Employment of Artificial Intelligence Mechanisms for e-Health Systems in Order to Obtain Vital Signs Improving the Processes of Online Consultations and Diagnosis

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***Abstract*— A large number of web-based e-Health applications have been developed through time, allowing doctors to access different types of functionalities, like knowing which medication the patient has consumed or performing online consultations. Internet systems for healthcare can be improved by using artificial intelligence mechanisms for the process of detecting diseases and obtaining biological data, allowing medical professionals to have important information that facilitates the diagnosis process and the choice of the correct treatment for each particular person.**

The proposed research work aims to present an innovative approach when compared to traditional platforms, by providing online vital signs in real time and allowing the visualization of all historical data of a patient. It aims to defend the concept of promoting online consultations, providing complementary functionalities to the traditional methods for performing medical diagnoses through the use of software engineering practices. This investigation led to the conclusion that, in the future, many medical processes will most likely be done online, where this practice is considered extremely helpful for the analysis and treatment of contagious diseases, or cases that require constant monitoring.

***Keywords*— Computer Vision, Artificial Intelligence, Healthcare, Software Engineering and e-Health.**

I. Introduction

This study aims to research the problem of performing a correct medical diagnosis, defending the concept of online consultations, by using a strategy of obtaining vital signs using cameras from common devices like a computer or mobile phone.

A. Context and Motivation

Over the last years, many improvements were developed using web technologies for therapeutic and curative services; e-Health combines several fields like medical informatics, business and public health, using the internet as an important vehicle for obtaining important information [1].

The usage of online systems for healthcare has been increasing, which can be helpful for handling contagious diseases or the treatment of chronic illness. This can contribute to a tendency to evolve some hospital systems towards remote ambulatory processes. The interaction between doctors, patients and prescriptions can be done online, being less time-consuming, shortening distances, and allowing this interaction to be performed in less developed regions, recognizing that health is important for all persons. Virtual consultations can indeed save lives.

Obtaining vital signs can help on the triage problem, identifying if a certain case requires intensive medical care, monitoring the response of a patient to therapy, determining the relative status of vital organs such as the heart and the lungs, observing trends in the health status, establishing a baseline for future comparison, or even helping to decide if an intervention is necessary.

The artificial intelligence research for healthcare has been increasing over the last years. Many studies have shown good results in the areas of disease detection and patient monitoring. Several processes are being used to increase the accuracy of predicting a pathology or determining the health condition of a person. Online healthcare systems can be complemented with Artificial Intelligence mechanisms, facilitating the process of diagnosing diseases and determining the most appropriate medical treatment to apply.

B. Problem Definition

The current online consultations fall short on providing sufficient information. Despite the fact that, on the last years, there were many improvements on the web tech, the current e-Health systems still have high implementation and maintenance costs, and do not provide many features. Hence, providing the doctor with vital signs in real time via web is expected to improve the diagnosis process, helping to identify possible diseases and determine their severity level.

The traditional processes require too much work, have high costs, are very time consuming and are prone to human error. Although it is recognized that the current Artificial Intelligence (AI) mechanisms still have some limitations, it is also true that their accuracy and performance can be increased at lower costs than the ones performed by a human in a laboratory [2]. Additionally, it can help a lot handling some diseases, like the viral ones, which are difficult to diagnose due to the time of development of the pathological agent. New functionalities can be integrated to the existing online applications being used, providing other important features that facilitate the work of the doctor, such as reading the vital signs via web.

C. Objectives and Research Questions

This research aims to offer an innovative solution for e-Health systems when compared to traditional processes, defending the theoretical concept of developing some medical activities online and increasing the performance of online consultations and prescriptions, advocating that there is a need to improve the current medical systems and methods.

