كلية الحاسبات والمعلومات

جامعة اسيوط

Vitalism

Towards Reshaping Healthcare

Vitalism Solution
(Contactless Estimation of Vital Signs Using Real-Time Video)

Prepared by

Mahmoud Sayed Youssef
Mina Nashat Fayez
Nada Essam Ali
Nourhan Ahmed Abdel-Fattah
MennaAllah Mahmoud Abdel-Raouf
Moataz Kayad Hamdy

Academic Supervisor

Dr. Ali Hussein Ahmed

Faculty of Computers and Information (Bioinformatics),
Assuit University.
2022-2023

Acknowledgement

First and foremost, I would like to express my deepest gratitude to my supervisor, Dr. Ali Hussein, for their invaluable guidance, support, and expertise throughout the entire project. Their unwavering dedication and commitment to the success of this project has been truly inspiring.

I am incredibly grateful for the opportunity to work on such a groundbreaking and innovative project, one that has the potential to revolutionize healthcare and make it more accessible to people everywhere. The Vitalism System, an AI-powered, video-based solution for remote measurement of vital signs in near real-time, is a true game-changer in the field of medical technology.

I would also like to acknowledge the contributions of other professors and colleagues from the Faculty of Computers and Information, Assiut University, who have provided valuable insights and feedback throughout the development process. Their expertise and support have been invaluable in bringing this project to fruition.

I would be remiss if I did not recognize the hard work and dedication of my friends and team members Mina, Nada, Moataz, Nourhan and MennaAllah, who have worked tirelessly alongside me on this project. Their contributions have been immeasurable and have played a crucial role in the success of the Vitalism System. I am honored to have had the opportunity to work with such a talented and dedicated team.

As the team leader of this project, I am proud of the effort and dedication we have all put into this project and I am honored to be part of the team that brought Vitalism System to life.

Finally, I would like to express my gratitude to my family and friends for their unwavering support throughout my academic journey. Without their love and encouragement, this project would not have been possible.

I am Mahmoud Sayed Youssef, and I am honored to have had the opportunity to lead this project and bring this revolutionary solution to the world of healthcare.

Mahmoud Sayed Youssef

Table of Contents

Abstract

Vitalism (Contactless Estimation of Vital Signs Using Real-Time Video)

Vitalism is a cutting-edge project that utilizes video data analysis to extract vital signs from humans. The project utilizes low-cost, high-quality portable cameras and employs advanced image and signal processing techniques to extract features from videos that are invisible to the human eye. The extracted features include vital signs such as heart rate (HR), heart rate variability (HRV), oxygen saturation (SpO2), respiratory rate (RR), and blood pressure.

The development of low-cost but high-quality portable cameras has significantly contributed to the growth of video data analysis in various fields such as surveillance, security, and medicine. The ability to extract vital signs from videos opens up new possibilities in the field of healthcare, allowing for non-invasive monitoring of patients, and enabling healthcare professionals to make more accurate and timely diagnoses and treatment plans.

The key techniques used in the Vitalism project is (rPPG) and wavelet filtering of monochrome video data. The pumping of blood to various parts of the body from the heart in rhythmic fashion causes subtle changes in the skin tone of humans. These changes are periodic in nature, corresponding to the heartbeat. By using wavelet filtering, the Vitalism project is able to extract these subtle changes and use them to accurately measure vital signs such as heart rate and heart rate variability.

The Vitalism project also utilizes advanced algorithms to extract other vital signs such as oxygen saturation, respiratory rate, and blood pressure. These vital signs are important indicators of a person's overall health and well-being and are often used by healthcare professionals to monitor patients. By using video data analysis to extract these vital signs, the Vitalism project provides users with a non-invasive and cost-effective way to monitor himself.

The Vitalism project is a significant advancement in the field of healthcare and has the potential to revolutionize the way vital signs are measured and monitored. The use of video data analysis to extract vital signs allows for non-invasive and cost-effective monitoring of patients, enabling healthcare professionals to make more accurate and timely diagnoses and treatment plans. The Vitalism project is an exciting new development in the field of healthcare and has the potential to improve the lives of millions of people around the world.

Chapter 1

(Software Proposal)

1.1 Introduction

Vitalism is a belief that living organisms are fundamentally different from non-living entities because they contain some non-physical element or are governed by different principles than are inanimate things. The name of the project, Vitalism, is derived from this belief and is closely related to the concept of vital signs. Vital signs, such as Heart Rate (HR), Heart Rate Variability (HRV) and Oxygen Saturation (SpO2), are important indicators of a person's physiological and emotional wellbeing. The measurement of these vital signs is the most important step in the medical field to know the patient's current condition and is a basic task in biomedical metrology to ensure the safety of the individual.

Conventional devices for measuring vital signs mostly take contact-based measurement approaches. The most common methods used for contact-based measurement are Electrocardiogram (ECG), sphygmomanometer, and pulse oximeter. However, contact measurement has several disadvantages, such as the risk of skin irritation and germ contamination, and it significantly limits the freedom of body movement of the patients, which could lead to severe discomforts.

Therefore, the development of remote-based measurement approaches able to measure vital signs is considered a major advance in the field of health. Measuring vital signs from home or from your current location without resorting to going to the hospital is very important for some people who cannot go to the hospital and whose conditions are critical and do not have enough time to go to the hospital. The invention of a method like this will greatly contribute to solving some of the problems facing these people and will greatly contribute to medical progress to facilitate the measurement of these vital signs accurately and quickly.

In recent years, remote methods for measuring vital signs have been developed based on the principle of photoplethysmography (PPG). PPG is a technique used to measure the volumetric changes in the blood affected by the heartbeat. PPG is usually obtained using pulse oximetry to measure vital signs. A normal pulse oximeter monitors the circulation of blood in the dermis layer under the skin. With each cardiac cycle, the heart pumps blood. However, these methods have some drawbacks, which is where the rPPG technology comes in.

The rPPG technology measures vital signs with a phone's camera by selecting the region of interest (ROI) on the skin and inferring the rPPG signal from the color changes. This technology eliminates the need for contact with the body and skin, reducing the risk of skin irritation and germ contamination. Moreover, it eliminates the limitation on freedom of body movement and provides a non-invasive, easy and fast way to measure vital signs. In this project, we will explain in detail how the rPPG technology works and its potential applications in the field of health.

1.2 Problem Statement

The Vitalism software aims to solve the following problems:

1. Difficulty and irregularity of measuring vital signs for early diagnosis and prevention of diseases, such as heart disease and hypertension.
2. The inability of conventional methods, such as the ECG device, which require physical contact with the patient, to be used for some populations, such as those with burns or disabilities.
3. Risk of infection associated with traditional methods of measuring vital signs.
4. The need for remote monitoring of patients' vital signs during the COVID-19 pandemic.
5. Sensitivity of rPPG methods to motion and illumination artifacts.
6. Lack of a fast, effective, inexpensive, and convenient method suitable for all age groups, especially the elderly and people with disabilities.
7. The use of traditional sensors for vital statistics monitoring in NICU, which might cause damage to the already fragile skin of these infants [1].
8. Lack of an electronic medical record for patients to be used by specialists when needed.
9. Lack of sufficient awareness of the importance of measuring vital signs.
10. Difficulties in measuring vital signs of people in the wild, such as those undertaking mountain climbing trips.
11. The need for a way to extract vital signs from videos, such as heart rate, heart rate variability, oxygen saturation, respiratory rate, and blood pressure.
12. Increasing the costs of traditional medical devices and increasing their size.
13. The inability of pregnant women to go to the hospital to measure their vital signs because this is stressful for them and the inability to follow up on the health status of the elderly.
14. People suffering from hospital phobia and fear of medical devices.

The Vitalism software aims to solve these problems by utilizing video data and advanced image and signal processing techniques to extract vital signs remotely and at low cost, making it more accessible for people who have difficulty going to hospitals or who have third-degree burns, and reducing the risk of infection in the medical setting.

1.3 Objectives

The overall objective of the vitalism project is to facilitate the process of measuring vital signs on a periodic basis by providing a fast, effective, inexpensive, and convenient method suitable for all age groups. The Vitalism project is a healthcare initiative that aims to provide a fast, effective, inexpensive, and convenient method for measuring vital signs on a periodic basis. The ultimate goal of this project is to spread awareness of the importance of regularly monitoring one's health state in order to facilitate early diagnosis and prevention of diseases such as heart disease and hypertension.

One of the main issues that the vitalism project aims to address is the inability of conventional methods, such as the ECG device, to be used for certain populations, such as those with burns or disabilities. These traditional methods require physical contact with the patient, which can be uncomfortable, painful, or even impossible for certain groups of people. Additionally, there is a risk of infection associated with traditional methods of measuring vital signs.

Another important issue that the vitalism project aims to address is the need for remote monitoring of patients' vital signs during the COVID-19 pandemic. The pandemic has highlighted the need for remote monitoring to reduce the risk of infection and allow for the continued monitoring of patients in isolation.

The vitalism project also aims to address the sensitivity of rPPG methods to motion and illumination artifacts. rPPG, or remote photoplethysmography, is a method of measuring vital signs using a camera and specialized algorithms. The sensitivity of this method to motion and illumination artifacts can introduce errors into the measurement, and the project aims to find rPPG algorithms that work with minimal error using deep learning methods.

The project also aims to address the lack of a fast, effective, inexpensive, and convenient method suitable for all age groups, particularly the elderly and people with disabilities. Traditional sensors used for vital statistics monitoring in NICU might cause damage to the already fragile skin of infants. The project aims to develop a solution that is safe for all age groups.

Furthermore, there is a lack of an electronic medical record for patients to be used by specialists when needed. Additionally, there is a lack of sufficient awareness of the importance of measuring vital signs among the general public. The project aims to educate the public on the importance of measuring vital signs and provide an electronic medical record for patients.

Another issue that the vitalism project aims to address is the difficulties in measuring vital signs of people in the wild, such as those undertaking mountain climbing trips. The project aims to find a way to extract vital signs from videos, such as heart rate, heart rate variability, oxygen saturation, respiratory rate, and blood pressure.

Increasing costs of traditional medical devices and their size is also an issue that the vitalism project aims to address. The project aims to make it more common to measure vital signs using the camera of a smartphone instead of wearable devices by integrating rPPG into an application.

Furthermore, the project aims to address the inability of pregnant women and the elderly to go to the hospital to measure their vital signs. People suffering from hospital phobia and fear of medical devices will also be addressed by the project.

To address these issues, the vitalism project focuses on utilizing rPPG technology to examine existing studies and develop new solutions. The aim is to find rPPG algorithms that work with minimal error using deep learning methods, and to contribute to the field of healthcare. Additionally, the project aims to make it more common to measure vital signs using the camera of a smartphone instead of wearable devices by integrating rPPG into our application.

1.4 System Overview

Vitalism is a remote-based measurement system that utilizes RGB camera technology to estimate vital signs such as Heart Rate (HR), Heart Rate Variability (HRV) and Oxygen Saturation (SpO2). The system is designed to overcome the limitations of traditional contact-based measurement methods such as Electrocardiogram (ECG), sphygmomanometer, and pulse oximeter.

The system architecture of Vitalism is divided into two main components: a mobile and desktop applications and a cloud-based server. The mobile application, which is available for Android devices, is used to capture live video of the user's face and estimate the vital signs using a technique called remote photoplethysmography (rPPG). The user can select a region of interest on the skin, such as the forehead, and the application will infer the rPPG signal from the color changes in the skin caused by changes in blood flow.

The cloud-based server is responsible for storing and processing the data collected by the mobile application. It uses machine learning algorithms to analyze the data and estimate the vital signs. The server also provides a user-friendly web interface that allows users to view and download their vital sign data. The web interface also allows users to create an electronic medical record (EMR) for themselves.

The interactions between the mobile application and the cloud-based server are secured through a secure socket layer (SSL) encryption. The user data is also encrypted at rest and in transit to ensure privacy and security.

The main features of the Vitalism system include the ability to estimate vital signs remotely using a standard RGB camera, the ability to view and download data through a user-friendly web interface, and the ability to securely store and process data in the cloud. The system also allows the user to create an electronic medical record (EMR) for themselves.

The system's inputs are the video captured by the mobile application, and the outputs are the estimated vital signs. The system's performance characteristics include high accuracy and low latency, making it an ideal solution for both personal and professional use. The system also solves the problem of light and luminance by measuring the distance between the user and the camera.

Overall, Vitalism is a valuable tool for monitoring vital signs remotely, providing a convenient and non-invasive alternative to traditional contact-based measurement methods. It allows users to create an electronic medical record (EMR) for themselves, and also addresses the problem of light and luminance. With its high accuracy and low latency, it can be used for both personal and professional use.

1.5 Methodology and Technical Approach

The Vitalism project aims to facilitate the process of measuring vital signs on a periodic basis by providing a fast, effective, inexpensive, and convenient method suitable for all age groups. To achieve this objective, the project will utilize the remote Photoplethysmography (rPPG) technology and employ deep learning algorithms. In this section, the methodology and technical approach of the Vitalism project will be discussed in detail.

Step 1: Literature Review:
The first step of the project will be a comprehensive review of existing literature on rPPG and its applications in the field of healthcare. The focus will be on the use of rPPG technology for measuring vital signs such as heart rate, heart rate variability, oxygen saturation, respiratory rate, and blood pressure. This review will include studies on the limitations and challenges of rPPG technology, and the current state of the art in this field.
The outcome of this step will inform the selection of the most appropriate deep learning algorithms for the development of the Vitalism project.

Step 2: Data Collection:
The next step will be the collection of a large and diverse dataset to train the deep learning algorithms. This dataset will consist of videos of individuals of different ages, ethnicities, and health conditions, along with corresponding ground truth vital sign data. The data will be collected from various sources, including existing public databases, and through a data collection campaign that will be specifically designed for this project. The data collection campaign will involve the recruitment of participants from various populations, including the elderly, people with disabilities, pregnant women, and individuals in remote areas, among others.

Step 3: Pre-processing of Data:
Once the data has been collected, it will be pre-processed to ensure that it is suitable for use in the training of deep learning algorithms. This pre-processing will include data cleaning, data normalization, and data augmentation. The data cleaning process will involve removing any data that is missing, incorrect, or irrelevant. Data normalization will ensure that all data values are on the same scale, making it easier for the deep learning algorithms to learn from the data. Data augmentation will involve creating additional data samples by transforming

the existing data in various ways, such as rotation, scaling, and flipping. This will help to prevent overfitting and improve the robustness of the algorithms.

Step 4: Algorithm Development for extract vital signs:
Today, photoplethysmography (PPG) is one of the most used methods to measure the pulse. PPG signal is produced by the periodic beat of the heart and is used to measure parameters such as pulse, oxygen saturation, and blood pressure.

PPG is an optical technique based on observing light intensity changes on data [2,3]. Contact PPG sensors in wearable devices and medical equipment estimate the heart rate by taking light reflected from the skin using a light-emitting diode (LED). The components of reflected light consist of the amount of light absorbed by the skin and the pulse signals that change in time, which contributes to the absorption of light by the capillaries [4].

Since blood is red, it absorbs green light. When the heart beats, the amount of blood under the skin increases, leading to the absorption of more green light. The amount of light that reflects back from the skin provides information about the pulse, enabling us to perform contactless PPG studies. Non-contact measurement is possible with high sensitivity cameras by using ambient light as a source. The rPPG signal can be extracted from the light spectrum of the image acquired by a video camera.

Pulse estimation is made with meaningful data remaining after the obtained signals are cleared from noise. With proper lighting, changes in blood flow and blood volume can be observed with light reflected from the facial skin. However, recent research has shown that ambient light can be sufficient to obtain a PPG signal [5].

Although many rPPG algorithms have been presented on this subject, which has been of interest to many researchers for many years, a consistent application has not yet been accepted. This is because most developers/researchers tend to create their own test cases using a variety of cameras and have not specified the algorithms usually used for compression, making it difficult to reproduce [6].

Deep learning-based video processing plays an important role in these studies. Unlike existing images, videos have both spatial information and temporal dynamics. Therefore, we need to take advantage of different models to solve any video related problem using machine learning. Also, when testing methods, we need to use different datasets of both genders, different ages, a wide variety of skin tones, and some with thick facial hair and/or glasses.

Step 5: Testing and Validation:
The Vitalism application will be tested and validated through a series of user studies and clinical trials. The objective is to measure the accuracy and reliability of the vital sign measurements obtained through the application and to compare the results with traditional methods.

The first step will be small-scale user studies with a select group of individuals to gather data on the ease of use, accuracy, and overall user experience of the application. This will help identify any potential issues or areas for improvement in design and functionality.

Once the user studies are completed, a larger-scale clinical trial will be conducted in collaboration with healthcare institutions and practitioners. This trial will involve a larger group of participants and will measure their vital signs over several weeks or months. The results will be analyzed to determine the overall accuracy and reliability of the vital sign measurements obtained through the application, and to compare the results with traditional methods such as ECG devices.

The Vitalism application will also be tested for its ability to accurately measure vital signs in real-world scenarios, such as remote or low-light environments and in individuals with mobility or other health issues. This will further validate its ability to provide accurate and reliable vital sign measurements in a range of circumstances and populations.

1.5.1 PPG Based Methodology

PPG is a methodology that makes use of low-intensity infrared (IR) light. When light passes through biological tissues, it is absorbed by bones, skin pigments, and both venous and arterial blood. The changes in blood flow as shown in Figure 1 can be detected by PPG sensors as changes in the intensity of light because light is absorbed more strongly by blood than surrounding tissues.

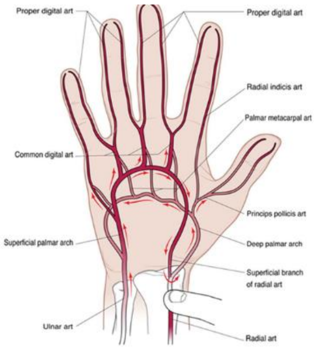


Figure 1: Blood flow in the hand

The voltage signal from PPG is proportional to the amount of blood flowing through the blood vessels, and even small changes in blood volume can be detected. However, it cannot be used to quantify the amount of blood. A PPG signal has several components, including volumetric changes in arterial blood associated with cardiac activity, variations in venous blood volume that modulates the PPG signal, a DC component showing the tissue's optical property, and subtle energy changes in the body.

There are some major factors affecting the recordings from PPG, such as the site of measurement and the contact force between the site and the sensor. These factors can have a significant impact on the accuracy of the recordings, so it's important to be aware of them when using PPG for medical purposes [7].

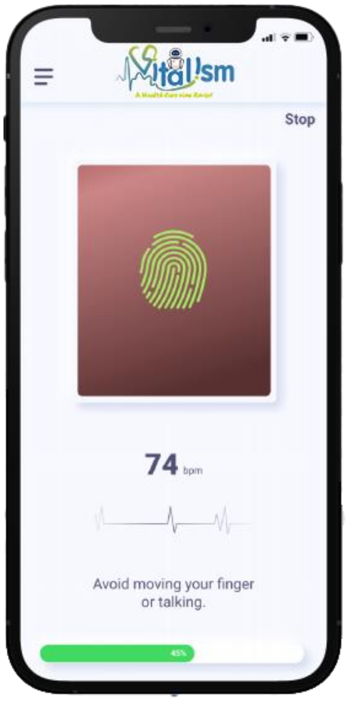
Oxygen Saturation Calculation (SpO2)

Oxygen saturation, also known as SpO2, measures the amount of oxygen in the red blood cells. A healthy adult's normal oxygen saturation is between 95% and 100% [8]. If a person has a chronic health condition that affects the lungs, blood, or circulation, tracking their oxygen saturation regularly is important. A level below 95% is not normal and a level below 90% requires emergency care.

PPG has been used in remote imaging of the distribution of arterial oxygen saturation (SpO2) in a tissue, which can be valuable in medical diagnostic studies and telemedicine for remote monitoring of patients' health. SpO2 calculation uses both red and infrared light. The absorbance of red light and infrared light by the pulsatile blood changes with the degree of oxygenation. The BVP signal obtained from the reflected light is divided into two components: the alternating current component resulting from arterial blood and the direct current component resulting from underlying tissues, venous blood, and constant part of arterial blood flow. The DC component is subtracted, and the AC component is amplified of the R and IR lights and used to calculate the SpO2 level in the blood using equation as given:

$$\mathrm{SpO2} = A - B \times \frac{\mathrm{ACR}/\mathrm{DCR}}{\mathrm{ACIR}/\mathrm{DCIR}}$$

Where A and B are parameters that can be calibrated by using a standard pulse oximeter. This vital sign is measured by Finger (PPG) mode for challenging conditions, Vitalism has implemented a backup contact-based solution. The contact-based solution extracts a PPG signal when users place a finger on the rear camera of a smartphone.as shown in Figure2. Vitalism automatically detects when conditions are not ideal for contactless rPPG extraction and suggests using the contact-based extraction.as shown in Figure 3.



Avoid moving your finger or talking.

Figure 2: Measure Spo2 using Finger (PPG).

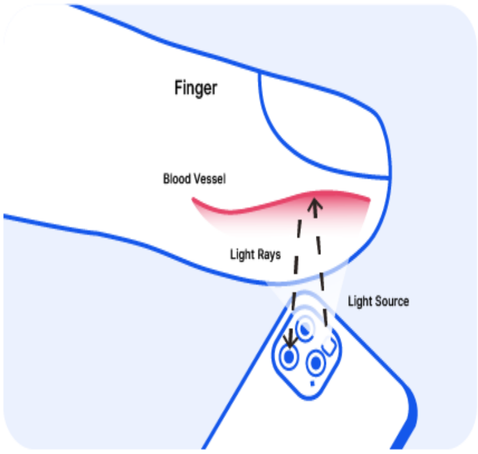


Figure 3: Contact-based PPG.

1.5.2 Face Detection and Skin Detection Using Viola-Jones Algorithm

Face detection and skin detection are two of the most important components in the development of the Vitalism system. Vitalism is a health monitoring system that relies on the measurement of the remote photoplethysmography (rPPG) signal to provide real-time health data to users. The rPPG signal is obtained from the skin and it provides information about the heart rate and blood flow. Therefore, accurate face and skin detection is critical for the accurate measurement of the rPPG signal.

In the Vitalism system, the Viola-Jones [9] face detection technique is used to automatically detect the face of the subject. This step provides bounding box coordinates defining the subject's face. This is important because the face is the key component that provides the rPPG signal. The Viola-Jones algorithm is a well-known and widely used face detection technique that is effective in detecting faces in images and videos.

The Viola-Jones algorithm starts by creating simple Haar features by hand. Haar features are simple patterns that are used to detect faces in images and videos. These patterns are created by hand, and they are used to detect faces in images and videos. Once the Haar features are created, the image is converted into an integral image. The integral image is a calculated version of the source image, and each point in the integral image is the sum of pixels above and to the left of the corresponding pixel in the source image as shown in Figure 4.

The integral image is used to take advantage of subtractions to achieve the same result as making additions for each pixel value for all features. This process is faster and more efficient than making additions for each pixel value for all features. Once the integral image is created, the delta values for each feature on an image region are calculated and a machine learning meta-algorithm, Adaboost, is trained for each feature.

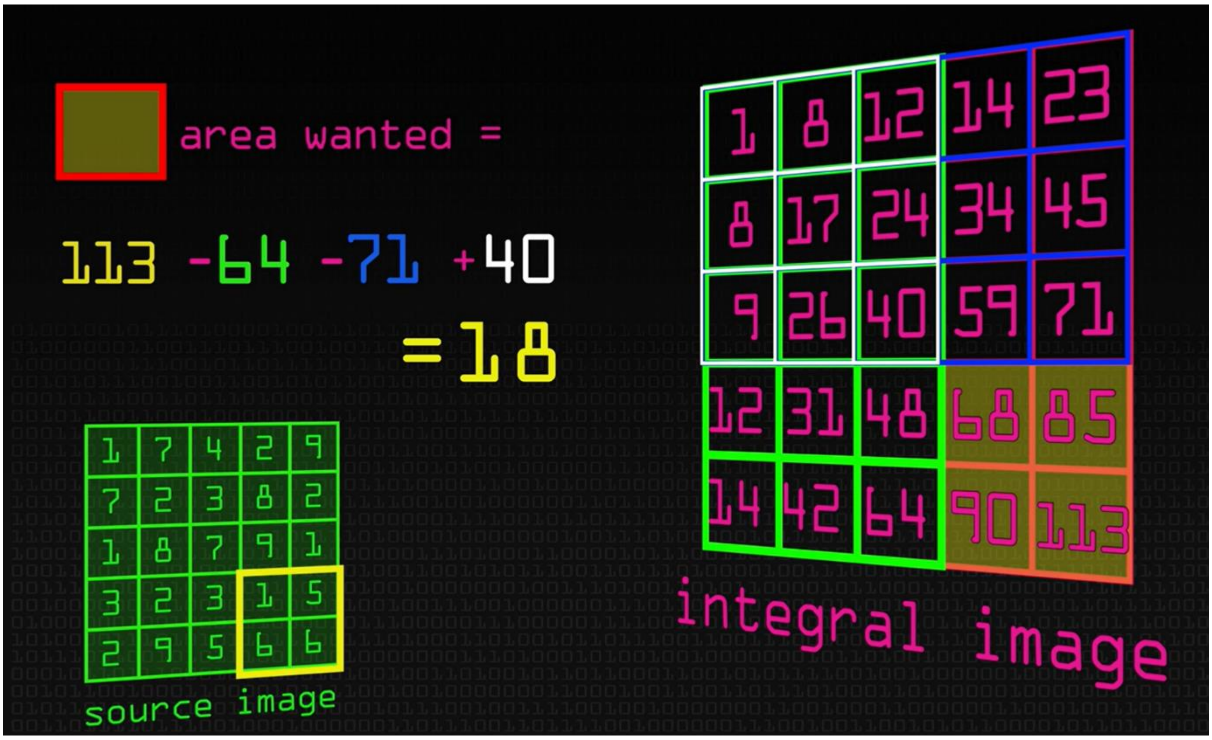


Figure 4: Using the integral image for the area wanted calculation. [10]

The Adaboost algorithm is a machine learning meta-algorithm that is used to create a classifier for each Haar feature. These classifiers are considered "weak" classifiers because they are not very effective on their own. However, when used together in the attentional cascade, they become a powerful classifier. The weak classifiers are sorted by error rate and the best ones are selected based on a threshold value and added to the attentional cascade.

The attentional cascade is a set of weak classifiers that, when used together, make a powerful classifier. This powerful classifier is then loaded, and the image is gradually passed through each classifier. The result of this process is the detection of the face in the image or video.

After detecting the face, the next step is skin detection and removal of non-skin pixels. This step is critical because the rPPG [13] signal is obtained from the skin as shown in Figure 5. The skin detection is performed on every frame to filter out non-skin pixels. The area of interest, the skin part, is the ROI piece. The pixels in the ROI are spatially averaged, and the process is repeated for each video frame. The result of this process is then used to obtain the rPPG signal.

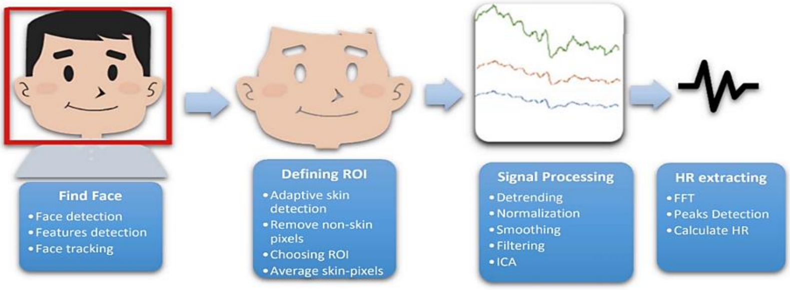


Figure 5: Obtained rPPG signal from ROI. [11]

For HR for example since the HR is usually a periodic signal, the BVP signal can be transformed into the frequency domain and retain only the components between 30-240 Hz as this is the human HR range using the Fast Fourier Transform ,which It is a faster version of the Discrete Fourier Transform (DFT). FFT [12] converts the time domain of a signal into frequency domain and produces a clean pulse waveform from which peaks are detected. The inter-beat intervals obtained from these peaks are then filtered and used to compute heart rate and heart rate variability. FFT was applied to the selected signals and their power spectrum was obtained. The frequency corresponding to the highest power of the spectrum in an operational frequency band is determined as the pulse frequency.

1.5.3 rPPG Based Methodology

Remote photoplethysmography (rPPG) is the It is the same principle of PPG, but it is a contactless measurement. It measures the variance of red, green, and blue light reflection changes from the skin, as the contrast between specular reflection and diffused reflection. Specular reflection is the pure light reflection from the skin. Diffused reflection is the reflection that remains from the absorption and scattering in skin tissue, which varies by blood volume changes. We can see an illustration of the main principles of rPPG as shown in Figure 6.

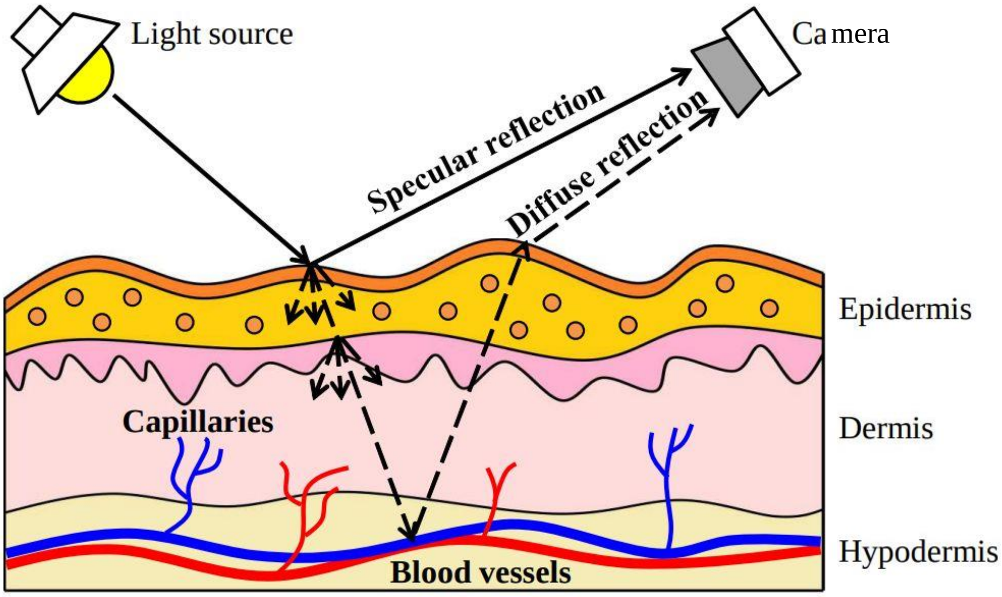


Figure 6: The skin reflection model that contains specular and diffuse reflections, where only the diffuse reflection contains pulsatile information [13]

The following pipeline demonstrates an advanced video data processing as shown in Figure 7 that includes multiple techniques to extract a robust BVP signal such as face detection, face landmarks prediction, extraction of face regions providing high quality signals, intensity-based signal extraction, and noise removal techniques to diminish motion and light noises. The camera of a smartphone captures the face video which is streamed to a back-end cloud. A deep learning-based face landmarks prediction model processes the streaming video frames and calculates the vital signs.

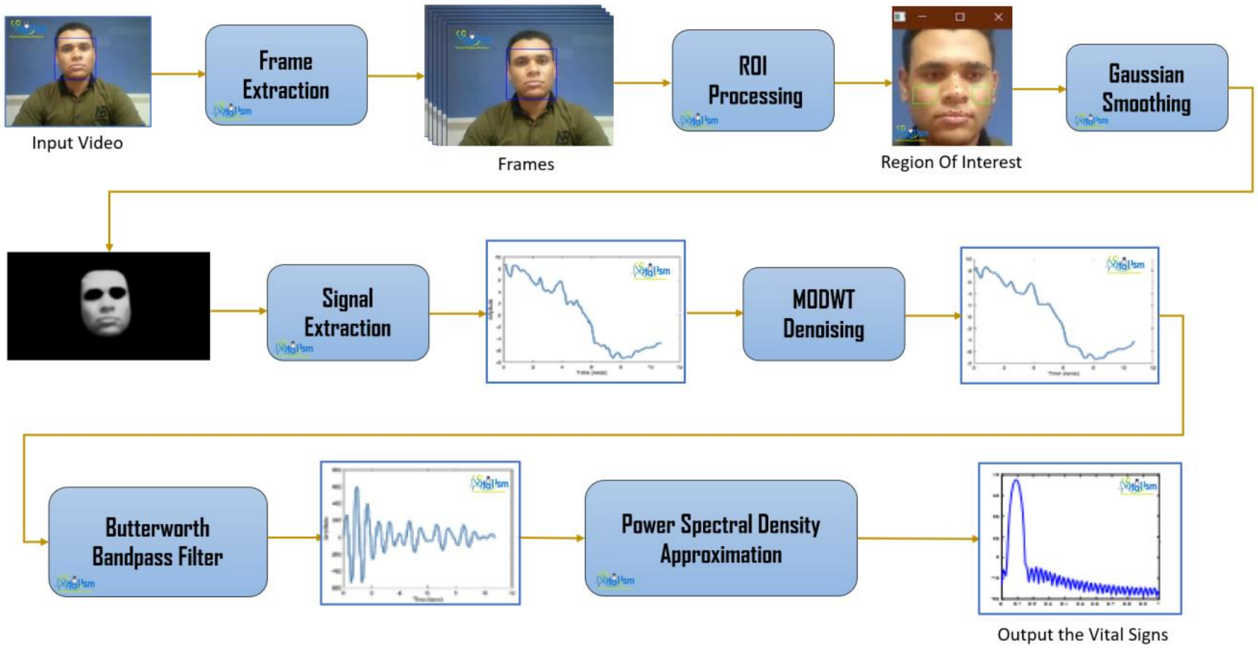


Figure 7: Processing steps for extraction of vital signs from a video.

Previous pipeline works as following:

1- Video acquisition and frame extraction

The first step of the procedure involves the video acquisition of the subject. Body parts like face can be focused on within the video. The video acquired is processed through various steps to obtain the pulse rate of the subject. An algorithm can be developed to extract frames from the video. The number of frames in a video can be calculated using the formula below.
Num of frames = $D *$ frame rate
Where D = duration of video in seconds and the frame rate is in fps If a video with a frame rate of 30 fps is acquired for 7 seconds, 210 frames will be extracted from the given video. Each of the frames is further processed in a stepwise fashion.

1.1- Frame Extraction for monochrome video processing

The first video processing algorithm designed to extract heart rate from video involves simple monochrome processing. In this method, each extracted RGB frame obtained from the video is first converted to a monochrome frame. A frame at any discrete time is an array of matrices of pixels, containing red, green and blue (RGB) values. This corresponds to a gray scale value Y (t) at any discrete time given by the weighed sum of RGB values [14]:

$$Y\ (t) = 0.299R\ (t) + 0.587G\ (t) + 0.114B\ (t)$$

The above equation can be used to compute the gray level for each pixel of each frame.

1.2- Frame extraction for HSI/color video processing

Another similar approach is the use of color domain for heart rate extraction. This method focuses on the use of HSI domain to create frames and heart rate signals for further processing. In this method, the RGB frames obtained from the video are first converted to HSI domains. Like a 3 channel RGB image HSI domain too has three channels namely Hue (H), Saturation (S) and Intensity (I). These three channels can be derived from RGB domain by the relations below [15].

$$H = \begin{cases} \theta & if\ B \le G \\ 360 - \theta & if\ B > G \end{cases}$$

Where,

$$\theta = cos^{-1}\left\{\frac{{}^{1}/_{2}\,[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)]^{1/2}}\right\}$$

Similarly,

$$S = 1 - \frac{3}{(R+G+B)}[min(R,G,B)]$$

And,

$$I = \frac{1}{3}(R+G+B)$$

From the equations above, three channels of HSI domain are obtained. Each channel can be separately processed along the line of processes as monochrome channel and waveform from each channel can be derived. Experimental results showed that only Hue and Intensity channels display the nature of heart waveform, hence, the saturation channel is not further processed.

2- Region of interest (ROI) selection from each frame

The parts of body like the face excluding the eye area can be considered to be the ROI for the experiment. The eyes are excluded to avoid noise due to eyeball movements. The ROI is assumed to be the same for the entire processing of the still video of the subject. A mask can be created using a global thresholding algorithm.

2.1- Global Thresholding

The simple implementation and speed of computation makes thresholding one of the most used segmentation methods available. The scheme is based on the principal of segregating the pixel values into groups. One such procedure involves global thresholding. In this process we convert a given frame to grayscale image, select a random threshold value, divide all the pixel values into groups based on the threshold value. The means of each pixel values from each group are calculated and a new value of threshold (T) is updated as follows.

$$T = random\ value \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.first\ initalization$$

Step1: $m_1 = mean\ of\ intensities\ of\ image\ below\ T$

Step2: $m_2 = mean\ of\ intensities\ of\ image\ above\ T$

Step 3: $T = \frac{(m_1+m_2)}{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..new\ value\ of\ T$

The steps (1), (2) and (3) are repeated until the difference between T values in successive iteration becomes less than the predefined value [15]. The image is then segmented between the new-found threshold values. As the present research considers still videos of subjects, the ROI can be set the same for the whole video. Besides, as the experimental videos are of 7 seconds in length, constant ROI makes sense. Further work involves updating of ROI after certain time intervals.

3- Gaussian Smoothing

Spatial filtering is one of the important tools in image processing. The use of spatial masks for image processing is called spatial filtering. The masks used are called spatial filters. These spatial filters are useful as they offer versatility and a lot of computational simplicity as compared to frequency domain filters. These filters basically consist of a neighborhood and a specific operation that leads to enhanced image upon application. At any point (x, y) in the image, the response, g(x, y), of the filter is the sum of products of the filter coefficients and the image pixels encompassed by the filter and is given by the relation:

$$g\ (x,\ y) = \omega\ (-1,\ -1)\ f\ (x - 1,\ y - 1) + \omega\ (-1,\ 0)\ f\ (x - 1,\ y) + \omega\ (0,\ 0)\ f\ (x,\ y) + \cdots$$
$$+\ \omega\ (1,\ 1)\ f\ (x + 1,\ y + 1)$$

The general equation for the masking of an image of size M x N using an m x n spatial filter is given by the equation below.

$$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} \omega(s,t) f(x+s, y+t)$$

Where M=2a+1 and N=2b+1

Figure 8 shows the basic operation for spatial filtering [15].

