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Remote Real-Time Monitoring System for Out-Of-Hospital Patients

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Abstract
This paper proposes the design for remote real time monitoring for out of hospital patients using simple and interactive design system developed using LabVIEW software and Arduino controller, which is used to acquire data from the sensor is used to monitor the vital conditions of the body of the patients. The system proposed is designed to meet the needs of senior citizens who are mostly the number 1 target when it comes to high risk disease which can affect outpatient elderly people suffering from conditions like cardiac arrest and other related heart diseases. The system proposed and implemented measures 5 vital parameters relating to common diseases suffered by out of hospital patients. In this system Electrocardiography (ECG), Skin Sweat Conductance Response (SCR), Skin temperature and Respiration derived from Electrocardiography (ECG). Analysis of the system is done by performing two tests, using simulated recorded data and live volunteer subjects not entirely suffering from any particular diseases. Simulation test is done using recorded data from Medical PhysioBank for patients suffering from different kind of heart diseases such as atrial block, Tachycardia and Bradycardia conditions while the other test is performed using volunteer subjects to show the feasibility of the system and achievable results when using live subjects. The system implemented was able to detect up to 87-92% accuracy of the QRS for the ECG, with sensitivity of 76%, for the derived respiration algorithm used and 96.1% accuracy to thermometer measured skin temperature using the system. The real-time monitoring for system achieved using Web publisher provides robust accessibility to the monitored system using internet access from any location with link to the client server.

Keywords: *Labview, ECG, SCR, temperature.*

I. INTRODUCTION

Over the years there have been significant breakthroughs in the area of informatics system. Through the advancement of such system in the health department and services, the need for the development for the monitoring system in remote areas for out of hospital patients has given rise to the requirement for the real time monitoring systems [1-5].

Out of hospital patients are usually patients who require medical attention or diagnosis in a clinic or hospital and do not require hospitalization for not more than 24hours. Unlike hospitalized patients where monitoring is done through cable equipment, it is different for outpatients as the monitoring has to be performed remotely from the patient's home while enabling the patient the luxury of continuing with their daily routines while at the same time keeping track of their conditions [6,7].

With the increasing number of population for hospitalized patients and increasing pressure in existing medical infrastructure there is great need for systems which could be used to reinvent Medicare for patients suffering from vital disease which may not be easy to diagnose always by symptoms known by patients. The most affected group of people range from all cross ages but highest number of risks have been associated with senior citizens. This is simple because due to old age their health precaution tend to be lower and are

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often the victim of any crucial sudden illness which sometimes results in hospitalization or worse even loss of life [8-12].

The need for close monitoring of vital health has increased in recent years, thanks to the technological advancements that have invaded the markets all over the western world and rising developing markets [13].

The system will be used to keep track of any out-patient suffering from high risks disease which require close care analysis or sudden illness which can require routine diagnosis by a medical practitioner. The system which is proposed in this paper requires a system to be implemented to provide proactive approach to patient care rather than just reactive care for patients. This technology allows patient – doctor monitoring to be of high quality assurance especially with fact that it saves both specialist time and patient's costs of medical checkups and frequent consultation hours. The simplicity of the device has been established from the fact that under all low-lying sudden high risk diseases all of them share distinct vital signs which are routinely checked by medical professionals [14-20].

Remote Real-time Monitoring System (RRMS) offers new innovative ways of caring for people while maximizing sustainability engineering by reducing medical cost due to hospitalization and travelling costs for medical consultations for patients who may require continuous medical check-up. Most of the vital health diseases are often associated with Heart risk diseases such as blood pressure, heart attack, ECG abnormality and respiratory abnormality which is pose as silent killers. The need for the development of the system which is discussed offer evident methodologies, implementation techniques and design statistical analysis aimed at improving medical caring for patients thus improving the quality of life of the patient thereby reducing the need for patient caretakers. With increased economic need to reduce medical cost and increased financial burden on hospitals, the need for a system which can offer an alternative easy and cost effective system for remote monitoring patients living with high risk diseases has paved a way for demand and necessity for such systems to be designed.