The proposed solution can be used as a complement to the current systems, adding more functionalities using web applications like reading the patient's vital signs. Some interesting outcomes of this work that can be considered are the possibility of reaching less developed regions, reducing the risk of contagion of the doctor, lower costs, taking lesser time and providing more mechanisms that can complement the existing ones. The research aims to add a new methodology to the process of interaction between the doctor and the patient. The study focuses on the application of AI mechanisms on e-Health systems, complementing the current ones and facilitating the process of diagnosis and determining the severity of illnesses. The main objectives of the dissertation are to:

- Increase the accuracy of the readings of the vital signs obtained via a sensor like a camera. (#Objective_1).
- Make a web application that stores the health status of the patient, based on the readings obtained, helping the physician to have historical data and analyze better the situation of a certain patient (#Objective_2).

The following research questions allow to properly determine the problem and fundament this paper, facilitating the achievement of the above proposed objectives:

- How can the vital signs be obtained from a camera capturing the face of the user and the thumb? (#Research_Question_1).
- How can an application be developed to store historical data of the previous obtained information such as body temperature, blood pressure (systolic and diastolic), cardiac frequency, oximetry, and respiratory rate? (#Research_Question_2).

Answering these questions will allow achieving the proposed objectives. To achieve this goal, it was necessary to research the work of other authors, develop applications, and perform tests comparing the results obtained with medical devices.

II. Theoretical Background, Literature Review and Related Work

Taking in consideration the objectives, the proposed questions, the necessary technologies and the research performed by other authors, this section will provide more insights concerning the topics related with the investigation in cause, demonstrating the nature of the problems, how other researchers approached for a solution and which limitations and challenges exist. The chapter will mention the difficulties in adding functionalities to web e-Health systems and describe the work of other researchers in obtaining the vital signs via the PPG signal, as well as theoretical concepts of software engineering processes that allow to develop web applications and to perform services and operations online.

The e-Health or "digital health" can be seen as a broad concept known worldwide that deals with digital tools and solutions that help improve the quality of life of the persons aiming to improve healthcare services. Remote healthcare can save waiting time for the patients, avoid booking delays and can be accessed in less developed regions [3].

A. Treatment of the Photoplethysmographic Signal

The Photoplethysmography (PPG) is an optical technique to detect changes of the blood volume, giving important information about the cardiovascular system; The waveform (see Fig. 1) has two components, the alternating current (AC) and the direct current (DC). The AC component corresponds to the variations of the blood volume that are synchronized with the heart movements. The DC component is non pulsatile and based on the reflected optical signals and light absorption from the tissues depending on the tissue structure as well as venous and diastolic arterial blood volume.

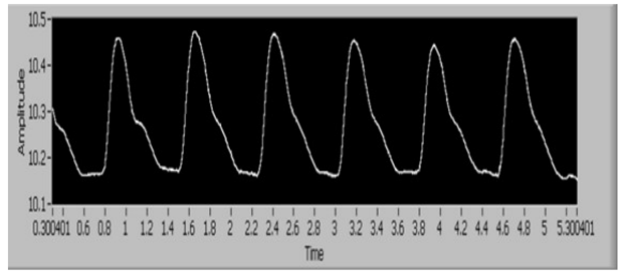

Fig. 1. The PPG signal acquired in LabView [4].

By using algorithm methods, such as, the Fast Fourier Transform (FFT) that converts a signal into separated spectral parts providing information about the frequency of the signal and Independent Component Analysis (ICA).

The formula used to calculate the oxygen saturation (SpO_2) can be based in the AC and DC of the blue and red channel [5].

$$SpO_2 = A - B\,\frac{AC_{RED}/DC_{RED}}{AC_{BLUE}/DC_{BLUE}} \tag{1}$$

To determine the cardiac frequency, previous studies have showed that the green channel has a stronger plethysmograph signal [6]. Nevertheless, any channel (ch), red, green, and blue can be normalized (x') via a function where μ is the average and σ the standard deviation of the function $x_{ch}(t)$ respectively.

$$x'_{ch}(t) = \frac{x_{ch}(t) - \mu_{ch}}{\sigma_{ch}} \tag{2}$$

The treatment of the PPG signal and the use of the algorithms described allow to determine vital signs like the cardiac frequency.

