative to other experiments. Facility of alerting the caregiver about the drug taking of the patient is one unique feature comparing with the existing systems. None of the solutions have not even mentioned the importance of drug taking for an elderly patient. Overall components of the proposed system will produce an optimized product which can be effectively used by patients with respiratory problems.

1.3 Research Problem

Majority of the elderly bedridden patients are getting treatments under their own roof and require special caring with continuous human monitoring. Problem with the human monitoring is that it requires well trained caregiver with sound knowledge and skills to keep eye on the patient all the time. Finding well qualified caregivers/private nurses is not an easy task while they are limited and already assigned for particular jobs. It requires high concentration level even for well trained and qualified caregivers to monitor the patient in every single second. Therefore an inexpensive system which can monitor multiple necessary facts about the patient's health would be ideal. Luxury of an automated patient monitoring system is that even a family member can become a caregiver to look after the patient since all the monitoring tasks is done through the system. With the industrialization and the globalization, most of the people are affected by respiratory problems and the majority of them are elderly people. Since deploying a system for all kinds of bedridden patient is not practical, system which is developed will be aimed for bedridden patients with respiratory problems.

1.4 Research Objectives

1.4.1 Main Objectives

- To implement an inexpensive, efficient and a reliable system which can effectively monitor elderly patients who are having respiratory problems and detect anomalies in order to minimize adverse events.
- To ease up the duties of the family caregiver where he/she can manage the day to day work while taking care of the patient and can save the amount of cost which is needed for a separate caregiver or a nurse.

1.4.2 Specific Objectives

- Provide continuous monitoring of the primary health parameters to minimize the adverse events which can occur.
- Provide solutions for the mental issues of the patient such as stress, anxiety by monitoring emotions where caregiver can pay more attention with much more special care.
- Reduce cost and time that requires to attend at hospital and clinics in order to monitor the health conditions.
- Help the caregiver to identify the abnormal respiratory sounds prior to meet the doctor where doctor can take necessary steps regarding the disease.
- Provide a mechanism to alert the caregiver in case of an abnormality of the patient detected.
- Provide a mechanism to alert the caregiver about the drug taking of the patient prior to exact time.

2 METHODOLOGY

2.1 Methodology

In this section, the steps of the process that are followed by the project team throughout the research project will be described. The main focus here is explaining the flow of the research project. It will describe which project development process to follow, how requirement gathering will be done, product overview, design deployment techniques and software requirements.

2.1.1 Development Life Cycle

Before starting the development of the system, the initial task is to select the most applicable methodology or the development model. The development process can be easier for developers and quality of the final result can be enhanced when the most appropriate design methodology is selected. Iterative waterfall method is selected to design and develop EPMS. In iterative waterfall method, the development can be happening specifying and implement just part of the system, which can then be reviewed in order to identify further requirements. Developing and improving the system is done step by step incrementally. Once a phase is completed, we can go back to the previous phase and correct the errors in that particular phase. Hence, defects can be detected at early stages.

