Monitoring and sensing COVID-19 symptoms as a precaution using electronic wearable devices

Josephine M.S.
Department of Master of Computer Application, Dr MGR Educational and Research Institute, Chennai, India

Lakshmanan L.
Department of Computer Science and Engineering, Sathyabama Institute of Science and Technology, Chennai, India

Resmi R. Nair
Department of Electronics and Communication Engineering, Easwari Engineering College, Chennai, India

Visu P. and Ganesan R.
Department of Computer Science and Engineering, Velammal Engineering College, Chennai, India, and

R. Jothikumar
Department of Computer Science and Engineering, Shadan College of Engineering and Technology, Hyderabad, India

Abstract

Purpose – The purpose of this paper is to monitor and sense the symptoms of COVID-19 as a preliminary measure using electronic wearable devices. This variability is sensed by electrocardiograms observed from a multi-parameter monitor and electronic wearable. This field of interest has evolved into a wide area of investigation with today’s advancement in technology of internet of things for immediate sensing and processing information about profound pain. A window span is estimated and reports of profound pain data are used for monitoring heart rate variability (HRV). A median heart rate is considered for comparisons with a diverse range of variable information obtained from sensors and monitors. Observations from healthy patients are introduced to identify how root mean square of difference between inter beat intervals, standard deviation of inter-beat intervals and mean heart rate value are normalized in HRV analysis.

Design/methodology/approach – The function of a human heart relates back to the autonomic nervous system, which organizes and maintains a healthy maneuver of inter connected organs. HRV has to be determined for analyzing and reporting the status of health, fitness, readiness and possibilities for recovery, and thus, a metric for deeming the presence of COVID-19. Identifying the variations in heart rate, monitoring and assessing profound pain levels are potential life saving measures in medical industries.

Findings – Experiments are proposed to be done in electrical and thermal point of view and this composition will deliver profound pain levels ranging from 0 to 10. Real time detection of pain levels will assist the care takers to facilitate people in an aging population for a painless lifestyle.

Originality/value – The presented research has documented the stages of COVID-19, symptoms and a mechanism to monitor the progress of the disease through better parameters. Risk factors of the disease are carefully analyzed, compared with test results, and thus, concluded that considering the HRV can study better in the presence of ignorance and negligence. The same mechanism can be implemented along with a global positioning system (GPS) system to track the movement of patients during isolation periods. Despite the
stringent control measurements for locking down all industries, the rate of affected people is still on the rise. To counter this, people have to be educated about the deadly effects of COVID-19 and foolproof systems should be in place to control the transmission from affected people to new people. Medications to suppress temperatures, will not be sufficient to alter the heart rate variations, and thus, the proposed mechanism implemented the same. The proposed study can be extended to be associated with Government mobile apps for regular and a consortium of single tracking. Measures can be taken to distribute the low-cost proposal to people for real time tracking and regular updates about high and medium risk patients.

Keywords COVID-19, Symptom, Detection, Pandemic, Internet of things, Heart rate monitoring

Paper type Research paper

Introduction

Wearable health devices are potential life savers, especially in this pandemic outbreak. Deeply alarmed by daily rising patient numbers and delay in deriving a suitable medication, COVID-19 or Coronavirus has seriously affected the nations. Despite the effect over affected patients, the pandemic has resulted in a complete breakdown of a developing nation. Economic and social growth of nations are affected by this pandemic. With limited knowledge about the disease and controlling measures, all potential parameters are taken into consideration for detecting and mitigating the spread of disease (Baumann et al., 2019). The distribution of wearable health devices is increased nowadays as a measure taken by individuals to stay alert about the symptoms and effects. Ambulatory monitoring of vital symptoms is continuously facilitated for minimizing the discomfort and inconvenience. Normal and daily activities of a human being should not be disturbed when these devices are worn (Sival et al., 2016).

Human body will exhibit numerous physiological values, which can be tracked for monitoring purposes. The signs range from electrical, biochemical and bio signals received from various parts of the body (Boyett et al., 2019; Ghosh et al., 2020). Health status of a person can easily be predicted based on the values observed from these physiological signs. These measurements are absolutely valid when the drug is administered and waited for monitoring reactions. Potential bio signals should be retrieved and processed accordingly through wearable devices and sensors. Understanding the signals and mapping them toward the reaction of drugs/diseases is important (Gao et al., 2006; Shahrestani, 2017) and wearable devices can be categorized according to the environment, mode of operation and types of individuals.