II. Proposed System Implementation

A. Hardware System

The prototype design consist of the 3 sensor circuit design which are used to measure the signals from the patient and processing them in microcontroller for wireless transmission of the data recorded to the LabVIEW software which is further developed to process the signal into vital components which are used to identify the condition of the out-patient remotely.

The sensor circuits developed are analog components consisting of amplifiers and primary filters for noise and other interferences. The sensor are all fitted to a shirt which is worn by the patient and leads for the measuring the signals form the skin of the patient are identified. Primarily for the ECG leads they are position in 3 lead vector form on chest of the patient to measure the atrial fibrillation of the heart as shown in Figure 8.

The concept design adopted for this design is shown on Figure 1, which will be used for the prototype and used for implementation design for this research work.

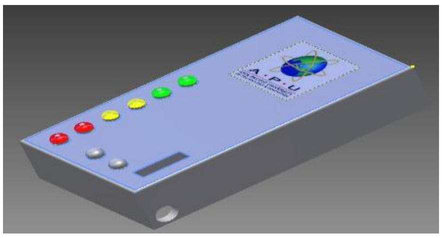

Figure 1: Design 3D for the acquisition board

Figure 2 shows the front panel of the control box which consist of the indicators, switches, potentiometer, lead connection, ports, display and sound outlet. There is the lid for closing the case and for battery holder for the system which can be replaced. The lid also allows easy access to the components inside for troubleshooting of the device incase there is a need to replace or change damaged electronic components.

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Figure 2: Control Box front panel

B. Software System

Figure 3 illustrates how the Back –End system interacts with remote client. An example shows the interaction with three Medical practitioners and the front- end system in real-time. Figure 3 is used to explain the services of the proposed system to the user/patient. Figure 3 illustrates a scenario where Medical **Practitioner A** and **Practitioner B** attempt to monitor or perform the progress in recovery analysis of an outpatient using the RRM system in a remote location. The Back –End allows limited number of authorised personnel at a time to be able to access the results and medical data of the patient under their care.

Since every reading has a real-time stamp when stored in the backup storage card and LabVIEW dashboard it allows **Practitioner A** and **Practitioner B** to view same data as it continues to be monitored. The client web link is continuously running as long as the Host Window from patient is active. The database system allows data to be stored to specific patient Logged to the RRM system.

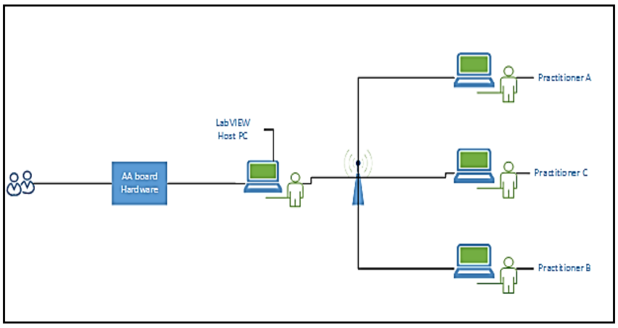
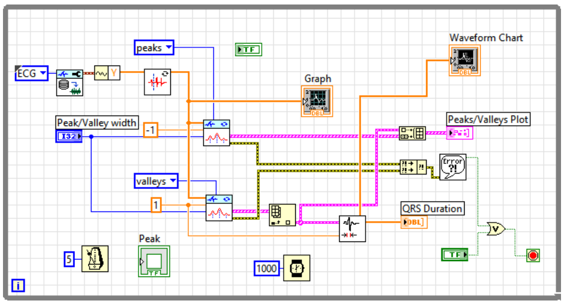
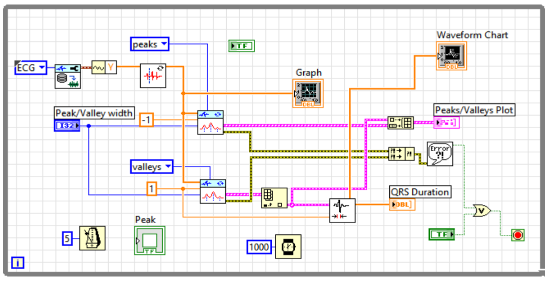


Figure 3: Interaction between Back-End and Remote System

The software implementation as shown in Figure 4 using Labview, further involves developing the program structures for the system from wireless communication server setup and GUI for the entire system and the developing of the web publisher GUI for monitoring the results being measured on the web and be able to be accessed from a remote PC from any geographical location with secured access and limited privacy invasion to the patient's information.