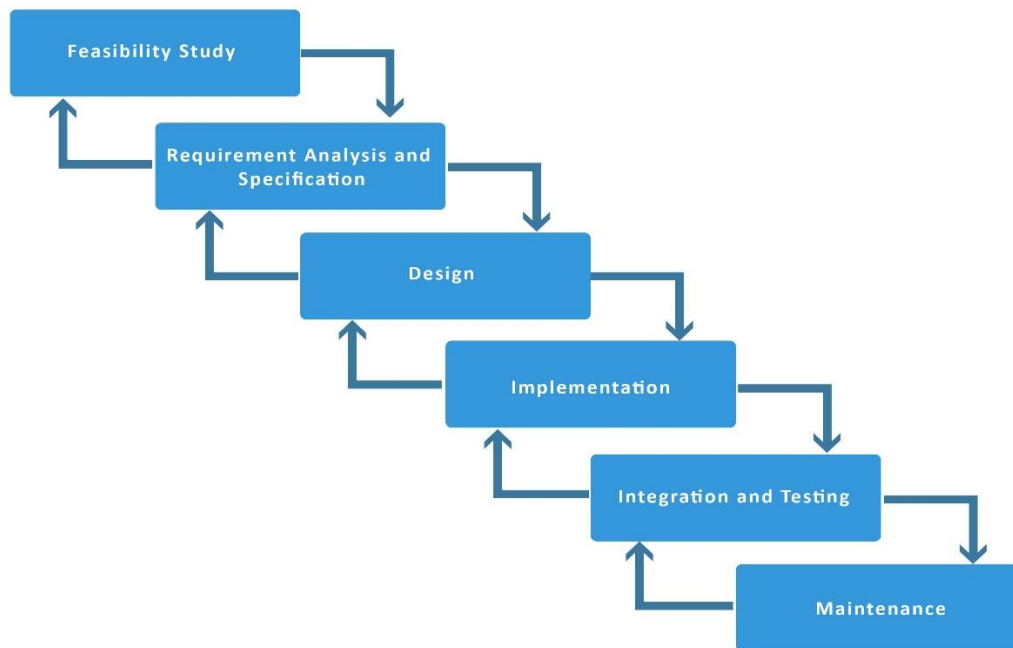


Figure 2.1 Waterfall life cycle model

2.1.1.1 Feasibility study

Before starting to develop the system at a glance, we needed to study whether the research project is viable. Here the team considered some areas to carry out the feasibility study. Some areas like budget, hardware feasibility, software feasibility was considered.

2.1.1.2 Requirement Analysis and Specification

In a research project, the requirement gathering and analysis part is the most important part. Especially studying about the research area is more important. Before starting to implement the system, we need to clarify whether the proposed system will give the correct solution. Since our team gathered information from a number of resources, we were able to get a clear picture of the problem and the current situation of the present video search engines on internet.

Finally, the system requirement specification will be created and it will consist of almost all the functional and non-functional requirements. There is no way you can have a complete picture of

what is going to be the output of the project by this time because of the nature of researches these functions can be slightly changed in future.