A multi-parameter analysis system is required for continuous and unconstrained patient health monitoring for providing health updates every second to a medical institution. The patients in a hospital and homes are subjected to profound pain over a prolonged period of time. This rate is ever increasing with the aging population. Ignorance to these pain levels and negligence to the right treatment increases the impact of complications, which finally leads to fatal results. The pain varies in its intensity levels and this metric cannot be explicitly defined until the patient expresses. While the patients with limited or no communicable option may not obey the gold standards of grading pain intensity 0 to 10. In such cases, care takers play a significant role in determining the pain by experience, knowledge, behavioral analysis and physical observations (Asensio et al., 2014; Lukowicz et al., 2002). To eliminate these complications, real time and continuous monitoring system is intended with the assistance of technological advancements.

Wearable electronics provide round the clock reports of physiological parameters obtained in real time and updates into a cloud server for medical opinions from experts. This ensures 24X7 processing and medical assistance. Sympathetic and parasympathetic activity levels are derived from wearable sensors and electrocardiogram records, which collects
heart rates and its variability (HRV). A window span is estimated for evaluating the heart beat variations. The process commences from extracting HRV features from electrocardiogram (ECG) reports and identifying the QRS. These features will be extracted from a 1–2 min’ window in short span and a day long window in a full span. Classical approach had a 5 min’ short window span, which failed to detect certain psychological and physiological variations (AiQ Smart Clothing, 2020). Three categorical analysis is performed on these observed variations, namely, Timed, Frequency-based and Branched Tree order of analysis. The following features are extracted from inter-frames of one second frame:

- Average of Inter Beat intervals, IBAvg.
- Standard deviation of inter-beat intervals, IBSD.
- Root mean square of difference between inter beat intervals, RMSDIB.

Interconnection and correlation between these three features in a given time period will be helpful in analyzing the HRV. The patients will be subjected to two kinds of pain levels in terms of electrical and thermal conditions. They will be rested in an environment with a sensory device, namely, Zephyr Bioharness 3, which is a wearable sensor. This device will capture electrocardiogram reports from patients’ heart in the form of an analog signal. This is transferred into the cloud environment for storage and offline processing. These sensors will continuously update the values, which are categorized into no pain to severe pain. The values are observed from the starting to ending time and features are selected from given window spans. Peaks and normalized events are marked within those observations for deducing the intensity of pain levels. A heating element is used to transfer the heat element to the patient from room temperature to 50°C. These tests are conducted in random order to determine the ability of the proposed system where multi-parameters are sensed in the right order. At last, the variance in heart rates are reported in the right time and faster than conventional methods, which improves the quality of treatments. The approach can later be introduced with sensing stroke detection and preventive measures to be used in patients with high chances of occurrence.

Related work
Numerous research and development has been carried out in internet of things (IoT) and environments are automated with values retrieved from these devices. IoT are devices, which incorporate into other networks and platforms for complete participation and recordings of significant entries. The observed values are usually the elements of real time alarms/alerts for handling life threatening situations. Cabled networks, wireless networks and integration of both the networks are suitable for deploying IoT sensors and devices. While monitoring of a human body from remote locations cannot deploy wired network architectures and the solution should be cost efficient. The pre-dominant combinations of a IoT network will be internet protocols, hardware and simple architectures (Statista, 2015; Berg Insight, 2014; Galletta et al., 2018; Khoie et al., 2017). Installation and maintenance of wired networks obviously imposed additional costs and difficulties in managing the network. Many researchers have explored the domain of smart health and automated health monitoring applications. Patients are monitored continuously even in the remote locations. Yet their information, if identified to be critical or credible, the same is transferred to the nearest medical practitioners/experts or hospitals. The intention of such applications is to provide round the clock medical care to patients who demand it the most. Apart from the cost of deployment, primary objectives are to save lives, cost and time of medical attention.
There are various challenges associated with building an application for 24/7 care, where collecting information, integrating them, cleaning, fusing and visualizing a common projection. Heterogeneous devices collect different bio-signals from different parts of the body, and hence, they have to be combined for a comprehensive vision. All data will be transferred from remote locations through internet protocols where security is another concern. Pre-processing of collected information has to be acknowledged by reliable methodologies as they contribute to sensible decisions made by medical experts. Various statistical measures analyze the collected information to make a decision or support in making a decision (Sundaravdivel, 2018; Ferro and Potorti, 2005; Monfredi et al., 2014; Sanyal and Nundy, 2018).

Smart health applications are a combined environment with multiple sensors. This is a new domain with a huge market and research perspectives. The sensors are designed to be simple, small and accessible through wireless mediums. Information from one location to another is sent in form of audio, video, text, real time recordings, etc. The objective of an application is to regulate the recorded information, order them and ensure that no potential information is lost in the medium or through pre-processing. Various approaches have been put into practice for processing information in this domain and they have included machine learning approaches for automatic detection of unique features. Many researchers designed and implemented a health monitoring system based on a visual monitor where the data are presented in form of a statistical representation. The persistent problem in handling information is the presence of noise and meaningless information. Redundancy in data also imposes a serious threat to automated decision-making systems as repeated information may demand utmost medical attention when it is not required. Some applications have concentrated on monitoring the patients post their surgeries. Especially, when systems analyze the chances of infections after surgeries, the systems are not permitted to take up their own decisions. Combined feedback from medical experts and automated systems have critical supporting information to facilitate the accuracy by 9%.