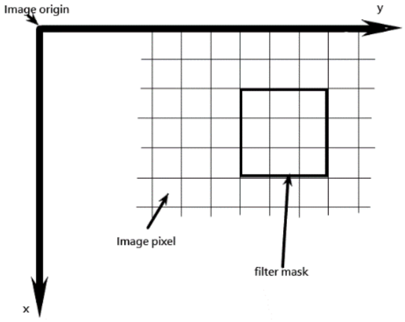


Figure 8: Implementation of spatial filtering

One such spatial filtering operation is Gaussian smoothing which blurs the image, removing sharp transition noises resulting in a smooth image. The output response of Gaussian smoothing filter is the average of the pixels contained in the neighborhood of the filter mask created from the Gaussian relation. The idea is to replace every pixel in an image by the average intensity values in the region of the filter. This method reduces sharp transitions corresponding to the high frequency noises. For the application of the research, sharp transitions are irrelevant as the theme is to focus on subtle changes in the intensity value. Thus, this filtering approach fits the requirement of the experiments. The mask is created using the relation below where h(x, y) is the mask and σ is the standard deviation.

$$h(x,y) = e^{\frac{-(x^2+y^2)}{2\sigma^2}}$$

A Gaussian smoothing filter of standard deviation (σ = 4) can be used for the experiment. This smoothing procedure removes high frequency noises from the frames and all that is left in the image are the subtle varying intensity values.

4- Signal extraction

As explained earlier, a video is a sequence of frames acquired at a certain frame rate. Typical frame rates range from 15-30 fps. This logic can be used to derive mean intensity levels from each frame 15-30 times a second to form the signal of interest. The intensity values from the ROI of each frame is taken and the mean of these intensity level values will give the average change in intensity in successive frames.

These average values form a signal which can be further processed to obtain the pulse waveform from the video. The first step towards processing is the removal of DC value from the video waveform in order to analyze the signal further. For the monochrome processing, as a single channel is used, we can obtain single waveform from a video. For HSI domain, two waveforms are obtained for each Hue and Intensity channels. These signals are processed further in later steps to obtain the pulse waveforms.

5- Wavelet-based denoising

The raw signal thus obtained comprises of features and noise. From elementary frequency domain analysis, it became apparent that the signal consisted of the desired Pulse waveform entangled with other noise in a close frequency range. Removal of such noise in the proximity requires segregation of the desired periodic signal from other signals of less significance. A signal denoising technique called Maximal Overlap Discrete Wavelet Transform (MODWT) has been employed as an appropriate transform for this purpose [16]. Maximal Overlap Discrete Wavelet Transform (MODWT) automatically computes coefficients for the data using Donoho and Johnstone's universal threshold and level-dependent thresholding.

If L is the length of the filter $h^{\sim}l$ and $g^{\sim}l$ be the rescaling filters, then the MODWT pyramid algorithm

Generates the wavelet coefficient $\left\{d_{j,n}^{(M)}\right\}$ and the scaling coefficient given by [17]:

$$d_{j,n}^{(M)} = \sum_{l=0}^{L-1} \tilde{h}l^{(M)}_{c_j-1,(n-2^j-l) \bmod N}$$

$$c_{j,n}^{(M)} = \sum_{l=0}^{L-1} \tilde{g}l^{(M)}_{c_j-1,(n-2^j-l) \bmod N}$$

Application of the MODWT should provide a signal that is more amenable for further analysis. In this analysis the choice of MODWT is based on its features which preserve the smooth time-varying structure that is otherwise lost during the application of the normal Discrete Wavelet Transform (DWT). The pulse wave signals of concern correspond to minor variation in the intensity levels. Also, the signal length is a concern as MODWT is statistically appropriate for the processing of arbitrary signals while DWT of level J0 can only be applied to signals whose length is a multiple of 2^{J0} [18]. In other words, the smooth and detail coefficients of MODWT best fits the application in this research based on the literature [19].

6- Bandpass Filtering

A filter is a class of linear time invariant system that passes certain frequency component and attenuates other frequencies. The filter design process involves specification, approximation, and realization of the filter system. For the application of the research, a Butterworth bandpass filter is used after denoising filter. The normal heart rate lies in the region of [50, 200] beats/minutes for infants [20]. This is equivalent to [0.83, 3.33] Hz. This frequency range also helps to ignore certain low frequency features like respiration that introduces noise in the process. A 5th order filter is used to maximize output reliability and the output of the filtering procedure was a smooth signal that represented pulse rate. Figure 9 shows the frequency response of the filter used.

7- Power Spectral Density Approximation.

Power spectral density was estimated for the signal obtained after filtering via Welch's method [17]. This estimation method divides the signal into longest possible sections. It then computes modified periodogram for each segment using Hamming window. The periodograms are averaged to compute the final spectral estimate. This estimate gives the power per unit frequency. The frequency value with the maximum PSD is considered to be the pulse rate frequency (fPR). The pulse rate per minute is given by:

$$PR = 60 * fPR \text{ beats per minutes}$$

All the above steps if followed stepwise, will give heart rate as the output. It is possible to develop an algorithm with video as an input signal. The algorithm will have blocks for extracting frames, reading individual frames, and selecting the ROI, smoothening each of the frames, extracting a 1D signal from the frames, denoising the extracted signal, filtering it with a bandpass filter and finally analyzing power spectral density of the signal to render heart rate.

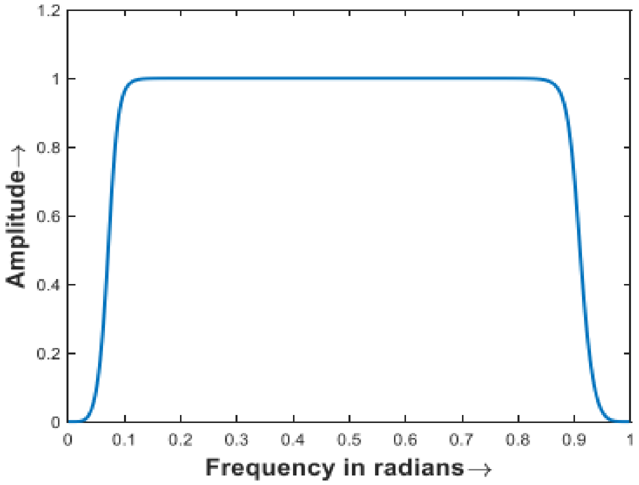


Figure 9: Frequency response of the Bandpass filter.

1.5.4 rPPG Signal Extraction.

In the Vitalism system, the rPPG signal extraction is a crucial component that allows for accurate measurement of vital signs. The rPPG signal is a physiological signal that reflects the blood flow changes in the microvasculature underneath the skin. The measurement of the rPPG signal is non-invasive and provides valuable information about an individual's heart rate, respiration rate, and blood pressure.

The first step in the rPPG signal extraction process is face detection and skin detection, which is achieved through the use of the Viola-Jones algorithm [9]. The algorithm automatically detects the face of the subject and provides bounding box coordinates that define the subject's face. The skin detection process filters out non-skin pixels and identifies the skin part, which serves as the region of interest (ROI).

After the face and skin have been detected, the next step is to perform spatially averaging on the pixels in the ROI. This process is repeated for each video frame and is used to obtain the rPPG signal. The rPPG signal is calculated by taking the average of the red, green, and blue (RGB) color channels for each pixel in the ROI as shown in Figure 10.

The rPPG signal is then processed and analyzed to extract information about the subject's vital signs. This information is used to track changes in the subject's health over time and to identify any potential health concerns.

The accuracy of the rPPG signal extraction process is crucial for the overall performance of the Vitalism system. A number of factors can affect the accuracy of the rPPG signal, including skin pigmentation, movement artifacts, and illumination changes. To mitigate these challenges, the Vitalism system employs advanced signal processing techniques, such as motion correction and noise reduction, to ensure accurate and reliable measurement of the rPPG signal.

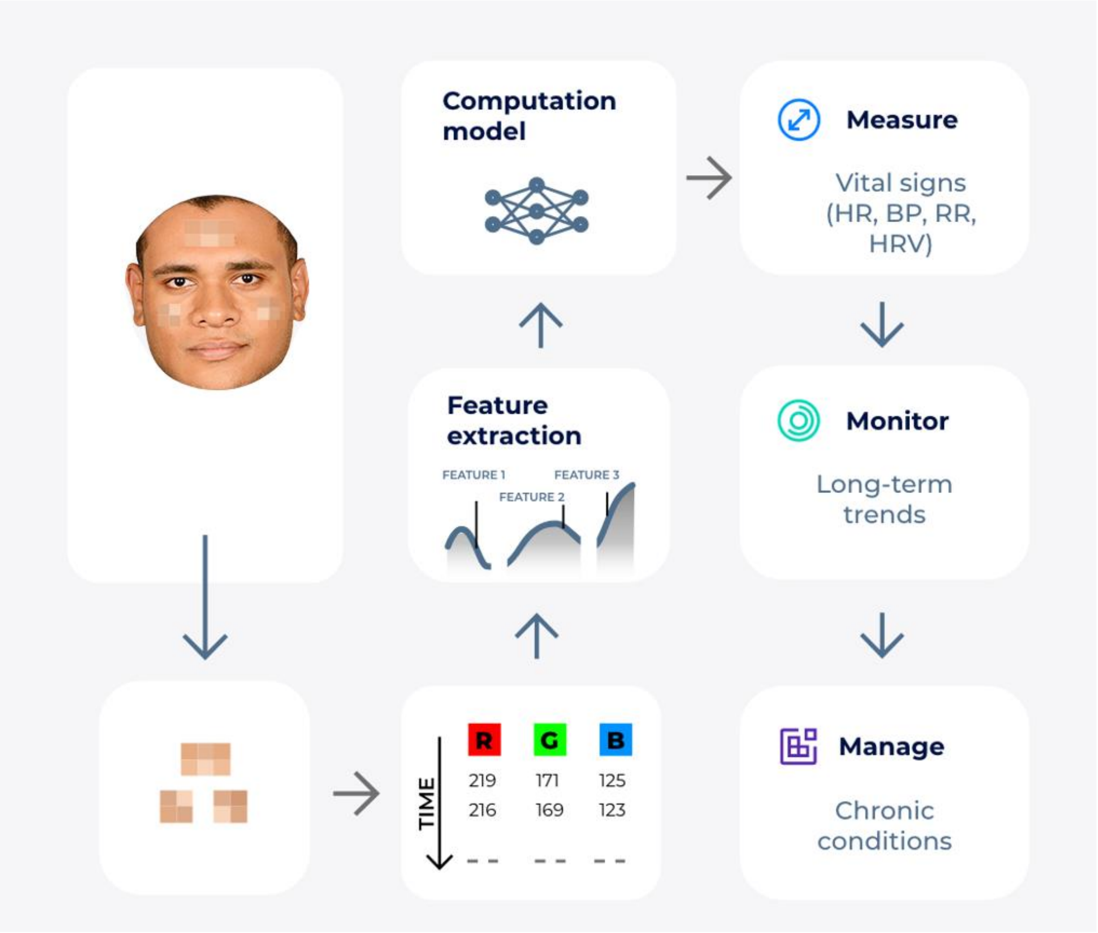


Figure 10: Estimation of RGB Color Channels from ROI's Pixels and Extract the Vital Signs .

In conclusion, the rPPG signal extraction process in the Vitalism system is a critical component that enables the accurate measurement of vital signs. The use of the Viola-Jones algorithm for face and skin detection, combined with advanced signal processing techniques, ensures that the rPPG signal is accurately and reliably extracted. This information is then used to monitor the subject's health and to identify any potential health concerns.

1.5.5 Vital Signs rPPG based Calculation.

The measurement of physiological parameters from external surface of the body is mainly related to the cardiorespiratory activity and the characteristics of both the respiratory and cardiovascular systems. The respiratory system is composed primarily of the chest wall, lungs, and diaphragm Figure 11. When dealing with the need for external recording of breathing-related movements, the Chest wall is surely the best measurement site.

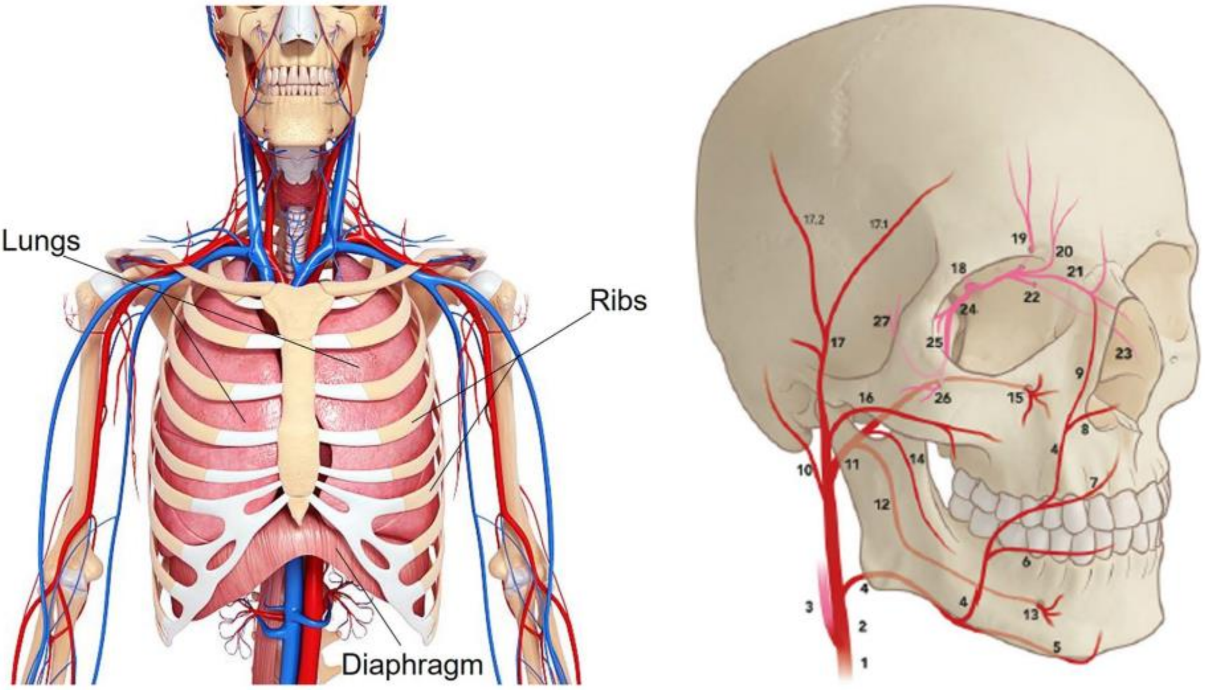


Figure 11: Anatomy of Respiratory system.

Vitalism application calculates three different vital signs from the extracted BVP signal using rPPG method such as Heart Rate, Heart Rate Variability, and Respiratory Rate as described below:

I. Heart Rate (HR)

The human heart consists of four chambers: the left atrium, the left ventricle, the right atrium, and the right ventricle. The atriums act as receiving chambers, contracting to push blood into the ventricles. The ventricles serve as pumps, transporting oxygenated blood to the body's tissues and deoxygenated blood and carbon dioxide back to the heart. Heartbeats are composed of phases of contraction and relaxation [21].

Heart Rate (HR) is a term used to describe the number of heart beats per minute and serves as an indicator of autonomic nervous system activity and metabolic rate. Various factors can affect HR, including physical fitness, psychological status, diet, drugs, and the interaction of genetics and the environment [22]. A normal resting HR is 60 to 100 beats per minute for healthy adults. Tachycardia, a high HR, is defined as above 100 bpm at rest, while bradycardia, a low HR, is defined as below 60 bpm at rest [23]. the relationship between elevated resting HR and cardiovascular risk has been demonstrated in several large-scale epidemiological studies.

Those studies provide strong confirmation that increased HR is an independent risk factor for all-cause and cardiovascular mortalities [24, 25]. Thus, the need for an easy-to-use and accessible method to measure and monitor HR is clear. Vitalism's HR algorithm uses the photoplethysmography (PPG) signal recorded from facial skin tissue (remote PPG - rPPG). The algorithm identifies the heartbeat peaks, which represent the contraction of heart ventricles.

II. Heart Rate Variability (HRV)

Heart rate (HR) is the number of heart beats per minute. Heart Rate Variability (HRV) is the fluctuation in the time intervals between adjacent heartbeats (RR intervals – RRi) [26]. HRV is generated by heart-brain interactions and autonomic nervous system processes and reflects regulation of autonomic balance, blood pressure, blood vessel diameter, gas exchange, gut, and heart.

A healthy heart is not a metronome, and heartbeats do not occur at constant intervals, but rather with a small variance between them. This variability in heartbeats provides the flexibility to rapidly cope with an uncertain and changing environment. Physical or emotional stress results in faster, monotonic heartbeats, causing HRV to decrease. Relaxation results in slower, less regular heartbeats, and higher HRV. Normal HRV is associated with a lower risk to develop depression and post-traumatic stress disorder. Additionally, decreased HRV has been identified as an independent predictor of cardiovascular and overall mortality.

HRV is a noninvasive method that can be used to evaluate autonomic nervous system activity and physical and emotional status in a variety of clinical situations. Vitalism's HRV algorithm uses the photoplethysmography (PPG) signal recorded from facial skin tissue (remote PPG - rPPG). The algorithm identifies the heartbeat peaks, which represent the contraction of heart ventricles (R peaks of the QRS complex of the ECG wave).

III. Respiration Rate (RR)

The main function of the respiratory system is gas exchange, where oxygen is transferred from the environment into the bloodstream and carbon dioxide is expelled. When inhaling, air passes to the lungs and gas exchange occurs when oxygen diffuses into the lung capillaries in exchange with carbon dioxide. Exhalation starts after gas exchange and the air containing carbon dioxide returns to the external ambient through the nose or mouth. The respiratory system also has secondary functions like filtering, warming, and humidifying the inhaled air [27, 28].

There is a close relationship between respiration and heart activity. Heart rate is regulated by respiration, increasing during inhalation and decreasing during exhalation. Respiration Rate (RR), or the number of respirations per minute, is a clinical parameter that represents ventilation, i.e., the movement of air in and out of the lungs [27]. The normal RR varies from person to person but generally lies between 12-20 respirations per minute at rest. RR is a valuable diagnostic and prognostic marker of health used in a range of clinical settings to identify abnormalities.

In hospital healthcare, RR is a highly sensitive marker of acute deterioration. Elevated RR is a predictor of cardiac arrest and in-hospital mortality and can indicate respiratory dysfunction. Currently, RR is usually measured by manually counting chest wall movements, which is a time-consuming, inaccurate, and poorly executed process. There is a great need for a non-intrusive, automatic method of measuring RR.

Vitalism's RR algorithm uses the photoplethysmography (PPG) signal recorded from facial skin tissue (remote PPG - rPPG). The rPPG signal comprises a pulsatile component (AC) provided by the cardiac variations in blood volume that arise from heartbeats, and a DC component affected by various factors, including respiration.

IV. Blood Pressure (BP)

The heart pumps the blood through the blood vessels to all parts of the body. Blood Pressure (BP) is generated by the force of blood pushing against the walls of the arteries. It is measured in millimeters of mercury (mmHg) and is recorded as two numbers: systolic BP, the highest pressure (normal range 90- 130 mmHg) in blood vessels (when the heart contracts), and diastolic BP, the lowest pressure (normal range 60-90 mmHg) in blood vessels (when the heart muscle relaxes) [29].

Hypertension, also known as high or raised BP, is a condition in which the blood vessels have persistently raised pressure. Elevated BP is the most important risk factor for death and disability worldwide, affecting more than one billion individuals and causing an estimated 9.4 million deaths every year.

As the importance of ambulatory BP has been stressed in many recent studies, it can be deduced that while continuous monitoring is required in daily life for accurate diagnosis of BP and cardiovascular health, the conventional cuff-based method is not practical due to its inconvenient and cumbersome nature.

PPG (photoplethysmography) is a non-invasive, simple and low-cost tool that can reflect blood flow in blood vessels and blood volume changes. The PPG waveform comprises a pulsatile ('AC') physiological waveform attributed to blood volume changes with each heartbeat and is superimposed on a slowly varying ('DC') baseline with various lower frequency components attributed to respiration, sympathetic nervous system activity, and thermoregulation. The PPG technology has been used in a wide range of commercially available medical devices for measuring blood pressure, oxygen saturation, cardiac output, and for assessing autonomic function.

Camera-based approaches make it possible to derive remote PPG (rPPG) signals, and therefore enable a non-invasive measurement of BP. Various methods relying on machine learning techniques have recently been published [for example: 30,31,32].

Vitalism's BP algorithm uses the photoplethysmography (PPG) signal recorded from facial skin tissue (rPPG). The algorithm extracts face video images, produces a rPPG signal, analyzes the data using AI, and provides the end user with BP measurements in real time.

1.5.6 Deep Learning Based Methods

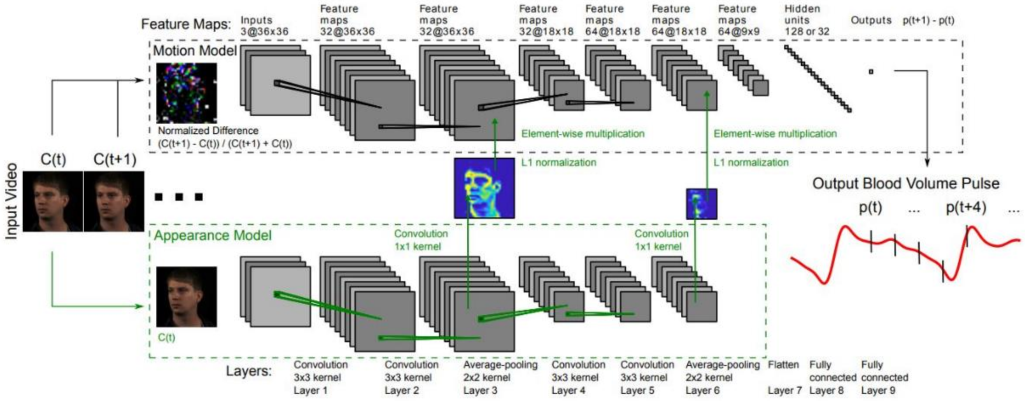


Figure 12: The illustration of DeepPhys architecture from the original paper [33]

We plan to carry out our measurements with deep learning methods using Pulse Rate Detection and UBFC-RPPG Datasets to compare our results, which is our main approach. We hope that deep learning will reduce error rates as a result of these measurements. DeepPyhs [33] provides visualization of physiological information in videos using convolutional attention networks. It processes RGB or infrared videos and can accurately obtain heart rate. The main purpose of PhysNet [34] approach as shown in Figure 12 is using a Spatio-temporal network for rPPG signals from videos. Then it compares rPPG signals with Ground Truth ECG values. The method makes peak detection to find Interbeat Interval for Average Heart Rate and Heart Rate Variability as shown in Figure 13.

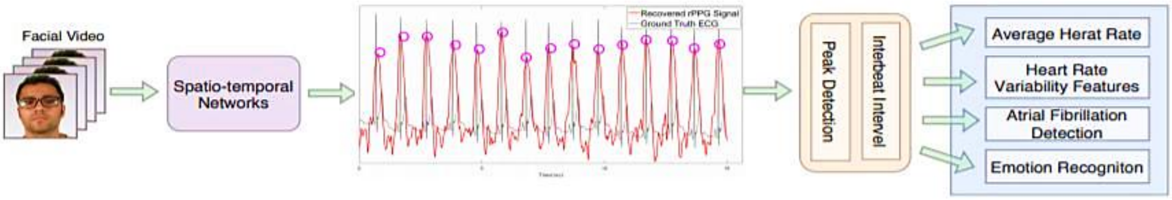


Figure 13: rPPG signal measurement using Spatio-temporal Networks [34]

1.5.7 Flowchart of Proposed Algorithms

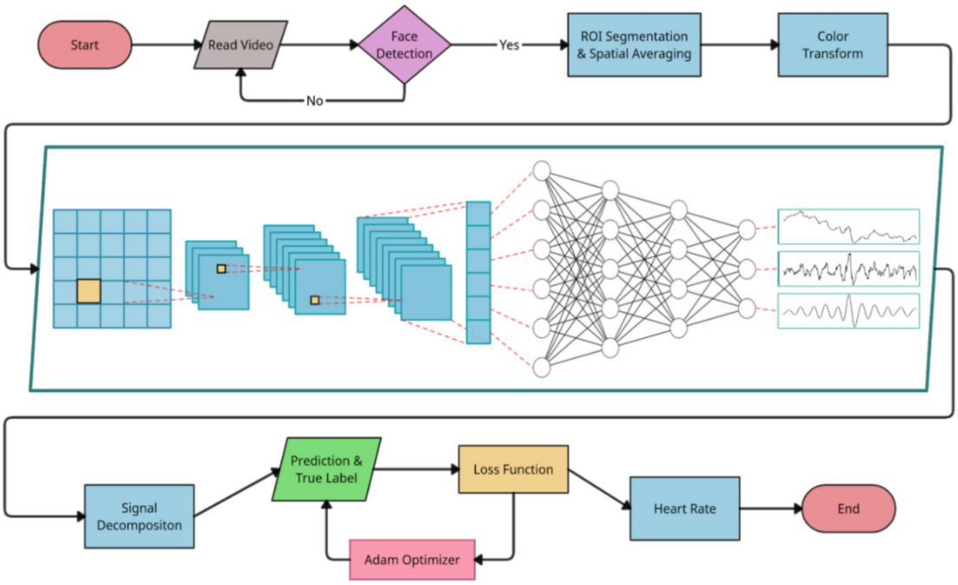


Figure 14: Flowchart of proposed algorithm

1.5.8 The Dataset

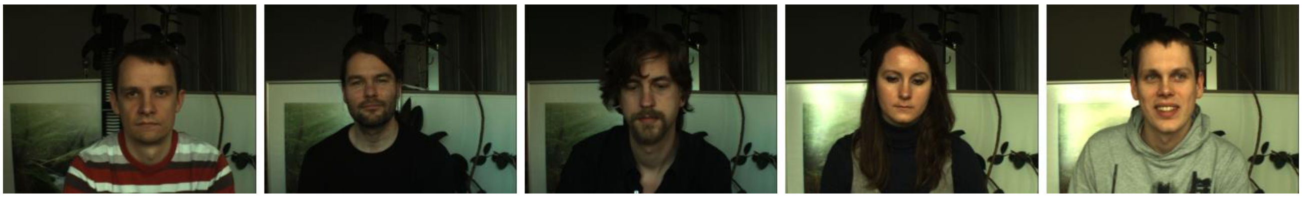


Figure 15: A few examples from PURE dataset.

Pulse Rate Detection Dataset - PURE [35] data set as shown in Figure 15 consists of 10 persons (8 male, 2 female) that were recorded in 6 different setups:

- Head is steady
- Talking without head movements
- Slow translation
- Fast translation - twice slow translation speed - average speed was 7% of the face height per second

- Small head rotation up to 20°
- Medium head rotation up to 35°

So, there is a total number of 60 sequences of 1 minute each. We can see a few example frames in Figure 16. The image sequences of the head and the reference pulse measurements were recorded. The videos were captured at a frame rate of 30 Hz with a cropped resolution of 640x480 pixels and a 4.8mm lens. Reference data were captured using a finger clip pulse oximeter that provides pulse rate wave and SpO2 readings with a 60 Hz sampling rate.

1.6 Evaluation and Maintenance

The Vitalism system will be evaluated and maintained over time through a combination of performance metrics and monitoring processes. These include:

- Heart rate (HR) accuracy: The system will be evaluated by comparing the HR measurements obtained using the Vitalism system with those obtained using a conventional HR monitoring device, such as an electrocardiogram (ECG) as shown in Figure 16. The error rate between the two measurements will be used as a metric to evaluate the performance of the system.

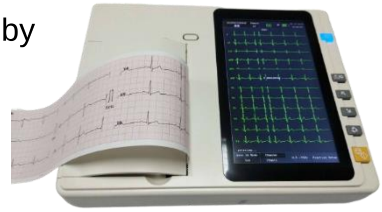


Figure 16: Electrocardiogram (ECG) Machine. [36]

- Heart rate variability (HRV) accuracy: Similar to HR, the HRV measurements obtained using the Vitalism system will be compared with those obtained using a conventional HRV monitoring device. The error rate between the two measurements will be used as a metric to evaluate the performance of the system.
- Oxygen saturation (SpO2) accuracy: The system will be evaluated by comparing the SpO2 measurements obtained using the Vitalism system with those obtained using a conventional SpO2 monitoring device, such as a pulse oximeter as shown in Figure 17. The error rate between the two measurements will be used as a metric to evaluate the performance of the system.

Figure 17: Pulse Oximeter.[37]

- Respiratory rate (RR) accuracy: The system will be evaluated by comparing the RR measurements obtained using the Vitalism system with those obtained using a conventional RR monitoring device, such as a Respiratory inductive plethysmography (RIP) as shown in Figure 18. The error rate between the two measurements will be used as a metric to evaluate the performance of the system.

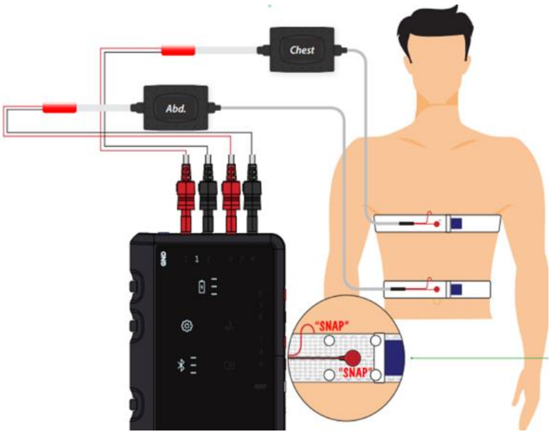


Figure 18: RIP (respiratory inductance plethysmography).[38]

- Blood pressure (BP) accuracy: The system will be evaluated by comparing the BP measurements obtained using the Vitalism system with those obtained using a conventional BP monitoring device, such as a sphygmomanometer as shown in Figure 19. The error rate between the two measurements will be used as a metric to evaluate the performance of the system.

Figure 19: Sphygmomanometer.[39]

Maintenance: The system will be regularly maintained to ensure that it is functioning correctly and that any issues are addressed promptly. This will include regular testing, troubleshooting, and software updates as needed. Additionally, the system will be monitored for any signs of wear or damage and will be repaired or replaced as necessary to ensure optimal performance, and the Vitalism system will be continuously updated to incorporate new research findings and advancements in technology to improve its performance.

To further ensure the reliability of the system, regular testing will be done to monitor the quality of the signal and to improve the performance of the system. This will include the use of different datasets, such as the ones from the people with different ages, genders, and skin tones, to evaluate the generalization capabilities of the system. Additionally, the system will be tested in different environments with varying lighting conditions, to ensure that it can work in different scenarios.

Overall, the Vitalism system aims to provide accurate and reliable measurements of vital signs, such as HR, HRV, SpO2, RR, and BP, in a fast, effective, inexpensive, and convenient manner. The system will be evaluated and maintained over time to ensure that it continues to meet these goals and that it remains a valuable tool for health monitoring.

Chapter 2
(Software Analysis)

2.1 Introduction

The Vitalism project is aimed at revolutionizing the way people measure their vital signs on a periodic basis. The project seeks to provide a fast, effective, inexpensive, and convenient method suitable for all age groups. The problem analysis and motivation for the project stem from the difficulties associated with conventional methods of measuring vital signs, as well as the increasing importance of early diagnosis and prevention of diseases such as heart disease and hypertension.

2.1.1 Problem Analysis and Motivation

Vital signs are an essential aspect of monitoring a person's health and wellbeing. However, the conventional methods of measuring vital signs have been a long-standing challenge in the healthcare industry, which is why the development of Vitalism is crucial. There are several difficulties associated with the traditional methods of measuring vital signs, including irregularity and difficulty, inability to be used for certain populations, risk of infection, sensitivity to motion and illumination artifacts, lack of fast, effective, and convenient methods for all age groups, particularly the elderly and people with disabilities [40], and the need for remote monitoring amid the COVID-19 pandemic.

The irregularity and difficulty of measuring vital signs using conventional methods are a significant challenge in the healthcare industry. This difficulty is further exacerbated by the high cost of measuring vital signs in hospitals, which is one of the reasons why people do not follow up on their health regularly. In a world where over 1 billion people live in extreme poverty, the lack of affordability of vital sign monitoring is a critical concern. As a result, the number of deaths due to heart disease as shown in Figure 20 and high blood pressure, which are the most common causes, is increasing.

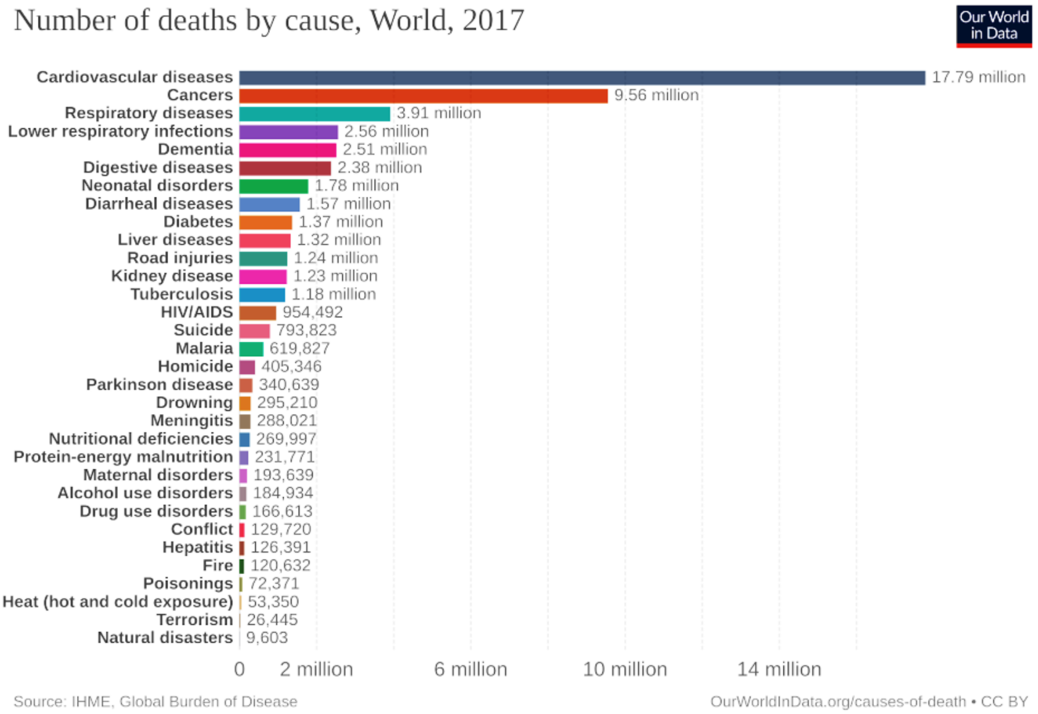


Figure 20: Information from individuals sentenced to death and their families and representatives.[41]

Inability to be used for certain populations, such as those with burns or disabilities as shown in Figure 21, is another difficulty associated with conventional methods of measuring vital signs. A survey of hospitalized patients from January 2020 to December 2020 showed that there are six types of bacteria that can cause infection. In addition, 1 in 3 adults with disabilities between the ages of 18 to 44 do not have a usual healthcare provider, and 1 in 3 adults with disabilities 18 to 44 years have an unmet healthcare need because of cost in the past year. This issue is further compounded by the lack of a fast, effective, inexpensive, and convenient method suitable for all age groups, particularly the elderly and people with disabilities.

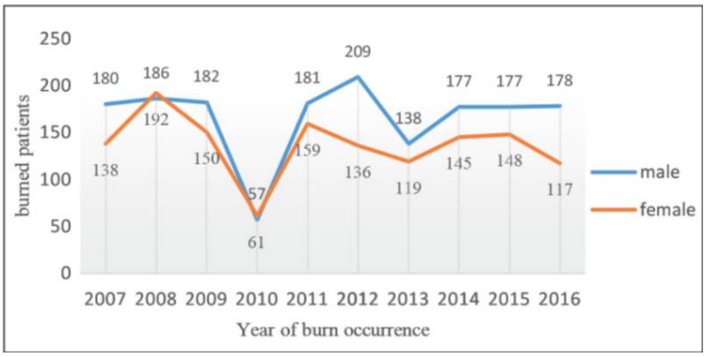


Figure 21: Trend of admitted patients from 2007 to 2016.[42]

The COVID-19 pandemic [43] has further highlighted the need for remote monitoring of patients' vital signs. This has led to a growing demand for solutions that can be used from the comfort of one's home, without the need for physical contact with medical professionals. Traditional devices for measuring vital signs that come into contact with the body and skin increase the risk of skin irritation and bacterial contamination.

In addition to the difficulties associated with conventional methods of measuring vital signs, there is also a lack of an electronic medical record for patients to be used by specialists when needed. This lack of history of the patient makes it challenging for healthcare providers to determine the patient's condition, as they rely on the patient's history to make an accurate diagnosis [44]. Furthermore, pregnant women are unable to go to the hospital to measure their vital signs, which can be stressful for them. This issue is compounded by the fact that the pregnancy rate for U.S. women in 2009 was 102.1 per 1,000 women aged 15-44 [45].

Finally, people who suffer from hospital phobia [46] and fear of medical devices are also at a disadvantage when it comes to measuring their vital signs. For these individuals, the need for remote monitoring is crucial, as going to the hospital can be fatal for them.