(b)



(b)

Figure 4: LabVIEW programme

C. PCB Design

After completing the testing for the ECG sensor circuit, the circuit is prototyped to a PCB board as shown in Figure 5.

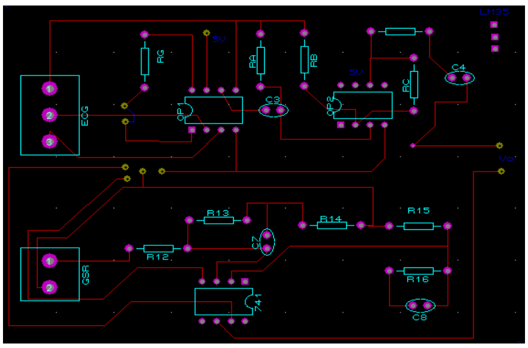


Figure 5: PCB design Proteus

Preparing the Acid for the etching process is done by mixing the Hydrochloride acid mixed with warm water to reduce the concentration of the acid and

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the warm water is used to quicken the etching process for the PCB design for the ECG and SCR circuits. PCB designed system is shown in Figure 6.

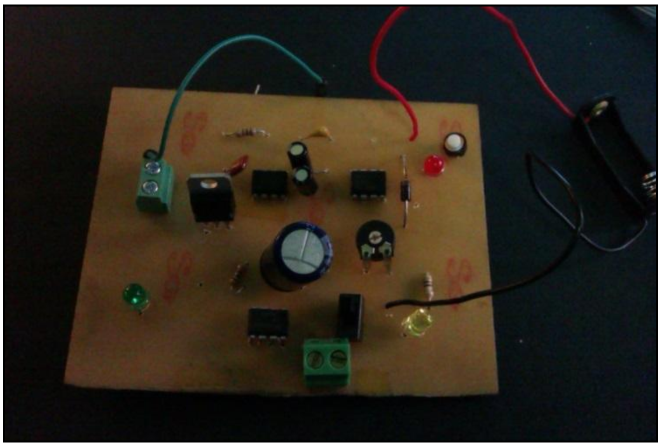

Figure 6: PCB design circuit after fabrication

III. SIMULATION AND HARDWARE RESULTS

A. Simulation Result

Figure 7 shows the GUI design for the front panel for Patient monitoring in LabVIEW. In this window the patient is able to see detailed vital parameters being measured from the body and those which are processed from utilizing the main measured vital components. The designed GUI is made as basic and user friendly to allow even senior aged users to be able to deduce and understand the readings monitored and displayed.

Figure 7: GUI measuring the patient vital parameters

A similar remote GUI is designed using LabVIEW to remote monitor all the vital parameters in real-time in correlation with patient GUI. The GUI designed adopts the web host remote panel control method. In this GUI, only the physician or medical practitioner caring for the patient having the login credentials is able to access and change or edit any information relating to the patient.

B. Hardware Result

The experimental setup for testing and collecting the results from the implemented system is performed using the MIT-BIH data base. The data base is composed of half-hour recordings of ECGs of 48 ambulatory patients suffering from arrhythmia cardiac problems. Using these recorded results to simulate the environment for the system to identify the QRS complex and analyse the HR, HRV and peak detection to identify the abnormalities of the heart the simulation is tested oversampled data.

The next experimental setup is done using the volunteer subjects to acquire the real signals from the subject's body under different condition of testing of the sensors to monitor the changes in temperature, SCR and ECG with environment, eating, exercise and when subject is moving. Figure 8 shows the ECG lead placements on the chest and ECG recorded using system is displayed.