2.1.1.3 Design

2.1.1.3.1 Designing the System

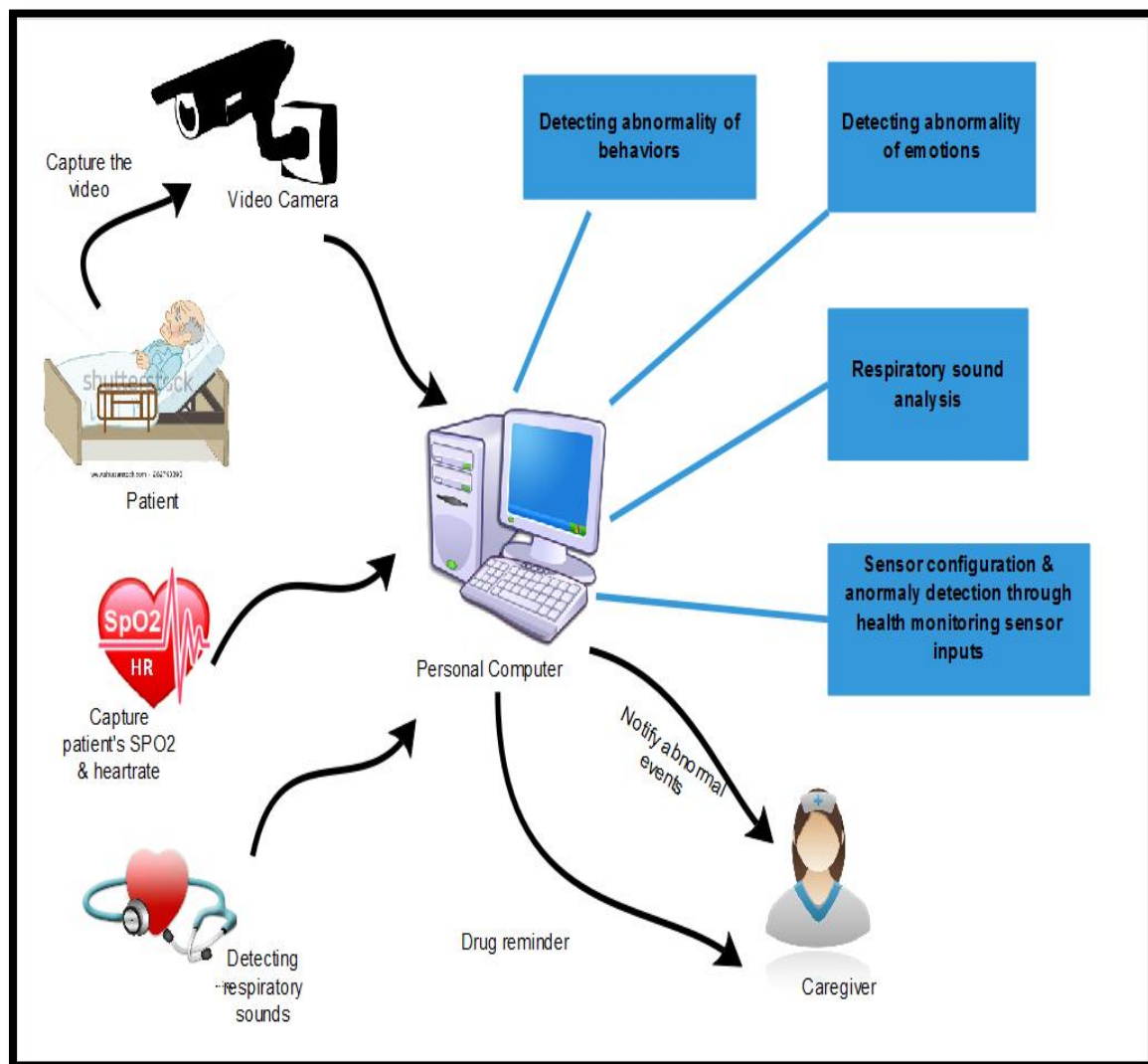


Figure 2.2 High level Architecture of the system

2.1.2 Hardware Interfaces

This section shows the necessary hardware interfaces which will be used by the developer in order to produce EPMS.

Arduino Uno 3

Since it is not possible to send serial inputs straight away in to the PC, Arduino Board was used as controller.



Figure 2.3 Arduino Board

Pulse SpO2 Sensor

Pulse SpO2 Sensor is being used to detect heart rate and the oxygen percentage of the blood.

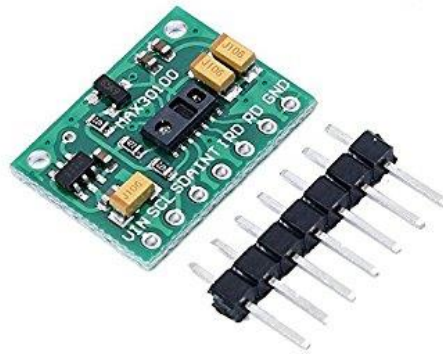


Figure 2.4 Pulse SpO2 Sensor

Web Camera

Web Camera will be in use to detect the emotions and the behaviors of the patient.



Figure 2.5 Web Camera

Bluetooth Module

Bluetooth Module was used to transfer the data to the PC which will be captured by the Arduino Board.

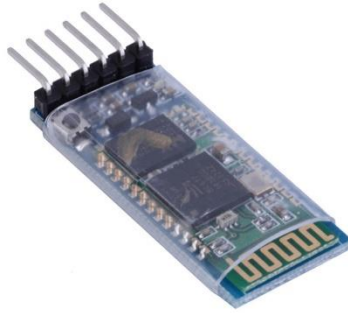


Figure 2.6 Bluetooth Module

Stethoscope

Stethoscope is being utilized to capture the respiratory sounds.



Figure 2.7 Stethoscope

Microphone

Microphone was used to record the captured signal in order to send to the PC.