In conclusion, the difficulties associated with conventional methods of measuring vital signs and the growing demand for remote monitoring solutions have created a need for an innovative solution like Vitalism. By 2025, when most of today's undergraduates will be in their mid-30s, more than 5 billion people on our planet will be using ultra-broadband, sensor-rich smartphones far beyond the abilities of today's iPhones, Androids, and Blackberries. Vitalism has the potential to be integrated into existing mobile phones, making it accessible to people in resource-constrained environments, making it an innovative solution for measuring vital signs.

2.1.2 Scope of the Project

The Vitalism project is focused on addressing the challenges associated with conventional methods of measuring vital signs by utilizing rPPG technology. The project scope includes the following activities:

i. Research: The project will examine existing studies and develop new solutions to find rPPG algorithms that work with minimal error using deep learning methods.
ii. Development: The project will develop a fast, effective, inexpensive, and convenient method of measuring vital signs using rPPG technology. This will be integrated into an application that can be used on smartphones.

iii. Accuracy: The project will aim to provide accurate results using rPPG technology and reduce the risk of infection associated with traditional methods of measuring vital signs.
iv. User-Friendliness: The project will address the sensitivity of traditional methods to motion and illumination artifacts and provide a solution that is suitable for all age groups, including the elderly and people with disabilities.
v. Remote Monitoring: The project will provide remote monitoring of patients' vital signs during the COVID-19 pandemic.
vi. Contribution to Healthcare: The project will contribute to the field of healthcare by making it more common to measure vital signs using the camera of a smartphone instead of wearable devices.

The project scope is limited to the development of an rPPG-based application for measuring vital signs using a smartphone camera and does not include the development of wearable devices or any other related hardware.

2.1.3 Target User Groups

The target user group for the Vitalism project is quite diverse. It encompasses individuals of all ages who are interested in regularly monitoring their health, as well as healthcare professionals who are seeking a fast, effective, affordable, and convenient method of measuring vital signs.

The target group also includes people with disabilities who cannot use traditional methods to measure vital signs. Monitoring their health conditions in hospitals can also be stressful for them, as well as elderly people who are unable to visit the hospital to monitor their health.

In addition, the project targets pregnant women, who may need to monitor their vital signs to check on their baby. Newborn babies also have sensitive skin prone to irritation from conventional devices. People with infectious diseases may also want to avoid close contact with others when measuring their vital signs.

People who suffer from hospital phobia (Nosocomephobia), or fear of hospitals, can benefit from the Vitalism project as it offers a solution for measuring their health score without having to visit a hospital. Medical staff can also use the project to monitor their patients, and astronauts, athletes, hospital patients, and others who require constant monitoring of vital signs to watch for signs of dangerous health problems.

The Vitalism project offers a non-invasive and user-friendly solution for anyone who needs to measure their vital signs regularly. It means strapping cardiac and respiratory sensors directly to the chest, wrist, or abdomen, without the need for wiring which can be uncomfortable and restrictive.

2.1.4 Definitions, Acronyms and Abbreviations

a. Definitions

(1) HR is the normal beating rate of the heart for adults which ranges from 60 to100 beats per minute (BPM) during rest. During exercise, the heart rate may increase up to around 180 BPM.

(2) HRV: Heart Rate Variability.

(3) PPG: Photoplethysmography is a technique that is used to measure volumetric changes of the blood in the vessels.

(4) rPPG: remote Photoplethysmography is a method used to estimate heart rate from contactless methods.

(5) Pulse oximetry is an instrument used to measure the oxygen saturation in a person's blood.

b. Acronyms and abbreviations

(1) HR: Heart Rate	(2) ECG: Electrocardiogram
(3) COVID-19: Coronavirus disease 2019	(4) NICU: Neonatal Intensive Care Unit
(5) EHR: Electronic Health Record	(6) HRV: Heart Rate Variability
(7) PPG: Photoplethysmography	(8) rPPG: Remote Photoplethysmography
(9) ROI: Region of Interest	(10) IBI: Interbit Interval
(11) FFT: Fast Fourier Transform	(12) HF/LF: High Frequency/Low Frequency
(13) RMSE: Root Mean Square Error	(14) BVP: Blood Volume Pulse

2.2 Related Work

The main subject of our project is to measure the heart rate of the person without touching the person. We do this with rPPG technology, so we measure heart rate with an RGB camera. We estimate the heart rate by selecting the region of interest on the skin and inferring the rPPG signal from the color changes. Below we give a brief overview of the methods in the literature. We group the methods as contact and remote (non-contact) methods.

2.2.1 Contact Methods

Contact methods of vital sign measurement have been in use for several decades and involve physical contact between the patient and the measuring device. The most commonly used contact method is the electrocardiogram (ECG), which measures the electrical activity of the heart. Other contact methods include blood pressure monitors, and pulse oximeters. Despite the widespread use of contact methods, they have several limitations, including the need for physical contact with the patient, the risk of infection, and the inability to be used for certain populations, such as those with burns or disabilities. Additionally, traditional sensors for vital sign monitoring in neonatal intensive care units (NICUs) may cause damage to the fragile skin of infants.

Figure 22: Finger pulse oximeter

Photoplethysmography (PPG) is a technique used to measure the volumetric changes in the blood affected by the heartbeat. PPG is usually obtained using pulse oximetry to measure the heart rate. A normal pulse oximeter monitors the circulation of blood in the dermis layer under the skin.

With each cardiac cycle, the heart pumps blood. The pressure pulse is damped by the time it reaches the skin but is still enough to distend the arteries and arterioles in the subcutaneous tissue. The change in volume caused by the pressure pulse is detected by illuminating the skin with light from a light-emitting diode (LED) and measuring the amount of light transmitted or reflected by a photodiode. Each cardiac cycle appears as a peak.

PPG technology is also used in other applications, such as measuring blood oxygen saturation, blood pressure, cardiac output, respiration, and assessing arterial disease. Additionally, the shape of the PPG waveform can vary from subject to subject and with the location and manner in which the pulse oximeter is attached as we can see in Figure 22.

2.2.2 Remote Methods

Remote methods of vital sign measurement eliminate the need for physical contact with the patient, making them more convenient and less risky. Remote methods can be divided into two categories: indirect and direct methods. Indirect methods use information about the patient's environment or behavior to infer vital signs.

a. Independent Component Analysis (ICA) Method

The ICA (Independent Component Analysis) tries to separate a multivariate signal into independent non-Gaussian signals.

For example, an audio signal is the numerical addition, at each time t, of signals from different sound sources. In this signal, the problem is whether it is possible to separate these subscripts to sources from the observed entire signal. If the statistical independence assumption is correct, blind ICA separation of a mixed signal gives very good outcomes.

Additionally, ICA can be used for signals that are not generated by mixing for analysis purposes. This process is shown in Figure 23,24.

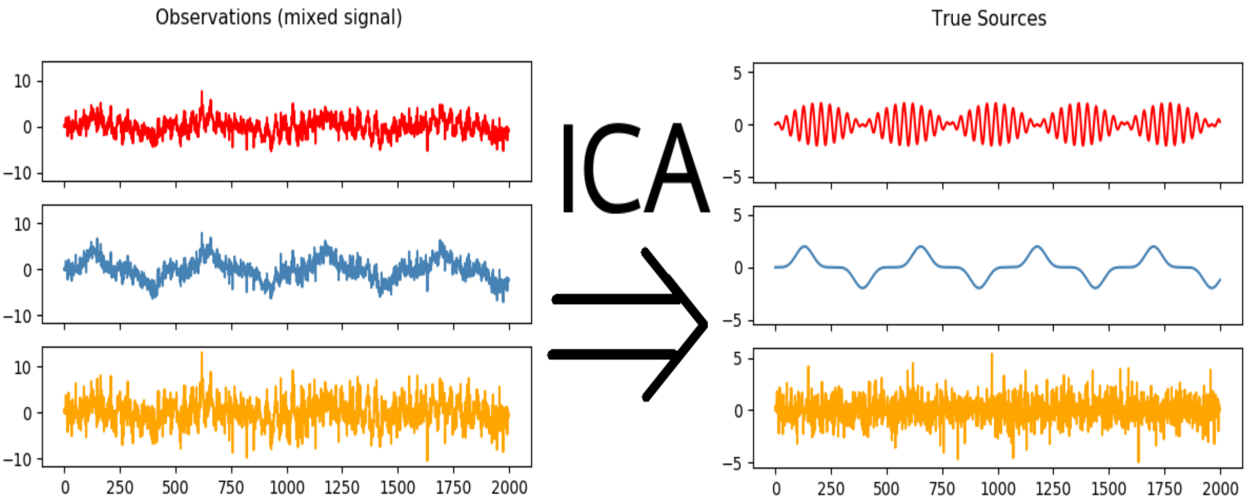


Figure 23: ICA working example.

In the ICA model formulas $x_1(t)$, $x_2(t)$ and $x_3(t)$ red, green and blue signals. Source signals are represented by $s_1(t)$, $s_2(t)$ and $s_3(t)$.

$$x_i(t) = \Sigma\, a_{ij} s_j(t) \text{ for each } i = 1,2,3$$

$$x(t) = As(t)$$

The column vectors $x(t) = [x_1(t), x_2(t), x_3(t)]T$, $s(t) = [s(t), s(t), s(t)]T$.

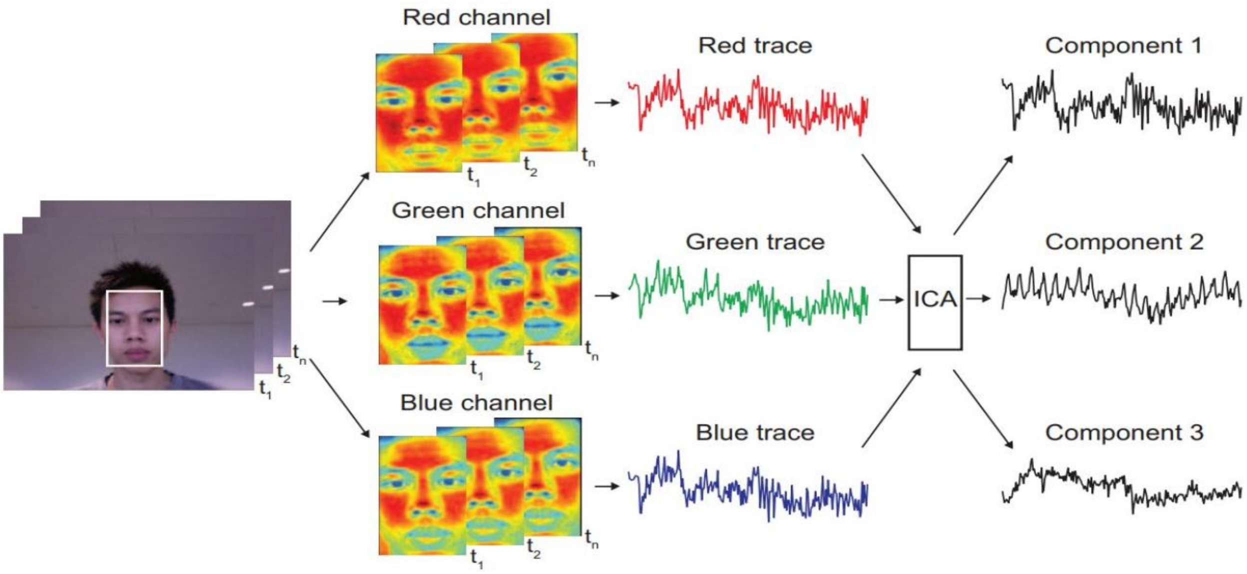


Figure 24: A diagram showing the processing of two source signals. [47]

b. Chrominance-Based (CHROM) Method

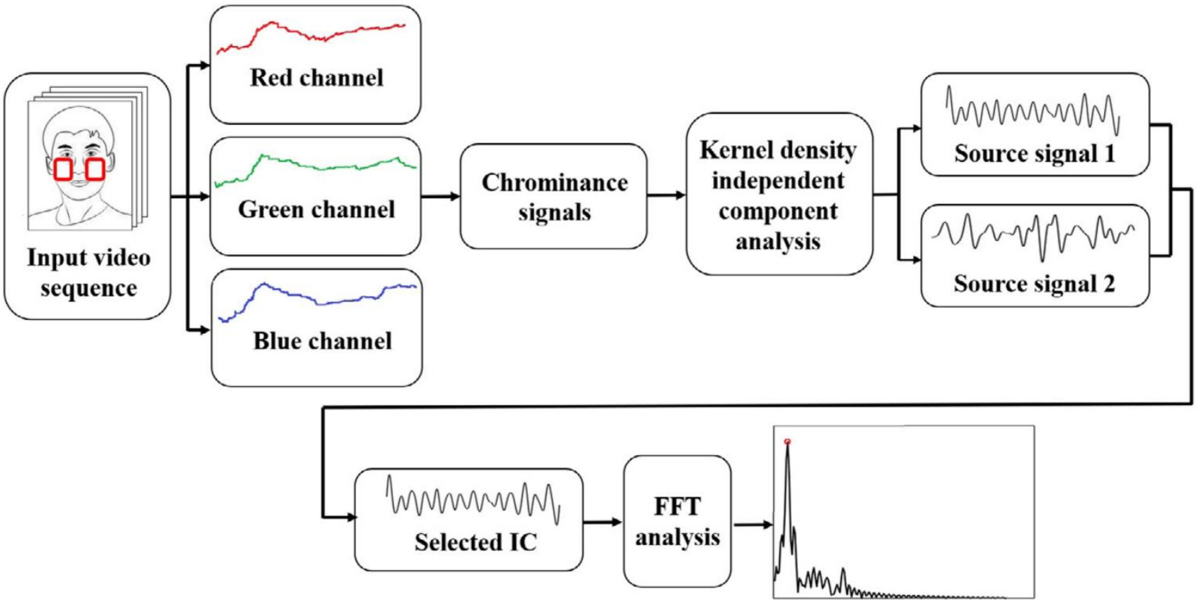


Figure 25: CHROM schema with ICA. [48]

CHROM [49] signal processing method allows obtaining the pulse signal in case of specular and motion artefacts. RGB channels are reflected in a chrominance subspace. Here the movement component is largely eliminated. The CHROM method creates a vector using a standard skin tone. It obtains the pulse signal using an alpha setting. However, these settings sometimes may not match the actual situations and as a result, the method may fail. We can see the schema of CHROM in Figure 25.

c. Green - Vercruysse (GREEN) Method

According to the premise of the GREEN [50] method, the green channel contains the powerful plethysmographic signal, consistent with the fact that hemoglobin absorbs green light better than red and on the other hand passes through sufficiently deeper into the skin as compared to blue light to study the vasculature. This method used Fourier transforming for filtering. For steps, we can look at Figure 26.

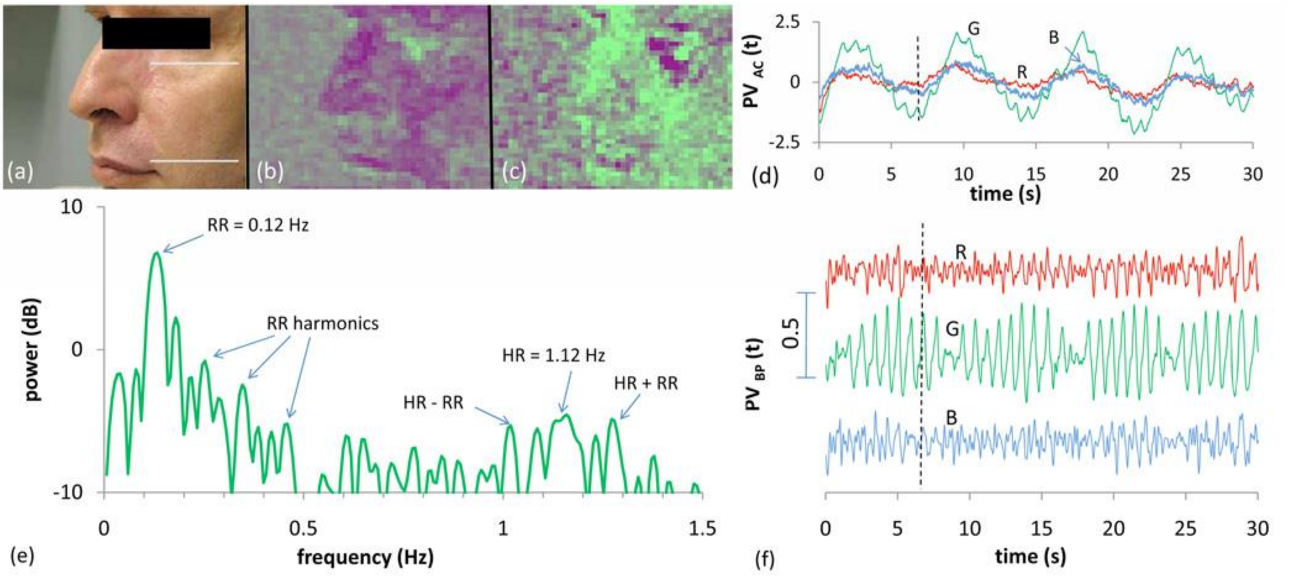


Figure 26: An example of pulse amplitude modulation. [50]

d. Plane-Orthogonal-to-Skin (POS) Method

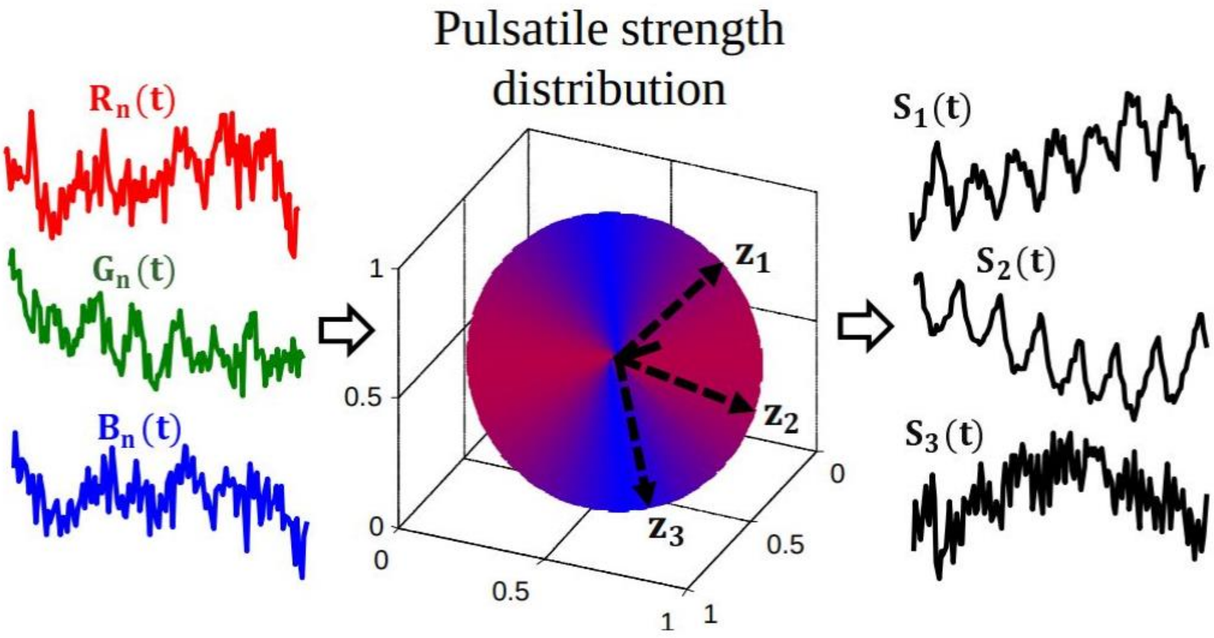


Figure 27: The distribution of the pulsatile strength on the plane orthogonal to 1 as a function of z. [51]

POS [51] primarily makes skin-detection and only takes signals from the skin. The POS algorithm suggests adding the 2SR property to the model. 2SR or data-driven method is a new development. It creates a subject dependent skin-colour area and tracks the colour-change over time to measure the pulse, also the sudden colour is determined depending on the statistics of the skin pixels. From Figure 27, we can see that the projection direction is highly related to the pulsatility that determines the signal quality, different z may give very different projected signals.

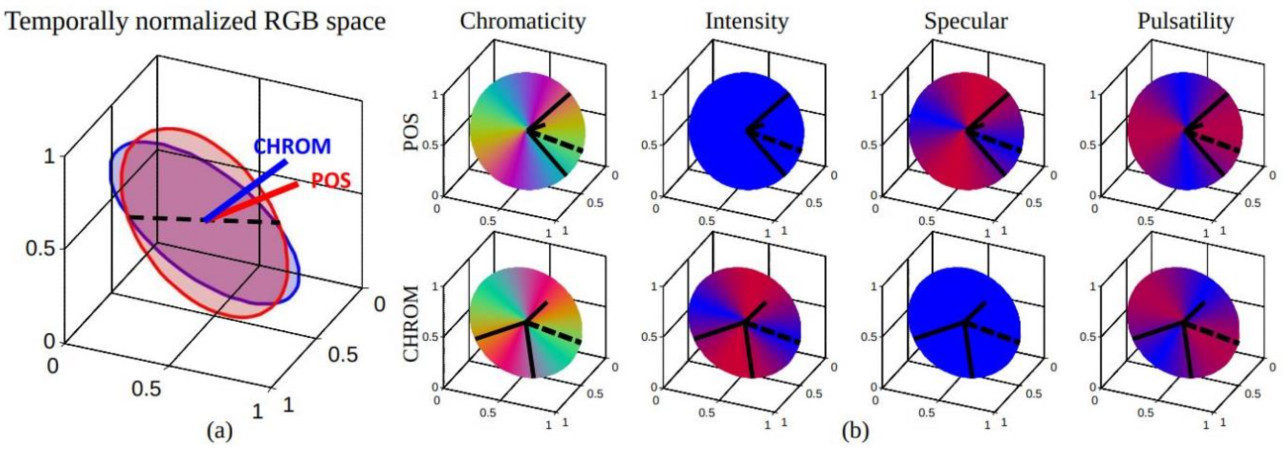


Figure 28: (a) The projection planes of POS and CHROM in the temporally normalized RGB space. (b) The projection planes of POS and CHROM have different chromaticity distributions

As we can see in Figure 28, POS and CHROM [49] have different distributions of volume and reflective variations. In this context, the solid black line shows the primary normal vector and projection axes in both. So, we can say that both have different advantages and disadvantages.

2.2.3 Review Our System and The Existing Systems

Case	**Vitalism**	**Aerosense Wavve** [52]	**Traditional Method** [53]	**The Philips** [54]
Time	25-35 seconds	50 seconds	About 5 minutes	40 seconds
Measurements	HR,HRV,SPO2,BP,RR	HR,RR	HR,HRV,SPO2,BP,RR	HR,RR
Price	Free download	50$	3870$	20$
Availability	All time	All time	Sometimes it is not available.	All time
Infection	Uncaused	Uncased	May caused	Uncaused
EMR	Exist	There is no	There is no	Exist
Maintenance	Easy	Easy	Difficult	Easy
Notification	Yes	Yes	No	No
Platform	Android ,Desktop app	Android	No	Android
Contact Status	Offline/Online	Online	Offline	Online
Virtual Trials	Yes	No	No	No
Patient Triage	Yes	No	No	No
Medication Adherence	Yes	No	No	No
Wellness Program	Yes	Yes	No	Yes
Claims Processing	Yes	No	Yes	No

2.3 System Requirement

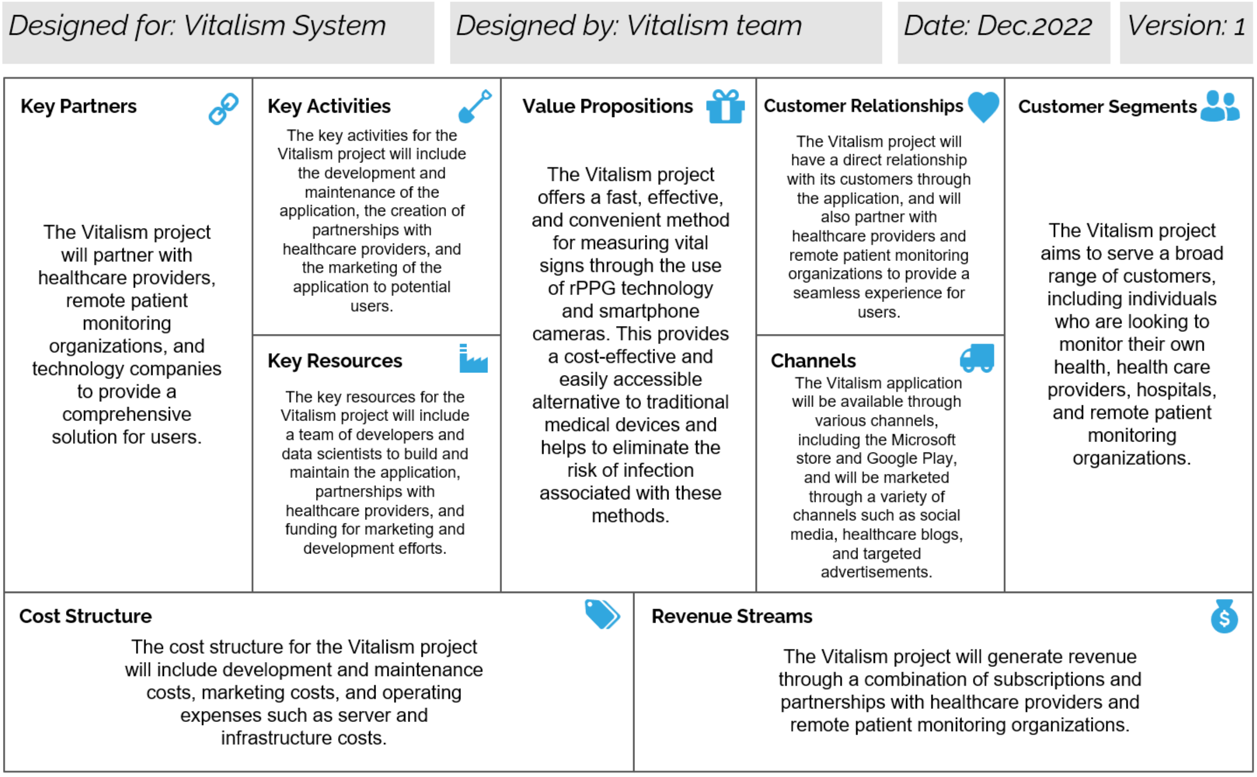
System requirements are an essential component of the Vitalism project, as they outline the specific needs and goals that must be met in order to achieve success. In this section, we will describe the business needs and requests, as well as the business value and benefits that the Vitalism project is expected to provide.

2.3.1 Project Sponsor

The Egyptian Ministry of Higher Education in general and the Faculty of Computers and Information (Bioinformatics), Assuit University in particular finance the project and financial support and work to meet any needs of the project from the beginning of the project until its completion.

2.3.2 Business Model Canvas

The Business Model Canvas for Vitalism can be broken down into the following key elements as shown in Figure 29:



Designed for: Vitalism System | *Designed by: Vitalism team* | *Date: Dec.2022* | *Version: 1*

Key Partners

The Vitalism project will partner with healthcare providers, remote patient monitoring organizations, and technology companies to provide a comprehensive solution for users.

Key Activities

The key activities for the Vitalism project will include the development and maintenance of the application, the creation of partnerships with healthcare providers, and the marketing of the application to potential users.

Key Resources

The key resources for the Vitalism project will include a team of developers and data scientists to build and maintain the application, partnerships with healthcare providers, and funding for marketing and development efforts.

Value Propositions

The Vitalism project offers a fast, effective, and convenient method for measuring vital signs through the use of rPPG technology and smartphone cameras. This provides a cost-effective and easily accessible alternative to traditional medical devices and helps to eliminate the risk of infection associated with these methods.

Customer Relationships

The Vitalism project will have a direct relationship with its customers through the application, and will also partner with healthcare providers and remote patient monitoring organizations to provide a seamless experience for users.

Channels

The Vitalism application will be available through various channels, including the Microsoft store and Google Play, and will be marketed through a variety of channels such as social media, healthcare blogs, and targeted advertisements.

Customer Segments

The Vitalism project aims to serve a broad range of customers, including individuals who are looking to monitor their own health, health care providers, hospitals, and remote patient monitoring organizations.

Cost Structure

The cost structure for the Vitalism project will include development and maintenance costs, marketing costs, and operating expenses such as server and infrastructure costs.

Revenue Streams

The Vitalism project will generate revenue through a combination of subscriptions and partnerships with healthcare providers and remote patient monitoring organizations.

Figure 29: Business Model Canvas of Vitalism

2.3.3 Business Need

The Vitalism project is motivated by the need for a fast, effective, inexpensive, easy, and convenient method for measuring vital signs on a periodic basis. making early diagnosis and prevention of diseases such as heart disease and hypertension challenging. Additionally, the traditional methods require physical contact with the patient, which can be a challenge for certain populations, such as those with burns or disabilities. Furthermore, there is a risk of infection associated with these methods, and remote monitoring is necessary during the COVID-19 pandemic.

2.3.4 Business Request

The business request for the Vitalism project is to develop a solution that addresses these challenges and provides an efficient and convenient or easy method for measuring vital signs. This solution should be suitable for all age groups and be able to extract vital signs from videos, such as heart rate, heart rate variability, oxygen saturation, respiratory rate, and blood pressure.

2.3.5 Business Value

The Vitalism project has the potential to provide numerous benefits for the healthcare industry and its stakeholders. Firstly, it will increase the accessibility and convenience of measuring vital signs, making it easier for individuals to monitor their health state on a regular basis. This will facilitate early diagnosis and prevention of diseases and reduce the risk of infection associated with traditional methods. Secondly, the Vitalism project will provide an electronic medical record for patients, which can be used by specialists when needed. This will help improve the efficiency of healthcare and reduce costs.

2.3.5.1 Measurability/Measuring Success

In order to measure the success of the Vitalism project, the following criteria will be used:

- **I.** Accuracy of Vital Signs Measurement: The application should be able to determine the region of interest (ROI) area accurately and track it throughout the video. The success of the application will be measured by comparing the root mean squared error (RMSE) and mean absolute error (MAD) of the vital signs (Heart rate, Heart rate variability, Oxygen saturation, Respiratory rate, and Blood Pressure) measured by our method with the reference values. A target RMSE of less than 5 units and a high level of correlation (measured by Pearson correlation) will be considered as successful.
- **II.** User Satisfaction and Adoption: User satisfaction and adoption rate of the application will be monitored. The success of the project will be evaluated by measuring the number of individuals who regularly monitor their vital signs and the impact this has on early diagnosis and prevention of diseases.
- **III.** Impact on Health: The impact of the application on the health of the individuals will be measured by monitoring the number of individuals who are able to diagnose and prevent diseases early.
- **IV.** Return on Investment: The financial return on investment will be measured by comparing the cost of traditional machines used in hospitals with the cost of the Vitalism application. The success of the project will be evaluated by the number of individuals who download and use the application regularly, leading to a return on investment for the platform affiliated with this application or that will purchase it.
- **V.** By monitoring and measuring these criteria, the success of the Vitalism project can be accurately determined, and necessary changes and improvements can be made to ensure its success in the future.

2.3.5.2 Benefits/Implications

- Improved accuracy and consistency of vital sign measurements, as the application uses deep learning methods to provide accurate readings.
- Increased access to healthcare services, especially for those who live in rural or remote areas where hospitals and clinics may be far away.
- Convenient and non-invasive method for monitoring vital signs, which reduces the risk of infection and discomfort for patients.
- Easy-to-use application that can be downloaded on personal mobile phones, making it accessible to everyone.
- Electronic medical record keeping, which helps to reduce medical errors and improve the overall efficiency of the healthcare system.
- Increased patient engagement and self-awareness of health, leading to early detection and prevention of diseases.
- Increased revenue and business opportunities for healthcare providers, as they will have access to a large pool of patients who are actively monitoring their vital signs.
- Positive impact on public health by reducing the burden of chronic diseases and promoting healthy lifestyles.

Overall, the Vitalism project has the potential to significantly improve the quality and accessibility of healthcare services, making it easier for individuals to monitor and maintain their health, leading to better health outcomes.

2.3.6 Specific Problem or Limitation

Despite the many potential benefits of the Vitalism project, there are several challenges and limitations that must be overcome. One of the main challenges is the sensitivity of rPPG methods to motion and illumination artifacts. Additionally, there is a need to find rPPG algorithms that work with minimal error using deep learning methods. Another challenge is the need to educate individuals about the importance of regularly monitoring their vital signs. Furthermore, there is a need to ensure that the Vitalism application is accessible and convenient for all age groups, including the elderly and people with disabilities.

Another limitation of the Vitalism project is the need for a stable internet connection in order to use the application. This may limit its usage in remote or underdeveloped areas with limited access to the internet. Additionally, there is also the challenge of privacy and security concerns with the storage and use of personal medical information. The Vitalism project will need to ensure that the data collected by the application is secure and protected, to prevent unauthorized access and potential misuse.

Moreover, the accuracy and reliability of the vital signs measurement can be affected by different factors such as skin pigmentation, skin condition, and the presence of tattoos or makeup. The Vitalism project will need to address these limitations and find solutions to ensure the accuracy of the readings.

Finally, there is also the need to validate the Vitalism project with clinical studies, in order to demonstrate its effectiveness and reliability, and gain the trust of healthcare providers and patients.

2.4 Feasibility Study

A feasibility study is an assessment of the practicality and potential success of a project. It is a crucial step in determining whether or not a project should move forward. The feasibility study of the Vitalism project would include an analysis of the following:

2.4.1 Technical Feasibility

Our approach is based on the fact that due to the flow of blood to various parts of the body, there occurs a slight variation in the pixel values of successive frames of the video of that body part. However, due to subtleness of this variation the extraction of pulse rate from video of a subject requires an algorithm that can select the region of interest from the video, note the subtle changes in pixel values, filter the noise and magnify them. The proposed algorithm follows all the above-mentioned steps and can extract pulse rate from the video of any subject. The steps involved are described in the sub-headings below.

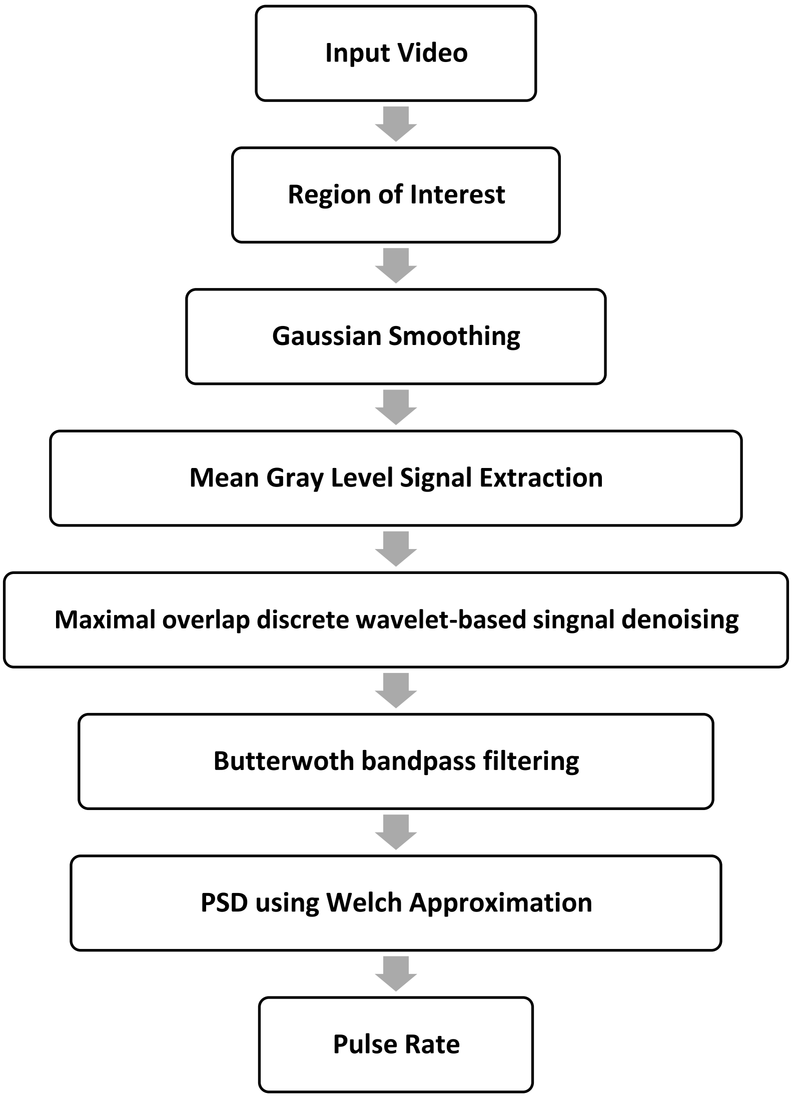
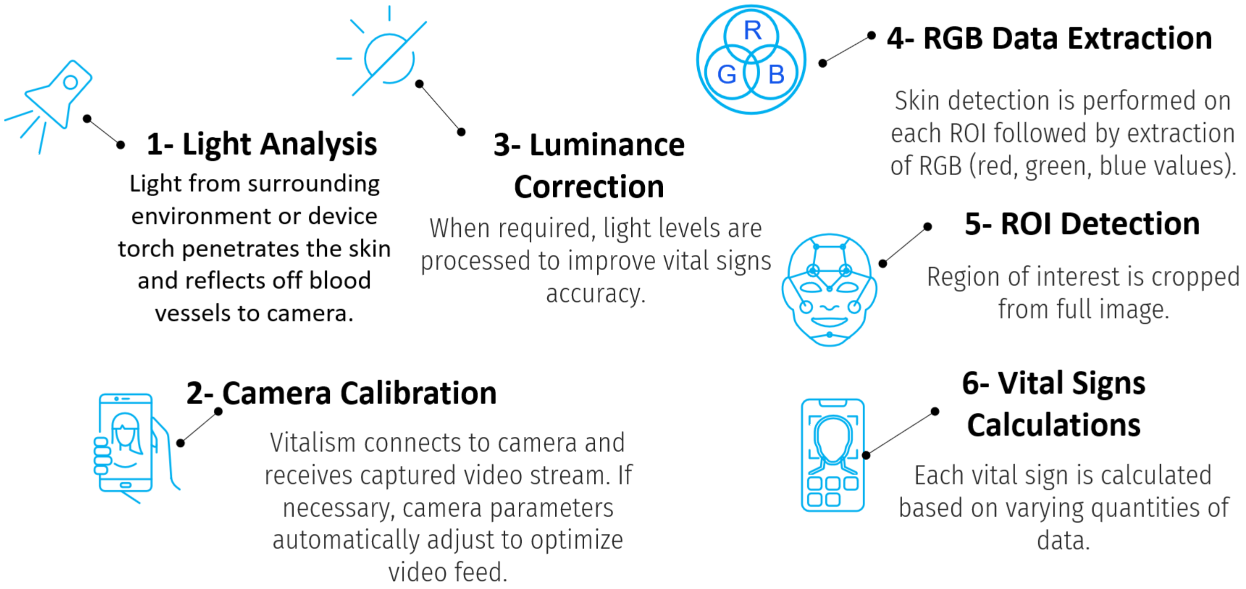


Figure 30: Flowchart illustrating multiple steps involved in extraction of pulse rate from video.