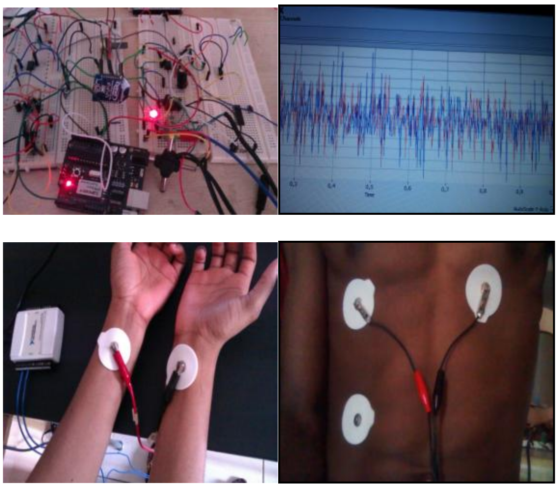

Figure 8: ECG lead system, measured and displayed

C. Remote Monitoring

The measured parameter data is displayed on the patient window through the web publisher window which only allows the patient to constantly see the updates and changes in the body and the parameters which are monitored by the medical practitioner.

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Figure 9 shows the patient windows and web publisher of the main window.

Figure 9: Remote monitoring of server PC and client PC

IV. TESTING RESULTS

The testing of the system is performed by acquisition of the signals from the patient body and the values recorded are tabulated for further analysis.

A. ECG Testing

ECG data collection of subjects at rest while sitting is shown in Table 1. Measuring the ECG of the subject volunteers with different activities measured after 5 minutes from performing the activity is tabulated in Table 2. The results of the ECG signal measured from the subjects are measured using NI DAQ on digital scope in LabVIEW.

Table 1: ECG data collection of subjects at rest

subjects	***Age***	***ECG Activity (V)***	***Gain, Rg***
1	22	0..0023	2.3
2	23	0.0014	1.4
3	25	0.0012	1.2
4	24	0.0021	2.1
5	25	0.0024	2.4

Table 2: ECG measurement after performing activity

	ECG, Activity, V		
Subject	***Relaxed***	***After Eating***	***After activity***
1	0..0023	0.0024	0.0032
2	0.0014	0.0019	0.0023
3	0.0012	0.0021	0.0026
4	0.0021	0.0027	0.0031
5	0.0024	0.0025	0.0029

B. SCR Testing

SCR measurement when subjects are tested using different items is shown in Table 3. The testing is performed using food, a scary video clip, a room with warm temperature and finally the truth test. The response of the subjects to the stimuli's is measured in the graph as a signal waveform.

Table 3: SCR measured data

Subject	***Resistance, Ω***	***Conductance, μS***
1	1630	613.5
2	1824	548.2
3	1260	793.7
4	1483	674.3
5	1530	653.6

C. Temperature Testing

The LM35 temperature sensor is placed on the subjects to measure the temperature of the subject. The skin temperature measured results from the subject volunteers are recorded in Table 4 showing temperature readings measured against time, with change in activities performed similar to the ECG activities. Measuring rest temperature using thermometer and Lm35 temperature sensor for project is shown in Table 4. Test measuring using LM35 temp sensor is shown in Table 5 and Table 6, after exercising and eating.

Table 4: Measured temperature from volunteers at rest

Subject	***Thermometer temperature (^0C)***	***Experimental temperature (^0C)***	***Absolute % error measurement***
1	34.7	33.3	4%
2	38.3	36.4	4.9%
3	36.8	34.7	5.4%
4	37.5	35.4	6.4%
5	38.4	37.8	1.6%

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Table 5: Measured temperature after 5 min exercise

Subject	*Thermometer temperature (^0C)*	*Experimental temperature (^0C)*	*Absolute % error measurement*
1	36.3	35.1	3.3%
2	40.6	39.3	3.2%
3	39.3	39.1	0.5%
4	41.2	39.6	3.9%
5	40.2	39.7	1.2%

Table 6: Measured temperature 10 min after eating

Subject	*Thermometer temperature (^0C)*	*Experimental temperature (^0C)*	*Absolute % error measurement*
1	38.3	37.2	2.9%
2	38.2	37.3	2.4%
3	38.7	38.2	1.3%
4	39.2	38.6	1.5%
5	38.7	38.2	1.3%

D. Heart Rate Testing

Since the respiration signal is derived from the ECG signal, the results in testing during the ECG test for the volunteers are reflected over the signal waveform generated with different fluctuations during different test experiments and are tabulated as shown in Table 7.

