An Efficient Algorithm for Heart Attack Detection using Fuzzy C-means and Alert System using IoT

Kriti Gupta
Department of Computer Science and Engineering
Amity University Uttar Pradesh (AUUP)
Noida, India
kritig4@gmail.com

Pallavi Kaul
Department of Computer Science and Engineering
Amity University Uttar Pradesh (AUUP)
Noida, India
kaulpallavi514@gmail.com

Arashdeep Kaur
Department of Computer Science and Engineering
Amity University Uttar Pradesh (AUUP)
Noida, India
akaur@amity.edu

***Abstract*—This paper presents a mathematical model for heart attack detection and alert system from a list of factors using Internet of Things (IoT) devices namely, sensors, Arduino UNO board and GSM module. This robust mathematical model helps in preventing a patient from getting sudden heart attack by sending a notification on their mobile in the form of message or email. This paper gives a brief study about the parameters on which heart attack depends and the values that are recommended by a doctor for a healthy body. The comparative analysis with the existing technique indicates that the proposed algorithm outperforms in terms of accurate detection of heart attack in human beings. Results obtained show that the proposed algorithm is competent enough yielding an accuracy of 82%.**

Keywords—Internet of Things (IoT); Heartbeat sensor; Arduino UNO board; Alert system;

I. INTRODUCTION

Heart is the most precious organ of the body. It pumps blood in the cardiovascular system consisting of veins and arteries by which blood reaches in all parts of the body. In humans, heart is present just behind and slightly left side of the breastbone. Inappropriate diet or hypertension may cause dysfunction of the heart which may lead to heart failure or commonly known as heart attack. In the present scenario, only doctors can predict a heart attack by several tests performed manually. But in today's hustling life, due to lack of time it becomes difficult for people to go for their regular checkups or take elder people to the hospital for their regular checkups. This may result in the sudden heart attack of a person which cannot be prevented and leads to death of that person.

Due to increasing hypertension and bad dieting schedule of the people, the number of heart attacks are also increasing. This requires the automation of the health checkup of a person so that a person is well informed before any of the factors leading to heart attack rise to dangerous levels. He can visit a doctor and take proper medication that may prevent a heart attack.

Such automation can be done with the help of Internet of Things (IoT). The interconnection of everyday objects across a network is known as IoT. It leads to a highly-distributed network of devices that can communicate with humans as well as other devices. It has wide scope of applications for e.g. Smart buildings, home automation, smart cities, smart healthcare systems. In this paper application of IoT is proposed by using heartbeat sensor and Arduino UNO board in order to notify the patient whenever he is prone to a heart attack so that he can take measures beforehand and prevent from getting the actual attack.

There can be two levels of heart attack risk. One is border-line level and another is high risk. In borderline level the subject under consideration may take medicines and be prevented from the heart attack but in high risk level the subject under consideration has to consult a doctor and get proper treatment in order to save his life.

Figure 1 shows plaque formation in the arteries of heart which is one of the reason of heart attack. [1] Plaque is a waxy substance which is formed inside coronary arteries due to intake of wrong diet. This plaque blocks the flow of oxygen rich blood into the heart and results in heart attack.

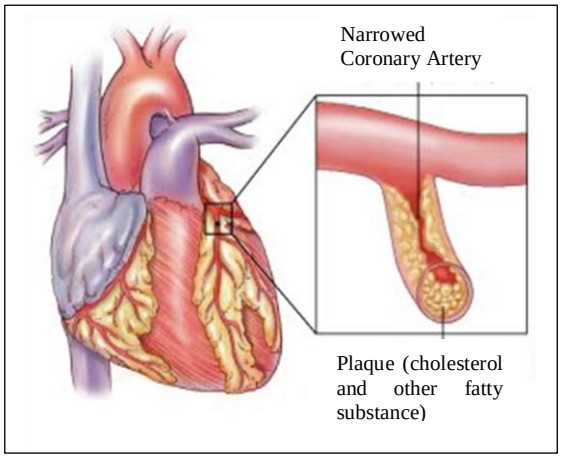

Figure 1: Plaque Formation in Heart

This paper presents a mathematical model for detection of heart attack minutes before it occurs using fuzzy c-means clustering algorithm. This algorithm helps in obtaining the

distributions for the intensity of targeted heart attack risk [2]. The FCM (fuzzy c-means) helps in forming clusters at the border-line level and high risk level for accurate detection of chances of heart attack to occur.