Information Systems can use the Photoplethysmogram (PPG) signal to obtain viral signs among other possibilities. In other research studies, the beats per minute (BPM) calculation by a camera shows close results to the ones reported by medical devices. The values obtained by a software/prototype can be compared with the ECG values (at 1000Hz), mainly for the green channel. There are many AI for Computer Vision studies that use the Region of Interest (ROI) detection mixed with the Fast Fourier Transforms (FFT) [7]. The accuracy of the values reported must be high and have a low error margin when compared with other equipment. Processes like Joint Approximation Diagonalization of Eigen-matrices (JADE) to separate observed mixed signals into latent source signals and FFT (ECG uses the Fourier Series) allows to calculate the vital signs values based on the spectrum considering duration, frequency and distance, the analysis should take in consideration noise and luminosity.

Some OpenCV algorithms allow obtaining the ROI and later divide the capture into 3 Independent Components (ICA) [7]. The 3 divisions can be normalized before applying FFT and present the values of the 3 ICA with normalized Red, Green, Blue (RGB) values. As stated previously, studies mention that the green channel has a stronger plethysmographic signal (PPG). In AI for Computer Vision, the sense of sight is usually studied in more depth. In the human retina, the fovea deals with cones of high density, which are colored (red, blue, or green) sensitive cells that require bright light conditions and the periphery that works with high density of rods, which are color-insensitive cells, thus being favorable for low light conditions. Fixing objects at night can make them invisible: the lack of rods in the fovea limits our ability to perceive what we are focusing on in low-light conditions [8].

B. *Web Services and Application Programming Interface*

Web Services and Service Oriented Computing reduce the costs of building new systems for a variety of reasons. They allow communication between applications or part of the application so they can use existing applications and services without having to develop the application from scratch. A Web Service is a way for two machines to communicate over a network, and an API is an application that uses a set of definitions and protocols allowing one application to communicate with another application. Extensible Markup Language (XML) or JavaScript Object Notation (JSON) among others are used to tag data, Simple Object Access Protocol (SOAP) is a messaging protocol used to exchange structured information, Web Services Description Language (WSDL) is primarily for describing available services via XML and Universal Description Discovery and Integration (UDDI) is for listing which services are available. These can be searchable over the network and can also be called properly [9]. When called, Web Services can provide functionalities to the customer who calls this Web service.

REST (REpresentational State Transfer) is an architectural standard based on a set of rules, standards and guidelines on how to develop a web API. An agreed system of structuring an API saves time on decision-making as well as time on understanding how to use it. A service is a function that is well defined, independent, and does not depend on the context or state of other services. Web services technology is the most common connection technology in service-oriented architectures. The availability and effective utilization of these new features and capabilities requires the restructuring of many existing applications.

III. Applications for the Doctors

This section describes an application developed in the scope of this research for the physicians, named "AI Care", which has a primary care approach where the vital signs are described, and explains how they are obtained via the internet. The "AI Care" solution is composed by a set of integrated applications, which are described in the following sections.

The research work aims to defend a new concept of online consultation and diagnosis adding features that traditional processes do not have such as providing the vital signs remotely and on real time via camera making the diagnosis process easier during video chat consultations. Traditional processes can be improved with online diagnosis features like the ones described in this chapter based on artificial intelligence mechanisms to facilitate the work of the physician and at lower costs than traditional processes.

A. *Contextualization and Overview*

Using artificial intelligence (AI) for Computer Vision, the vital signs like the body temperature, blood pressure, systolic values, diastolic values, cardiac frequency, oxygen saturation and respiratory rate can be obtained and stored, in order to understand the health status of the patient.

This work consists in implementing artificial intelligence mechanisms over healthcare web systems when interacting with the patients, and to improve the display of information. On a primary care perspective, the presented solution comprises obtaining vital signs like body temperature, blood pressure, systolic values, diastolic values, cardiac frequency, oxygen saturation and respiratory rate. This fulfils the research objective #Objective_2, to perform some of the healthcare activities online and virtual consultations aided with a video chat developed in NodeJS combined with access to the clinical data of the patients during the conversation and obtaining the vital signs in real time.