Table 7: Heart Rate measured

Subject	*HR Actual Beats (bpm)*	*HR detected Beats (bpm)*	*Accuracy %*
1	73	76	96
2	57	60	95
3	84	88	95
4	93	103	90
5	56	56	91

E. Analysis using Statistical Packages

The ECG signal acquired from 5 of the subjects are analysed after processing using histogram is shown in Figure 10, to identify the differential R-R intervals of the subjects tested in comparison to the normal ECG signal, where R-R mean and standard deviation is then calculated.

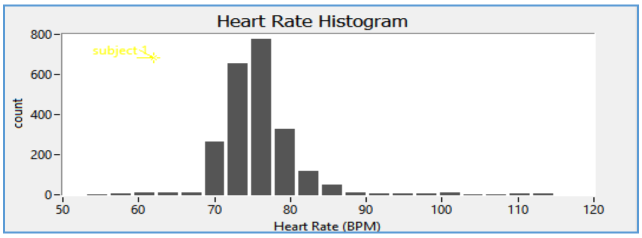

Figure 10: Heart Rate Histogram

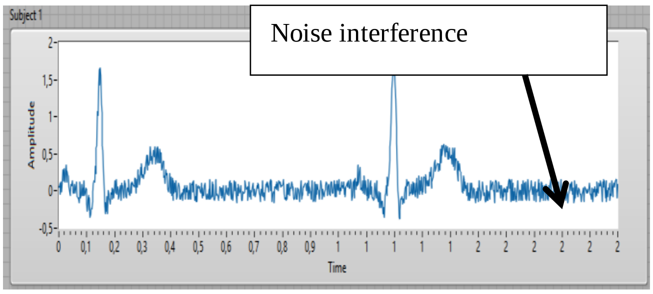

Figure 11: HRV analysis for subject 1

The time domain plot as shown in Figure 11, also shows the histogram analysis for abnormality in R-R interval. From the Histogram the peaks of motion artifacts were larger than the R-wave in the real-time recorded ECG. For HRV analysis of other subject real signals, testing was done and the summary of the results have been presented in the Table 8.

The heart rate analysis shows the difference in different people when tested under similar activities. The results are discussed to interpolate the range to identify the threshold for HR maximum and minimum alert generation.

Table 8 HRV analysis for other subjects

Subject	*QRS Amplitude Mean (mV)*	*R-R std (ms)*	*HR mean (bpm)*	*QRS width mean (ms)*
1	1.5	45	76	74
2	1	281	60	130
3	1.7	214	88	87
4	1.9	239	103	102
5	1.1	309	56	121

Spectral Analysis

From the ECG signal analysed the HRV FFT Spectrum VI and the HRV AR Spectrum VI enables frequency-domain analysis as shown are Figure 12-14.