The main objective of this paper is to design an automatic heart attack detection system. In this paper, fuzzy c-means is used to check the heart attack causing factors of a person that they are under control or not. The proposed algorithm can efficiently detect chances of heart attack using fuzzy c-means (FCM) clustering technique. Thus, this paper aims to achieve a mathematical model that will predict sudden heart attacks in human beings and save their lives on time by sending a message or e-mail to the registered user employing the use of IoT.

The rest of the paper is organized as follows: Section II contains a literature review of the work done by various authors regarding this research. Section III describes a proposed methodology, Section IV give results and discussion and Section V draws a conclusion and future work.

II. LITERATURE REVIEW

This section gives a detailed overview of existing works done by various authors in the field of heart attack detection or prediction. From the existing literature, it has been seen that authors have tried to predict heart attack using data mining approach, fuzzy approach, monitoring ECG signal, monitoring other factors such as blood pressure, heartbeat, body temperature and by applying image processing on heart sample image to detect the presence of plaque. The automation of heart attack detection can decrease deaths caused due to heart attacks and help better cure of human lives. Thus, it has a very useful impact on society.

Data mining technology is used to predict data on the basis of hidden pattern observed in the data. Srinivas et al. have analyzed various algorithms of heart attack prediction in their paper [3]. The algorithms analyzed in their paper are namely, Decision Tree, Neural Network, Multilayer Perceptron (MLP), Bayesian model and SVM with an accuracy of 82.5%, 89.7%, 82% and 82.5% respectively. According to their result MLP acquires highest accuracy of 89.7% as compared to other algorithms because syndrome is a collection of symptoms, which is a concept that is developed by mean of mapping symptoms to TCM expert's brain. Since, syndrome is recognized by human brain therefore, MLP is considered as best model. According to their research time series modeling can be used to implement false alarm rate and more of continuous data should be used instead of categorical data so as to study patient's morbidity condition with respect to clinical care. On the other hand, Satapathy et al. [4] have analyzed the data of heart patients on the basis of their Active smoking, passive smoking, excessive alcohol intake, physical inactivity, high blood cholesterol, high blood pressure, diabetes mellitus, overweight, gender, increasing age, family history, obesity and overweight. They performed (ANOVA) Analysis of variance in their paper to predict risk levels. Their research concludes that such parameters can be used to determine heart attack when prediction of doctor's is varying between 2.5 - 30.5%. [5] These parameters have been studied by Raihan et al. and with data mining approach they have been able to design system that can predict heart attack risk. In their research, they have been able to develop a score with the help of these parameters using risk score tree, chi square correlation, p-value, Fisher's exact test and finally the score calculation. The main purpose of their research is to build an android application which can predict IHD (Ischemic Cardiac Disease) and prevent sudden deaths and morbidities, but it is still in experimental phase.

Another method proposed by authors in the prediction of heart attack detection is real time analysis using Fuzzy approach. Fuzzification of neural network [6] has been presented by Sapna et al. in their paper. They have classified heart diseases into two categories as: modifiable and non-modifiable. The modifiable risk factors include smoking, hypertension, diabetes mellitus, cholesterol, sedentary life style i.e. physical inactivity, deficiency of vitamins, obesity, mental stress and alcoholism, while the non-modifiable risk factors include age, family history and male sex. In their research, they have concluded with experimental results that diabetic patient has symptoms of fat in blood and obesity and overweight comes in secondary risks. But this research is limited only to diabetic patients and patients with problem of obesity and overweight while the problem of heart attack extends to other causes also such as hypertension, smoking, alcoholism, blood pressure etc. An IoT based system proposed by [7] Kumar et al. takes the patient's body temperature, heartbeat, respiration rate and body temperature as input and shows the output on a device anywhere in the world with the help of Raspberry Pi. This would help in collecting data of all factors causing heart attack and on applying fuzzy based logic or data mining techniques on such data would give more accurate prediction of heart attack. Bhunia et al. have proposed [8] a fuzzy assisted data collection and gave an alert system for health-care system using Arduino board and e-health-care system. Using body temperature, heart-rate, blood-oxygen and respiration as parameters for Fuzzy based logic system they have been able to design a system that can detect heart related diseases with the help IoT.