B. *Online Consultations*

Concerning the objective of making a medical analysis more effective (#Objective_1), the authors consider that the presence of the doctor during the process is an added-value, because he can provide clinical information concerning the readings obtained and inform the patient on how to proceed. Therefore, the application "AI Care" has an online chat (see Fig. 2), which is shown side-by-side with vital signs data, and an integrator that stores the information in a database and manages the information, so doctors can have a complete archive of a certain patient. The database has 19 tables, some of them connected via foreign keys, where the information inserted by the doctor is stored.

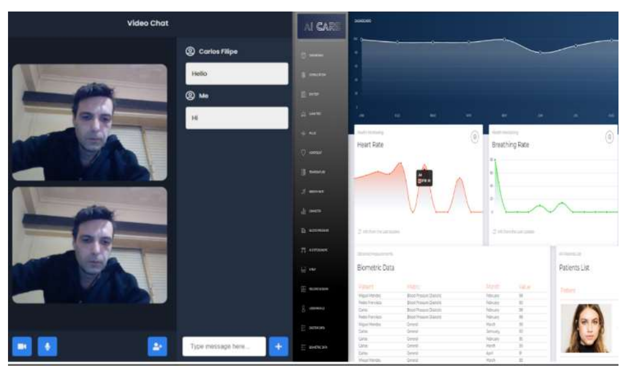

Fig. 2. During the chat, the doctor can visualize the historical data of the patient. Adapted from the code of [10].

C. *Primary Care Analysis Based in Obtaining Vital Signs*

Some primary care activities can be done online. This section shows a web process of diagnosing a patient taking in consideration the vital signs obtained via a camera sensor. The health reference values for this analysis are considered to be those that are – or very close to – the currently considered normal for an adult user at rest (no physical activity, lying down or sitting), with no known pathologies and no acute disease symptoms.

Reference Values Considered in this Program:

- Body temperature: 35.5º to 37.5º centigrade.
- Blood Pressure:
  - Systolic: 90 to 140 mmHg.
  - Diastolic: 60 to 90 mmHg.
- Heart rate: 60 to 80 beats per minute.
- Oximetry: oxygen saturation ≥ 95%.
- Respiratory rate: 12 to 18 breaths per minute.

D. Body Temperature

Body temperature refers to the production of heat in the body and the mechanisms for its regulation and maintenance, essential to maintain systemic homeostasis (stability that the body needs to perform its functions properly). The usage of OpenCV and Python allows to get the temperature values via web camera. The program requires the installation of OpenCV libraries. Two applications were developed to get the temperature via IR web camera, one in Python (see Fig. 3) and the other in MatLab.

The process used via python was based in applying a mask and a heatmap to the images obtained by the IR camera and after applying the formulas to the RGB values obtained, mainly the green channel in order to obtain the body temperature, the application was placed web via Flask.

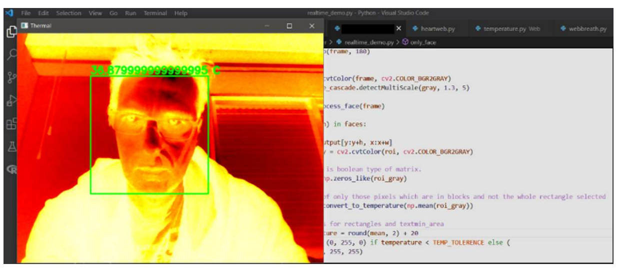

Fig. 3. Obtaining body temperature via Python. Adapted from code [11].

E. Blood Pressure

Blood pressure or blood tension is the force that the blood exerts on the walls of the arteries during its circulation, and results in two measures:

- Systolic blood pressure or "maximum" blood pressure appears first and measures the force with which the heart contracts and "expels" the blood from its interior.

- Diastolic blood pressure or "minimum" blood pressure: this is the second value and concerns the measurement of pressure when the heart relaxes between each beat.