Figures 30 and 31 show the flowchart and multiple steps involved in the extraction of pulse rate from a video using monochrome video respectively. All these steps are followed for the HIS domain as well.



1- Light Analysis
Light from surrounding environment or device torch penetrates the skin and reflects off blood vessels to camera.

2- Camera Calibration
Vitalism connects to camera and receives captured video stream. If necessary, camera parameters automatically adjust to optimize video feed.

3- Luminance Correction
When required, light levels are processed to improve vital signs accuracy.

4- RGB Data Extraction
Skin detection is performed on each ROI followed by extraction of RGB (red, green, blue values).

5- ROI Detection
Region of interest is cropped from full image.

6- Vital Signs Calculations
Each vital sign is calculated based on varying quantities of data.

Figure 31: Processing steps for extraction of pulse rate from a video.

The technology is available and available to build Vitalism application, as we are using remote photoplethysmography (rPPG) to remotely measure vital signs such as respiratory rate and heart rate, we also use photoplethysmography (PPG) in a contact method between the mobile and the person.

Photoplethysmography (PPG)

The principles of PPG are the following: Using the example of a wearable, such as a heartrate-sensing watch, light emits to the skin from one sensor and a second sensor detects how much light is returned to the device. This forms the contrast between emitted light and reflected light. The amount of reflected light changes according to the blood volume, which is caused by capillary dilation and constriction, hence it can estimate the heart rate.

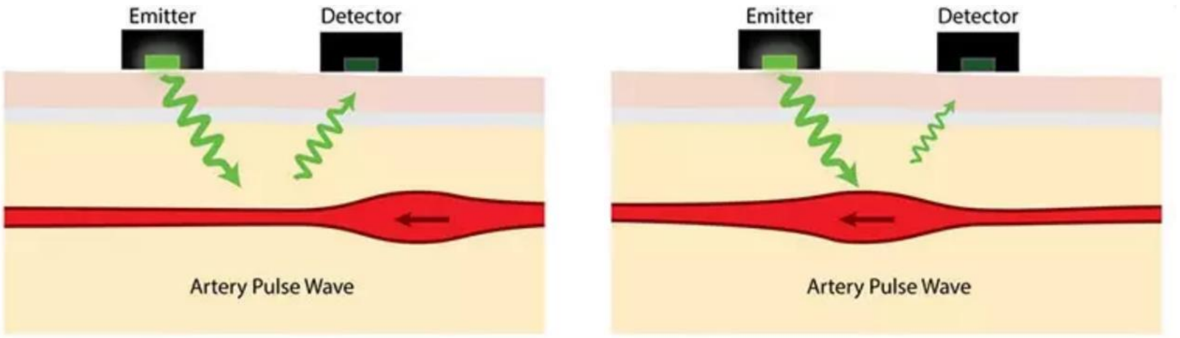


Figure 32: Optical heart rate sensing.

Left: lower pressure preceding the pulse wave means narrower arteries and less absorption (higher reflectivity) of the green light source. Right: a higher blood pressure pulse causes wider arteries and more light absorption (lower reflectivity) [55] as shown at Figure 32.

Remote Photoplethysmography (rPPG)

It is the same principle, but it is a contactless measurement. It measures the variance of red, green, and blue light reflection changes from the skin, as the contrast between specular reflection and diffused reflection. Specular reflection is the pure light reflection from the skin. Diffused reflection is the reflection that remains from the absorption and scattering in skin tissue, which varies by blood volume changes as shown at Figure 33.

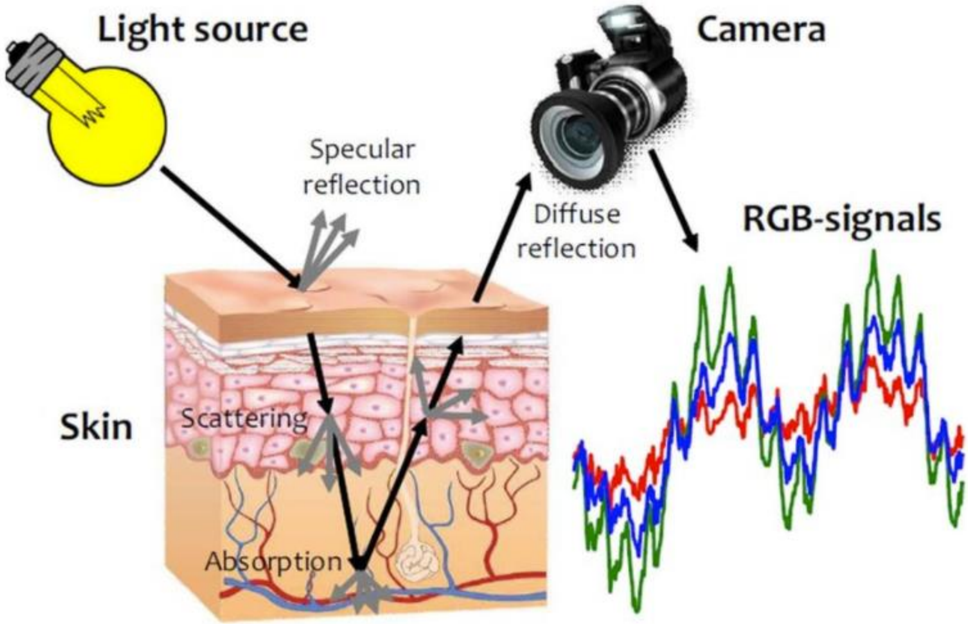


Figure 33: The rPPG setup which normally consists of the light source, camera, and pulsating skin area.

The approach to remote detection is the following:

1. [Skin pixel selection] The face in the captured webcam image is detected and modeled in order to determine facial landmarks and head orientation. Subsequently, approximately the top two-thirds of the face, where most of the blood vessels are concentrated, is selected as the region of interest.
2. [Signal extraction] The average of each pixel colors (red, green, blue) of the region is measured over time (both specular + diffuse reflections).
3. [Signal filtering] The noise from the head motions is detected by fitting the facial model and then noise-free heart rate is produced.
4. [Output calculations] By detecting peaks, inter-beat intervals are measured and then the heart rates and heart rate variability are estimated.

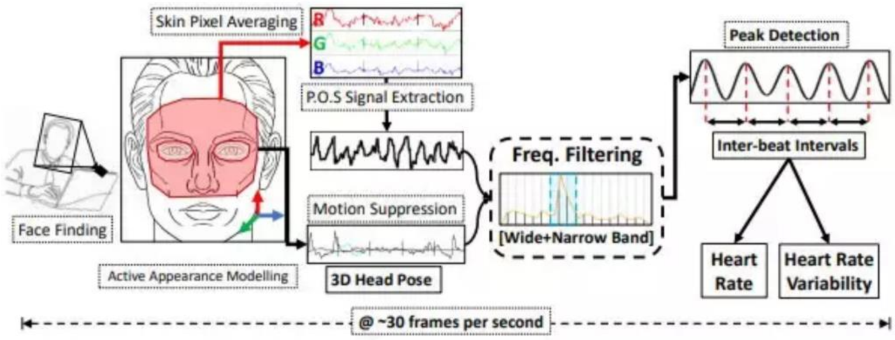


Figure 34: An overview of the proposed heart rate and heart rate variability estimation pipeline (left to right). [56]

The face in captured camera images is detected and modelled to track the skin pixels in the region of interest. The average value of RGB signals is extracted over time. In parallel, the head movements are tracked and used to suppress motion noise. The process of filtering the wide and narrow band signals produces a clean pulse waveform from which peaks are detected. The inter-beat intervals obtained from these peaks are then used to compute heart rate and heart rate variability. The full analysis can be performed in real time on a computer [57] as shown at Figure 34.

- **Face Reader (rPPG) validation study**

In the validation study, 25 participants were asked to watch a video (still condition) and to consume different food stimuli, ranging from liquid to solids (water, yoghurt, chicken, sausage), and the other way around. To validate the RPPG by Face Reader, BIOPAC ECG and BIOPAC PPG were used.

Within the still condition, the measurement of RPPG was successful. However, during food consumption, the differences between measurements from RPPG and ECG were bigger during consumption, indicating that RPPG underestimated higher heart rates. The movement of the face during food consumption disturbed the RPPG measurement. On the other hand, BIOPAC ECG and PPG showed high agreements.

- **Recommended conditions.**

As a result of my research, the following conditions are recommended for Face Reader RPPG:

1. Use of high resolution and uncompressed cameras since both lead to a more accurate heart rate detection.
2. Use of good light conditions, solely from a front lamp. However, avoid frontal lighting that is too strong, to prevent overexposure. A ceiling lamp causes overexposure, which interrupts the skin color detection.
3. Avoid video compression. Video compression decreases the resolution and video quality.

Moreover, rPPG measurement is sensitive to motion of the head. It is recommended to use a setting where participants are sitting and not moving too much. A high correlation between the gold standard and RPPG in these situations has been observed in many studies. Because of increasing attention to remote PPG, these drawbacks are expected to be solved, at least partly, with the improvement of algorithms in the near future.

2.4.2 Economic Feasibility

The economic feasibility of a project refers to the assessment of the project's financial viability, including its potential costs, benefits, and risks. In the case of the Vitalism project, it is important to carefully evaluate its economic feasibility to determine whether it is a viable investment.

	2023	2024	2025	2026	2027	Total
Benefits of Vitalism						
Users' subscription to Vitalism	0	300,000 LE	600,000 LE	840,000 LE	907,200 LE	2,647,200 LE
The advertisement we display on Vitalism	0	10,000 LE	25,000 LE	75,000 LE	120,000 LE	230,000 LE
Sales from hardware devices...	0	0	100,000 LE	200,000 LE	350,000 LE	650,000 LE
Total Benefits	**0**	**310,000 LE**	**725,000 LE**	**1,115,000 LE**	**1,377,200 LE**	**3,527,200 LE**
Development Costs						
Research and development	5,000 LE	8,000 LE	2,500 LE	2,500 LE	2,000 LE	20,000 LE
Software development	100,000 LE	25,000 LE	0	0	25,000 LE	150,000 LE
UI and UX design	6,000 LE	1,000 LE	0	3,000 LE	0	10,000 LE
Server	12,000 LE	13,000 LE	15,000 LE	17,000 LE	20,000 LE	77,000 LE
Animation and Illustration	2,000 LE	1,000 LE	0	0	1,000 LE	4,000 LE
Upload on google play store	750 LE	0	0	0	0	750 LE
Hardware Design and Testing	0	10,000 LE	0	0	0	10,000 LE
Total development costs	**125,750 LE**	**58,000 LE**	**17,500 LE**	**22,500 LE**	**48,200 LE**	**271,750 LE**
Marketing and sales costs Market						
research and analysis	0	15,000 LE	15,000 LE	10,000 LE	20,000 LE	60,000 LE
Advertisement and promotion	0	75,000 LE	50,000 LE	30,000 LE	25,000 LE	180,000 LE
Sales team and expenses	0	0	30,000 LE	35,000 LE	40,000 LE	105,000 LE
Total marketing and sales costs	**0**	**90,000 LE**	**95,000 LE**	**75,000 LE**	**85,000 LE**	**345,000 LE**
Operational costs						
Employee salaries and benefits	9,000 LE	18,000 LE	24,000 LE	26,000 LE	33,000 LE	110,000 LE
Office rent and utilities	0	50,000 LE	120,000 LE	120,000 LE	120,000 LE	410,000 LE
Legal and insurance expenses	0	15,000 LE	10,000 LE	5,000 LE	5,000 LE	35,000 LE
Total Operation costs	**9,000 LE**	**83,000 LE**	**154,000 LE**	**151,000 LE**	**158,000 LE**	**555,000 LE**
Total Project costs	**134,750 LE**	**231,000 LE**	**266,500 LE**	**248,500 LE**	**291,200 LE**	**1,171,950 LE**
Net benefits(Total Benefits-Total Costs)	**(134,750 LE)**	**79,000 LE**	**458,500 LE**	**866,500 LE**	**1,086,000 LE**	**2,355,250 LE**
Cumulative Net Cash Flow	**(134,750 LE)**	**(55,750 LE)**	**402,750 LE**	**463,750 LE**	**622,250 LE**	
Return on Investment (ROI)	**200,96%**					
Break-Even Point	**1,12 Years**					

A ROI of 200.96% means that the net profit of the investment in Vitalism is 200.96% of its initial cost. In other words, if the initial cost of the investment was 100 LE, then the net profit would be 200.96 LE.

The break-even point is the point at which the cost of an investment is equal to its revenue. It is the point at which the investment will start to generate profit. A break-even point of 1.12 years means that it will take 1.12 years for the investment in Vitalism to reach the point where the cost of the investment is equal to its revenue. Beyond this point, the investment will generate profit.

2.4.3 Organizational Feasibility

Vitalism is a new mobile application aimed at revolutionizing the way people measure their vital signs. The application measures vital signs such as pulse rate, blood oxygen levels, and respiration rate through a user's smartphone camera. The objective of this feasibility study is to evaluate the organizational viability of the Vitalism project.

Market Demand:

There is a growing demand for non-invasive and accessible methods of measuring vital signs. Traditional methods of measuring vital signs require the use of specialized equipment and trained personnel. However, the availability of smartphones and advancements in technology have made it possible to measure vital signs in a non-invasive and convenient manner. This growing demand presents a significant opportunity for Vitalism.

Investment:

The investment required for the Vitalism project is considered significant in the medical sector, as it involves investing in and saving the cost of traditional machines used in hospitals to measure vital signs. Additionally, for the application to be used on a regular basis, it must be downloaded to the user's personal phone, providing a return on investment for the platform affiliated with the application or for those who purchase it.

Marketing Plan:

The Vitalism team has developed a comprehensive marketing plan to promote the application and reach its target audience. The application will be uploaded to a marketing platform and made available for anyone who wants to use it. The marketing plan includes various strategies to raise awareness of the application, such as digital advertising and social media promotions.

Labor Market:

The current labor market presents a favorable environment for the success of the Vitalism project. The growing demand for non-invasive and accessible methods of measuring vital signs combined with the marketing plan developed by the Vitalism team, increase the likelihood of success in the market.

2.5 The Interviews

We have conducted several interviews with some people to understand some of the difficulties they encounter in measuring vital signs, to know their needs to measure these vital signs, and to know their opinion on the Vitalism project.

The interviews were of different ages and people with different jobs in order to get acquainted with the various ideas that helped us develop the project and try to overcome the problems facing these people.

Interview 1

Person interviewed : Mohammed Ahmed

Director: Medical user

Interviewer: Nourhan Ahmed

Summary of interview : he asked some questions like:

1-whether measuring vital signs is important, and he answered, “Yes , its measurement is very important, because it may prevent a lot of damage.

2- “Do you do annual blood tests for you and your family ” ? and he answered “Yes “

3- Do you monitor your vital signs regularly ,he answered “No”.

4- Do you prefer to monitor the health of you and your family at home or in the hospital? he answered, “At hospital”.

5- What could be an obstacle to you in periodically monitoring your vital signs ?, he answered “There isn't much time for regular check-ups and some medical units aren't actually well equipped for such a thing and even if these units do have the required equipment, it'll be too crowded and probably full of undetected diseases. So I'd prefer not to go there unless absolutely necessary, which could be too late if I do have some sort of a health problem.”

6 Do you think you need an alarm for your health condition? he answered “Yes”.

Interview 2

Person interviewed : Ali Mohammed

Director: Professor

Interviewer: Mahmoud Alyosify

Summary of interview: he asked some questions like:

1-whether measuring vital signs is important, and he answered, “Yes, its important”.

2- “Do you do annual blood tests for you and your family ,?and he answered “NO”

3- Do you monitor your vital signs regularly ,he answered “Yes”.

4- Do you prefer to monitor the health of you and your family at home or in the hospital? he answered, “At Home”.

5- What could be an obstacle to you in periodically monitoring your vital signs ?, he answered “waiting at hospital(time)”

6 Do you think you need an alarm for your health condition? He answered “Yes”.

Interview 3

Person interviewed : Mahmoud Ali

Director: Student

Interviewer: Menna Mahmoud

Summary of interview: he asked some questions like:

1-whether measuring vital signs is important, and he answered, "Yes, its measurement is very important, because it may prevent a lot of damage".

2- Do you do annual blood tests for you and your family ? ,and he answered "Yes"

3- Do you monitor your vital signs regularly ,he answered "No".

4- Do you prefer to monitor the health of you and your family at home or in the hospital? he answered, "At home".

5- What could be an obstacle to you in periodically monitoring your vital signs ?, he answered "The cost and Time".

6 Do you think you need an alarm for your health condition? he answered "Yes".

Questionnaires

1-how old are you?

2-what is the gender?

3-Do you suffer from any health problems?

4-Do you monitor your vital signs regularly?

5- Do you prefer to monitor the health of you and your family at home or in the hospital?

6- How important is it to monitor vital signs periodically?

7- What could be an obstacle to you in periodically monitoring your vital signs?

8-Do you think that you need an alarm for your health condition?

Details notes:

1-Most of the users suffer from the problem of time when going to the hospital.

2-Also, one of the common problems in measuring vital signs is the continuity of measuring them and the need to measure them continuously.

2.6 Definition of Requirements

The requirements of the Vitalism project can be defined as the essential elements and functionalities that must be present in the application in order to achieve its objectives. The Vitalism application must meet both functional and non-functional requirements in order to be successful.

2.6.1 Functional Requirements

The functional requirements specify the specific functions or capabilities that the system must have, such as the ability to determine the Region of Interest (ROI) on the face, track the ROI throughout the video, measure vital signs like Heart rate (HR), Heart rate variability (HRV), Oxygen saturation (SpO2), Respiratory rate (RR), and Blood Pressure (BP), store and access patient's electronic medical records, and display the vital signs results with minimal error.

2.6.2 Non-Functional Requirements

The non-functional requirements specify the quality attributes of the Vitalism application, such as its usability, reliability, performance, and security. These requirements describe how the system must behave and how well it must perform and are critical for ensuring that the system meets the expectations of its users and stakeholders. The non-functional requirements include having a user-friendly interface, accessibility and convenience for all age groups, secure storage and protection of personal medical information, a high level of user satisfaction, compatibility with multiple devices, fast and reliable performance even in areas with limited internet access, and compliance with relevant privacy and security regulations.

2.7 Use Cases

These use cases are examples of how the Vitalism application can be used to improve healthcare outcomes and support patient care. By providing real-time monitoring and tracking of vital signs, the Vitalism application will help healthcare professionals make informed decisions and improve patient outcomes. Vitalism's use cases describe a sequence of Action at system as shown in Figure 35, and it's divided into the following use cases:

1- Sign up.
2- Remote Patient Monitoring.
3- Telehealth.
4- Virtual Trials.
5- Medication Adherence.
6- Patient Triage.
7- Elderly Care.
8- Monitoring of children.
9- Measurement of a wider range of vital signs.

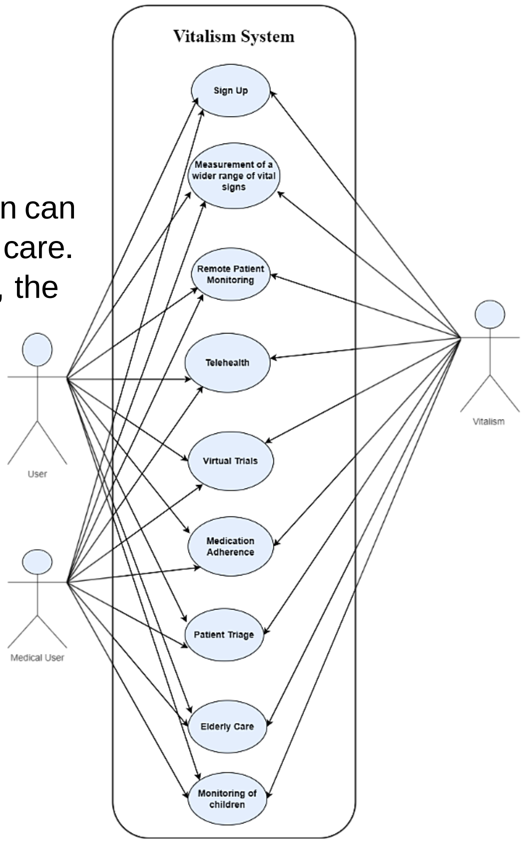


Figure 35: UML Diagram Describing Vitalism Actions.

1- Sign Up Use Case.

In this use case, users can sign up for the Vitalism application by creating an account. This can be done through a social media login or by entering basic personal information. This allows the user to access the application's features and track their vital signs over time.

Use case: Sign up	**ID:** UC -1	**Priority:** High

Actor: User

Description: This use case describes how will the user registers an account

Trigger: The user wants to create an account at Vitalism System.
Type: ☑External ☐Temporal

Preconditions:
The user has access to the internet and a device capable of accessing the Vitalism System website or application.
User will register for the first time.
The user's device must have a camera in good condition.

Normal Course:	**Information for Steps:**
1. The use case starts when the user clicks the “Sign Up” tab on the navigation bar.	
2. The user navigates to the signup page, enters their personal information, such as name, email, and password, and creates an account.	user ‘s name, birth of data, gender, blood type, marital status, weight, height, diseases,
3. The user keys in the details and clicks “Sign Up” button.	
4. The system notifies the User that the account has been created.	
5. The system displays the user’s profile page.	Message will show from the system .

Alternative courses:	
1.1 User Enters Invalid User Account Information (branch at step 3)	
1.2 user has already an account :	
1. The user clicks the “ log in ” tab on the navigation bar	
2. The user will enter his information (Email & password)	Email & password
3. The system displays the user’s profile page.	Message will show from the system .
1.3 The user may choose to sign up using their social media account, such as Facebook or Google, instead of creating a new account.	

Postconditions:
1. The user’s details are stored in the database.
2. The user has a new account, can access the features of the Vitalism System, and can be identified as a registered user.

Exceptions:

1. The user may not have internet access, or the website or application may not be working properly preventing them from being able to create an account.
2. Error entering information.

Summary Inputs	**Source**	**Outputs**	**Destination**
Username gender medical data about user blood type diseases email password weight & height	User	1- A new account 2- Registered user status	Vitalism System database for storing user information.

2- Measurement of a Wider Range of Vital Signs Use Case.

In this use case, the Vitalism application can be used to measure a wider range of vital signs, including heart rate, respiratory rate, heart rate variability, blood pressure, and oxygen saturation. This allows healthcare providers to have a comprehensive view of the patient's health and make informed decisions accordingly.

Use case: Measurement of a Wider Range of Vital Signs	**ID:** UC -2	**Priority:** High

Actor: Measurement of a wider range of vital signs

Description: The system can be used to measure a wider range of vital signs such as Heart Rate, Heart Rate Variability, and Oxygen Saturation

Trigger: The need to measure a wider range of vital signs beyond the traditional ones.
Type: ☑External ☐Temporal

Preconditions:
1. The system must be properly calibrated.
2.Calibrated devices must be available to measure the additional vital signs.

Normal Course: 1-User login to the system 2-User chooses which vital sign would like to measure. 3-The system measures a wider range of vital signs such as Heart Rate, Heart Rate Variability, and Oxygen Saturation ← 4-The system stores the measurement to patient's Electronic medical record →	**Information for Steps:** Patient's vital sign data Measurements of a wider range of vital signs
Alternative courses: 1.1 The system can be used to measure additional vital signs using different devices or methods, such as using a smartphone camera to measure heart rate. (Branch at step 2)	

Postconditions:
1. The system provides accurate and reliable measurements of a wider range of vital signs.

Exceptions:
E1: If the system or the devices used for measurement are not properly calibrated or malfunction, it will not be able to provide accurate measurements.

Summary Inputs	**Source**	**Outputs**	**Destination**
User's Video data (ROI)	Devices used to measure vital signs.	Measurements of a wider range of vital signs	Medical staff and patients' medical records.

3- Remote Patient Monitoring Use Case.

Patients can remotely monitor their vital signs using the Vitalism application. The application uses cutting-edge technology to accurately track and display the user's vital signs, allowing them to keep track of their health without having to visit a hospital.

Use case: Remote Patient Monitoring	**ID:** UC -3	**Priority:** High

Actor: User

Description: The Vitalism System can be used for remote monitoring of patients' vital signs, allowing doctors and caregivers to keep track of their patients' health status without the need for in-person visits. This can be particularly useful for patients with chronic conditions, elderly patients, or patients who live in remote areas.

Trigger: the need for remote monitoring of patients' vital signs.
Type: ☑ External ☐ Temporal

Preconditions:
1. The patient must have the Vitalism System installed on their device and be registered as a user.
2. The patient must also have provided consent for remote monitoring.

Normal Course:	**Information for Steps:**
1. The doctor or person who wants to follow up on the user can search for the username.	Username
2. Then he sends a follow-up request by pressing the Follow-up button.	
3. Then a notification will be sent to the user that there is someone who would like to follow him.	Notification for the user.
4. The user accepts or rejects the follow-up.	
5. The user accepts.	
6. A notification will be sent to the doctor or follower that the follow-up has been accepted.	Notification for the follower. .
7. The follower is allowed to enter the user account.	
8. The doctor can follow the user's vital signs.	
9. He can also make a message to the user.	

Alternative courses:	
1.1 The user refused to continue. Thus, the person is not allowed to follow the user.	
1.2 Typing the username when searching is wrong(step 1)	Username
1.3 Remote monitoring can also be conducted through other devices such as wearables or traditional medical devices.	

Postconditions:
1. The doctor can view the user's account.
2. The user can follow his doctor remotely and quickly.
3. The patient's vital signs have been successfully captured and transmitted, and doctors and caregivers have been provided with a better understanding of the patient's health status.

Exceptions:

In cases where the patient is unable to use the system or does not provide consent for remote monitoring, traditional in-person visits may be necessary.

Summary Inputs	**Source**	**Outputs**	**Destination**
Patient's face video captured by camera . patient's consent for remote monitoring.	Patient's smart phone camera.	Vital sign data, patient's health status	Cloud platform for processing and doctors and caregivers for monitoring.

4- Telehealth Use Case.

In this use case, patients can consult with their healthcare provider via the Vitalism application. The application allows the healthcare provider to view the patient's vital signs in real-time, allowing them to make informed decisions about the patient's health and provide guidance accordingly.

Use case: Telehealth	**ID:** UC -4	**Priority:** High

Actor: Patient

Description: This use case describes the use of the system for telehealth consultations, in consultation with doctors, and improving access to health care for patients.

Trigger: the patient's desire to have a telehealth consultation with their doctor.
Type: ☑External ☐ Temporal

Preconditions:
1. The user must have a registered account with the Vitalism System
2. Having access to a device with a camera.
3. Having a scheduled appointment with their doctor.
4. Doctor must have access to the account and data of the user who wants to consult.

Normal Course:	**Information for Steps:**
1. The user logs into the Vitalism System	→ Info for login
2. The patient measures their vital signs.	→ Vital signs
3. If the vital signs are dangerous or unstable, the user in this case consults the doctor to help him.	→ Call request to doctors or follower.
4. The doctor or follower can view the patient's vital signs in real-time and conduct the consultation remotely**.**	←
5. If the measurements are not dangerous or normal, it is not necessary to contact the doctor or the emergency **.**	Consultation

Alternative courses:	
1. The patient may be unable to provide real-time vital sign measurements 1.1In this case the consultation would proceed without that information.	
2. The doctor or follower does not answer.	→ Call Emergency
2.1 The application makes an emergency call to the hospital and ambulance to take necessary measures.	← Ambulance

Post conditions:
1. The patient's vital sign measurements and telehealth consultation are recorded in their electronic medical record.
2. The doctor can make any necessary recommendations or adjustments to the patient's treatment plan.
3. The Emergency call and arrival of the ambulance to the rescue .

Exceptions:
1. If the patient's device or internet connection is not working properly.
2. The telehealth consultation may be delayed or unable to proceed.
3. The patients does not enable any doctor for his Account .

Summary Inputs	**Source**	**Outputs**	**Destination**
1.The user's login information 2.Call request to doctor 3.Real-time vital sign measurements	1.User 2.The patient's device 3.phone Camera	1.The patient's vital sign measurements 2.Telehealth consultation results	1.The patient's electronic medical record 2.user

5- Virtual Trials Use Case.

In this use case, researchers can use the Vitalism application to access data for use in research studies. This allows them to collect data in a non-invasive manner, while still gaining valuable insights into the health and wellness of participants.

Use case: Virtual Trials	**ID:** UC -5	**Priority:** Low

Actor: Researcher or Study sponsor

Description: This use case describes conduct virtual clinical trials, allowing researchers to collect vital sign data from participants remotely**.**

Trigger: researcher or study sponsor wants to conduct a virtual clinical trial using the Vitalism System.
Type: ☑External ☐ Temporal

Preconditions:
1. Participants in the study have access to a device with a camera, such as a smartphone, that can be used to capture face videos.
2. Participants must be willing and able to provide consent to participate in the study and have their vital sign data collected and used for research purposes.

Normal Course:	**Information for Steps:**
1. Participants in the study would use the device with a camera to capture face videos.	→ Face videos
2. Face videos would be streamed to the back-end cloud platform for processing.	→ Face videos processed.
3. The deep learning-based face landmarks prediction model would process the video frames and calculate the vital signs.	
4. The researchers would then have access to the collected data to analyze and use for their study.	→ Vital signs
Alternative courses: **1.**Instead of using face videos(step 1) 1.1 Researchers could also use other forms of remote monitoring such as wearable devices or self-reported data, to collect vital sign data from participants.	→ Vital signs

Post conditions:
1. The study is completed, and the researchers have collected vital sign data from participants remotely, which can be used for their research.

Exceptions:
1. If the participants are not able to provide consent or unable to provide face videos
2. The study cannot be conducted using the Vitalism System.

Summary Inputs	**Source**	**Outputs**	**Destination**
1. Face videos captured using a device with a camera, such as a smartphone.	1. User	1. Vital signs data calculated from the face videos by the deep learning-based face landmarks prediction model.	1. Researchers conducting the study.

6- Medication Adherence Use Case.

In this use case, healthcare providers or caregivers can use the Vitalism application to monitor a patient's medication adherence. The application can send reminders to the patient or alert the provider if the patient is not taking their medication as prescribed.

Use case: Medication Adherence	**ID:** UC -6	**Priority:** High

Actor: patient

Description: This use case describes the feature of monitor patients' vital signs and medication adherence, alerting caregivers and doctors if there are any issues. This can help to improve patient outcomes and reduce costs associated with non-adherence.

Trigger: A patient begins taking medication as prescribed by their doctor and measure his vital signs
Type: ☑ **External** ☐ **Temporal**

Preconditions:
1-The patient must have an account with the Vitalism system
2-Patient’s medication regimen must be entered into the system by a healthcare professional.

Normal Course:	**Information for Steps:**
1. patients log in to the system.	
2. Choose the calendar button.	
3. Enter the medicine name and time of taking it.	Name of medicine and time
4. Choose vital sign and time.	Vital sign and time
5. He can modify any record.	
6. He can choose number of times to be reminded.	
7. patients click confirm.	
8. System shows message of confirmation.	improved medication adherence
9. The system continuously monitors the patient's vital signs and medication adherence.	
10. System will alert caregivers and doctors if there are any issues with medication non-adherence.	

Alternative courses:	
1.1 patient enter name of medicine which it isn't suitable for him (branch at step 3)	Medicine name
1. System show message that it isn't suitable for him and give him another one	Alerts or notifications of non-adherence
2. System alerts caregivers and doctors monitoring the patient’s health status	
3. Return to Normal Course (step 4)	

Postconditions:

1. patient's medication adherence is improved.
2. Patient’s healthcare team is able to intervene early if there are any issues.

Exceptions:
E1:If the patient does not have access to the system or does not comply with the system's prompts, the system will not be able to monitor adherence.

Summary Inputs	**Source**	**Outputs**	**Destination**
Medicine name Vital sign name	patient Patient	improved medication adherence Alerts or notifications of non-adherence	patient Caregivers and doctors monitoring the patient's health status.

7- Patient Triage Use Case.

In this use case, patients can use the Vitalism application to track their vital signs and assess their health status. This allows patients to stay informed about their health and seek medical attention if necessary.

Use case: Patient Triage	**ID:** UC -7	**Priority: Medium**

Actor: Caregivers

Description: This use case describes the feature of patient triage, allowing doctors and caregivers to quickly assess the health status of patients and prioritize those who need the most urgent attention.

Trigger: A patient arrives at a medical facility and needs to be assessed for their health status.
Type: ☑External ☐ Temporal

Preconditions:
1- The user is registered
2-the user has the authority of following up the patients.
3-The patient has consented to having their vital signs measured and recorded, and the medical facility has access to the Vitalism System.

Normal Course:	**Information for Steps:**
1-The patient's vital signs are measured and recorded using the Vitalism System	Patient's vital signs
2-Data is analyzed to assess the patient's health status	
3-The patient is then triaged based on the results, with those in the most urgent need of attention prioritized.	Patient's health status, triage level
4-caregiver login to the system	
5-Showing patient's Electronic Medical Records	
Alternative courses: 1.1The patient's vital signs could be measured and recorded using other methods, such as traditional medical equipment, or the patient could be triaged based on different criteria (branch at step 1) 1-caregivers will record these measurements	

Postconditions:
1. The patient has been triaged and the medical staff has a better understanding of the patient's health status.

Exceptions:
E1: The patient is unwilling or unable to have their vital signs measured, or the Vitalism System is not available or not functioning properly.

Summary Inputs	Source	Outputs	Destination
Patient's vital signs	Vitalism System	Patient's health status, triage level	Medical staff responsible for triaging patients.

8- Elderly Care Use Case.

In this use case, the Vitalism application can be used to provide care for elderly individuals. The application can continuously monitor their vital signs, allowing caregivers to respond quickly in case of any emergencies or changes in health status.

Use case: Elderly Care	**ID:** UC -8	**Priority:** High

Actor: User.

Description: The system can be used to monitor the vital signs of elderly patients, alert caregivers and family members if there are any issues and provide them with a better understanding of their loved one's health status.

Trigger: The use case is triggered when an elderly patient requests for monitoring of vital signs.
Type: ☑External ☐Temporal

Preconditions:
1. The patient or the caregiver must have a registered account on the Vitalism System, and the patient must have agreed to the monitoring of their vital signs.

Normal Course:	**Information for Steps:**
6. The system captures the video of the patient's face using a smartphone camera and processes the video to extract vital signs such as heart rate, respiratory rate, and oxygen saturation.	Vital Signs
7. The system then alerts the caregivers and family members if there are any issues with the patient's vital signs.	Alerting
Alternative courses:	
4. The system can also provide an option for caregivers to monitor multiple patients at the same time.	
5. The system can also provide an option for caregivers to set thresholds for vital signs, and alerts will be sent only when the thresholds are exceeded.	

Postconditions:

1. The caregivers and family members are provided with a better understanding of their loved one's health status and any issues with the vital signs are addressed in a timely manner.

Exceptions:

1. The system may not be able to extract vital signs if the video quality is poor.

2. If the patient is not cooperative during the video capture process, the system may not be able to extract accurate vital signs.

Summary Inputs	**Source**	**Outputs**	**Destination**
-Video of the patient's face captured using a smartphone camera.	-Smartphone camera.	-Vital signs such as heart rate respiratory rate oxygen saturation -Store Vital sign	-Caregivers and family members -Vital Sign

9- Monitoring of Children Use Case.

In this use case, the Vitalism application can be used to monitor the vital signs of children. The application stores the data in the electronic medical record (EMR) and continuously tracks the child's vital signs, allowing parents and healthcare providers to assess their health and growth.

Use case: Monitoring of Children	**ID:** UC -9	**Priority:** High

Actor: user has children

Description: The system can also be used to monitor the vital signs of children by scanning their faces, to detect any health problems and send alerts to their parents.

Trigger: The trigger for this use case is the need to monitor the vital signs of children in a non-invasive way.

Type: ☑ External ☐ Temporal

Preconditions:

1. The parent has children account for his children to store his children 's vital signs in EMR.

Normal Course:	**Information for Steps:**
1. scanning the faces of children to detect any health problems. →	Vital Signs
2. Send alerts to their parents if any issues are detected. →	Alert

Alternative courses:

1. Use a stationary device in the child's room that captures vital sign data and sends alerts to parents.
2. Using a mobile application or a web portal for real-time monitoring of the child's vital signs.
3. Send notifications to the parents or caregivers in case of any abnormalities.

Postconditions:

1. would be the detection of any health problems in children.
2. the ability to send alerts to their parents.

Exceptions:

1. would include technical difficulties with the technology used to detect health problems.
2. issues with the accuracy of the scans.