Yet these systems are facing certain limitations where a system cannot be completely relied for making medical decisions (Rocha, 2018; Shewan and Henein, 2018). The following points were observed and documented from the surveyed articles:

- Lack of complete information collected from patients; environments due to a number of factors.
- Noisy and repeated information.
- Demand of numerous hardware, connectivity and other devices for monitoring.
- Inconvenience caused to patients.
- Heterogeneous information demands additional processing steps for fusion.

Moving over to the inevitable requirement for the current situation, COVID-19 is presumably evolving from severe acute respiratory syndrome (SARS) viruses (Wankhede, 2019; Niaid, 2020; WHO, 2019, 2020) and is highly threatening than its predecessors. The number of affected cases around the world is alarmingly rising, spreading in areas with minimal social distancing and unhygienic practices of affected patients. The effects of SARS were much worse, but COVID-19 if left unattended causes drastic outcomes including fatality. The other diseases of the same origin were subjected to limited areas and affected far lesser number of people in 2003 and 2012, respectively. It is feared that COVID-19 affected an average of 2.5 other people when social distancing, sanitization is ignored (Diao et al., 2018).
The statistical analysis has revealed that COVID-19 has been the reason for the demise of thrice the fatality when compared to SARS. Primary organ and system of a human body, which gets affected due to Corona is the respiratory system where the patients face shortness of breath and need ventilators to assist (Sundaravdivel, 2018; Agi, 2020). As there is no medication till date, prevention is the only option left to people and governments. SARS have resulted in the demise of 10% of people it affected. People under the age of 10 and above 60 are prone to the disease, which evolved to affect multiple age sectors nowadays. Nations with limited medical facilities are prone to a higher fatality rate as they cannot accommodate affected people at the moment (Zygiaris, 2013). Having said that prevention is better than cure, this article presents a technique to monitor the HRV with lesser invasive and painless measures to monitor the progress or onset of the said disease.

Proposed methodology
The recent cases of COVID-19 are said to be controlled with a temperature suppressing tablet such as Paracetamol or Dolo. Many patients, to travel or escape from normal routine checkups, isolations and other discriminating activities by the government/societies, have taken the suppressing tablets without any consultation of doctors. Sadly, the virus has evolved not to exhibit any explicit symptoms in the recent weeks. Problems with thermal scanning devices has a limitation of the procession and the same cannot be the final metric for deeming as a symptom for COVID-19. Until the availability of a successful medication, the government has to work on preventing the spread of disease to even more people. Hence, a system with better reliability is required for detecting the symptoms of COVID-19, based on which the present technique is proposed.

Measuring the HRV is emphasized in the proposal, which is a measure of variations between the heart beats of affected patients. This parameter was considered to be the primary symptom as this cannot be manipulated by any suppressing medications. HRV has been used for measuring the stress level of people, identify chronic heart diseases, assess and report the stability of immunity in a person, and thus, predict the speed of recovery from a critical illness. These conditions have made the measurement of HRV as an ideal parameter for validating the symptoms of COVID-19 (Figure 1).

The patient is rested in a room with normal temperature and bounded to a chair. A wearable sensor is connected to the chest area to monitor and record data about the heart rates. Electrical input is provided through a finger on one hand by using a digital transcutaneous electrical nerve simulation device. The voltage is incremented until the tolerance level of the patient is attained. Similarly, another heating element is attached to forearm of the patient. The temperature level is increased from 32°C to 50°C in a random
interval. The wearable sensor will register the HRV every second in an electrocardiogram report. This report is later analyzed by the proposed approach in divided into a number of smaller time windows. The patient will be provided with an alerting button to stop the tests immediately irrespective of completion for safety purposes. Once the ECG report is obtained, the approach intends to segregate the values from 0–10 indicating the least possible level and maximum possible level of pain intensities. This will eliminate the nominal outputs and reduce computation costs. The Maximum possible level is identified as the peak above which no data is found. The peak distance is estimated from already available information about normal heart beat rates. The window spans will be limited to 30 s frames to improve the quality of sensing profound pain intensities. Heart rates are normalized from training sets available through medical institutions. Variances in heart beats are analyzed by means of the above-mentioned features.

The progressive pain intensities are observed in every incremented time window after the electrical and thermal inputs are tested upon the patients. Different time frames are considered individually to point out the significant increase of pain levels from normal time frames. The proposed time window is of 30 s. HRV is expressed as the features estimated from subtraction of pain values from rest values from inter beat rates (Figure 2).