The reading of blood pressure is usually measured in millimeters of mercury (mmHg). When blood pressure is normal, it allows blood to be distributed throughout the body, reaching all organs. If the blood pressure is chronically high (hypertension) or when it increases suddenly, it has negative consequences for health, being responsible, for example, for cerebrovascular accidents, cardiac infarctions (death of heart cells), among other possibilities. For cases where blood pressure is too low (hypotension) blood flow on cells can decrease, compromising the nutrition and oxygenation of the cells, including brain cells. A mobile application was developed in Java using Android studio to obtain this value detecting the face of the user and treating the RGB values obtained by the phone camera.

F. Cardiac Frequency

The cardiac frequency rate is the number of times your heart beats per minute. Changes in heart rate may indicate the existence of cardiac and non-cardiac pathologies and may compromise the nutrition and oxygenation of the cells, including the brain cells. In order to measure the heartbeats, an application was developed in Python that measures the cardiac frequency in real time based in computer vision, showing the obtained readings on the monitor. The results from the webcam detection were compared and tested with the ones provided by medical devices and the clock sensor. By analyzing the Python code (see Fig. 4), we can see that the values obtained by the green channel allowed to determine the heart frequency. The information provided will facilitate a clinical analysis.

```
import cv2
import time
import numpy as nump
from matplotlib import pyplot as plot

figura = plot.figure()
auxiliar = figura.add_subplot(111)
coracaobeat_counter = 128
captured = cv2.cv2.VideoCapture(0)
captured.set(cv2.CAP_PROP_FRAME_HEIGHT, 1280)
captured.set(cv2.CAP_PROP_FRAME_WIDTH, 1920)
captured.set(cv2.CAP_PROP_FPS, 60)

coracaobeatvalues = [0]*coracaobeat_counter
timescoracaobeat = [time.time()]*coracaobeat_counter

while(True):

    x, y, w, h = 950, 300, 500, 500
    ret, frame = captured.read()
    picture = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
    imagemmcut = picture[y:y + h, x:x + w]
    coracaobeatvalues = coracaobeatvalues[1:] + [nump.average(imagemmcut)]
    timescoracaobeat = timescoracaobeat[1:] + [time.time()]
    auxiliar.plot(timescoracaobeat, coracaobeatvalues)
    figura.canvas.draw()
    plotimagemm = nump.fromstring(figura.canvas.tostring_rgb(),
                                  dtype=nump.uint8, sep='')
    plotimagemm = plotimagemm.reshape(figura.canvas.get_width_height()[::-1] + (3,))
    plot.cla()

    cv2.imshow('Graph', plotimagemm)
    cv2.imshow('Crop', imagemmcut)
    if cv2.waitKey(1) & 0xFF == ord('q'):
        break
captured.release()
cv2.destroyAllWindows()
```

Fig. 4. Python code used to obtain the heartbeat.

G. Oximetry

The Oximetry is a test that lets you know how much oxygen is being carried in the blood. The oxygen level measured with an oximeter is called the arterial oxygen saturation level (SaO_2). The SaO_2 is the percentage of oxygen that blood carries (in red blood cells) compared to its maximum carrying capacity on arteries. The lack of oxygen in the blood reduces its supply to the cells and may be inadequate for its needs, a condition that can cause serious cell damage and even lead to death. The peripheral oxygen saturation (SpO_2) is the percentage of haemoglobin molecules in the peripheral blood saturated with oxygen, and is a value similar to SaO_2, with the advantage that it can be measured through a pulse oximeter. To perform this test, an alternative approach was used to measure the SpO_2, which requires appropriate lightning and placing the thumb close to the web cam. The formula used to calculate the SpO_2 can be based in (1). An application was developed in MatLab taking in consideration the RGB values obtained by the web camera after pressing the thumb (see Fig. 5).

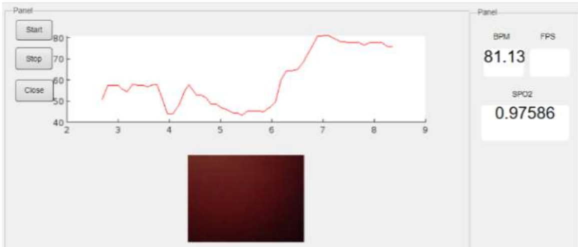

Fig. 5. Obtaining the percentage of oxygen on the blood arteries.