Authors have also used ECG to detect heart beat and predict heart attack. Kappiarukudil et al. have done real-time monitoring [9] of heart beat by transmitting ECG signals to patient's phone in their paper. Their proposed system consists of a wearable device through which they can transfer ECG signals to a mobile unit. So, this system would provide continuous checkup for the regularity in heart beat for that patient. Since the system depends only on ECG signals therefore, it has a very low accuracy. In order to remove false alarm, sensors such as blood pressure monitor, diabetes and respiration needs to be incorporated. Another research [10] proposed by Gupta et al. gives a smart Health Care Kit based on IoT. Their system collects data such as heart rate, blood pressure and ECG signal of the patient and send alerts to the doctor so that he has full knowledge of the patient's health time to time. But their system lacks in collecting diabetic conditions of the patient and, therefore, would be incapable to detect heart attack caused by diabetes or obesity. [11] Wolgast et al. have designed a wireless body area network (BAN) in order to detect heart attack. Their model is also based on collection of data of ECG signals. Same approach has been followed by Prittopaul et al. [12] in their paper. They have proposed a Cyber Physical System (CPS) which consists of a small wearable device that transmits ECG signal to the patient's phone and alert in the case of any emergency or irregularities in heartbeat. Their model can only detect heart failure occurring

due to variation in heart rate since it is completely based on the data gathered by ECG signals and neglects heart failure caused due to smoking, obesity, alcohol intake, physical inactivity etc. Along with ECG signals and blood pressure Kassem et al. [13] proposed a system that would send the patient's location as well to the doctor through an email, so that in case of emergency, instant help could be provided to the patient anywhere and anytime. Mudigoudar et al. proposed that cardiac plaque is the main cause for cardiac arrest and thus its detection would help in detection of heart attack. Their paper presents Cardiac Blockage Detection on FPGA platform by means of canny edge detector and watershed image processing algorithms [14]. The accuracy of detection of this module is dependent upon the quality of the input image.

A recent study done by Khairuddin et al. also proposes that Electrocardiography (ECG) alone is not enough to predict heart attack [15]. They propose that the computational output is inaccurate and further it has high computational complexity. Thus, by taking into consideration other health factors the detection of heart attack can be made possible and an alert system as proposed by Akram et al. [16] can be made to alert the patient and doctor. In their paper, they have developed an end-to-end communication solution that can facilitate the patient as well as the Rescue Service Providers.

III. Proposed Methodology

This paper proposes an automated mathematical model of heart attack detection system with the help of fuzzy c-means algorithm. This proposed model can be implemented using MATLAB 7.8 or above. Detailed description of the steps used in proposed methodology is given in this section.

This proposed methodology has been formed by taking into consideration the data of real time patients and monitoring their health at regular intervals. During their health monitoring various factors were considered that have been consulted by different physicians dealing in cardiac arrests. The factors along with their range of normal values under which the patient is found to be healthy enough are given in the table and they are found to be the only factors that must be taken care of while predicting the risk of heart attack. If these factors are incorporated with the IoT technology, then a platform is made which will alert the patient taken under consideration as well as the doctor that the value of one of the given factors is getting abnormally high or low levels and that the patient may be under the risk of getting a heart attack. Once the risk is detected the patient gets a text message on their phone and they can take necessary medications or preventive method to protect themselves from getting a heart attack. In this way the maximum number of sudden heart attacks can be cured by taking preventive measures leading towards the development of a healthy society.

A database of more than 500 patients and the factors governing heart attack serves as input to this model. The factors include heart rate, total cholesterol, high density lipids (HDL), low density lipids (LDL), triglycerides, homocysteine, C-Reactive Protein (CRP), Lipoprotein a, blood pressure (systolic), blood pressure (diastolic), blood sugar (fasting) and blood sugar (post prandial) [17]. These factors have been considered for the development of proposed heart attack detection algorithm by consulting various cardiac experts and are given in Table I.

TABLE I: *Factors causing heart attack*

Factors	**Normal Level**	**Borderline**	**High Risk**
Heart Rate	60-80 beats per minute	40-60 bpm & 80-100 bpm	below 40 & above 100 bpm
Total Cholesterol	less than 200 mg/dL	200-239 mg/dL	240mg/dL and above
HDL (High Density Lipids)	60 mg/dL and above	40-59 mg/dL	less than 40 mg/dL
LDL (Low Density Lipids)	less than 129 mg/dL	130-189 mg/dL	190 mg/dL and above
Triglycerides	less than 150 mg/dL	150-499 mg/dL	500 mg/dL and above
Homocysteine	15-30 µmol/L	30-100 µmol/L	100 µmol/L and above
CRP (C-Reactive Protein)	less than 1mg/L	1-3 mg/L	more than 3 mg/L
Lipoprotein a	less than 30mg/dL	NA	30 mg/dL and above
BP (systolic)	less than 120 mm Hg	120-139 mm Hg	140 mm Hg and above
BP (diastolic)	less than 80 mm Hg	80-89 mm Hg	90 mm Hg and above
Blood Sugar (fasting)	less than 100 mg/dL	NA	100 mg/dL and above
Blood Sugar (Post prandial)	less than 140 mg/dL	NA	140 mg/dL and above

Fuzzy c-means clustering algorithm is applied on these factors to group these factors into clusters that can be further categorized into two categories namely: prone and not prone to heart attack. A fully automated technique is proposed that can be used by a layman or a professional in both general and

specific manner. Figure 2 depicts a flowchart that forms the basis for detection of heart attack in patients.