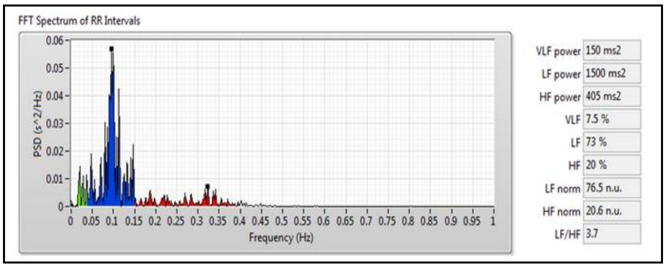

Figure 12: AR Spectrum of R-R Intervals

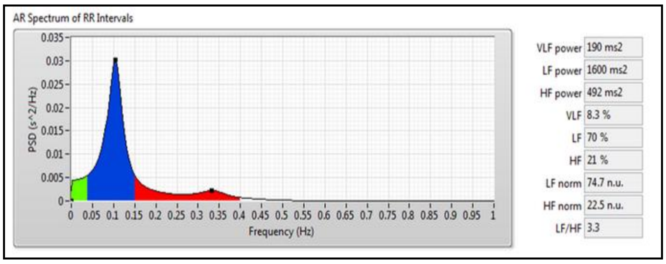

Figure 13: Frequency domain spectrum

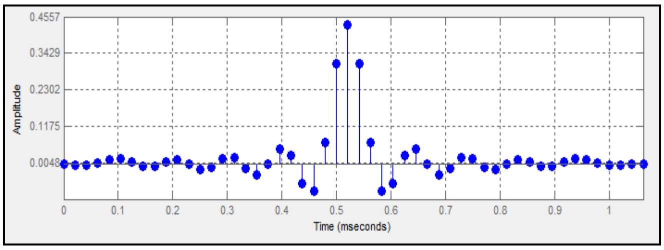

Figure 14: Frequency time domain analysis

Though R-R interval signals vary significantly over time, to deploy real time analysis and continuous remote monitoring Joint Time-Frequency Analysis (JTFA) analysis stationary and time-frequency behaviour of the Heart variability. The continuous wavelet transform in Figure 16 shows qualitative analysis performed by utilizing the time-frequency plots.

ECG Peak Detection results

In analysing real signals, it provide an average error of the major peaks of the signal used for identifying the R-R interval for HR calculation. When using a live signal during testing of volunteers, the peak detection method had some discrepancy in identifying the major pulse peaks with consecutive minor peaks of the signal as shown in Figure 15.

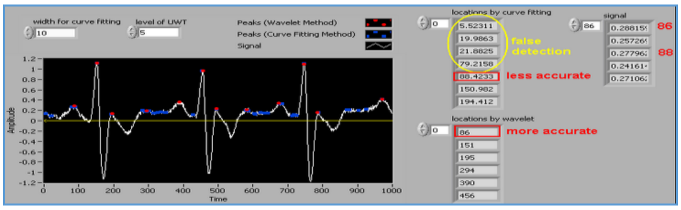

Figure 16: ECG Peak detection results variation

To solve this problem an approach to rule out minor peak is implemented using advanced wavelet to increase the Peak Detection accuracy. The signal after applying the advanced wavelet at [Db4] is presented in Figure 17 for one subject.

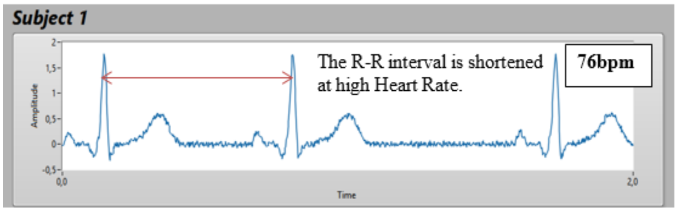

Figure 17: ECG Signal after Advanced Wavelet Transform

The proposed system when tested with the MIT-BIH for analysis using the program developed for signal processing however showed a predictability of 93% of the EDR signal after processing the ECG signal used for the database and the recorded samples of volunteers. The system implemented was able to detect up to 87-92% accuracy of the QRS for the ECG, with sensitivity of 76%, for the derived respiration algorithm used and 96.1% accuracy to thermometer measured skin temperature using the system. The overall accuracy of the system achieved 93.4% after testing using 5 volunteers.

CONCLUSION

The design and development of a system for monitoring the vita body parameter for out of hospital patients was successfully designed and implemented. The results of the system obtained during the testing of the system showed promising potential of developing the system a which could be further used to monitor additional information form the patient's body which could be used for acute patients in and out of hospital.

Improvements to the system could be made by reducing artifacts noise due to transient baseline

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change caused by changes in the electrode-skin impedance with electrode motion. Acquiring the signals when the patient is walking or moving provided an over lapping signal with noise over the normal measured ECG signal.