Deriving a model for experimentally sensing the pain levels will improve the quality of medical care provided by medical professionals. This controlled environment will enhance the lives saving measures without any mortality rates. The methodology also has its own limitations of mishandling the subjects, which was addressed in this mechanism as patients were provided with a decision to continue the tests or not. Tree-based derivation methods will produce the expected results in a faster rate and reduce the waiting time for treatments.

The proposed approach will commence from the design and implementation of a sensing device with no inconvenience to the patients. The same should be having sufficient battery power to operate in remote locations for a prolonged time from charge to charge. A low battery warning is also provided to charge the batteries and replaceable batteries will increase the potential of this proposal. It is also proposed to incorporate a GPS module to facilitate a location-based treatment plan. The WIFI module associated with these sensors
will transfer location and real time data about heart rates to cloud-based server maintained in the medical institutions. Observed HRV will be processed based on window frames in minimal intervals for faster processes. Different values from HRV analysis are considered for this multi-parameter patient monitoring module. Minimal values from ECG are eliminated from further processes to reduce computation time and improving efficiency. Highly significant variability values are highlighted to warn the patients of next possible effects and advise them to locate the nearest hospital. Mean values and average values of variance between inter heart beats are primarily the basic component of this proposal. Decrease in values of root mean square values of inter beats and percentage of variations change in concurrent frames of ECG will denote reduction of parasympathetic activity. This, in turn, indicates the dramatic change in HRV.

This method intends to propose a relationship between HRV and intensity of profound pain in heart diseases. The model will be able to differentiate pain levels from zero to severe and advise the patients in the next course of actions. Processing time of this proposal is considerably lesser than previous strategies. Shorter intervals of windows are considered to detect and report even a minor variation of pain. Intensity of pain when found longer will be viewed by medical institutions and necessary treatment plans will be derived.

**Results and discussions**

A real time heart rate monitoring system using technologies such as wearable sensors and IoT will promise a preventive measure for cerebrovascular diseases. Patients of all age groups may use this proposal to be well-connected with medical experts and receive a timely treatment. This proposal discusses the possibility of establishing a well-demonstrated environment with multiple sensors to detect potential information from human beings, process them in an efficient pain analyzing mechanism and provide round the clock connectivity. The proposed system analyzed the values of a HRV through standard deviation NN (SDNN) intervals observed through every day of an affected patient. The patient is said to be affected by COVID-19 on April 5, 2020. As the symptoms are said to raise only after a week, mild symptoms can be observed on the fifth day from the onset. The preliminary symptoms are mild temperature hikes and body aches specializing the limbs. Polymerise chain reaction tests will not be able to return the reliable results as the virus has

![Figure 3. SDNN and HRV value plots](image-url)
evolved to hide the symptoms. In recent cases, many negative patients on the first test have turned positive on the third test.

The following Figure 3 illustrates that oxygen saturation level is above 98% from the day of getting affected by COVID-19. Though the clinical symptoms are not visible in the patients’ cases, there are multiple instances where HRV and SDNN intervals cross each other in the below figure.

From the following figure, the obvious risk factor of COVID-19 can be detected through temperature and respiratory illness. Given that temperature suppressing medications affect the recordings of the system, and respiratory troubles happen typically at the last stage of the disease, we have to look for the reliable system and parameter. The next risk factor, which explicitly demonstrates the risks associated with COVID-19 is the HRV. This justifies the need of such parameters and monitoring mechanism in the present study. The following figure also educates the medical practitioners to take according measures to concentrate on patients at a higher risk and to prevent the progression from medium risk to high risk. The proposed system was capable of predicting the risk levels of COVID-19 patients with an accuracy of 98% and this cannot be bypassed with other medications. HRV was the primary test parameter where sensors were deployed to monitor the fluctuations. With normal testing procedures, HRV ensures that prediction can be even more accurate with the proposed system. The tested data set included the following parameters, namely, age, height, weight, gender, systolic blood pressure, diastolic blood pressure, glucose level, smoking, drinking habits, level of physical activity and history of cardiovascular diseases in the past present (Figure 4).

Conclusion
The presented research has documented the stages of COVID-19, symptoms and a mechanism to monitor the progress of disease through better parameters. Risk factors of the disease are carefully analyzed, compared with test results, and thus, concluded that considering the HRV can work better in presence of ignorance and negligence. The same mechanism can be implemented along with a GPS system to track the movement of patients during isolation periods. Despite the stringent control measurements for locking down all industries, the rate of affected people is still on the rise. To counter this, people have to be educated about the deadly effects of COVID-19 and foolproof systems should be in place to control the transmission from affected people to new people. Medications to suppress temperatures, will not be sufficient to alter the heart rate variations, and thus, the proposed mechanism implemented the same. Proposed...
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**Further reading**


**Corresponding author**

Visu P. can be contacted at: pandu.visu@gmail.com

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