Summary Inputs	**Source**	**Outputs**	**Destination**
-The scans of children's faces and the technology used to detect health problems.	- stationary device -EMR	-Vital signs	-EMR -Smart phone

2.8 Management Plan

The Management Plan for Vitalism is an essential part of the project to ensure its success. It outlines the steps to be taken in organizing the work and minimizing mistakes that could occur. By following the management plan, the team will be able to move forward in a structured and organized manner towards the successful completion of Vitalism.

This plan is designed to provide a clear understanding of the project's objectives, as well as the resources, time, and budget required to achieve those objectives. The management plan also defines the roles and responsibilities of the project team members and outlines the communication plan to keep everyone informed and on track. This plan is essential for ensuring that the Vitalism project is completed successfully, within the given timeframe and budget constraints.

2.8.1 Current State of the Project

The current state of the project highlights the progress made so far, including the completion of documentation, UI/UX, and the start of implementation to extract heart rate. Additionally, preparations are underway for the website presentation and the Front-End Android.

2.8.2 Phases

The management plan for Vitalism consists of a series of phases, each with specific tasks and objectives. The goal of each phase is to bring the project closer to completion and ensure that it meets the desired standards as shown in Figure 36. The phases include:

Phase 1: Project initiation and research. This phase involves deciding the subject of the project, identifying the problem, and conducting a literature survey of related work in the field of RPPG, PPG, EVM, and other relevant topics.

Phase 2: Planning and documentation. During this phase, the team will review the related work, plan the methodology, and complete the first chapter of the documentation, which includes the project proposal.

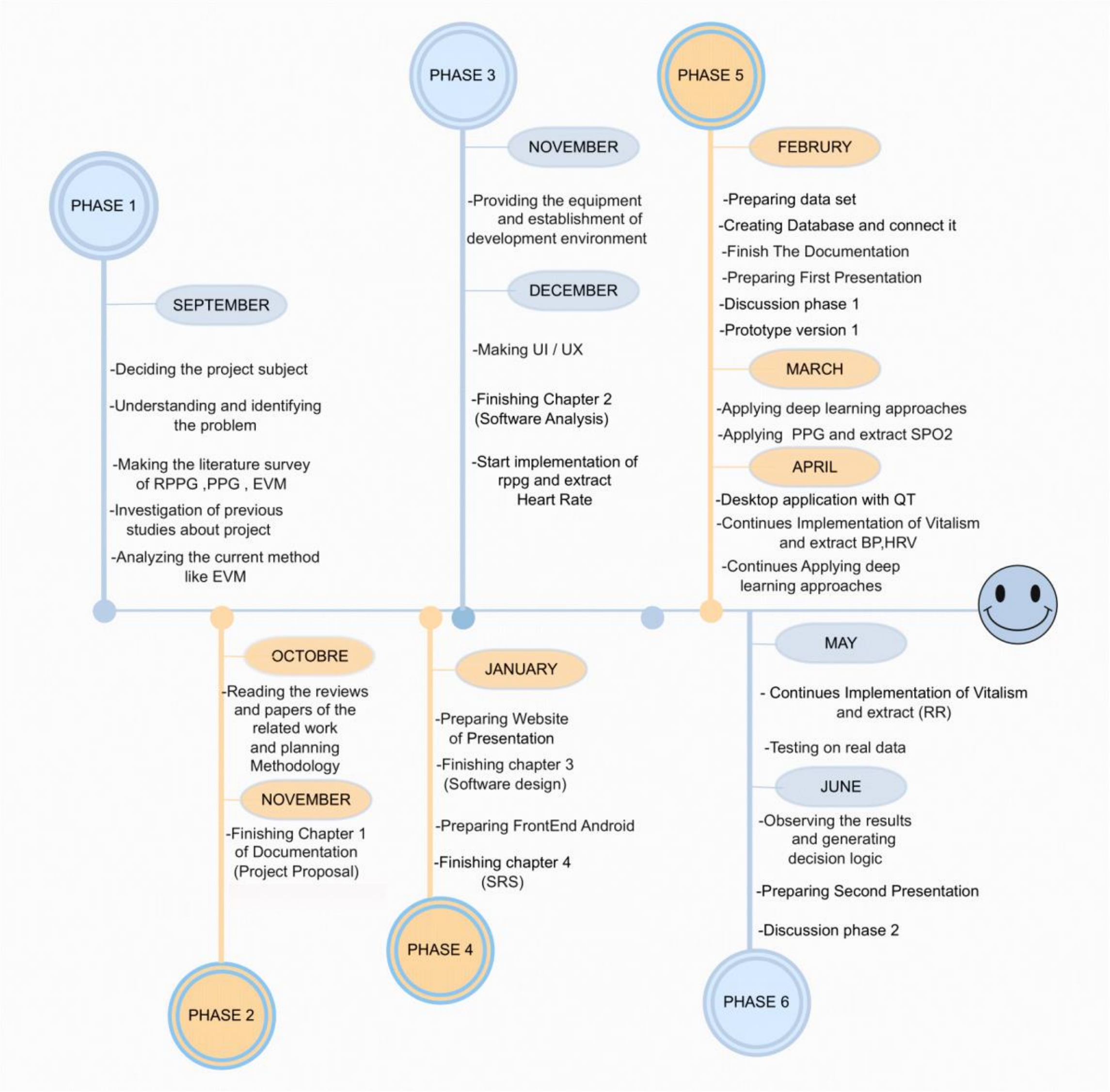
Phase 3: Development environment setup and implementation. In this phase, the team will provide the equipment, establish the development environment, design the UI/UX for the mobile application, and begin the implementation of RPPG to extract heart rate.

Phase 4: Front-end development and system requirements. The team will prepare the website for presentation, complete the software design and system requirements, and prepare the front-end for the Android application.

Phase 5: Data preparation and prototype development. The team will prepare the data set, create the database, finish the documentation, prepare the first presentation, and create the first prototype. They will also apply deep learning approaches to extract SPO2 and BP and HRV, and develop a desktop application using QT.

Phase 6: Testing and second presentation. In the final phase, the team will continue the implementation of Vitalism to extract RR, test with real data, observe the results, and generate decision logic. They will also prepare the second presentation.

Each phase will be managed carefully to ensure that the project stays on track and that the goals are achieved.



PHASE 1

SEPTEMBER

-Deciding the project subject

-Understanding and identifying the problem

-Making the literature survey of RPPG ,PPG , EVM

-Investigation of previous studies about project

-Analyzing the current method like EVM

PHASE 2

OCTOBRE

-Reading the reviews and papers of the related work and planning Methodology

NOVEMBER

-Finishing Chapter 1 of Documentation (Project Proposal)

PHASE 3

NOVEMBER

-Providing the equipment and establishment of development environment

DECEMBER

-Making UI / UX

-Finishing Chapter 2 (Software Analysis)

-Start implementation of rppg and extract Heart Rate

PHASE 4

JANUARY

-Preparing Website of Presentation

-Finishing chapter 3 (Software design)

-Preparing FrontEnd Android

-Finishing chapter 4 (SRS)

PHASE 5

FEBRURY

-Preparing data set

-Creating Database and connect it

-Finish The Documentation

-Preparing First Presentation

-Discussion phase 1

-Prototype version 1

MARCH

-Applying deep learning approaches

-Applying PPG and extract SPO2

APRIL

-Desktop application with QT

-Continues Implementation of Vitalism and extract BP,HRV

-Continues Applying deep learning approaches

PHASE 6

MAY

- Continues Implementation of Vitalism and extract (RR)

-Testing on real data

JUNE

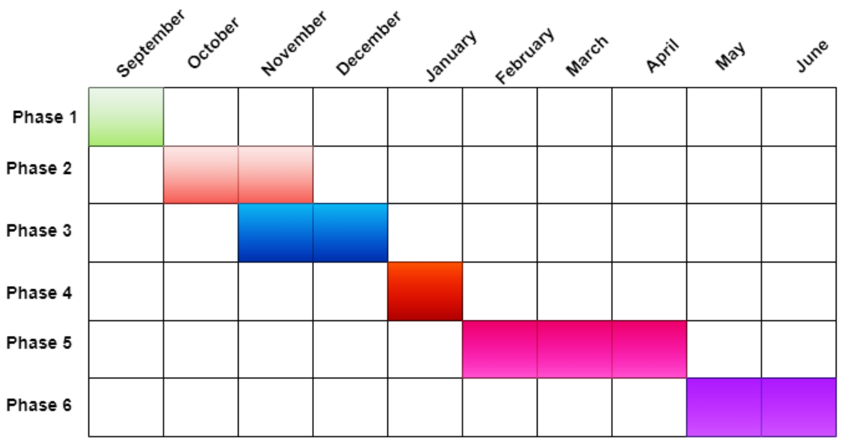
-Observing the results and generating decision logic

-Preparing Second Presentation

-Discussion phase 2

Figure 36: Phases and Timeline of Vitalism Project .

2.8.3 Gantt Chart & Timeline



	September	October	November	December	January	February	March	April	May	June
Phase 1	🟩									
Phase 2		🟥	🟥							
Phase 3			🟦	🟦						
Phase 4					🟧					
Phase 5						🟪	🟪	🟪		
Phase 6									🟪	🟪

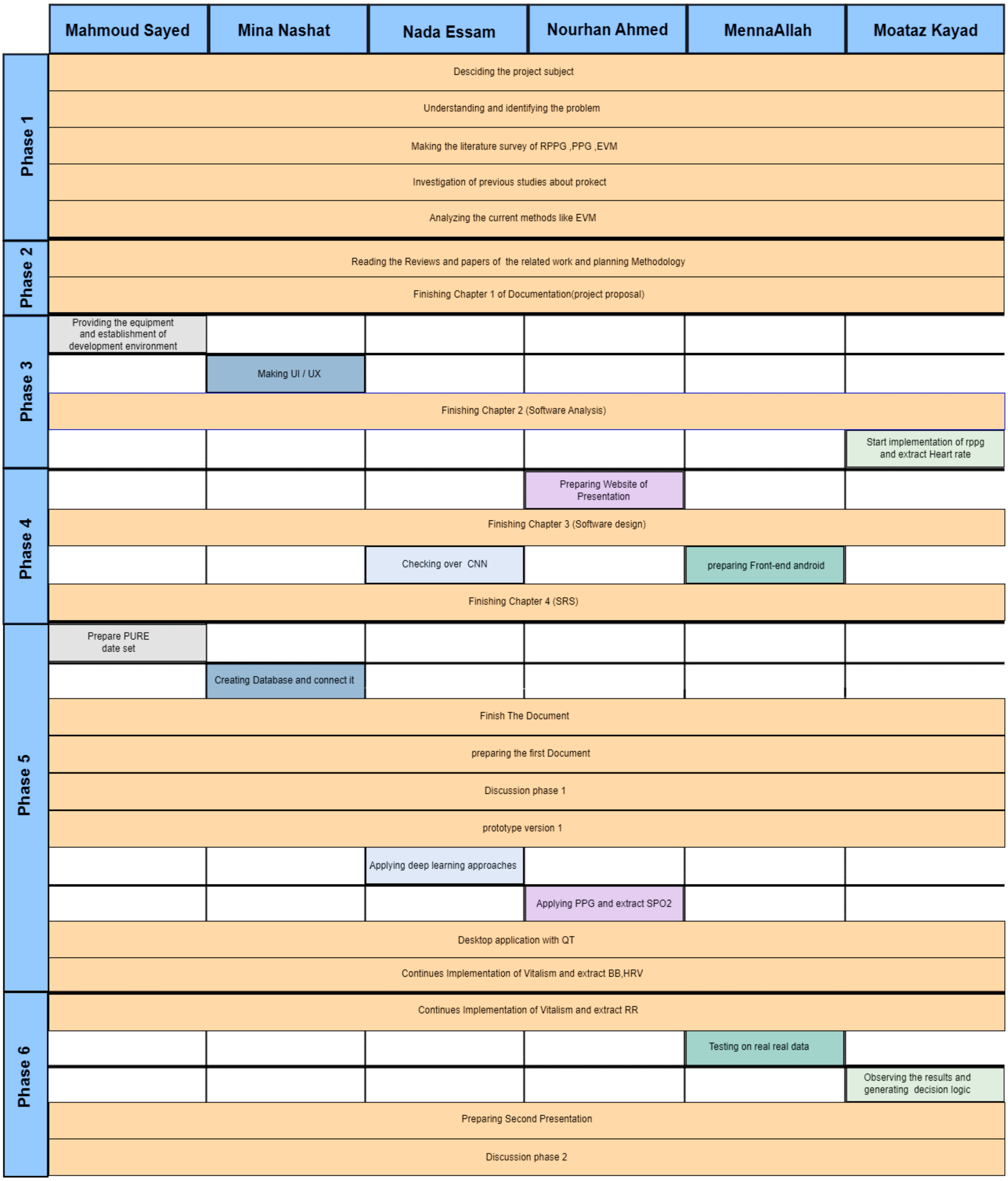
Figure 37: The Gantt Chart of General Management and Time Plan of Vitalism Project .

2.8.4 Task plan with Milestones

	Task Description	Expected Output	2022				2023					
			Sep	OCt	Nov	Dec	Jan	Feb	MaR	APr	May	Jun
1	Deciding the project subject.	Researching project subjects, checking existing solutions, discussing improvement ideas	✓									
2	Understanding and identifying the problem	Focusing on the fundamentals of the problem, determining the solution's impact area, examining existing studies and solutions	✓									
3	Making the literature survey of RPPG,PPG,EVM	Understanding the RPPG, PPG, EVM Algorithms	✓									
4	Investigation of previous studies about the project	Understanding the solution methods of current approaches and understanding the problems they cannot solve	✓									
5	Analyzing the current method like EVM.	Understanding the EVM method and how help in solving our problem		✓								
6	Reading the reviews ,papers of the related work and planning Methodology	Preparation and delivery of the document		✓								
7	Finishing Chapter 1 of Documentation (Project Proposal)	Preparation and delivery of the Problem statement, Objectives, System Overview, and Methodology of our project			✓							
8	Provision of equipment & Establishment of development environments	Selection of computers and Mobiles phone with suitable cameras and installation of environments required for developers			✓							
9	Making UI / UX	Finishing user interface of the project				✓						
10	Finishing Chapter 2 (Software Analysis)	Defining Scope of the Project, Target User Groups, System Requirement, Feasibility study, Interviews, Functional and non-functional Requirements, Management Plan				✓						
11	Start implementation of rPPG and extract Heart Rate	Finishing rPPG implementation and extract Hear rate				✓						
12	Preparing Website of Presentation	Finishing website page for presentation					✓					
13	Finishing chapter 3 (Software design)	Preparation System Architecture, Data Design, components Design, and Requirements matrix					✓					
14	Preparing Front-end Android	Finishing Front-end of android application					✓					
15	Finishing chapter 4 (SRS)	Defining Overall Description, System Features, and Business Rules					✓					
16	Ask to get PURE dataset from Technische Universität Ilmenau	Finding datasets suitable for use in rPPG studies and permitted for use in academic studies, taking necessary permissions.						✓				
17	Creating Database and connecting it	Preparation of database						✓				
18	Finish The Documentation	Completing the final work, preparing documents						✓				
19	Preparing First Presentation	Presenting the final version of the project and its results						✓				
20	Prototype version 1	Delivery of heart rate and UI design						✓				
21	Applying deep learning approaches	Understanding and applying deep learning approaches and discussing the expected improvement							○			
22	Applying PPG and extract SPO2	Finishing extracting oxygen saturation							○			
23	Desktop application with QT	Preparation of desktop GUI								○		
24	Continues Implementation of Vitalism and extract BP and HRV	Finishing extracting Blood Pleasure and Heart Rate Variability								○		
25	Continues Applying deep learning approaches	Continues Understanding and applying deep learning approaches and discussing the expected improvement.								○		
26	Continues Implementation of Vitalism and extract (RR)	Finishing extracting Respiratory Rate									○	
27	Testing on real data	Testing the project with live subjects simultaneously using a pulse oximeter and recording results, observing the results, and measuring the accuracy									○	
28	Observing the results and generating decision logic	Preparation and delivery of Vitalism Application										○

2.8.5 Division of Responsibilities Among Team Members

Division of Responsibilities Among Team Members is an important aspect of the Management Plan for the Vitalism project. This helps to ensure that every team member understands their role and responsibilities, and it also helps to distribute the workload evenly as shown in Figure 38,39.



<table>
<tr><th></th><th>Mahmoud Sayed</th><th>Mina Nashat</th><th>Nada Essam</th><th>Nourhan Ahmed</th><th>MennaAllah</th><th>Moataz Kayad</th></tr>
<tr><td rowspan="5">Phase 1</td><td colspan="6">Desciding the project subject</td></tr>
<tr><td colspan="6">Understanding and identifying the problem</td></tr>
<tr><td colspan="6">Making the literature survey of RPPG ,PPG ,EVM</td></tr>
<tr><td colspan="6">Investigation of previous studies about prokect</td></tr>
<tr><td colspan="6">Analyzing the current methods like EVM</td></tr>
<tr><td rowspan="2">Phase 2</td><td colspan="6">Reading the Reviews and papers of the related work and planning Methodology</td></tr>
<tr><td colspan="6">Finishing Chapter 1 of Documentation(project proposal)</td></tr>
<tr><td rowspan="4">Phase 3</td><td>Providing the equipment and establishment of development environment</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Making UI / UX</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Finishing Chapter 2 (Software Analysis)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Start implementation of rppg and extract Heart rate</td></tr>
<tr><td rowspan="4">Phase 4</td><td></td><td></td><td></td><td>Preparing Website of Presentation</td><td></td><td></td></tr>
<tr><td colspan="6">Finishing Chapter 3 (Software design)</td></tr>
<tr><td></td><td></td><td>Checking over CNN</td><td></td><td>preparing Front-end android</td><td></td></tr>
<tr><td colspan="6">Finishing Chapter 4 (SRS)</td></tr>
<tr><td rowspan="10">Phase 5</td><td>Prepare PURE date set</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Creating Database and connect it</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Finish The Document</td></tr>
<tr><td colspan="6">preparing the first Document</td></tr>
<tr><td colspan="6">Discussion phase 1</td></tr>
<tr><td colspan="6">prototype version 1</td></tr>
<tr><td></td><td></td><td>Applying deep learning approaches</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td>Applying PPG and extract SPO2</td><td></td><td></td></tr>
<tr><td colspan="6">Desktop application with QT</td></tr>
<tr><td colspan="6">Continues Implementation of Vitalism and extract BB,HRV</td></tr>
<tr><td rowspan="5">Phase 6</td><td colspan="6">Continues Implementation of Vitalism and extract RR</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Testing on real real data</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Observing the results and generating decision logic</td></tr>
<tr><td colspan="6">Preparing Second Presentation</td></tr>
<tr><td colspan="6">Discussion phase 2</td></tr>
</table>

Figure 38: Table of Division Responsibilities
for Vitalism Project Team.

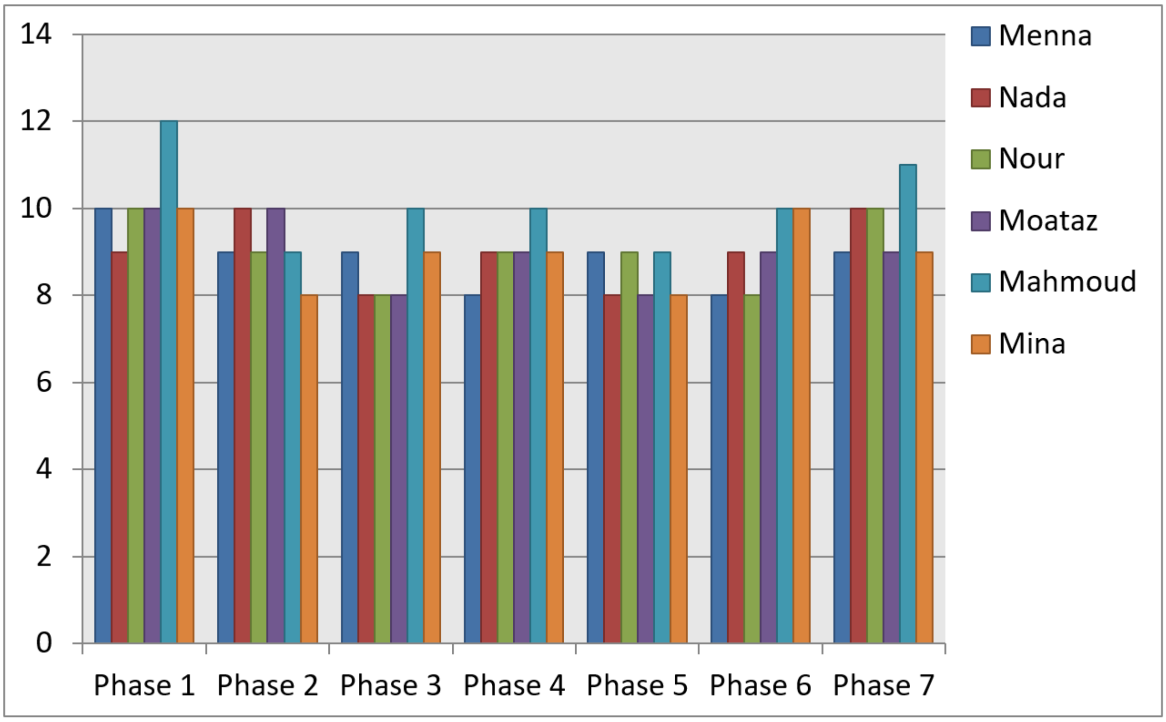


Figure 39: Bar chart of Division Responsibilities for Vitalism Project Team.

2.8.6 Risk Management

Risk management is a critical aspect of the management plan for Vitalism. It involves identifying, assessing, and prioritizing potential risks associated with the project, and then implementing strategies to minimize or mitigate those possible risks as shown in Figure 40. This helps ensure the success and smooth execution of the project.

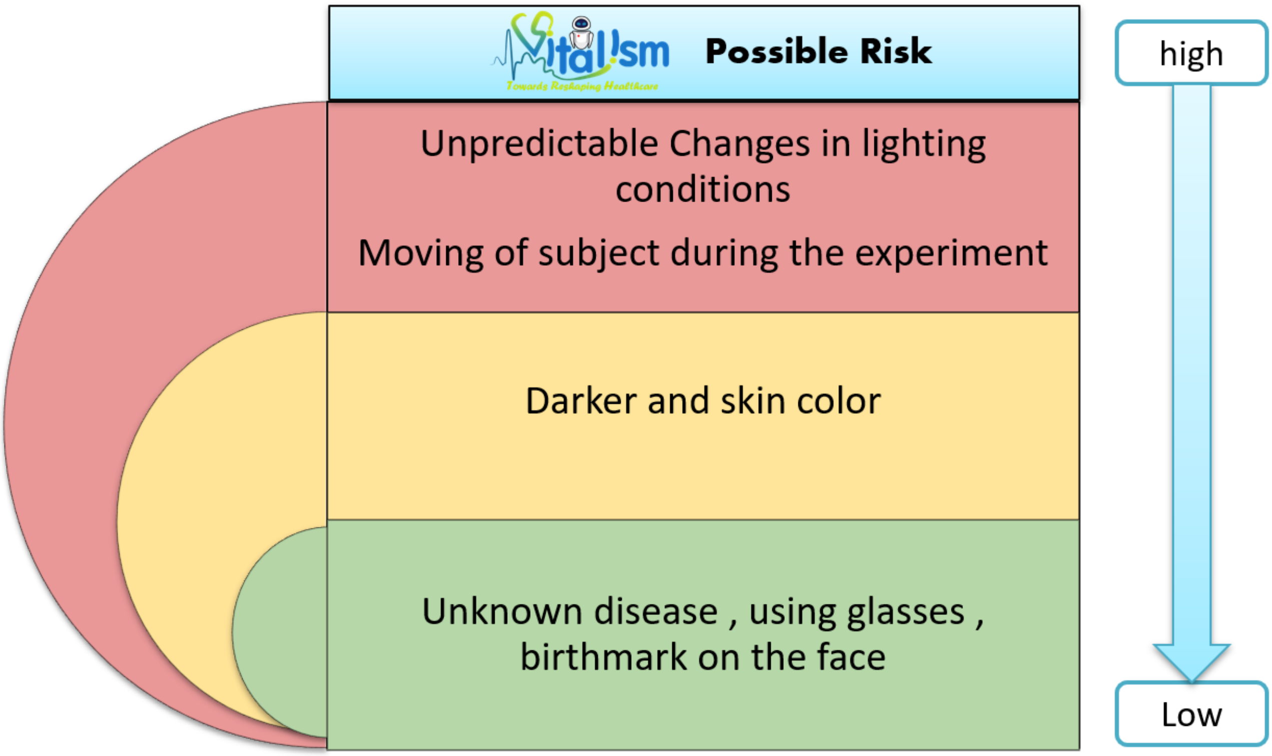


Figure 40: The Possible Risks of Vitalism .

Chapter 3

(Software Design)

3.1 Introduction

The software design for Vitalism is a critical phase of the project, as it lays the foundation for the development of a robust and scalable healthcare solution. The software design defines the architecture, modules, and interfaces of the Vitalism application, considering the functional and non-functional requirements and use cases. The software design must consider the needs of the users, stakeholders, and customers, as well as the constraints and limitations of the technology.

The software design must also ensure that the application is user-friendly, secure, and reliable, while also providing high performance and functionality. The software design must provide a clear and concise vision of the Vitalism application and ensure that it meets the expectations of all stakeholders involved in the project. When the detailed design is complete, the analysis of the requirements traceability documents should show the relationship between the software design components and the software requirements providing evidence that all requirements are accounted for.

3.1.1 Project Background/Purpose

The purpose of the Vitalism project is to develop a comprehensive and user-friendly telehealth platform that will enable patients to monitor and track their vital signs remotely. The platform will use rPPG technology to measure various vital signs such as heart rate, heart rate variability, oxygen saturation, respiratory rate, and blood pressure. The collected data will be stored in the patient's electronic medical record (EMR) and will be accessible by healthcare professionals in real-time.

The primary goal of the Vitalism project is to provide a cost-effective and convenient solution for remote patient monitoring, especially for patients with chronic conditions who need frequent monitoring. The platform will help healthcare professionals to make informed decisions and improve patient outcomes by providing real-time monitoring of vital signs.

In addition, the Vitalism platform will also support telehealth consultations, virtual trials, and medication adherence tracking. With its user-friendly interface and accessibility for all age groups, the Vitalism platform will improve the overall patient experience and support better health outcomes.

Overall, the Vitalism project aims to revolutionize the healthcare industry by providing a comprehensive telehealth solution that will improve the quality of patient care and make it more accessible and convenient.

3.1.2 Hosting Platform

The Vitalism project can be hosted on various hosting platforms including cloud hosting platforms like Microsoft Azure and Google Cloud Platform (GCP).

Google Firebase is a set of hosting services for various types of applications including Android, iOS, JavaScript, Node.js, Java, Unity, PHP, and C++. It offers NoSQL and real-time hosting of databases, content, social authentication (Google, Facebook, Twitter and GitHub), and notifications, and real-time communication server. It also provides machine learning applications such as face recognition that can be used in the Vitalism project.

Google Cloud Platform (GCP) is a suite of cloud computing services offered by Google that runs on the same infrastructure as Google's end-user products such as Google Search, Gmail, Google Drive, and YouTube. It provides a set of management tools and a series of modular cloud services including computing, data storage, data analytics, and machine learning. To use GCP, registration requires a credit card or bank account details.

3.2 System Architecture

The Vitalism system architecture and distributed system as shown in Figure 41 is a comprehensive framework that incorporates multiple components and technologies to provide seamless and effective healthcare solutions. It comprises of various modules and tools, including real-time monitoring and tracking of vital signs, telehealth services, virtual trials, medication adherence, patient triage, and elderly care. The architecture is designed to ensure scalability, reliability, security, and performance, to provide optimal results for healthcare professionals and patients alike. The system leverages modern technologies such as cloud computing, artificial intelligence, machine learning, and big data to offer a highly interactive, intuitive, and customizable solution. Ultimately, the Vitalism system architecture aims to improve patient outcomes and support efficient and effective patient care.

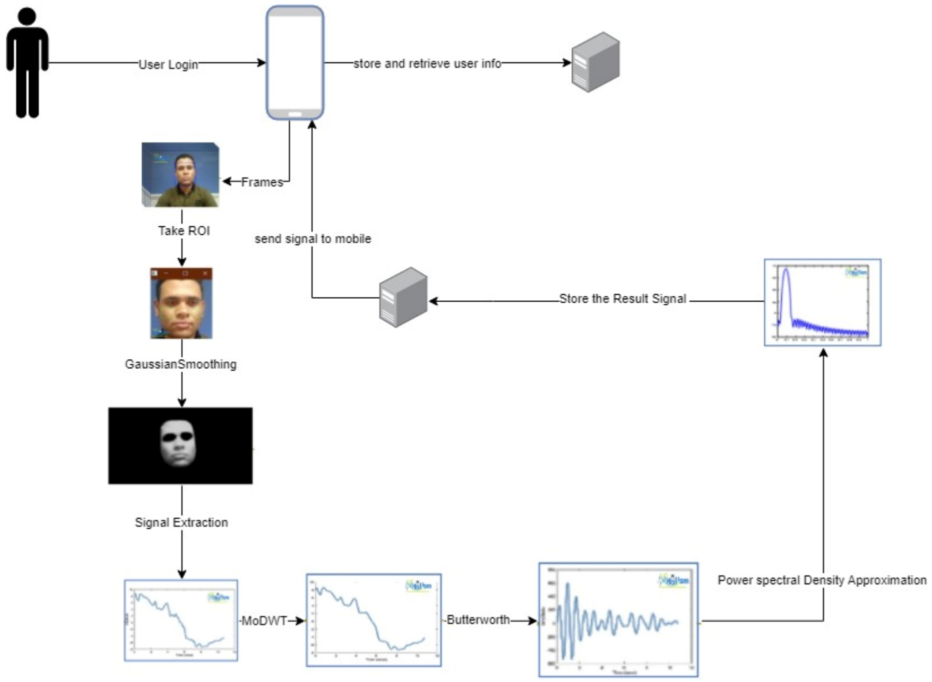


Figure 41: Distributed System Life Cycle of Vitalism .

3.2.1 Architectural Design

The Vitalism project architecture is a multi-tier architecture as shown in Figure 42 that involves the following layers:

Front-end layer: This layer is responsible for presenting the data to the user through a graphical user interface (GUI). The GUI is implemented using Qt 6 in python language in Desktop applications, and java in android.

Application layer: This layer contains the business logic of the application and is responsible for processing and transforming data from the backend layer into a form that can be displayed by the front-end layer. The application layer is implemented using a server-side language such as python.

Backend layer: This layer is responsible for storing and retrieving data from a database. It contains the database management system and the database itself, which is typically implemented using a relational database such as SQL, SQLite, or room database.

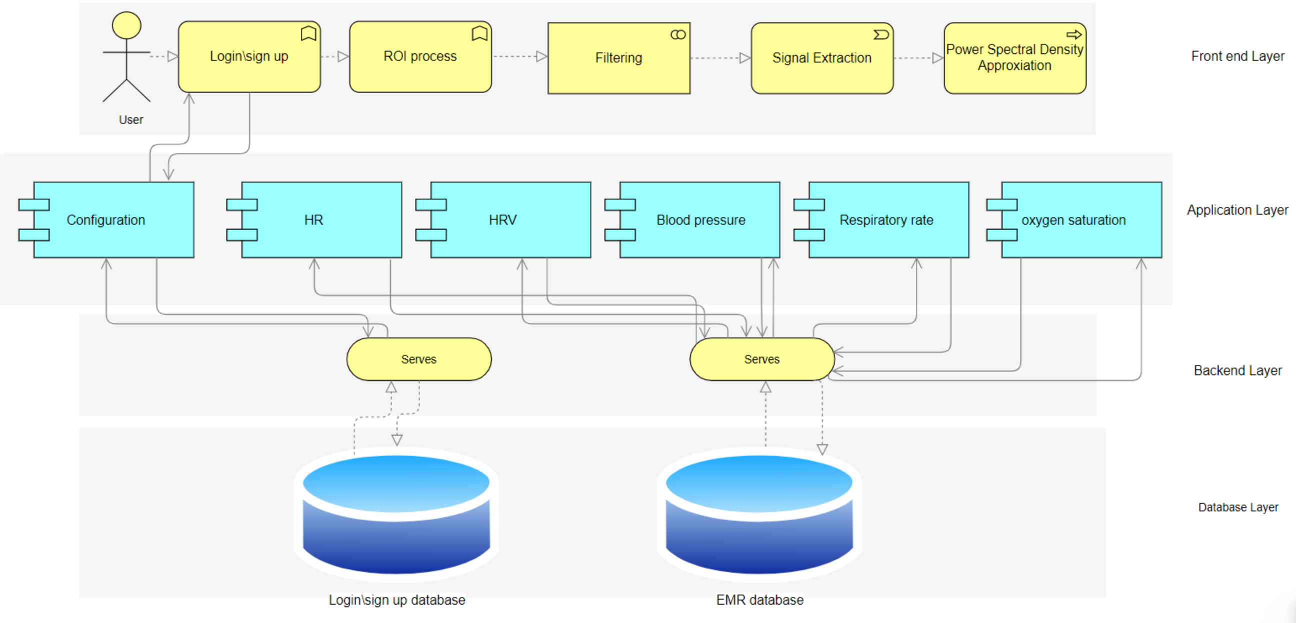


Figure 42: Multi-tier Architecture of Vitalism.

3.2.2 Decomposition Description

Decomposition refers to the process of breaking down a complex system into smaller, more manageable components. In the case of the Vitalism project, the system architecture can be decomposed into several different components that each contribute to the overall functionality of the system. These components may include:

1. **User Interface**: This component is responsible for providing a user-friendly interface for patients, caregivers, and healthcare professionals to interact with the system.
2. **Data Collection and Management**: This component is responsible for collecting, storing, and managing patient data, including vital signs and medical history.
3. **Data Analytics**: This component is responsible for analyzing patient data to identify trends and patterns, and to make informed recommendations for patient care.
4. **Communication and Notification**: This component is responsible for facilitating communication between patients, caregivers, and healthcare professionals, and for sending notifications for important events or updates.

5. **Remote Monitoring**: This component is responsible for remotely monitoring patients and collecting vital sign data in real-time.
6. **Clinical Decision Support**: This component is responsible for providing recommendations and guidance to healthcare professionals to support informed decision-making.
7. **Compliance and Security**: This component is responsible for ensuring that the system is compliant with all relevant regulations and standards, and that patient data is protected and secure.

Each of these components can be further decomposed into smaller components to provide a more detailed understanding of the system architecture and its functionality.

3.2.3 Design Rationale

The multi-tier architecture was chosen for the Vitalism project because it provides a clear separation of concerns and allows for a scalable and maintainable system. The front-end layer focuses on presentation and user interaction, the application layer focuses on business logic, and the backend layer focuses on data storage and retrieval. This decomposition makes it easier to manage and update the system, as changes to one layer do not affect the other layers. The use of APIs to communicate between layers also allows for greater flexibility in changing and updating individual components.

3.3 Data Design

The Data Design section of Vitalism documentation outlines the architecture of the software and how the various components interact with each other. It defines the different modules of the system, their functionalities, and the data structures that they use, and the relationships between the different modules and their data flow are also described. This section provides an overview of the data flow within the system and how the various modules interact with each other to perform the necessary operations.

3.3.1 Data Description

The data description of Vitalism can be divided into three entities, each representing different aspects of the application as shown in Figure 43. These entities are the user, the doctor, and the patient.

The user entity represents the person who is measuring his vital signs and saving them in the application. This entity has a many-to-many relationship with the vital signs, as one user can have multiple vital sign readings, and one vital sign reading can belong to multiple users.

The doctor entity represents the medical professionals who follow up on the patients. This entity also has a many-to-many relationship with the patients, as more than one doctor can follow up on multiple patients.

The patient entity represents the person who records the medication they are taking. This entity also has a many-to-many relationship with the medication, as one patient can take multiple medications and one medication can be taken by multiple patients.

Both the user and the doctor entities have common attributes, which are displayed in the entity called a person. This entity holds the distinctive qualities that are shared between both the user and the doctor. The patient entity, on the other hand, has its own unique attributes that are specific to the patient.

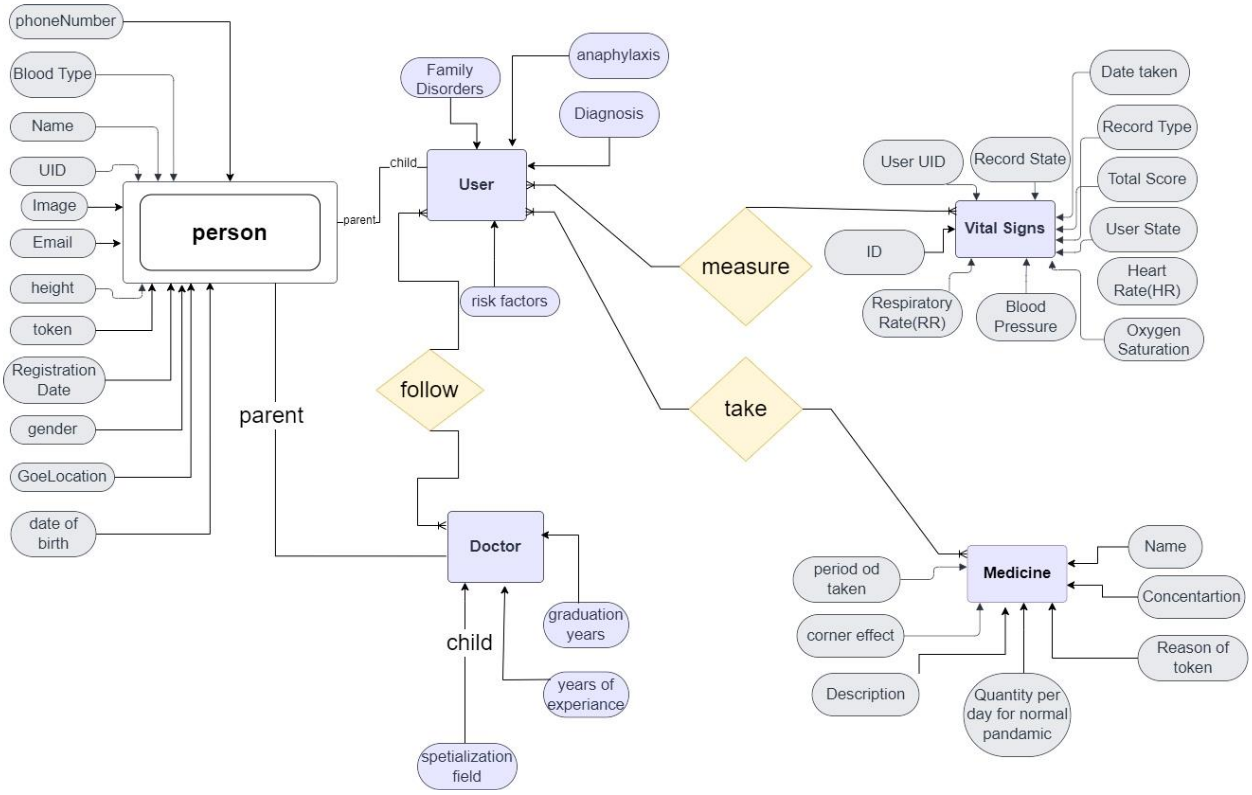


Figure 43: Data Description of Vitalism.