Figure 2.8 Microphone

2.1.3 Software Interfaces

For the implementation of the EPMS, following software interfaces were used.

- OpenCV library – For behavior recognition and emotion recognition purposes.
- Dlib library – For face detection.
- MATLAB – For signal processing.
- Python 2.7 – For the implementation of the emotion recognition component.
- Java – For the implementation of behavior recognition component and anomaly detection via sensor inputs component.
- Aurdino IDE – To get the sensor inputs.

2.1.4 Communication Interfaces

Once the necessary values from the sensors are obtained by the main board they had to be transmitted to the PC for the necessary processing to take place. Therefore Bluetooth was one of the major communication interface.

2.1.5 System Interfaces

NEXMO API is being used to alert the caregiver with a text message.

2.1.6 Memory Constraints

All the processing had been done in the PC and it requires minimum of 2GB of RAM and free space of at least 10 GB.

2.1.7 Operations

This section describes what operations should be or can be performed by user in order to use the services of the system.

- Mount the camera and do the calibration properly.
- Set up the sensors on the body of the patient.
- Plug the stethoscope to the PC using the analog port.
- Run the component of the system separately.
- Enter necessary details of the patient in the system.

2.1.8 User Characteristics

The software is intended for use by the caregiver or the parties who are having elderly patients with respiratory issues in their domestic arena. Elder's homes and Elder care agencies can be effectively assisted by this system, if there are patients who are suffering from respiratory problems and responsible persons of those places will eventually become users of the system.

The other category of user is the Administrator who is responsible for configuring the system.

2.1.9 Constraints

- PC is compulsory for the system.
- Necessary sensors and the stethoscope have to be equipped to the patient.
- High resolution web camera should be set on top of patient's bed covering the bed area while more focusing on the face.

2.1.10 Assumptions and Dependencies

2.1.10.1 Assumptions

- Patient is equipped with the necessary sensors and the stethoscope.
- Patient is living under normal environmental conditions.

- Most users have mobile phones.
- Users who interact with the system have at least a slight knowledge about handling a PC and mobile phones.

2.1.10.2 Dependencies

- The system is immensely depend on the hardware, because data transmitted from the sensors and the stethoscope are essential for the analysis process.

2.1.11 Software System Attributes

EPMS should not fail at any time during. Testing of the system should be done extensively in order to make sure the system fits perfectly into the environment.

2.1.11.1 Reliability

Reliability is an Ability of a computer program to perform its intended functions and operations in a system's environment, without experiencing failure (system crash). Reliability is measured as the probability that a system will not fail and that it will perform its intended function for a specified time interval [6]. Thus system should be reliable enough because it has to produce accurate suggestions. EPMS will be able to work with sensors and other hardware parts without leading the whole system crash.

2.1.11.2 Availability

The system could be accessed whenever in need and availability is the ratio of time a system or component is functional to the total time it is required or expected to function [7]. Ratio should be a higher value to achieve high availability of the system. EPMS will be implemented with high availability and necessary testing will be done to check whether high availability has maintained or not.

2.1.11.3 Security

Security is the protection of the data against unauthorized access [8]. EPMS will be and exposing health values of the patient and those are confidential information, the security of those data has to be considered. Those data have only to be visible for the intended parties. Ethical issues which might arise from this kind of system have to be considered. To achieve those goals password usage is more important.

2.1.11.4 Maintainability

Maintainability is defined as the probability of performing a successful repair action within a given time. In other words, maintainability measures the ease and speed with which a system can be restored to operational status after a failure occurs [9]. The system should be modularized in order to achieve good maintainability. The sensors should be able to replace individually without replacing the whole system. The application design also needs to facilitate maintainability.

2.2 Testing

We have planned to perform testing in five testing phases. They are Unit testing, Module testing, Integration testing, System testing and User acceptance testing. User acceptance testing will be done using end users of the system.

2.2.1 Unit Testing

Unit testing is a method used to test individual units of source code to determine whether they are relevant to use. A unit is the smallest testable part of an application. Unit testing is done by each member of the group individually. The units of a member are tested by other members

those who are not the developer of that particular unit. In this manner, all the units of the project are tested after completing once development.