H. Respiratory Frequency

The respiratory rate is the number of breaths per minute, i.e., the number of times the combination of inspiration (entry of air into the lungs) and exhalation (exit of air from the lungs) occurs in one minute. The respiratory rate can be evaluated by counting only the number of inspirations per minute, by observing the chest expansion at each inspiration, that is, by counting how many times the chest goes up. An application was developed in Python and placed online via Flask, which is based on the RGB values obtained by the camera and takes in consideration motion, velocity, the maximums and the minimums of the cardiac frequency (see Fig. 6).

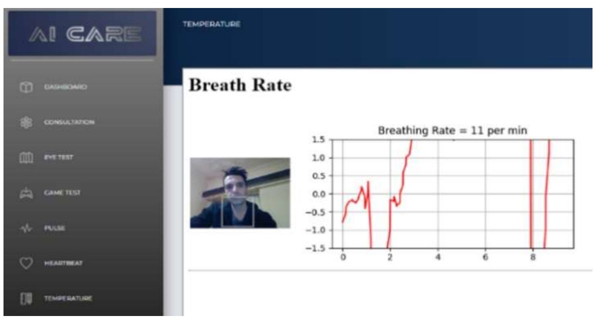

Fig. 6. Obtaining the breath rate and adding to the clinical record of the patient. Adjusted from the code [12].

IV. Test Analysis, Results and Validations

This section shows the results and tests made for the presented artifacts, based on a set of prototypes and processes, allowing the answering of the research questions. The analysis is based on the results and specific hardware was required to perform the tests such as a pulse blood pressure monitor, an oximeter, a smart watch, a camera and an IR thermometer. In order to check the accuracy results, tests were done between the values obtained by the web application and the values obtained by the medical devices. The tests were performed in an indoor environment with artificial and natural light, most of the readings were close to the ones detected with medical devices. Via OpenCV is possible to measure the distance of the face from the camera during readings. The analysis was done to a group of 12 people, being six females and six males with ages between 20 and 80 being some of them healthcare professionals. The test is based on monitoring the values of body temperature, blood pressure (considering the systolic and diastolic readings), cardiac frequency, oximetry, and respiratory rate.

After getting the readings from the developed applications, the values were compared with the ones obtained by physical devices in order to determine the accuracy of the presented prototypes, the information obtained was stored in the database and a high level of satisfaction was noticed from the users because for some cases the process of obtaining the values did not require high efforts like the ones requested by some traditional processes. The accuracy was high regarding the measurement of cardiac frequency, breath rate and temperature. Concerning oximetry and blood pressure, the values showed a lower accuracy, because these used an approach based in applying formulas to the RGB readings obtained by an infrared (IR) camera. The results show that AI for computer vision nowadays allows the reporting of vital signs values close to the ones obtained via medical devices, which means image treatment processes can open new trends in the future for healthcare. The tests performed allowed the retrieval of conclusions, e.g., concerning the satisfaction, the results obtained were high when compared with traditional methods. From the several prototypes evaluated, a preference was noticed for the reading of the cardiac frequency. The study focused on different strategies using AI mechanics to perform medical activities taking in consideration the health status of the patients.

Concerning the primary care approach, the solution comprised obtaining vital signs using IR cameras. Although the accuracy was high in some cases, the oximetry measurement is a complex process. The presented solution was based in a formula used by other researchers presenting a prototype as an approach for the problem. Concerning the blood pressure, the traditional processes require for some cases compression to facilitate the process of obtaining the pressure values. The present prototype instead simply uses nothing more than the phone camera and takes in consideration the RGB values of the ROI. Nevertheless, comparing the results, it was noticed that the objectives were achieved. Most of the testers found that the applications developed achieved the objectives and that could be used for diverse medical situations. In some of the applications, some difficulties were noticed during the tests, mainly in getting the readings because the web camera must detect the body parts that it's going to interact with, requiring in most cases a correct placement of the users, with a distance of around 70 cms from the sensor. If the necessary body parts are not detected, the applications would not work.