In conclusion, the data description of Vitalism provides a comprehensive understanding of the entities, their relationships, and attributes that are used in the application. The information helps to understand how the application works, and the relationships between the various entities and their attributes.

3.3.2 Data Dictionary

A data dictionary is a collection of descriptions of the data objects or items in a data model for the Vitalism system. It defines the structure, characteristics, and relationships of the data within the system.

In the Vitalism system, a data dictionary is used to document the data elements and their attributes, including data type, length, format, and any constraints. The data dictionary helps to ensure that the data is consistent and accurate throughout the system. Here are some of the data elements in the Vitalism system's data dictionary:

1- The User

Field	Type	Nullable	Default
Name	Varchar(30)	No	Null
Global Id	Varchar(30)	No	Null
Token	Varchar(60)	No	Null
Date of Birth	Int (40	No	Null
Date of birth	Long	No	0
Date of registration	Long	No	0

Gender	Int(4)	No	Null
Phone	Varchar(15)	Yes	Null
Blood Type	Int(4)	No	Null
E-mail	Varchar(30)	No	Null
Geo location	Pair of string (24)	No	Null
Height	Float(4)	Yes	Null
Weight	Float(4)	Yes	Null
Image	Byte array	Yes	Null
Diagnosis	Int(4)	Yes	Null
Family Disorders	Varchar(40)	Yes	Null

2- The Medical Users

Field	**Type**	**Nullable**	**Default**
Name	Varchar(30)	No	Null
Global Id	Varchar(30)	No	Null
Token	Varchar(60)	No	Null
Date of Birth	Long	No	0
Gender	Int(4)	No	Null
Phone	Varchar(15)	No	Null
Blood Type	Int(4)	No	Null
E-mail	Varchar(30)	No	Null
Geo location	Pair of string (24)	No	Null
Height	Float(4)	Yes	Null
Weight	Float(4)	Yes	Null
Image	Byte array	Yes	Null
Specialization field	Int(4)	No	Null
Years of exp	Int(4)	No	Null
Graduation year	Int (4)	No	Null

3- Vital Signs

Field	**Type**	**Nullable**	**Default**
ID	Long(8)	No	Null
User Id	Varchar(40)	No	Null
Date Taken	Long	No	0
Record State	Int (4)	No	Null
Record Type	Int(4)	No	Null
Total Score	Int(4)	No	0
User State	Int(4)	No	Null
Heart Rate (HR)	Int(4)	No	0
Respiratory Rate (RR)	Int(4)	No	0
Blood Pressure	Pair of Int(8)	No	0
Oxygen Saturation	Int(4)	No	0

4- The Medicines

Field	**Type**	**Nullable**	**Default**
ID	Varchar(20)	No	Null
Name	Varchar(30)	No	Null
Concentration	Double(8)	No	0
Description	Varchar(200)	yes	No Description
Quantity per day	Double(8)	Yes	0
Reason of taken	Varchar(20)	Yes	Unknown
Corner Effects	String array	Yes	Null
Period of taken	Long array	Yes	Null

3.4 Components Design

The components design describe communication, interfaces, algorithms, and the functionalities of each component regarding the whole software design.

3.4.1 User Authentication Module

The User Authentication Module in the Vitalism Project is responsible for verifying the identity of a user before allowing them access to the application. It is a critical component of the system, as it ensures that only authorized users can view and manipulate sensitive personal health data.

The module is implemented using standard authentication techniques such as username/password combinations or other forms of two-factor authentication. The user's credentials are verified against a database that stores information about authorized users. If the user's credentials are verified, the module grants access to the application and sets up a session for the user, allowing them to use the system for a specified amount of time before having to re-authenticate.

The user authentication module also provides a mechanism for users to reset their passwords in the event that they forget them. This process typically involves sending a password reset link to the user's email address, which they can use to reset their password.

Vitalism provides effective protection against unauthorized login attempts to prevent unauthorized access to sensitive data. A user authentication module for vitalism provides the following capabilities as the functional requirements:

Register new users: User must register in application with some data which application need it such as name, age, gender ,etc. One of the important data for authorized login is the email and the password .

Email Confirmation: Email Confirmation verify the validity of this email address. The way to do this verification is through a random and unique token, long enough so that it cannot be guessed by brute force. It sends this token to that email address, included in the URL pointing to the verification page of the application. The user must access that URL so that the application can verify that the verification email was received at the declared email address.

Password Recovery : Password Recovery done by requesting a user ID (usually a username or email address), validating that the user ID corresponds to an active user account, and sending the user an email with a randomly generated token to the previously validated email address.

In addition, the user authentication module includes security measures to prevent unauthorized access to sensitive data. For example, the module may implement measures such as encryption, secure socket layer (SSL), and secure data storage to ensure the confidentiality and security of user data.

In conclusion, the User Authentication Module is a crucial component of the Vitalism Project that ensures that only authorized users can access sensitive personal health data, while also providing a secure and convenient way for users to manage their account information.

3.4.2 Data Storage Module

The Vitalism system has a data storage module where data is collected and organized. There are four main entities in the data storage module or ERD as shown in Figure 44, which are the user, doctor, vital sign, and medicine.

The user entity holds information about the person who is measuring their vital signs. This entity contains attributes such as Name, Global ID, token, age, Date of birth, Date of registration, Gender, PhoneNumber, Blood Type, E-mail, Geo Location, Height, Weight, Image, Diagnosis, and Family disorders. This entity has a many-to-many relationship with both the doctor and vital sign entities.

The doctor entity holds information about the medical professional who is following up on the patients. This entity contains attributes such as Name, Global ID, token, Date of birth, Gender, Phone, Blood Type, E-mail, GeoLocation, Height, Weight, Image, specialization field, years of experience, and graduation year. The doctor entity has a many-to-many relationship with the user entity.

The vital sign entity holds information about the vital signs that are measured by the user. This entity contains attributes such as ID, User ID, Date Taken, Record state, Record Type, Total score, User state, Heart rate (HR), Respiratory rate (RR), Blood Pressure, and Oxygen Saturation. This entity has a one-to-many relationship with the user entity.

The medicine entity holds information about the medication that is taken by the user. This entity contains attributes such as ID, Name, concentration, Description, Quantity per day for normal pandemic, Reason of taken, Corner effects, and Period of taken. This entity has a many-to-many relationship with the user entity.

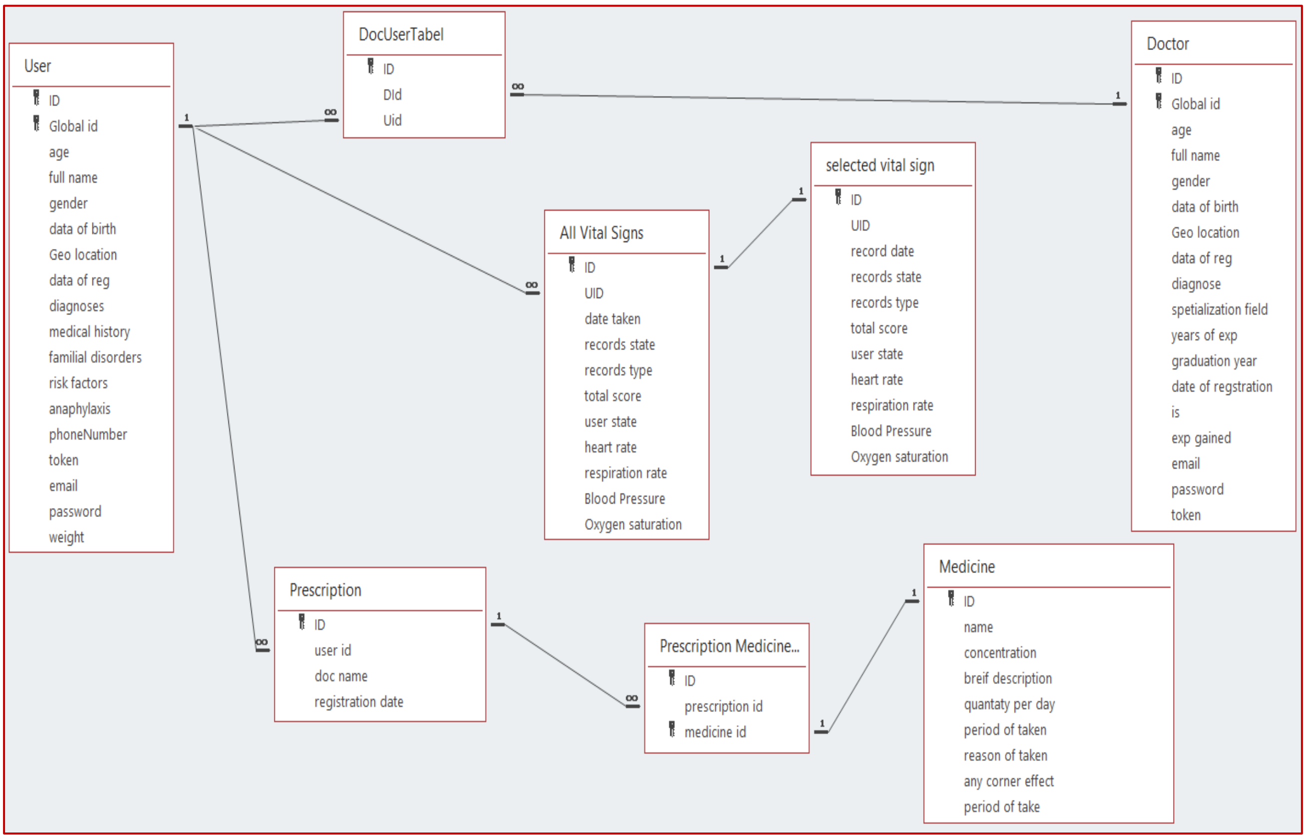


Figure 44: Simple visualization for Entity Relationship Diagram (ERD) of Vitalism.

In conclusion, the data storage module of the Vitalism system contains four main entities that hold information about the users, doctors, vital signs, and medication. The relationships between the entities allow for the effective organization and retrieval of data.

3.4.3 User Interface Module

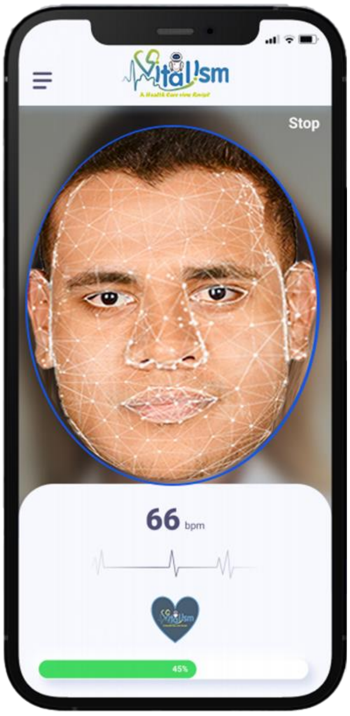


Figure 45: Example of UI of Vitalism.

The User Interface (UI) module of the Vitalism project is a critical component that allows users to interact with the system. In order to facilitate the measurement of vital signs. It provides an intuitive and user-friendly interface for users to view and manage their data.

The following are some key features of the Vitalism UI module:

Data Display: The UI provides an interface for users to view their vital sign data, including respiratory rate, heart rate, and other vital sign measurements. The data is displayed in a clear and easy-to-understand format, allowing users to track their progress and see trends over time.

Data Management: The UI provides an interface for users to manage their data like email, password or name and including the ability to delete or edit data .

User Account: The UI provides an interface for users to create their accounts Through the registration process if it is the first time to enter the application and manage their user accounts. Through the Login process If he has already registered, including the ability to change their password , edit their personal information, and view their privacy settings.

Notifications: The UI provides notifications to users about changes in their vital sign data, including alerts for significant changes and reminders for routine vital sign measurements. It also gives a notification to the user through the e-mail (OTP) if he has forgotten the password and wants to set a new password. The application also sends a notification to the user monitor if the vital signs are not good or gives an emergency warning if the user monitor does not respond.

Customization: The UI provides options for users to customize the interface to suit their preferences, including the ability to change the display theme, font size, and other display settings. The UI module of the Vitalism project is designed to be simple and user-friendly, making it easy for users of all ages and technical backgrounds to interact with the system and track their vital sign data.

3.4.4 Data Processing Module

The data processing module in Vitalism is responsible for transforming raw data into meaningful information that can be used to determine the vital signs of a user. The following is a high-level overview of the steps involved in the data processing module:

1. Data Collection: The data processing module starts with the collection of raw data, which is obtained from the smartphone camera through the use of the rPPG technology.

2. Pre-processing: The raw data collected is pre-processed to remove any noise or artifacts that may have been present in the data. This step is critical for ensuring accurate results.
3. Feature Extraction: The pre-processed data is then processed to extract relevant features that are used to determine the vital signs. This may include the extraction of information related to heart rate, respiratory rate, and other important parameters.
4. Algorithm Implementation: The extracted features are then processed using a set of algorithms that are designed to determine the vital signs based on the data. These algorithms may include statistical methods, machine learning algorithms, and other techniques.
5. Data Analysis: The results obtained from the algorithm implementation are then analyzed to determine the vital signs of the user. This analysis may involve comparing the results to a reference database or applying additional algorithms to validate the results.
6. Data Storage: The final results of the data processing module are then stored in a database for future reference. This data can be used to track the user's vital signs over time and monitor any changes or trends that may be present.

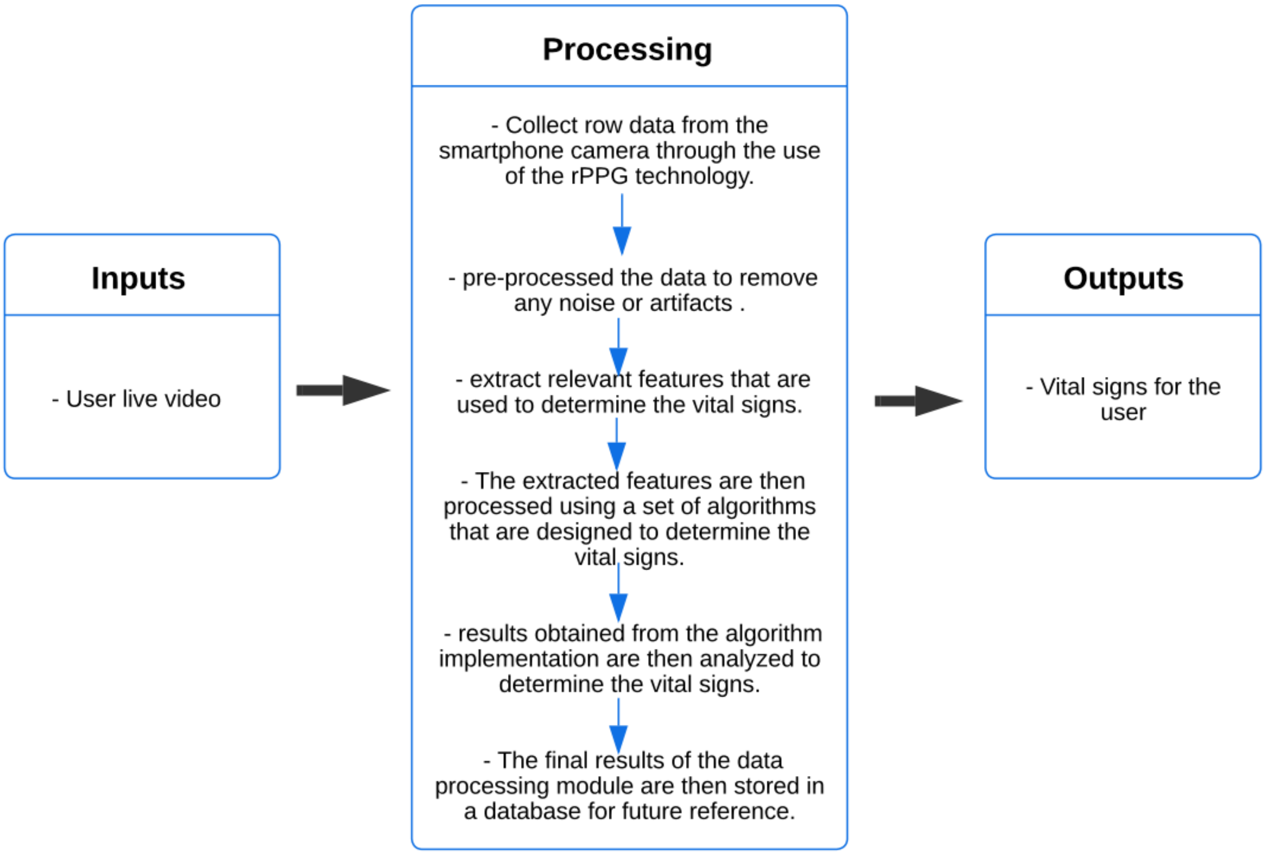


Figure 46: Data Processing Module in Vitalism.

The data processing module in Vitalism is designed to be fast, efficient, and accurate as shown in Figure 46. It is implemented using a combination of server-side programming languages and algorithms to ensure that the results are reliable and consistent.

3.4.5 Data Flow Diagram

A data flow diagram (DFD) is a graphical representation of the flow of data in an information system. A data flow diagram can be used to represent the data flow of Vitalism, including the various stages of data processing and the flow of data between different modules of the system. This DFD can be used to understand the data flow in the Vitalism system and to identify any potential issues or areas for improvement. Here is an overview of a possible DFD for the Vitalism system show in Figure 47.

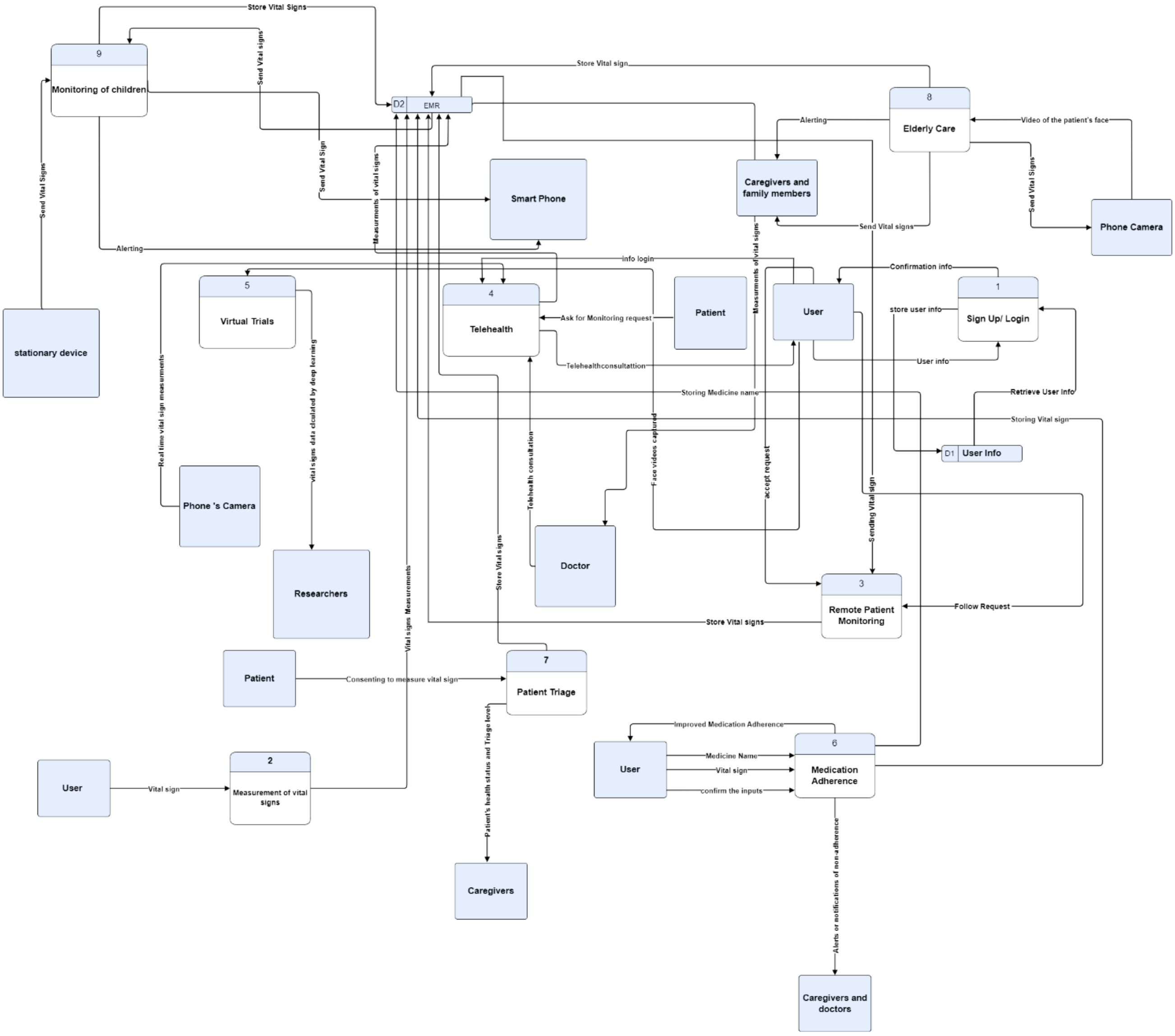


Figure 47: Data Flow Diagram (DFD) of Vitalism.

In conclusion a neat and clear DFD can depict a good amount of the system requirements graphically. It shows how information enters and leaves the system, what changes the information and where information is stored. The purpose of a DFD is to show the scope and boundaries of a system as a whole. It may be used as a communications tool between a systems analyst and any person who plays a part in the system that acts as the starting point for redesigning a system.

3.4.6 Vitalism End-to-End Framework

The end-to-end framework is a crucial part of the software development process as it helps to identify and fix bugs, improve the user experience, and ensure that the system meets the requirements of the users. The Vitalism end-to-end framework facilitates remote monitoring of user's vital signs specifically Heart Rate, Heart Rate Variability, Oxygen Saturation, Respiratory Rate, and Blood Pressure via the Vitalism Software Development Kit (SDK) as shown in Figure 48, and it's outlining the complete process of how the Vitalism application works from start to finish.

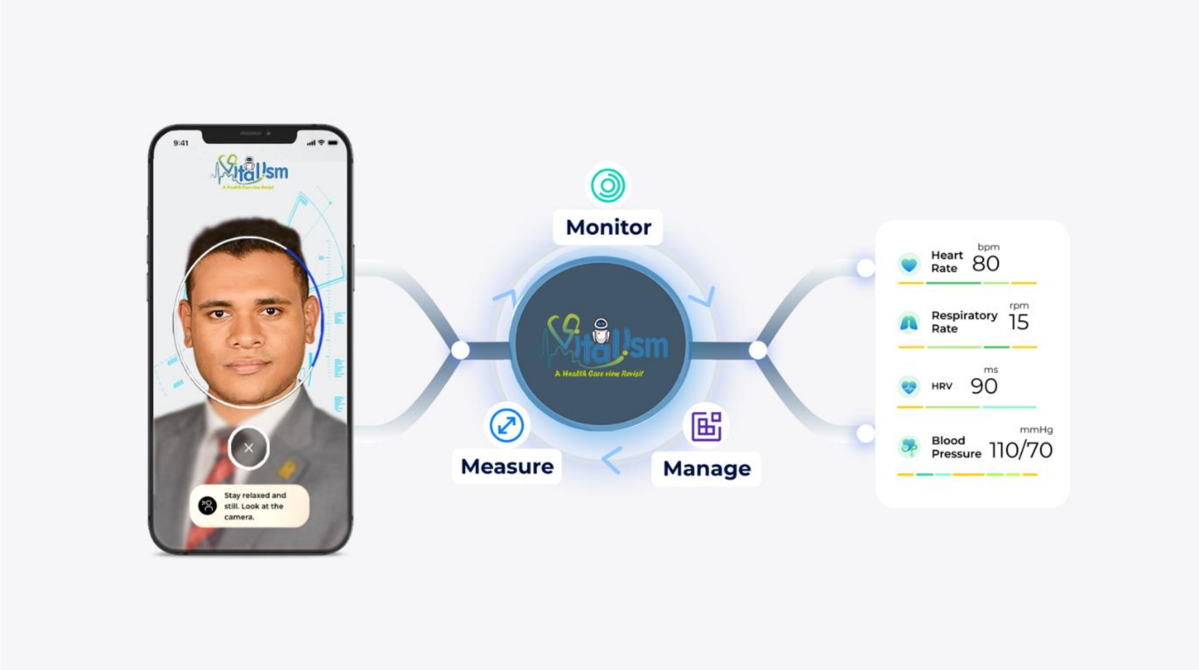


Figure 48: Overview Vitalism Software Development Kit (SDK).

The Vitalism end-to-end framework is a comprehensive system designed to provide a clear understanding of how the application operates and how it can be used to support patient care. The framework consists of three main subsystems:

1. **Front-end Application**

This subsystem is composed of a mobile application called Vitalism that works on Android starting from version 7 Noga API (26) and a desktop application called Vitalism that works on Windows 8 and higher. The mobile application requires a phone with a camera resolution of at least 680 * 480 pixels, at least 4GB of RAM, and a processor with at least 2 cores. The desktop application requires 8GB of RAM, a multicore processor (Core i5 with 6 cores), and at least 500 MB of free storage.

2. **Back-end Data Processing**

The second subsystem is the cloud server that processes the video frames and estimates vital signs. The application uses Firebase, which is automatically managed by Google, and is based on NoSQL. The backend is linked to a database, which represents the third subsystem.

3. **Cloud Database**

The third subsystem is the cloud database that stores the user's data and vital history. The desktop application uses MySQL for local caching, while the server uses both MySQL and NoSQL databases. The front-end application pulls data from this database and displays the readings to the user. The cloud database allows the vital signs to be saved for registered users, so they can monitor their historical measurement data and share it with medical professionals if needed.

A detailed description of each subsystem is provided below.

Subsystem 1: Front-end Application

The front-end application, Vitalism, needs to be installed on the user's smartphone or PC. After the user logs in, the application switches on the front camera and starts processing the user's video locally. When the estimated vital signs are returned by the back end, the application displays the readings to the user on the front-end User Interface (UI). This allows users to interact with the application and view past measurements.

Subsystem 2: Back-end Data Processing

The processing of the video data is performed in 6 steps, as shown in Figure 49. In step 1, the luminance and brightness of the input video are analyzed, and only videos with appropriate lighting are processed further. In step 2, a deep learning-based model is used to detect the face and predict face landmarks in the video by segmenting it into specific areas referred to as Regions of Interest (ROIs). In step 3, the raw Blood Volume Pulse (BVP) signals are extracted from the ROIs. In step 4, the raw signals are processed and filtered to remove any noise or artifacts. In step 5, the processed signals are used to estimate the vital signs, such as heart rate and respiration rate. Finally, in step 6, the vital signs are returned to the front-end application and displayed to the user.

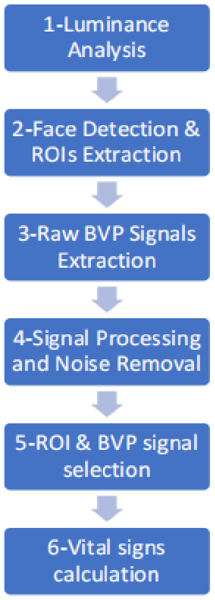


Figure 49: Processing of the Video Data.

Subsystem 3: Cloud Database

The cloud database stores the user's vital signs and measurement history. The front-end application pulls the data from the database and displays it to the user on the UI. The database also allows registered users to save their vital sign measurements and view their historical measurement data. The database uses both MySQL and NoSQL databases, with the desktop application using MySQL for local caching. The cloud database enables medical professionals to access the patient's vital sign data if needed.

3.5 User Interface Design

The User Interface (UI) of Vitalism is a critical component that provides a seamless user experience. It is designed to be simple and intuitive, allowing users to quickly and easily access the information and features they need.

The following is a high-level overview of the Vitalism User Interface:

1. The Login screen is the first thing the user sees when opening the application. Here the user can log in with their existing account or create a new one as shown in Figure 50. The login process is quick and secure, ensuring that user data is protected.

2. The Sign-Up screen allows the new user to enter his name, Date of birth, country, Blood type, Diagnosis, email, and password, and this information will be saved to his Electronic medical record, not all information is required in this phase but the user should complete

it later as shown in Figure 51. Users also can sign up with their google or Facebook accounts.

3. The Forget Password screen helps the user to reset his password in case of forgetting his password by entering his email and receiving OTP code as shown in Figure 52.

4. The Check Email screen will pop up to the registered user when entering his email to reset his password as shown in Figure 53.

5. The Verification screen shows user verification by entering the received OTP code to verify his email or reset his password as shown in Figure 54.

6. The Get Start1 screen shows instructions for the user to stay comfortable to ensure that vital signs are measured accurately as shown in Figure 55.

7. The Get Start2 screen shows instructions to the user asking him to avoid direct sunlight or lamp light and be in a good light environment as shown in Figure 56.

8. The Get Start3 screen asks the user to adjust his face within the designed frame and make sure he is not too far away from the camera to define his facial landmarks correctly as shown in Figure 57.

9. The Get Start 3 screen asks the user to put his face directly to the camera without rotation and make sure his forehead and cheeks are not covered as shown in Figure 58.

10. The Home page screen Responsible for connecting all the screens to each other, and the user can choose the Vital sign that he wants to measure. At the bottom of the screen, there are four shortcuts that the user can move between, which are the home page, profile page, result page, and medicine page as shown in Figure 59. After selecting the vital sign, the user can move to the details screen that contains details about the Vital sign.

11. The Details screen moves to the description interface, here information is shown about the vital sign that is being measured as shown in Figure 60, its definition, the importance of measuring it periodically, the extent of its impact on human health, and also shows the natural extent of it. Upon completion of the reading, the user presses the Measure button The vital sign and then moves to the interface where the vital sign will be measured via the live camera video.

12. The Vital sign measurement screen begins by opening the camera to measure the vital signs, observe some instructions that must be taken, such as lighting, taking off glasses, and anything that hinders the measurement in order to obtain more accurate measurements. It begins with the measurement of vital signs, and the measurement takes about 25-35 seconds, Then the results appear on the screen, and it will inform the user of the status of the vital signs as shown in Figure 61, If they are good or not, and if they are not good, then he will send a notification to the doctor or the observer for this user, and if the doctor does not answer and does not respond, the hospital will be automatically contacted or emergency.

13. The Result screen shows after measuring any vital sign the user can download the result and save it to his Electronic medical record in case as shown in Figure 62, he is the authorized user. The application will check his condition from the measurement and enable the caregivers to see his results and provide the necessary care.

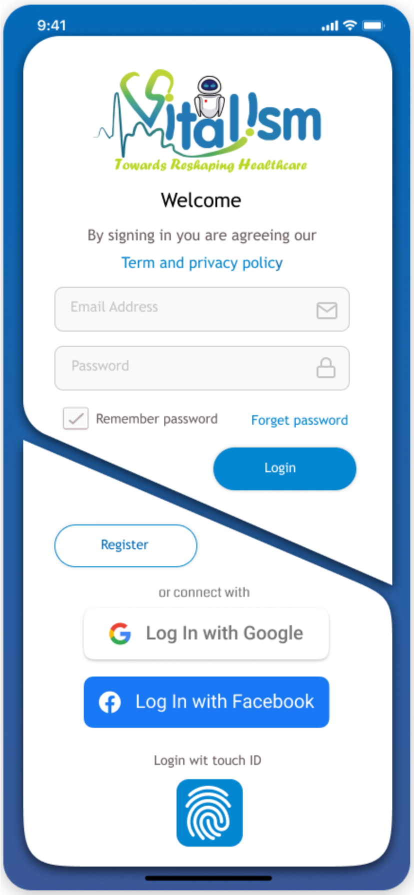
14. The Profile screen allows users to view their vital signs history, including their heart rate, blood pressure, oxygen saturation, and other data. Users can access this information by navigating to the relevant tabs within the profile screen as shown in Figure 63. They can also edit their personal information and update their profile details if necessary. Additionally, the profile screen includes options for users to change their account settings, including their password and other security-related options. The screen is designed to be secure and protected, ensuring that the user’s personal information is safe and protected. Overall, the profile screen of Vitalism provides users with a comprehensive view of their health and wellness information, enabling them to make informed decisions about their health and well-being.

15. The Notification screen displays the necessary notifications for the user. As the notifications of the people, you follow are displayed, and reminders to measure their vital signs. And if the vital signs of one of the people you follow are unstable or not good, he gives you a notification to me immediately to save the situation as shown in Figure 64. Among the features that distinguish the notification feature is the difference in the color of the notification according to the status of the notification. If the status of the notification is not serious, it appears in blue, and if the status of the notification is serious, then the measurement of vital signs is not good, then the notification appears in red, and if the user opens the notification and responds to the notification and reads it The application will not take any other reaction, but if the application sends the notification more than once and the user does not respond, the application will automatically contact the hospital and emergency to rescue the person.

16. The Search screen user searches for the account of other people, where it can be a doctor who wants to follow a patient or a user who wants to follow one of his relatives as shown in Figure 65. If the user wants to cancel the search, there is a word cancel in the interface, and there is a voice search feature by pressing the microphone icon in the search bar in that interface.

17. The Chat screen user sends a request to the doctor or the observer to follow up on his condition and if the doctor approves, the chatbot will automatically send the doctor a thank message for accepting the follow-up, and then the chatbot will inform him of the measurements that the user measured before accepting the follow-up and after acceptance as shown in Figure 66. Also, the user can talk to the doctor in the chat, get advice, tell the doctor, and explain any problem he is facing or any disease he suffers from.

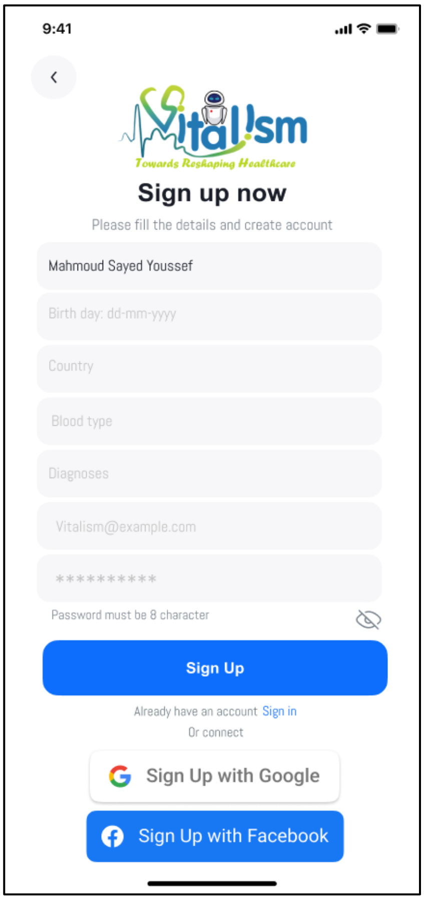
18. The Medicine screen shows medicine scheduling it reminds the user of medicine time, a brief description, and the side effects of every medicine as shown in Figure 67.



Welcome

By signing in you are agreeing our Term and privacy policy

Figure 50: Login Page.



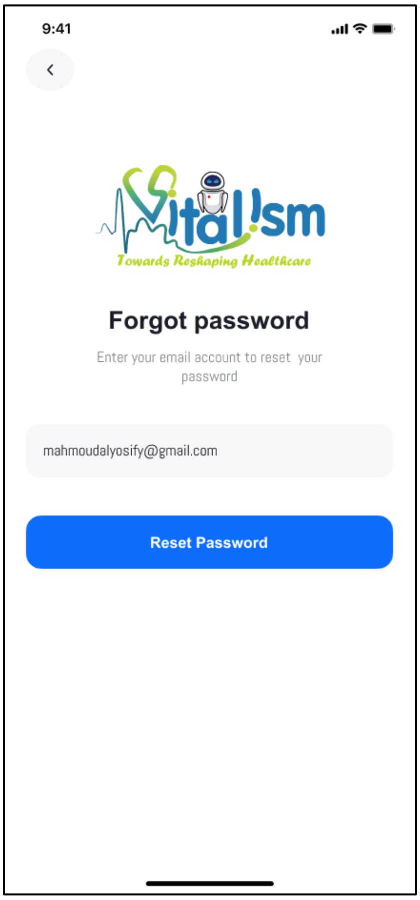
Sign up now

Please fill the details and create account

Mahmoud Sayed Youssef

Password must be 8 character

Figure 51: Sign Up Page.