2.2.2 Module Testing

Module testing is concerned with the testing of the smallest piece of software for which a separate specification exists.

2.2.3 Integration Testing

Integration testing is an important phase in testing. It is the time of software testing where individual software modules are combined together and tested as a group. It occurs after module testing and before validation testing. Modules that have been unit tested are the inputs for integration testing. The output is the integrated system which is ready for the system testing. Integration testing is also done by members of the group individually. The contribution of all four members is very important in integration testing.

2.2.4 System Testing

System testing is performed on a complete, integrated system to evaluate whether the system complies with its specified requirements. System testing falls within the scope of black box testing and as such should require no knowledge of the inner design of the code or logic. As a group, the integrated system is tested and modified if there are any bugs.

2.2.5 User Acceptance Testing

Testing Bugs less system will be developed after performing the system testing. Then a target group will do the user acceptance testing.

3 MEMBERS INDIVIDUAL CONTRIBUTION

- **Abeyrathne H.V.L.K.**

IT14073656

Respiratory Sound Analysis process was implemented by this member. R2016a version of MATLAB is being used to carry out the implementation. Module was built as a desktop application and it has an average accuracy of 88.7 %.

- **Sudasinghe S.P.L.P.**

IT14054532

Heart rate and SpO₂ (percentage of the oxygen amount in the blood) are two main parameters to check the health level of the patients who are suffering from respiratory issues important due to frequent changes in heart rate and the SpO₂ level.

Setting up suitable sensors according to the physical parameter such as heart rate and spo₂ is required. Captured incoming inputs should be sent to the computer via micro controller. Analysis of the heart rate is necessary to monitor the arrhythmia and further analysis on derivation of the SpO₂ is required. Finally a construction of a classification model will be done to classify the data in order to interpret.

If any arrhythmia of the heart beat or an abnormal deviation of the oxygen percentage in blood is (SpO₂) detected by the system it will alert the caregiver to be equipped for the event.

- **Chathurangi W.A.S.**

IT14069482

Patients with respiratory issues are having restlessness in case of a situation where they need more oxygen. Restless patients tend to change their position in the bed to gain more oxygen in to the body. Therefore monitoring the behaviors of the patient is much needed. The main objective of this component is to clarify the normal behaviors and the abnormal behaviors identify the abnormal behaviors of the patient.

In here Data of both the normal and abnormal behaviors of patients should be collected using the camera. And then construct a classification model for detecting the behavioral abnormalities. In here “Optical Flow Analysis method” will be used with Image processing and machine learning to fulfill the task.

If some abnormal behavior get detected by the system it will give some alert or some kind of reminder to the caregiver in order to be prepared for adverse situation

- **Ranathunga R.M.K.V.**

IT14044632

The identification of the emotions of a bedridden patient is a must whereas he/she may not have the ability to convey their feelings in more appropriate manner while absence of the caregiver. Therefore figuring out the abnormalities in the emotions of the patient let the system to alert the caregiver when in need.

In here data which is needed to detect emotion is collected via a video camera. And the captured data are send to a pc for the analyzing and for filtration processes. Since it is mainly targeting on bedridden patients, sometimes detecting face will be somewhat difficult due to movements in patient. In a situation like this the particular video frames should be reoriented. Then Filtered data will be classified using neural networks to detect normal and abnormal emotions

If an abnormality is detected the caregiver is notified by a message where necessary reactions can be performed.

4 CONCLUSION

Patient Monitoring has not been addressed with a complete solution with novel technology similar to this research study conducted. In this research human monitoring has been eliminated while introducing an automated system for patient monitoring. With this system it is expected to detect anomalies in the patient health parameters and motions. This system can reach its targeted audience easily since the proposed solution is inexpensive and efficient. System has the capability to alert the responsible person in order to minimize adverse events. Cost and time that requires to attend at hospitals and clinics can be reduced through this solution.

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