REFERENCES

1. Conn, N., Schwarz, K. and Borkholder, D. (2019). In-Home Cardiovascular Monitoring System for Heart Failure: Comparative Study. JMIR mHealth and uHealth, 7(1).
2. George, M., Mathew, S., Cyriac, N. and Antony, T. (2016). Patient Health Monitoring System using IOT and Android. Journal for Research, 2(1), p.102.
3. Ibrahim, A. and Zhuopeng, W. (2018). IOT Patient Health Monitoring System. Sangeetha.C.N. Int. Journal of Engineering Research and Application, 8(1).
4. IOT BASED PATIENT HEALTH MONITORING SYSTEM. (2017). International Journal of Advance Engineering and Research Development, 4(06).
5. James, W. (2019). Senior Retirement Lifestyles & Costs | Senior Living Retirement Options. [online] SeniorLiving.org. Available at: https://www.seniorliving.org/retirement/homes/cost/ [Accessed 25 Sep. 2019].
6. Jamil. Y. Khan and Mehmet R. Yuce (2010). Wireless Body Area Network (WBAN) for Medical Applications, New Developments in Biomedical Engineering, Domenico Campolo (Ed.), ISBN: 978-953-7619-57-2, InTech, Available from: http://www.intechopen.com/books/new-developments-in-biomedical-engineering/wireless-bodyarea-network-wban-for-medical applications.
7. K, B. and Muralidhara, D. (2019). Secured Smart Healthcare Monitoring System Based on Iot. International Journal on Recent and Innovation Trends in Computing and Communication, 3(7), pp.4958-4961.
8. Kau, A. & Jasuja, A., 2017. Health monitoring based on IoT using Raspberry PI. Greater Noida, IEEE, Volume 6, Issue 4.
9. Nithya and Mohammed Ezak, 2017. Rescue and Protection System for Underground Mine Workers Based On ZIGBEE. International Journal of Recent Research Aspects, Volume. 4, Issue 4.
10. PARKER, T. (2019). *Average Cost of a Nursing Home*. [online] The Balance. Available at: https://www.thebalance.com/average-cost-of-a-nursing-home-4177589 [Accessed 25 Sep. 2019].
11. Powermin.nic.in. (2019). Overview | Government of India | Ministry of Power. [online] Available at: https://powermin.nic.in/en/content/overview [Accessed 25 Sep. 2019].
12. Sardey, P., Pratik, D., Shalvar, D. and Shubham, G. (2017). IoT Based Patient Health Monitoring System. International Journal of Advance Engineering and Research Development (IJAERD), 4(6), pp.128-133.
13. Sizali, M. and Hashim, N. (2013). Wireless Patient Monitoring System. *International Journal of Science and Research (IJSR)*, [online] 2(8), pp.250-254. Availableat:https://pdfs.semanticscholar.org/8f8e/3338c31cc6ad5c5c6b43672ef37a61a94da1.pdf [Accessed 14 Jul. 2019].
14. Shelar, M., Singh, J. and Tiwari, M. (2013). Wireless Patient Health Monitoring System. International Journal of Computer Applications, 62(6), pp.1-5.
15. World Health Organization, (2015). The top 10 causes of death. Retrieved from http://www.who.int/mediacentre/factsheets/fs310/en/[7]. Raj, K. (2008). Embedded Systems. Retrieved from http://www.dauniv.ac.in/downloads/
16. Monitoring System Using GSM Technology. *International Journal of Mathematics and Research*, *1*(2). BRAIN, M. (2019). How Microprocessors Work. [Online] HowStuffWorks. Available at: https://computer.howstuffworks.com/microprocessor.htm [Accessed 14 Jul. 2019].
17. Hagargund, A.G., Srivastav, A., Nayak, C.K. and Singh, M.K., 2018, July. Smart and Automatic Health Monitoring of Patient Using Wireless Sensor Network. In 2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT) (pp. 1-7). IEEE.
18. Purnima, P. S. (2014) 'Zigbee and GSM based patient health monitoring system', 2014 International Conference on Electronics and Communication Systems (ICECS), pp. 1–5. doi: 10.1109/ECS.2014.6892762.
19. Sengeeth, K., Kumar, R.S., Kumar, R.S., Kumersan, T. and Venkatesh, C., Patient Monitoring System Using GSM Technology.
20. Taranovich., S, (2016) Pulse oximeter and heart rate integrated sensor module aids wearable designs. *EDN network.*