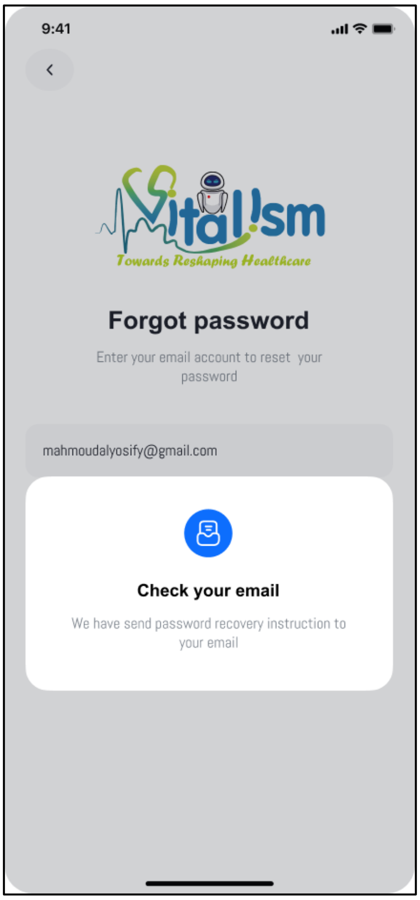


Forgot password

Enter your email account to reset your password

mahmoudalyosify@gmail.com

Figure 52: Forget Password Page.



Forgot password

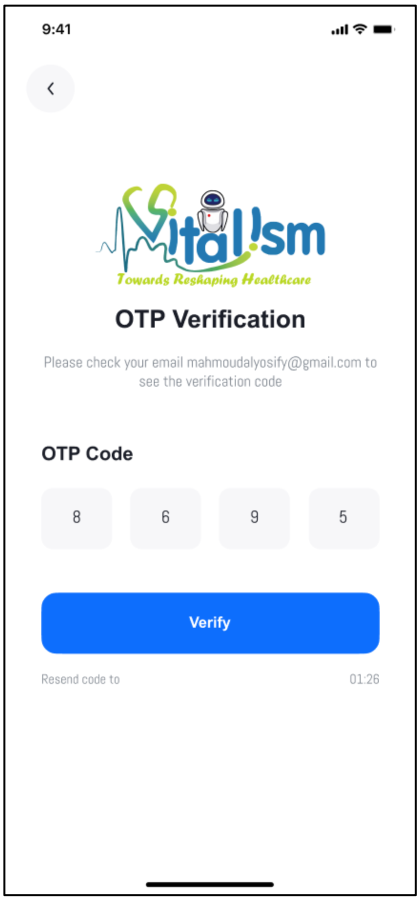
Enter your email account to reset your password

mahmoudalyosify@gmail.com

Check your email

We have send password recovery instruction to your email

Figure 53: Check Your Email Page.



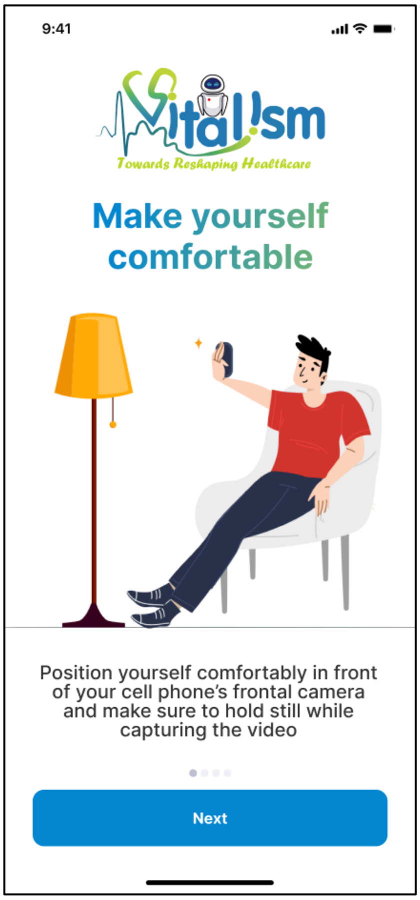
OTP Verification

Please check your email mahmoudalyosify@gmail.com to see the verification code

OTP Code

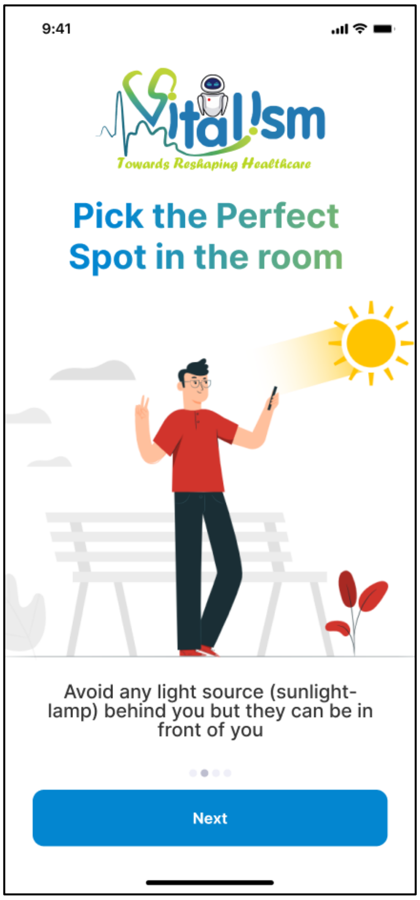
8 6 9 5

Figure 54: Verification Page.



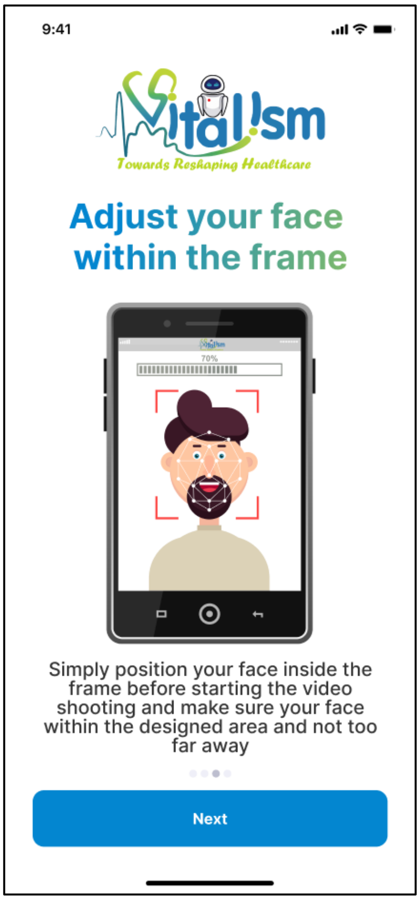
Position yourself comfortably in front of your cell phone's frontal camera and make sure to hold still while capturing the video

Figure 55: Get started 1.



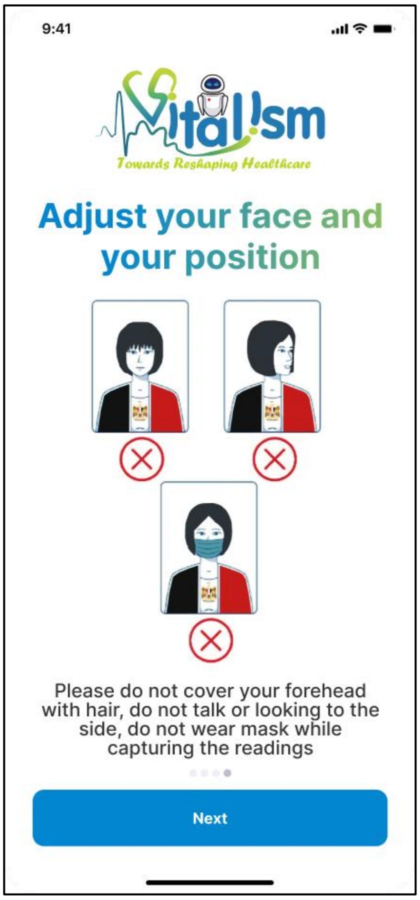
Avoid any light source (sunlight-lamp) behind you but they can be in front of you

Figure 56: Get started 2.



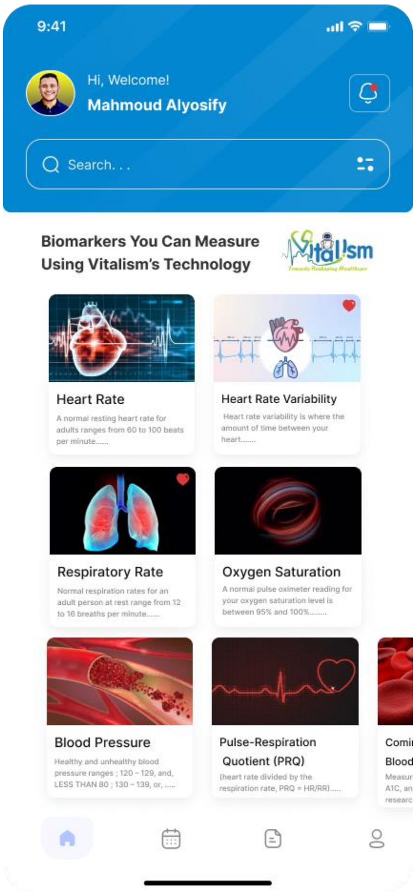
Simply position your face inside the frame before starting the video shooting and make sure your face within the designed area and not too far away

Figure 57: Get started 3.



Please do not cover your forehead with hair, do not talk or looking to the side, do not wear mask while capturing the readings

Figure 58: Get started 4.



A normal resting heart rate for adults ranges from 60 to 100 beats per minute......

Heart rate variability is where the amount of time between your heart.......

Normal respiration rates for an adult person at rest range from 12 to 16 breaths per minute......

A normal pulse oximeter reading for your oxygen saturation level is between 95% and 100%........

Healthy and unhealthy blood pressure ranges ; 120 – 129, and, LESS THAN 80 ; 130 – 139, or, ...

(heart rate divided by the respiration rate, PRQ = HR/RR).....

Figure 59: Home Page.

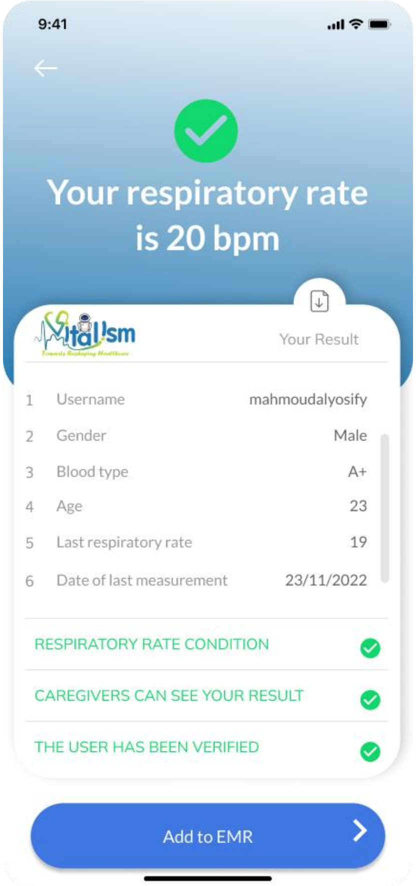
Heart rate, also known as pulse, is the number of times a person's heart beats per minute. It is a vital sign that is used to indicate a person's overall health status. A normal heart rate is between 60 and 100 beats per minute, however this can vary depending on factors such as age, sex, and activity level.

Heart rate is an important indicator of cardiovascular health. A heart rate that is consistently above or below the normal range may be a sign of an underlying medical condition such as heart disease or thyroid problems. A high heart rate, known as tachycardia, may be caused by conditions such as anxiety or anemia. A low heart rate, known as bradycardia, may be caused by conditions such as hypothyroidism or certain medications.

Heart rate can be easily measured by feeling the pulse on the wrist or neck, or using a Vitalism system. It is an important vital sign that should be regularly monitored, particularly for people with known heart conditions or risk factors for heart disease. By monitoring heart rate, healthcare providers can detect potential problems early and take steps to prevent or manage them...... Read More

Figure 60: Details page.

Figure 61: Vital Signs Measurement Page.



Your respiratory rate is 20 bpm

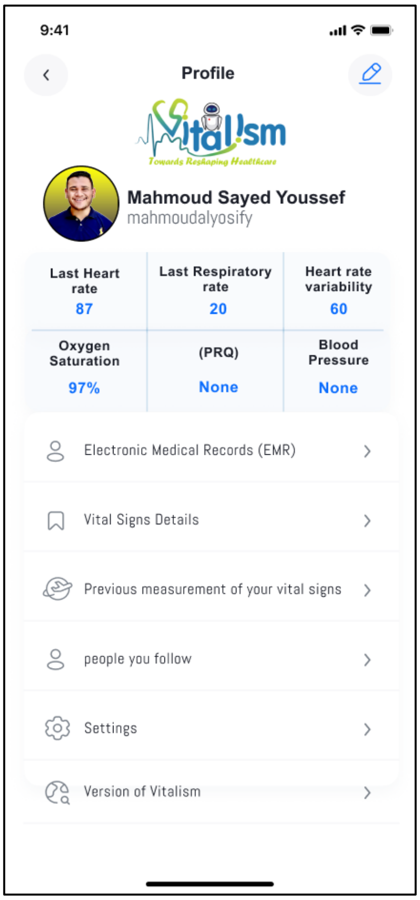
1	Username	mahmoudalyosify
2	Gender	Male
3	Blood type	A+
4	Age	23
5	Last respiratory rate	19
6	Date of last measurement	23/11/2022

RESPIRATORY RATE CONDITION ✓

CAREGIVERS CAN SEE YOUR RESULT ✓

THE USER HAS BEEN VERIFIED ✓

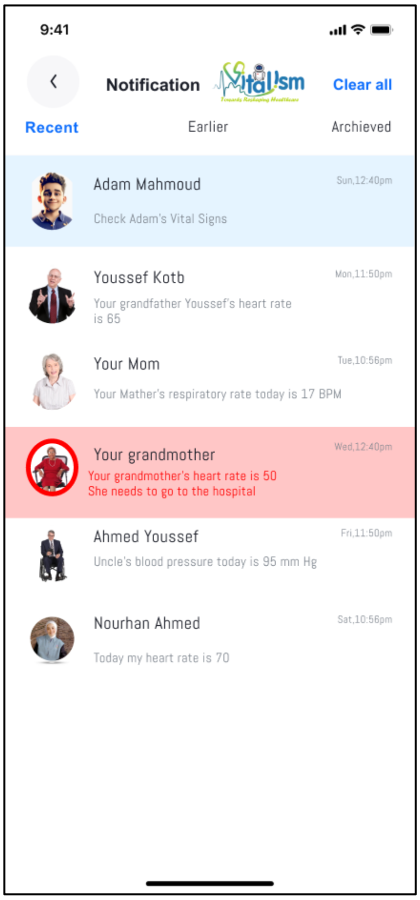
Figure 62: Result Page.



Mahmoud Sayed Youssef
mahmoudalyosify

Last Heart rate	Last Respiratory rate	Heart rate variability
87	20	60
Oxygen Saturation	**(PRQ)**	**Blood Pressure**
97%	None	None

Figure 63: User's Profile Page.



Adam Mahmoud Sun,12:40pm
Check Adam's Vital Signs

Youssef Kotb Mon,11:50pm
Your grandfather Youssef's heart rate is 65

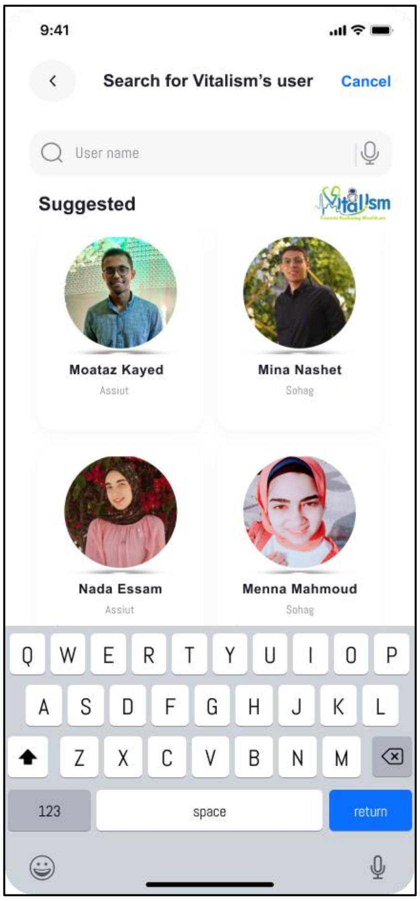
Your Mom Tue,10:56pm
Your Mather's respiratory rate today is 17 BPM

Your grandmother Wed,12:40pm
Your grandmother's heart rate is 50
She needs to go to the hospital

Ahmed Youssef Fri,11:50pm
Uncle's blood pressure today is 95 mm Hg

Nourhan Ahmed Sat,10:56pm
Today my heart rate is 70

Figure 64: Notification Page.



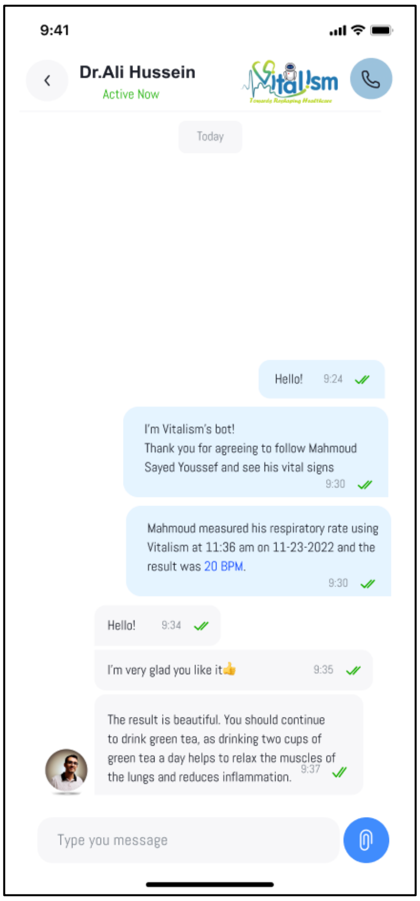
Moataz Kayed
Assiut

Mina Nashet
Sohag

Nada Essam
Assiut

Menna Mahmoud
Sohag

Figure 65: Search Page.



Hello! 9:24

I'm Vitalism's bot!
Thank you for agreeing to follow Mahmoud Sayed Youssef and see his vital signs 9:30

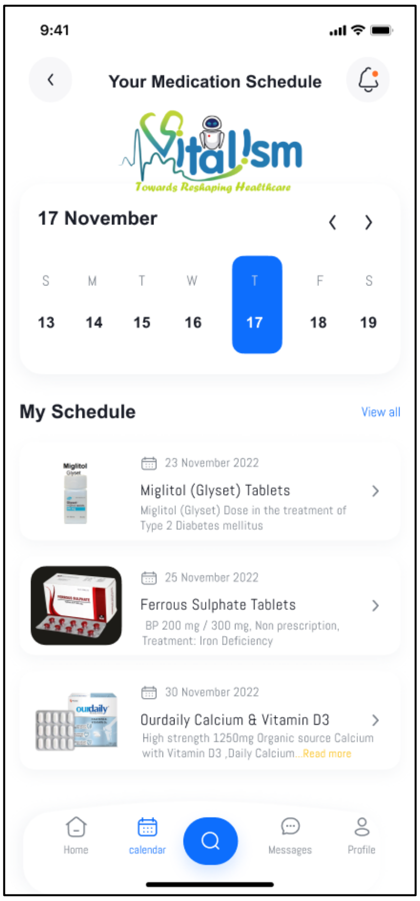
Mahmoud measured his respiratory rate using Vitalism at 11:36 am on 11-23-2022 and the result was 20 BPM. 9:30

Hello! 9:34

I'm very glad you like it👍 9:35

The result is beautiful. You should continue to drink green tea, as drinking two cups of green tea a day helps to relax the muscles of the lungs and reduces inflammation. 9:37

Figure 66: Chat Page.



23 November 2022
Miglitol (Glyset) Tablets
Miglitol (Glyset) Dose in the treatment of Type 2 Diabetes mellitus

25 November 2022
Ferrous Sulphate Tablets
BP 200 mg / 300 mg, Non prescription, Treatment: Iron Deficiency

30 November 2022
Ourdaily Calcium & Vitamin D3
High strength 1250mg Organic source Calcium with Vitamin D3 ,Daily Calcium...Read more

Figure 67: Medicine Page.

3.6 Testing and Quality Assurance

Testing is the process of making sure that the programs perform the intended tasks. Once the system is designed it should be tested for validity. In this phase various components of the system are integrated and systematically tested. During system testing, the system is used experimentally to ensure that the software does not fail, i.e., it will run according to its specification and in the way, users expect it to. The system is tested with special test data and the results are examined for their validity. Some of the users may be permitted to operate on the system so that the analyst can ascertain that the system can work in the specified environment. The testing approach for the Vitalism system will be a combination of manual and automated testing. The following types of tests will be performed:

Unit Testing: This type of testing will focus on individual components of the system, such as the user interface, data processing, and authentication modules. This testing ensures that each component is functioning correctly and meets the requirements specified in the design phase.

Integration Testing: This type of testing will focus on the integration of multiple components of the system. This testing ensures that the components are working together as expected and that there are no compatibility issues.

System Testing: This type of testing will focus on the entire system, including all components and their interactions. This testing verifies that the system meets all requirements and is functioning correctly.

Test Environment: The testing environment for the Vitalism system will consist of a test server and client devices. The test server will contain the latest version of the system and will be used for integration and system testing. The client devices will be used for unit and integration testing and will simulate real-world usage scenarios.

Test Data: The test data for the Vitalism system will consist of real and simulated data. Real data will be collected from volunteers and used to verify the accuracy of the system. Simulated data will be used to test the system's performance and scalability. The test data will be carefully selected to cover a range of scenarios and to ensure that all components of the system are thoroughly tested.

Functional Testing: Function testing determines whether the system is functioning correctly according to its specifications and relevant standards documentation.

Acceptance Testing: This is a final testing, if client is satisfied, signs for acceptance. Otherwise, if clients get errors or problems, the developer must modify the system again.

Testing stage is the one where the quality check takes place, and the testing approach for the Vitalism system will ensure that all components are thoroughly tested and that the system is functioning correctly. By using a combination of manual and automated testing, we can validate that the system meets all requirements and is ready for deployment. The testing environment and test data will provide a realistic representation of real-world usage scenarios and will help to uncover any potential issues before deployment.

3.7 Comparison Metrics

Root Mean Square Error (RMSE) is the standard deviation of the prediction errors. Prediction errors call as residuals as shown in Figure 68. Residuals can be measured by how far data points are from the regression line. The RMSE value is a measure of how far these residues have spread.

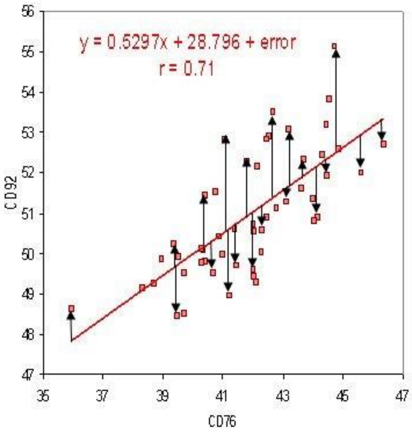


Figure 68: Residuals on a scatter plot [58].

RMSE value can be calculated as follows:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (Predicted_i - Actual_i)^2}{N}}$$

Mean absolute error (MAE) is a measure of errors between observations expressing the same phenomenon.

MAE is calculated as follows:

$$MAE = \frac{\sum_{i=1}^{n} |y_i - x_i|}{n} = \frac{\sum_{i=1}^{n} |e_i|}{n}$$

Signal-to-Ratio (SNR) is defined as the ratio of signal power to the noise power and calculated as follows:

$$SNR = \frac{P_{signal}}{P_{noise}}$$

The Mean Signal-to-Noise Ratio (MSNR) is a kind of matrix eigenvalue parsing method. Constructs the SNR function, predicts the separation matrix by eigenvalue decomposition or generalized eigenvalue decomposition. With this algorithm, the closed-form solution can be found without the iterative optimization process. MSNR can be calculated as follows:

$$MSNR = \frac{1}{N} \sum_{k=1}^{N} \left\{ 10log_{10} \left(\frac{S_k(f = f^*)}{\Sigma_{f \in F^*} S_k(f)} \right) \right\}$$

The correlation coefficient (r) is a measure of how close the points on a scatter plot are to the linear regression line. The correlation coefficient can be calculated as follows:

$$r = \frac{Cov(X, Y)}{\sqrt{s_x{}^2 s_y{}^2}}$$

where $Cov(X, Y)$ is the covariance and can be calculated as follows:

$$\mathrm{Cov}(X, Y) = \frac{\sum(X - X)(Y - Y)}{n - 1}$$

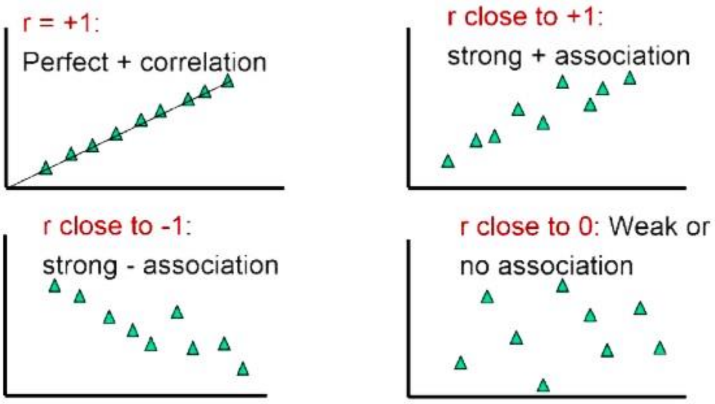


Figure 69: Example scatter plots for correlation coefficient [59].

3.8 Requirements Matrix

In Requirement Traceability Matrix, we set up a process of documenting the links between the user requirements proposed by the client to the system being built. In short, it's a high-level document to map and trace user requirements with test cases to ensure that for each and every requirement adequate level of testing is being achieved. We established it to make sure we place checks on the coverage aspect as shown below.

Requirement name	System component
1. User authentication	User authentication module
2. User interface	User interface module
3. Data processing and analysis	Data processing module
4. Data storage and retrieval	Data storage module
5. Vital signs monitoring	Vitalism End-to-End Framework
6. Data security and privacy	Data security and privacy module
7. User-friendly interface	User interface design
8. Accuracy and reliability	Testing and Quality assurance
9. Alerts and notifications Feature	Alerts and notifications module
10. Correctness	Evaluation and Maintenance
11.scalability and reliability	System Architecture
12.Data Management	Data Management module

Chapter 4
(Software Requirements Specification)

4.1 Introduction

The Software Specification Requirements (SRS) document of Vitalism outlines the functional and non-functional requirements of the Vitalism software. This document serves as a contract between the development team and stakeholders, defining the product's intended behavior, constraints, and features.

The SRS defines the system's functional requirements and performance characteristics and outlines the user interface and system architecture. This document is a comprehensive guide for the development team to ensure that the end product meets the expectations of the stakeholders and end-users.

The SRS will provide a clear understanding of the requirements, constraints, and objectives for the Vitalism software, and will be used as the basis for design, development, testing, and delivery.

4.1.1 Intended Audience and Reading Suggestions.

The intended audience of the Vitalism documentation are healthcare professionals, researchers, and developers in the field of telemedicine, remote patient monitoring, and medical device design. The documentation is written in a technical manner and assumes the reader has a basic understanding of these areas.

Reading suggestions for the Vitalism documentation include familiarizing oneself with the current state of telemedicine and remote patient monitoring technologies and their limitations, as well as understanding the concept of remote photoplethysmography (rPPG) and its use in monitoring vital signs. Familiarity with software development methodologies, user interface design, and data analysis would also be beneficial.

It is recommended that the reader carefully review all the chapters of the documentation, including the software proposal, software analysis, and software design, to fully understand the design and development process of Vitalism. Additionally, the reader should also review the management plan, risk management, and division of responsibilities among team members to understand the project organization and timeline.

In this present work, we utilize the extensive gamut of imaging technologies present in our smartphone camera, to measure and monitor bio-signals, towards better management of physical wellness, as well as towards taking precautionary and preventive action for alleviating medical issues.

4.1.2 Product Scope.

The product scope of Vitalism software is to provide a comprehensive health monitoring and management solution for individuals. This software will allow users to track their vital signs, manage their medication, and connect with emergency contacts. The user-friendly interface will enable users to easily measure and track their vital signs such as blood pressure, heart rate, and oxygen levels. The software will provide an in-depth analysis of the collected data and generate personalized health reports to help users make informed decisions about their health. In addition, the software will have features such as a search function, chat function, and a notification system to help users stay informed and connected with their health. The goal of Vitalism is to provide a comprehensive and reliable platform that empowers users to take control of their health and live a healthier life.

4.2 Overall Description

Vitalism is a software application designed to estimate the vital signs of an individual using a properly shot video. The vital signs estimated by the application include heart rate, respiratory rate, blood pressure, oxygen saturation, and heart rate variability. The application has been designed to have a user-friendly interface, making it easy to use for people from all backgrounds.

4.2.1 Product Perspective

Vitalism is an innovative health monitoring system that provides real-time information about the user's vital signs and overall health status. It is designed to be easy to use, reliable, and accurate, with a user-friendly interface that allows patients to monitor their own health with confidence. Vitalism is aimed at providing patients with better health outcomes and helping healthcare providers to deliver more effective care.

4.2.2 Product Functions

The vitalism system will provide a range of functions designed to help users monitor their health and receive real-time feedback on their vital signs. The main functions include:

i. Continuous monitoring of vital signs including heart rate, respiratory rate, and blood oxygen saturation levels.
ii. Real-time notifications and alerts to alert users of any changes in their vital signs that could indicate an underlying health condition.
iii. Easy-to-use interface for patients to view their vital signs and track changes over time.
iv. Integration with wearable devices and other health monitoring devices to provide a comprehensive view of the user's health status.
v. Ability to connect with healthcare providers for remote consultations and real-time health updates.

4.2.3 User Classes and Characteristics

The Vitalism system is designed for two primary user groups: non-medical users and medical users. non-medical users will use the system to monitor their own vital signs and receive real-time feedback on their health status and can monitor the vital sign of his/her followers, also can follow up with doctors by chatting with them in a chatbot and scheduling their medicine. Medical users will use the system to monitor the vital signs of their patients and provide remote consultations as needed, scheduling the medicine of their patients.

4.2.4 Operating Environment

The Vitalism system is designed to work on both hardware and software platforms to provide a seamless experience to the users. The hardware platform involves the use of an android device with camera, approximate sensor, and vision sensor along with a flash and a PC or laptop with a webcam. The software components and tools used to develop the project include android with C++ version 11, OpenCV, Camera and Firebase. The minimum required Android version for the application is 24, but this may vary with time. The database used for the android application is Room database based on SQLite.

For the desktop application, a web camera is used to capture live video and the tools used to obtain vital signs include OpenCV, Torch, Numpy, Pandas, Scipy, Dlib, Imutlis, Matplotlib, PyQt5, and PyQt-Graph packages.

4.2.5 Design and Implementation Constraints

The Vitalism system will be subject to various design and implementation constraints, including:

- Compliance with industry standards and regulations for medical devices.
- Integration with existing health monitoring systems and devices.
- User privacy and security, including the protection of sensitive health information.
- Medical users can follow 20 users and nonmedical users can follow 5 users only.
- Vitalism android system Requires at least Android version 8 and the volume of data 4 G Ram, a good camera with 680 × 420 PX resolution.
- Vitalism Desktop system with version windows 10 requires at least 4 G Ram with high processing CPU.
- Vitalism should also be integrated with another healthcare system such as (Electronic medical record) EMR database.
- Scalability and reliability, with the ability to handle large volumes of data and support many users simultaneously.

4.2.6 User Documentation

The Vitalism system will include a comprehensive user manual and other documentation to help users get the most out of the system. This will include information on how to use the system, troubleshooting tips, and advice on how to optimize performance.

4.2.7 Assumptions and Dependencies

The Vitalism system operates on several assumptions and dependencies, which are essential for its smooth and efficient functioning. Some of these are listed below:

1. Availability of wearable devices and other health monitoring equipment to continuously monitor vital signs.
2. Reliable internet connectivity to support real-time health updates, remote consultations, and backing up vital sign measurements.

3. User adoption of the system and willingness to use it to monitor their health.
4. Availability of trained healthcare providers to provide remote consultations and support.
5. The application is offline except for some features that require an internet connection.
6. Only verified user's measurements will be saved in the system.
7. The application will remind users to measure their vital signs and update their electronic medical records (EMR).
8. The measurement of heart rate, heart rate variability, blood pressure, and respiratory rate are based on the RPPG method, while the measurement of SpO2 depends on the PPG method.
9. Heart rate, heart rate variability, blood pressure, and respiratory rate measurements can be taken using both the android and desktop applications, while the measurement of SpO2 is limited to android applications due to the use of the flash.

These assumptions and dependencies are crucial for the proper functioning of the Vitalism system and will help ensure its success in improving patient health outcomes.

4.3 External Interface Requirements

The External Interface Requirements of Vitalism are a critical aspect of the overall design and implementation of the system. This section provides information and guidelines to ensure that the system will effectively and efficiently communicate with external components and devices. The goal of this section is to provide a comprehensive understanding of the hardware, software, and communication interfaces that are required for the proper functioning of Vitalism.

4.3.1 Hardware Interfaces

Vitalism should be compatible with a wide range of medical devices and equipment to collect patient data. For the Android application, the following are the requirements:

- ✓ Camera along with camera services and camera sensors such as approximate sensor and vision sensor to take videos in good lighting conditions.
- ✓ Mobile device must have at least 4 GB RAM with a high processing CPU.
- ✓ Internal storage for caching.
- ✓ Flash, if available.
- ✓ For the Desktop application, the following are the requirements:
- ✓ Camera web for taking videos in good lighting conditions.
- ✓ Python application can run on any desktop device with 8 GB RAM and a 5-core processor for acceleration and high-pool execution in the application.
- ✓ Internal storage for caching.
- ✓ Flash, if available.

4.3.2 Software Interfaces

Vitalism should be compatible with Windows as an operating system and should be integrated with other healthcare systems, such as electronic medical record (EMR) systems to ensure data interoperability and seamless integration. The following are the software requirements:

- ✓ The software is developed for Android and Windows 10.
- ✓ The database used for the Android application is the Room database based on SQLite.
- ✓ The minimum SDK or Android version required is 24 (android version) and may vary with time.
- ✓ Vitalism software uses libraries such as Open CV, NumPy, cv2, QMainWindow, pyqtSignal, and QObject.

4.3.3 Communications Interfaces

Communications interfaces are the interfaces that belong to any communication functions that are required and used in Vitalism software. The following are the communication requirements:

- ✓ Vitalism should support secure communication protocols such as HTTPS for data transmission.
- ✓ The system should be able to communicate with other devices and systems using standardized protocols such as HL7 and DICOM.
- ✓ The system will use HTML Forms to get feedback and data from the user.
- ✓ Vitalism should have the capability to generate reports and export data in various formats, such as PDF, CSV, and Excel.
- ✓ Vitalism uses video-based to capture the vital signs and measure it.
- ✓ The data that will be stored in the database for one user is estimated at about 20 MB.
- ✓ The user can sign up in the application by using their Gmail details.
- ✓ The email that the user will use can be "xxxxxxxx@your-website.com" and it does not require a specific type of website.

4.4 System Features

System Features for Vitalism:

Self-Monitoring: The system is designed to measure the vital signs of patients and display the results in real-time.

User Authentication: Vitalism includes a secure user authentication module that ensures only authorized personnel have access to patient data.

Data Processing: Vitalism processes the data of the patients and tracking the vital signs.

Alerts and Notifications: The system is capable of sending alerts and notifications to healthcare providers in real-time if the vital sign of a patient falls outside of a normal range.

Report Generation: Vitalism generates detailed reports of patient data that can be used for analysis and to support patient care decisions.

User-friendly Interface: Vitalism is designed with a user-friendly interface that allows healthcare providers to easily monitor and access patient data.

Mobile Compatibility: Vitalism can be accessed from a variety of devices, including mobile phones and tablets, to provide healthcare providers with easy access to patient's data.

Integration with Electronic medical Records (EMRs): Vitalism integrates with existing EMRs to provide a complete picture of a patient's health history.

Data Security: Vitalism includes robust security measures to ensure the confidentiality and privacy of patient data.

Remote Monitoring: Vitalism allows healthcare providers to monitor patient data from remote locations, enabling remote patient care.

User Customization: Vitalism allows healthcare providers to customize the system to their specific needs and requirements.

Historical Data Tracking: Vitalism maintains a historical record of patient data, allowing for easy tracking and analysis of patient progress over time.

4.5 Other Nonfunctional Requirements

Vitalism is a digital health platform designed to support overall health and wellness by monitoring and tracking vital signs and health metrics. In this section, we will describe the nonfunctional requirements critical to the system's success.

4.5.1 Performance Requirements

Scalability: Vitalism should be able to process and analyze substantial amounts of data in real-time with high accuracy and efficiency.

Response Time: The system should be able to handle simultaneous access by multiple users and provide quick and responsive results. The response to all the operations is good. Any interaction between the user and the system should not exceed 2 seconds.

User Satisfaction: The system is such that it stands up to the user's expectations.

Error Handling: Response to user errors and undesired situations that have been taken.

User friendliness: The system is easy to learn and understand. A native user can also use the system effectively, without any difficulties.

- **Operational**

Availability: The system should be designed to minimize downtime and ensure high availability; the system is available 24 hours.

Reliability: The system must be reliable, so that the user can use it safely and reliably, so the system runs on at least 97% reliability.

4.5.2 Safety Requirements

Vitalism should comply with all relevant safety regulations and standards to ensure the protection of user data and privacy.

The system should be designed to minimize potential risks to users, such as data breaches or unauthorized access.

If there is extensive damage to a wide portion of the database due to catastrophic failure, such as a disk crash, the recovery method restores a past copy of the database that was backed up to archival storage and reconstructs a more current state by reapplying or redoing the operations of committed transactions from the backed-up log, up to the time of failure.