The results obtained allowed performing an overall evaluation and appraise if the investigation objectives were achieved and answering the research questions. An assessment was done on the presented solutions as a complementary process to the existing e-Health applications. Most of the testers agreed that the implementation of AI mechanisms in software can provide more efficiency, control and functionality to the applications, and that applications with AI mechanisms will be suitable to be used in the future. The problem of performing medical activities via web can be approached via different perspectives being the systems focused on using different processes like online consultations and a process of obtaining the vital signs. Fig. 7 presents the values obtained by number of testers.

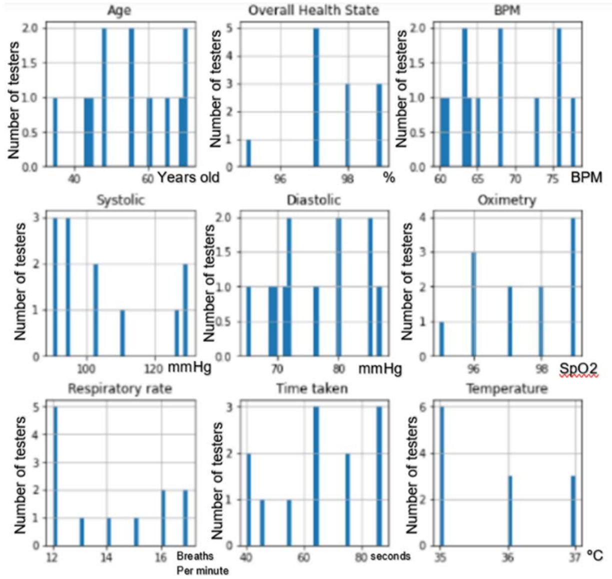

Fig. 7. Values obtained by number of testers.

V. Conclusions, Limitations and Future Research

The algorithms developed allowed to perform the desired functionalities and provide an innovative concept that can be helpful for contagious diseases or cases that require constant monitoring. The development process was described and tests were performed to validate the solution proposal in cause. The research took in consideration several sources of information and many articles of other researchers were analyzed in order to study the problem. The research work aims to defend the concept of an innovative process for performing online consultations and diagnosis adding features that traditional processes do not have such as obtaining the vital signs remotely via a camera with a video chat that facilitates the work of the physician by providing new tools at lower costs and on real time.

A. Limitations

Although the accuracy results of the readings of vital signs was high, experience says it is always possible to be even further improved as technology evolves. Many projects like smart watches among others have also showed satisfactory results and other approaches and research have been performed with considerable outcomes.

The level of lightning in some cases must be adjusted, cases of very low lightning or nonexistence will not allow to obtain the readings. The distance to the IR camera may also impact the results, and the sensor in some cases must detect the ROI otherwise the application will not work. The parameters that define a case as an emergency may vary due to age, or if the patient has done physical activity recently, or if he consumes certain medication, or has specific diseases. In those cases, the maximum and minimum limits may vary, and the user should report this situation via video chat, otherwise some emergencies may not be detected, or they may be defined incorrectly. Although the presented solution shows a possible approach to the process of diagnosis and consultation for some diseases, in some cases other strategies may need to be followed to complement the present analysis, like medical scans, biopsies, or other diagnosis processes, due to specifications of the medical condition of the patient.

B. Future Investigation

An application called "AI Care" was developed using several programming languages and the information of the readings was stored in a database. Possible futuristic research is the use of deep learning for other diseases, or adding more functionalities to e-Health application like combining data of certain symptoms and showing to the doctor how those symptoms were treated by other doctors, e.g., which pills were administrated and correspondent dosage and time frames, or the usage of ultrasounds for healing purposes among many other possibilities. This research aims to provide a contribution to the existing knowledge of e-Health applications showing an innovative approach for online consultations and diagnosis. Artificial intelligence mechanisms are currently being used in different areas like healthcare, industry, economics among others with many research challenges, some medical activities can be automated reducing the human error and allowing to help healthcare professionals in their activities.

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