4.5.3 Security Requirements

Vitalism should implement robust security measures to protect user data and prevent unauthorized access.

The system should be designed to meet industry standards for data encryption and secure communication.

All the administrative and data entry operators have unique login so system can understand who login into system is right now no intruders allowed except system administrative nobody cannot change record and valuable data.

4.5.4 Software Quality Attributes

Vitalism should be user-friendly and easy to use, with a clear and intuitive interface.

The system should be scalable and able to adapt to changing user needs and requirements over time.

The software should be thoroughly tested and validated to ensure high reliability and stability.

A bug free software which fulfills the correct need/requirements of the client.

The ability to maintain, modify information and update fix problems of the system.

Software can be used repeatedly without distortion.

Administrator and many other users can access the system, but the access level is controlled for each user according to their work scope.

4.5.5 Business Rules

Vitalism should comply with all relevant regulations and guidelines related to data privacy and security.

The system should be designed to support the growth and success of the business, including the ability to monetize the platform and generate revenue.

Vitalism should be designed to support the business strategy and goals, including the ability to integrate with other systems and platforms as needed.

5. Conclusion

The conclusion of Vitalism's documentation is a summary of the key findings and insights obtained from the four chapters of the document. These chapters have provided a comprehensive overview of the proposed software, from its initial proposal to the software requirements specification.

In the first chapter, the software proposal, the overall concept of the Vitalism software was introduced, and the key objectives were outlined. The software was envisioned as a comprehensive health monitoring platform that aims to provide users with an easy and convenient way to monitor their health and vital signs. The purpose of the software is to improve the health and well-being of users by providing them with accurate and reliable information about their health status, and by enabling them to easily track changes in their vital signs over time.

The second chapter, the software analysis, delved deeper into the requirements and constraints of the software. A thorough analysis of the market and competitors was conducted, and user requirements and constraints were identified. The results of the analysis provided important insights into the key features and functionalities that need to be included in the software to make it appealing to users and competitive in the market. This chapter also included a discussion of the potential challenges and limitations of the software, and how these could be addressed in the design and development process.

The third chapter, the software design, detailed the design of the software, including the user interface, system architecture, and the data storage model. The design was created in such a way as to meet the requirements outlined in the analysis, while also being aesthetically pleasing and easy to use. The design also took into account the technical constraints of the software and the hardware on which it will run, to ensure that it will be feasible to develop and implement.

The final chapter, the software requirements specification, provided a comprehensive description of the functional and non-functional requirements of the software. This chapter served as a contract between the development team and stakeholders, outlining the product's intended behavior, constraints, and features. It provided a clear understanding of the requirements, constraints, and objectives for the Vitalism software, and will serve as the basis for design, development, testing, and delivery.

In conclusion, the four chapters of the Vitalism documentation have provided a comprehensive overview of the proposed software and have set the foundation for its development. The software proposal, analysis, design, and requirements specification have all been carefully crafted to ensure that the end product meets the expectations of stakeholders and end-users. The Vitalism software has the potential to revolutionize the health monitoring industry, and this documentation will serve as a guide for its development and success. With its comprehensive approach to health monitoring and its user-friendly design, Vitalism has the potential to make a real difference in people's lives by improving their health and well-being. The development team is confident that the software will be a success, and that it will be widely adopted by users around the world.

6. Future Works

The Vitalism software has great potential to revolutionize the health monitoring industry and provide users with a convenient and comprehensive platform for monitoring their health and vital signs. As the development of the software continues, the team behind Vitalism has several future plans and goals to further enhance the user experience and add new features to the platform.

Some of the future work plans for Vitalism include:

I. Introducing groundbreaking bloodless blood tests - The team aims to add a feature that will allow users to measure hemoglobin, hemoglobin A1C, and cholesterol total using a smartphone or laptop camera.

II. Monitoring photosynthesis - Another goal is to add a feature that will enable the monitoring of the photosynthesis of the planet.

III. Health monitoring of children and the elderly - The team also plans to create a moving robot that can scan faces of children and measure their vital signs. If any health problems are detected, alerts will be sent to their parents, and the elderly can also be monitored.

IV. Adding games to increase user engagement - The team recognizes the importance of keeping users engaged and entertained while using the application. With this in mind, they plan to add games to the platform to prevent boredom and increase user passion.

V. Measuring vital signs using the Computer Mouse - Lastly, the team plans to add a feature that will allow users to measure their vital signs using their computer mouse. By placing their fingerprint on the left mouse button, which is present most of the time when using a computer, users will be able to easily measure their vital signs.

VI. These future plans and goals for Vitalism demonstrate the team's commitment to providing users with a comprehensive and innovative health monitoring platform. The future work outlined above will further enhance the user experience and provide users with new and exciting features.

7. Appendices

7.1 Appendix A:Professional Considerations

- **Methodological Considerations / Engineering Standards**
    - ✓ We will use GitHub to manage version control.
    - ✓ We will use Python, Kotlin and Java to develop the software.
    - ✓ We will use PURE dataset.
    - ✓ We will use the Waterfall Project Management Model for the software development process.
    - ✓ We will use Gantt charts for our management plan.
- **Societal / Ethical Considerations**
    - **Economical**

Since our studies do not require the use of devices such as Electrocardiogram , Sphygmomanometer, Respiratory inductive plethysmography, and Pulse Oximeter used in hospitals, it is an economically viable study as we can measure it using a simple webcam.

- **Environmental**

The equipment we will use in our work does not contain any substances that can pollute the environment.

- **Health and Safety**

Since the main purpose of rPPG is to calculate vital signs for non-contact patients, it is a method that can be used for every patient. In addition, it does not pose any threat to patients in terms of health and safety.

- **Legal Considerations**

Since the datasets and libraries, we will use are open source, they do not pose a legal problem.

7.2 Appendix B:Python Code for Heart Rate

The following Python codes were implemented to extract heart rate using Vitalism.

Main code of Vitalism

```
from ast import parse
import sys
import argparse


from PyQt5.QtWidgets import QApplication
from Vitalism.rppg.camera import Camera
from Vitalism.ui import MainWindow
from Vitalism.rppg import RPPG
from Vitalism.rppg.processors import ColorMeanProcessor,
FilteredProcessor
from Vitalism.rppg.hr import HRCalculator
from Vitalism.rppg.filters import get_butterworth_filter
from Vitalism.ui.cli import (get_detector, get_mainparser,
get_processor,
                           parse_frequencies, get_delay)


def main():
    parser = get_mainparser()
    args = parser.parse_args(sys.argv[1:])
    app = QApplication(sys.argv)

    roi_detector = get_detector(args)

    digital_lowpass = get_butterworth_filter(30, 1.5)
    hr_calc = HRCalculator(parent=app, update_interval=30,
winsize=300,
                           filt_fun=lambda vs:
[digital_lowpass(v) for v in vs])

    processor = get_processor(args)

    cutoff = parse_frequencies(args.bandpass)
    if cutoff is not None:
        digital_bandpass = get_butterworth_filter(30, cutoff,
"bandpass")
        processor = FilteredProcessor(processor,
digital_bandpass)

    cam = Camera(video=args.video, limit_fps=get_delay(args))
    rppg = RPPG(roi_detector=roi_detector,
                camera=cam,
                hr_calculator=hr_calc,
                parent=None,
                )
    rppg.add_processor(processor)
    for c in "rgb":
```

```
        rppg.add_processor(ColorMeanProcessor(channel=c,
winsize=1))

    if args.savepath:
        rppg.output_filename = args.savepath

    win = MainWindow(app=app,
                     rppg=rppg,
                     winsize=(1000, 400),
                     legend=True,
                     graphwin=300,
                     blur_roi=args.blur,
                     )
    for i in range(3):
        win.set_pen(index=i+1, color="rgb"[i], width=1)

    return win.execute()


if __name__ == "__main__":
    sys.exit(main())
```

Frame Extracting Function

```
import numpy as np
from PyQt5.QtCore import QObject, pyqtSignal
import scipy.signal


def bpm_from_inds(inds, ts):
    """Calculate heart rate (in beat/min) from indices and time
vector

    Args:
        inds (`1d array-like`): indices of heart beats
        ts (`1d array-like`): time vector corresponding to
indices

    Returns:
        float: heart rate in beats per minute (bpm)
    """

    if len(inds) < 2:
        return np.nan

    return 60. / np.mean(np.diff(ts[inds]))


def get_sampling_rate(ts):
    """Calculate sampling rate from time vector
    """
    return 1. / np.mean(np.diff(ts))
```

```
def from_peaks(vs, ts, mindist=0.35):
    """Calculate heart rate by finding peaks in the given signal

    Args:
        vs (`1d array-like`): pulse wave signal
        ts (`1d array-like`): time vector corresponding to pulse
signal
        mindist (float): minimum distance between peaks (in
seconds)

    Returns:
        float: heart rate in beats per minute (bpm)
    """

    if len(ts) != len(vs) or len(ts) < 2:
        return np.nan
    f = get_sampling_rate(ts)
    peaks, _ = scipy.signal.find_peaks(vs,
distance=int(f*mindist))

    return bpm_from_inds(peaks, ts)


def from_fft(vs, ts):
    """Calculate heart rate as most dominant frequency in pulse
signal

    Args:
        vs (`1d array-like`): pulse wave signal
        ts (`1d array-like`): time vector corresponding to pulse
signal

    Returns:
        float: heart rate in beats per minute (bpm)
    """

    f = get_sampling_rate(ts)
    vf = np.fft.fft(vs)
    xf = np.linspace(0.0, f/2., len(vs)//2)
    return 60 * xf[np.argmax(np.abs(vf[:len(vf)//2]))]


class HRCalculator(QObject):
    new_hr = pyqtSignal(float)

    def __init__(self, parent=None, update_interval=30,
winsize=300,
                 filt_fun=None, hr_fun=None):
        QObject.__init__(self, parent)

        self._counter = 0
        self.update_interval = update_interval
        self.winsize = winsize
        self.filt_fun = filt_fun
```

```
        self.hr_fun = from_peaks
        if hr_fun is not None and callable(hr_fun):
            self.hr_fun = hr_fun

    def update(self, rppg):
        self._counter += 1
        if self._counter >= self.update_interval:
            self._counter = 0
            ts = rppg.get_ts(self.winsize)
            vs = next(rppg.get_vs(self.winsize))
            if self.filt_fun is not None and
callable(self.filt_fun):
                vs = self.filt_fun(vs)
            self.new_hr.emit(self.hr_fun(vs, ts))
```

ROI Detect Function

```
from pathlib import Path
import warnings
import time

import cv2
import numpy as np
import mediapipe as mp
mp_drawing = mp.solutions.drawing_utils
mp_drawing_styles = mp.solutions.drawing_styles
mp_face_mesh = mp.solutions.face_mesh

from Vitalism.rppg.roi.region_of_interest import
RegionOfInterest, get_default_bgmask

resource_path = Path(__file__).parent.parent / "_resources"


def exponential_smooth(new_roi, old_roi, factor):
    if factor <= 0.0 or old_roi is None:
        return new_roi

    smooth_roi = np.multiply(new_roi, 1 - factor) +
np.multiply(old_roi, factor)
    return tuple(smooth_roi.astype(int))

def get_boundingbox_from_landmarks(lms):
    xy = np.min(lms, axis=0)
    wh = np.subtract(np.max(lms, axis=0), xy)

    return np.r_[xy, wh]

class ROIDetector:
    def __init__(self, smooth_factor=0.0, **kwargs):
        self.oldroi = None
        self.smooth_factor = smooth_factor
```

```
        super().__init__(**kwargs)

    def detect(self, frame):
        raise NotImplementedError("detect method needs to be
overwritten.")

    def get_roi(self, frame):
        roi = self.detect(frame)
        return roi
        # self.oldroi = exponential_smooth(roi, self.oldroi,
self.smooth_factor)

        # return self.oldroi

    def __call__(self, frame):
        return self.get_roi(frame)

class NoDetector(ROIDetector):
    def __init__(self, **kwargs):
        super().__init__(**kwargs)

    def detect(self, frame):
        h, w = frame.shape[:2]
        return RegionOfInterest.from_rectangle(frame, (0, 0), (h,
w))


class CaffeDNNFaceDetector(ROIDetector):
    prototxt = resource_path / "deploy.prototxt"
    caffemodel = resource_path /
"res10_300x300_ssd_iter_140000_fp16.caffemodel"

    color_mean = (128, 128, 128)

    def __init__(self, prototxt=None, caffemodel=None,
                 blob_size=(300, 300),
                 min_confidence=0.3,
                 **kwargs
                 ):
        super().__init__(**kwargs)
        print(self.caffemodel)
        self.blob_size = blob_size
        self.min_confidence = min_confidence
        if prototxt is None:
            prototxt = self.prototxt
        if caffemodel is None:
            caffemodel = self.caffemodel
        self.model = cv2.dnn.readNetFromCaffe(str(prototxt),
str(caffemodel))

    def detect(self, frame):
        h, w = frame.shape[:2]
        blob = cv2.dnn.blobFromImage(frame, 1.0, self.blob_size,
self.color_mean)
```

```
        self.model.setInput(blob)
        detections = self.model.forward()[0, 0, ...]
        for det in detections:
            if det[2] > self.min_confidence:
                x1, y1, x2, y2 = np.multiply(
                    det[3:7], (w, h, w, h)).astype(int)
                return RegionOfInterest.from_rectangle(frame,
(x1, y1), (x2, y2))
        return RegionOfInterest(frame)


class HaarCascadeDetector(ROIDetector):
    default_cascade = resource_path /
"haarcascade_frontalface_default.xml"

    def __init__(self,
                 casc_file=None,
                 scale_factor=1.1,
                 min_neighbors=5,
                 min_size=(30, 30),
                 **kwargs):
        super().__init__(**kwargs)
        self.scale_factor = scale_factor
        self.min_neighbors = min_neighbors
        self.min_size = min_size
        self.cascade = self._get_classifier(casc_file)

    def detect(self, frame):
        gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
        faces = self.cascade.detectMultiScale(gray,

scaleFactor=self.scale_factor,

minNeighbors=self.min_neighbors,
                                              )#
minSize=self.min_size)
        if len(faces) > 0:
            x, y, w, h = faces[0]
            return RegionOfInterest.from_rectangle(frame, (x, y),
(x+w, y+h))

        return RegionOfInterest(frame, mask=None)

    @classmethod
    def _get_classifier(cls, casc_file: str):
        if casc_file is not None and Path(casc_file).is_file():
            cascade = cv2.CascadeClassifier(casc_file)
        elif Path(cls.default_cascade).is_file():
            warnings.warn("cascade file '{}' not found, using
default instead"
                          "".format(casc_file))
            cascade =
cv2.CascadeClassifier(str(cls.default_cascade))
        else:
```

```
            raise IOError("cascade file '{}' not 
found".format(casc_file))

        return cascade


def get_facemesh_coords(landmark_list, frame):
    h, w = frame.shape[:2]
    xys = [(landmark.x, landmark.y) for landmark in 
landmark_list.landmark]

    return np.multiply(xys, [w, h]).astype(int)

class FaceMeshDetector(ROIDetector):
    _lower_face = [200, 431, 411, 340, 349, 120, 111, 187, 211]

    def __init__(self, draw_landmarks=False, refine=False, 
**kwargs):
        super().__init__(**kwargs)
        self.face_mesh = mp.solutions.face_mesh.FaceMesh(
            max_num_faces=1,
            refine_landmarks=refine,
            min_detection_confidence=0.5,
            min_tracking_confidence=0.5
        )
        self.draw_landmarks=draw_landmarks

    def __del__(self):
        self.face_mesh.close()

    def detect(self, frame):
        rawimg = frame.copy()

        frame.flags.writeable = False
        results = self.face_mesh.process(frame)
        frame.flags.writeable = True

        if results.multi_face_landmarks is None:
            return RegionOfInterest(frame, mask=None)

        if self.draw_landmarks:
            self.draw_facemesh(frame, 
results.multi_face_landmarks,
                               tesselate=True)

        landmarks = 
get_facemesh_coords(results.multi_face_landmarks[0], frame)
        facerect = get_boundingbox_from_landmarks(landmarks)
        bgmask = get_default_bgmask(frame.shape[1], 
frame.shape[0])

        return RegionOfInterest.from_contour(rawimg, 
landmarks[self._lower_face],
```

```
                                                      facerect=facerect,
bgmask=bgmask)

    def draw_facemesh(self, img, multi_face_landmarks,
tesselate=False,
                      contour=False, irises=False):
        if multi_face_landmarks is None:
            return

        for face_landmarks in multi_face_landmarks:
            if tesselate:
                mp.solutions.drawing_utils.draw_landmarks(
                    image=img,
                    landmark_list=face_landmarks,

connections=mp_face_mesh.FACEMESH_TESSELATION,
                    landmark_drawing_spec=None,
                    connection_drawing_spec=mp_drawing_styles
                    .get_default_face_mesh_tesselation_style())
            if contour:
                mp.solutions.drawing_utils.draw_landmarks(
                    image=img,
                    landmark_list=face_landmarks,

connections=mp.solutions.face_mesh.FACEMESH_CONTOURS,
                    landmark_drawing_spec=None,

connection_drawing_spec=mp.solutions.drawing_styles
                    .get_default_face_mesh_contours_style())
            if irises and len(face_landmarks) > 468:
                mp.solutions.drawing_utils.draw_landmarks(
                    image=img,
                    landmark_list=face_landmarks,
                    connections=mp_face_mesh.FACEMESH_IRISES,
                    landmark_drawing_spec=None,
                    connection_drawing_spec=mp_drawing_styles

.get_default_face_mesh_iris_connections_style())
```

Butterworth Filter

```
import numpy as np
import scipy.signal


def get_butterworth_filter(f, cutoff, btype="low", order=2):
    ba = scipy.signal.butter(N=order, Wn=np.divide(cutoff, f/2.),
btype=btype)
    return DigitalFilter(ba[0], ba[1])


class DigitalFilter:
```

```
    def __init__(self, b, a):
        self._bs = b
        self._as = a
        self._xs = [0]*len(b)
        self._ys = [0]*(len(a)-1)

    def process(self, x):
        if np.isnan(x):  # ignore nans, and return as is
            return x

        self._xs.insert(0, x)
        self._xs.pop()
        y = (np.dot(self._bs, self._xs) / self._as[0]
             - np.dot(self._as[1:], self._ys))
        self._ys.insert(0, y)
        self._ys.pop()
        return y

    def __call__(self, x):
        return self.process(x)


if __name__ == "__main__":
    fs = 30
    x = np.arange(0, 10, 1.0/fs)
    y = np.sin(2*np.pi*x) + 0.2*np.random.normal(size=len(x))

    import pyqtgraph as pg
    app = pg.QtGui.QApplication([])
    p = pg.plot(title="test")
    p.plot(x, y)
    ba = scipy.signal.butter(2, 3/fs*2)
    yfilt = scipy.signal.lfilter(ba[0], ba[1], y)
    p.plot(x, yfilt, pen=(0, 3))

    myfilt = DigitalFilter(ba[0], ba[1])
    yfilt2 = [myfilt(v) for v in y]
    p.plot(x, yfilt2, pen=(1, 3))
    app.exec_()
```

Region of interest at Vitalism

```
import functools

from multiprocessing.sharedctypes import Value
import cv2
import numpy as np


def pixelate(img, xywh, blur):
    if blur > 0:
```

```
        x, y, w, h = xywh
        slicex = slice(x, x+w)
        slicey = slice(y, y+h)

        tmp = cv2.resize(img[slicey, slicex], (w//blur, h//blur),
                                 interpolation=cv2.INTER_LINEAR)
        img[slicey, slicex] = cv2.resize(tmp, (w, h),

interpolation=cv2.INTER_NEAREST)

@functools.lru_cache(maxsize=2)
def get_default_bgmask(w, h):
    mask = np.zeros((h, w), dtype="uint8")
    cv2.rectangle(mask, (0, 0), (w, 5), 255, -1)

    return mask

class RegionOfInterest:
    def __init__(self, base_img, mask=None, bgmask=None,
facerect=None):
        self.rawimg = base_img

        self._mask = mask
        self._rectangle = None
        self._empty = True
        self._rectangular = False
        self._contours = None
        self._bgmask = bgmask
        self._facerect = facerect

        if mask is not None:
            self._rectangle = cv2.boundingRect(mask)
            self._empty = (self._rectangle[2] == 0 or
self._rectangle[3] == 0)

    @classmethod
    def from_rectangle(cls, base_img, p1, p2, **kwargs):
        # https://www.pyimagesearch.com/2021/01/19/image-masking-
with-opencv/
        mask = np.zeros(base_img.shape[:2], dtype="uint8")
        cv2.rectangle(mask, p1, p2, 255, cv2.FILLED)

        roi = RegionOfInterest(base_img, mask=mask, **kwargs)
        roi._rectangular = True

        return roi

    @classmethod
    def from_contour(cls, base_img, pointlist, **kwargs):
        # pointlist with shape nx2
        mask = np.zeros(base_img.shape[:2], dtype="uint8")
        contours = np.reshape(pointlist, (1, -1, 1, 2))
        cv2.drawContours(mask, contours, 0, color=255,
thickness=cv2.FILLED)
```

```
        roi = RegionOfInterest(base_img, mask, **kwargs)
        roi._contours = contours

        return roi

    def draw_roi(self, img, color=(255, 0, 0), thickness=3):
        if self.is_empty():
            return

        if self.is_rectangular():
            p1, p2 = self.get_bounding_box(as_corners=True)
            cv2.rectangle(img, p1, p2, color, thickness)
        else:
            cv2.drawContours(img, self._contours, 0, color=color,
                             thickness=thickness)

    def pixelate_face(self, img, blursize):
        if not self.is_empty():
            xywh = self._rectangle if self._facerect is None else
self._facerect
            pixelate(img, xywh, blursize)

    def is_rectangular(self):
        return self._rectangular

    def is_empty(self):
        return self._empty

    def get_bounding_box(self, as_corners=False):
        """Bounding box specified as (x, y, w, h) or min/max
corners
        """
        if as_corners:
            x, y, w, h = self._rectangle
            return (x, y), (x+w, y+h)
        return self._rectangle

    def get_mean_rgb(self, background=False):
        mask = self._mask
        if background:
            if self._bgmask is None:
                raise ValueError("Background mask is not
specified")
            mask = self._bgmask

        r, g, b, a = cv2.mean(self.rawimg, mask)
        return r, g, b

    def __str__(self):
        if self.is_empty():
            return "RegionOfInterest(empty)"
        if self.is_rectangular():
            return f"RegionOfInterest(rect={self._rectangle})"
```

```
        return f"RegionOfInterest(masked within
bb={self._rectangle})"
```

rPPG Function

```
from collections import namedtuple
from datetime import datetime
import pathlib

import numpy as np
import pandas as pd
from PyQt5.QtCore import pyqtSignal, QObject

from Vitalism.rppg.camera import Camera


def write_dataframe(path, df):
    path = pathlib.Path(path)
    if path.suffix.lower() == ".csv":
        df.to_csv(path, float_format="%.7f", index=False)
    elif path.suffix.lower() in {".pkl", ".pickle"}:
        df.to_pickle(path)
    elif path.suffix.lower() in {".feather"}:
        df.to_feather(path)
    else:
        raise IOError("Unknown file extension
'{}'".format(path.suffix))

RppgResults = namedtuple("RppgResults", ["dt",
                                         "rawimg",
                                         "roi",
                                         "hr",
                                         "vs_iter",
                                         "ts",
                                         "fps",
                                         ])


class RPPG(QObject):
    rppg_updated = pyqtSignal(RppgResults)
    _dummy_signal = pyqtSignal(float)

    def __init__(self, roi_detector, parent=None, camera=None,
                 hr_calculator=None):
        QObject.__init__(self, parent)
        self.roi = None
        self._processors = []
        self._roi_detector = roi_detector

        self._set_camera(camera)

        self._dts = []
        self.last_update = datetime.now()
```

```
        self.output_frame = None
        self.hr_calculator = hr_calculator

        if self.hr_calculator is not None:
            self.new_hr = self.hr_calculator.new_hr
        else:
            self.new_hr = self._dummy_signal

        self.output_filename = None

    def _set_camera(self, camera):
        self._cam = camera or Camera(video=0, parent=self)
        self._cam.frame_received.connect(self.on_frame_received)

    def add_processor(self, processor):
        self._processors.append(processor)

    def on_frame_received(self, frame):
        self.output_frame = frame
        self.roi = self._roi_detector(frame)

        for processor in self._processors:
            processor(self.roi)

        if self.hr_calculator is not None:
            self.hr_calculator.update(self)

        dt = self._update_time()
        self.rppg_updated.emit(RppgResults(dt=dt, rawimg=frame,
roi=self.roi,
                                           hr=np.nan,
vs_iter=self.get_vs,
                                           ts=self.get_ts,
fps=self.get_fps()))

    def _update_time(self):
        dt = (datetime.now() - self.last_update).total_seconds()
        self.last_update = datetime.now()
        self._dts.append(dt)

        return dt

    def get_vs(self, n=None):
        for processor in self._processors:
            if n is None:
                yield np.array(processor.vs, copy=True)
            else:
                yield np.array(processor.vs[-n:], copy=True)

    def get_ts(self, n=None):
        if n is None:
            dts = self._dts
        else:
```

```
            dts = self._dts[-n:]
        return np.cumsum(dts)

    def get_fps(self, n=5):
        return 1/np.mean(self._dts[-n:])

    def save_signals(self):
        path = pathlib.Path(self.output_filename)
        path.parent.mkdir(parents=True, exist_ok=True)

        df = self.get_dataframe()
        write_dataframe(path)

    def get_dataframe(self):
        names = ["ts"] + ["p%d" % i for i in
range(self.num_processors)]
        data = np.vstack((self.get_ts(),) +
tuple(self.get_vs())).T

        return pd.DataFrame(data=data, columns=names)

    @property
    def num_processors(self):
        return len(self._processors)

    @property
    def processor_names(self):
        return [str(p) for p in self._processors]

    def start(self):
        self._cam.start()

    def finish(self):
        print("finishing up...")
        if self.output_filename is not None:
            self.save_signals()
        self._cam.stop()
```

8. References

1. Hopkins Medicine. (n.d.). Newborn Skin 101 [Website]. Retrieved from https://www.hopkinsmedicine.org/health/wellness-and-prevention/newborn-skin-101
2. Kamal AAR vd. Skin Photoplethysmography-A Review, Computer Methods and Programs in Biomedicine, Cilt. 28, No. 4, 1989, s.257-269
3. Allen J. Photoplethysmography and Its Application in Clinical Physiological Measurement, Physiol Meas., Cilt. 28, No. 3, 2007, s.R1-39
4. Eugene L. Evan C. Chen-Yi L. Meta-rPPG: Remote Heart Rate Estimation Using a Transductive Meta-Learner, Institute of Electronics, National Chiao Tung University, 2020
5. Verkruysse W, Svaasand LO, Nelson JS. Remote plethysmographic imaging using ambient light. Optics Express, 2008, 16(26): 21434–21445
6. Li X, Chen J, Zhao G, Pietikäinen M. Remote heart rate measurement from face videos under realistic situations. In: Proceedings of the 2014 IEEEComputer Society Conference on Computer Vision and Pattern Recognition. 2014, 4264–4271
7. Cheriyedath, Susha. (2019, February 27). Photoplethysmography (PPG). News-Medical. Retrieved on January 29, 2023 from https://www.news-medical.net/health/Photoplethysmography-(PPG).aspx.
8. U.S. Food and Drug Administration. (n.d.). Pulse oximeter accuracy and limitations: FDA safety communication.
9. Paul Viola and Michael Jones (2001), Robust Real-time Object Detection, International Journal of Computer Vision.
10. Ward, A. (n.d.). Facial Detection: Understanding the Viola-Jones Algorithm. Medium. Retrieved February 1, 2023, from https://medium.com/@aaronward6210/facial-detection-understanding-viola-jones-algorithm-116d1a9db218. & Aphile SD. Detecting Faces (Viola Jones Algorithm) - Computerphile. https://www.youtube.com/watch?v=uEJ71VlUmMQ&t=448s (accessed).
11. Fouad, R. M., Omer, O. A., Ali, A. M. M., & Aly, M. H. (2019, February). Refining ROI selection for real-time remote photoplethysmography using adaptive skin detection. In 2019 International Conference On Innovative Trends In Computer Engineering (ITCE'2019) (pp. 6). IEEE. doi: 10.1109/ITCE.2019.8646412.
12. W. M. Gentleman and G. Sande, "Fast Fourier transforms for fun and profit", 1966 Fall Joint Computer Conference AFIPS Proc., vol. 29, pp. 563-578.
13. Wang, W., den Brinker, A. C., Stuijk, S., & de Haan, G. (2016). Algorithmic principles of remote ppg. IEEE Transactions on Biomedical Engineering, 64(7), 1479-1491.
14. Ntonfo, G. M. K., Ferrari, G., Raheli, R., & Pisani, F. (2012). Low-Complexity Image Processing for Real-Time Detection of Neonatal Clonic Seizures. IEEE Transactions on Information Technology in Biomedicine, 16, 375-382.
15. Gonzalez, R. C., & Woods, R. E. (2008). Digital Image Processing (3rd ed.). Pearson Education, Inc.
16. Yang, C., Cheung, G., & Stankovic, V. (2017). Estimating Heart Rate and Rhythm via 3D Motion Tracking in Depth Video. IEEE Transactions on Multimedia, 19, 1625-1636.
17. Chiann, C., & Moretin, P. A. (1998). A Wavelet Analysis for Time Series, Nonparametric Statistics. 10, 1-46.

18. Dghais, A. A., Ismail, A., & Tahir, M. (2013). A Comparative Study between Discrete Wavelet Transform and Maximal Overlap Discrete Wavelet Transform for Testing Stationarity. International Journal of Mathematical Science and Engineering, 7, 471-475.
19. Zhang, Z. et al. (2016). Choosing Wavelet Methods, Filters, and Lengths for Functional Brain Network Construction. PLoS ONE, 11(6), e0157243.
20. Hart, J. (2015). Normal Resting Pulse Rate. Journal of Nursing Education and Practice, 5(8).
21. Betts, J. G. (2013). Heart Anatomy. In Anatomy & Physiology, 787-846.
22. Zhang, G. Q., & Zhang, W. (2009). Heart rate, lifespan, and mortality risk. Ageing Research Reviews, 8, 52-60.
23. American Heart Association. (2017). All About Heart Rate (Pulse).
24. Dyer, A. R. et al. (1980). Heart rate as a prognostic factor for coronary heart disease and mortality: Findings in three Chicago epidemiologic studies. American Journal of Epidemiology, 112, 736-749.
25. Diaz, A., Bourassa, M. G., Guertin, M. C., & Tardif, J. C. (2005). Long-term prognostic value of resting heart rate in patients with suspected or proven coronary artery disease. European Heart Journal, 26, 967-974.
26. Selye, H. (1956). The stress of life.
27. Ali, M., Elsayed, A., Mendez, A., Savaria, Y., & Sawan, M. (2021). Contact and remote breathing rate monitoring techniques: A review. IEEE Sensors Journal.
28. Tu, J., Inthavong, K., & Ahmadi, G. (2012). Computational fluid and particle dynamics in the human respiratory system. Springer Science & Business Media.
29. Ettehad D, Emdin CA, Kiran A, et al. (2016). Blood pressure lowering for prevention of cardiovascular disease and death: A systematic review and meta-analysis. Lancet, 387(10022), 957-967. doi: 10.1016/S0140-6736(15)01225-8.
30. Yang S, Sohn J, Lee S, Lee J, Kim HC. (2021). Estimation and Validation of Arterial Blood Pressure Using Photoplethysmogram Morphology Features in Conjunction with Pulse Arrival Time in Large Open Databases. IEEE Journal of Biomedical and Health Informatics, 25(4), 1018-1030. doi: 10.1109/JBHI.2020.3009658.
31. Schrumpf F, Frenzel P, Aust C, et al. (2021). Assessment of Non-Invasive Blood Pressure Prediction from PPG and rPPG Signals Using Deep Learning. Sensors, 21(18), 86022. doi: 10.3390/s21186022.
32. Sugita N, Yoshizawa M, Abe M, Tanaka A, Homma N, Yambe T. (2019). Contactless Technique for Measuring Blood-Pressure Variability from One Region in Video Plethysmography. Journal of Medical and Biological Engineering, 39(1), 76-85. doi: 10.1007/s40846-018-03888.
33. Chen W, McDuff D. (2018). Deep Phys: Video-based physiological measurement using convolutional attention networks. In Proceedings of the European Conference on Computer Vision (pp. 349–365).
34. Yu Z, Li X, Zhao G. (2019). Remote photoplethysmography signal measurement from facial videos using spatio-temporal networks. In Proceedings of the British Machine Vision Conference (pp. 1–12).
35. Group for Neuroinformatics and Cognitive Robotics, Institute of Computer and Systems Engineering, Technical University of Ilmenau. (2014). Pulse Rate Detection Dataset (PURE) [Data set]. Retrieved from https://www.tu-ilmenau.de/en/university/departments/department-of-computer-science-and-automation/profile/institutes-and-groups/institute-of-computer-and-systems-

engineering/group-for-neuroinformatics-and-cognitive-robotics/data-sets-code/pulse-rate-detection-dataset-pure

36. Hitech-ly. (n.d.). ECG Machine: Electrocardiogram ECG Machine. [Online]. Available: https://www.hitech-ly.com/ecg-machine/electrocardiogram-ecg-machine/ [Accessed: January 20, 2023].
37. U.S. Food and Drug Administration. (2021). Pulse Oximeter Accuracy and Limitations: FDA Safety Communication. [Online]. Available: https://www.fda.gov/medical-devices/safety-communications/pulse-oximeter-accuracy-and-limitations-fda-safety-communication [Accessed: January 20, 2023].
38. Guyton, A. C. & Hall, J. E. (2021). BioCapture™: Acquiring Respiratory Effort data. [Online]. Available: https://www.glneurotech.com/wp-content/uploads/2021/03/G396-5018-Rev-B-RIP-Teaching-Notes.pdf [Accessed: January 20, 2023].
39. Wikipedia. (2023). Sphygmomanometer. [Online]. Available: https://en.wikipedia.org/wiki/Sphygmomanometer [Accessed: January 20, 2023].
40. Heighpubs.org. (2018). Human Journal of Contemporary Health. Retrieved from https://www.heighpubs.org/hjch/ach-aid1012.php
41. Amnesty International. (2019). Death Penalty. Retrieved from https://www.amnesty.org/en/what-we-do/death-penalty/
42. [Jahanpour Alipour,Afsaneh Karimi,Yousef Mehdipour]. (2020). Trend of admitted patients from 2007 to 2016 [Figure]. ResearchGate. Retrieved from https://www.researchgate.net/figure/Trend-of-admitted-patients-from-2007-to-2016_fig1_340279891
43. National Library of Medicine (US). (2022). Genetic and Rare Diseases Information Center [Book]. National Institutes of Health. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK554776/
44. [Joseph Thomas]. (2009). Title of the paper [Journal Article]. PMC. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2779965/
45. Sally C Curtin 1, Joyce C Abma, Stephanie J Ventura, Stanley K Henshaw. (2013). Title of the paper [Journal Article]. PubMed Central. Retrieved from https://pubmed.ncbi.nlm.nih.gov/24314113/
46. Michał Górski,Marta Buczkowska,Karolina Krzywkowska,Beata Całyniuk. (2022). Title of the paper [Journal Article]. PMC. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9035898/
47. Advancements in Noncontact, Multiparameter Physiological Measurements Using a Webcam Ming-Zher Poh, Daniel J. McDuff, and Rosalind W. Picard.
48. New insights on super-high resolution for video-based heart rate estimation with a semi-blind source separation method Rencheng Song, Senle Zhang, Juan Cheng, Chang Li, Xun Chen
49. De Haan, G., & Jeanne, V. (2013). Robust pulse rate from chrominance-based rPPG. IEEE Transactions on Biomedical Engineering, 60(10), 2878-2886.
50. Vercruysse, W., Svasand, L. O., & Nelson, J. S. (2008). Remote plethysmographic imaging using ambient light. Optics express, 16(26), 21434-21445.
51. W. Wang, A. C. den Brinker, S. Stuijk, and G. de Haan, “Algorithmic principles of remote ppg,” IEEE Transactions on Biomedical Engineering, vol. 64, no. 7, pp. 1479–1491, 2016
52. Aerosense Wavve . Vital Signs Radar. https://www.tvtradar.com/News_1/14.html (accessed 3/2/2023).

53. Bioevopeak Co., Ltd. traditional method. https://bioevopeak.com/product-category/medical-diagnosis-device/biochemistry-analyzer-reagents/ (accessed 3/2/2023).
54. Koninklijke Philips. Philips' Fourth-Quarter. https://www.philips.com/a-w/about/news/all-press-releases.html (accessed 3/2/2023).
55. NeuroData Lab. (2019, March). Every beat counts. Comparing Remote Webcam Heart Rate Detector to Wearables. https://medium.com/@neurodatalab/every-beat-counts-comparing-remote-heart-rate-webcam-detector-to-wearables-d8d59aab863c
56. Fouad, R. M., Osama A. Omer, Abdul-Magid M. Ali, and Moustafa H. Aly. 2019. “Refining ROI selection for real-time remote photoplethysmography using adaptive skin detection.” 2019 International Conference On Innovative Trends In Computer Engineering (ITCE’2019) 978-1-5386-5261-9, no. 19 (February): 6. 10.1109/ITCE.2019.8646412.
57. Gudi, A.; Bittner, M.; Lochmans, R. & Van Gemert, J. (2019) Efficient Real-Time Camera Based Estimation of Heart Rate and Its Variability. International Conference on Computer Vision (ICCV) Workshop.
58. Statistics How To. (n.d.). Website. Retrieved January 31, 2023, from www.statisticshowto.com
59. Boston University Medical Campus. (n.d.). Website. Retrieved January 31, 2023, from sphweb.bumc.bu.edu.