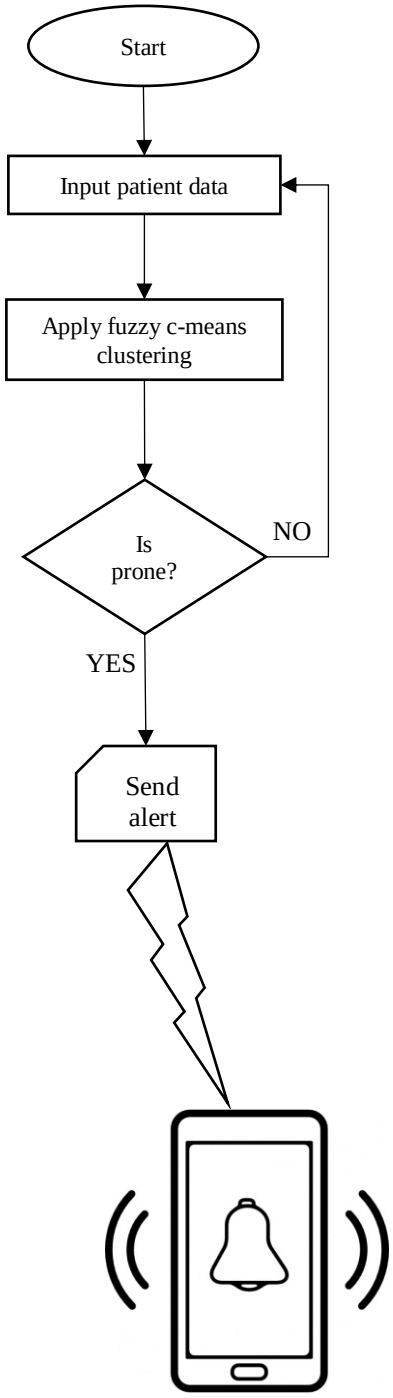

Figure 2: Flowchart for Detection of Heart Attack

Algorithm 1 shows the steps encountered in the process of detecting heart attack in human beings based on factors given in Table I.

Algorithm 1: To detect the possibility of heart attack

Step 1: Load the details of patient from .dat file named dataset.
data = load('dataset.dat');
//where, data contains the files extracted from dataset.dat.

Step 2: Convert the dataset values into an array.

$$X = [x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}] \quad (1)$$

Where, X is the array of factors that cause heart attack.
x_1 represents of heart-rate;
x_2 represents of total cholesterol;
x_3 represents of high density lipids (HDL);
x_4 represents of low density lipids (LDL);
x_5 represents of triglycerides;
x_6 represents of homocysteine;
x_7 represents of C-Reactive Protein (CRP);
x_8 represents of Lipoprotein a;
x_9 represents of blood pressure (systolic);
x_{10} represents of blood pressure (diastolic);
x_{11} represents of blood sugar (fasting);
x_{12} represents of blood sugar (post prandial);

Step 3: Apply fuzzy c-means clustering technique.
[center,U,obj_fcn] = fcm(data, n_clusters);
//where, center represents the center matrix of the //clusters
//U represents the membership function matrix.
//Obj_fcn represents the objective function.
//data is the matrix containing all the patient's //information
//n_clusters represents the number of clusters to be //formed which is 2.

Step 4: Compare the 2 clusters based on their membership values.
if(U(1,i)>U(2,i))
  p(1,i) = U(1,i);
else
  p(2,i)=U(2,i);
end
//where, p is the matrix containing compared values

Step 5: If (prone = true)
  disp('you are prone to heart attack');
  //send message
else
  goto step 1
  //read input of next patient

Step 6: End

IV. RESULTS AND DISCUSSION

In this experiment details of 100 patients serve as input. Based on the values given in Table 1 that shows the range of values lying in normal, border-line and high risk levels. The results obtained are categorized in 4 categories namely True Positive (A), True Negative (B), False Positive (C) and False

Negative (D). The accuracy, sensitivity and specificity is obtained using equation (2), (3) and (4).

$$Accuracy = \frac{(A+B)}{(A+B+C+D)} * 100 \quad (2)$$

$$Sensitivity = \frac{A}{(A+D)} \quad (3)$$

$$Specificity = \frac{B}{(B+C)} \quad (4)$$

Table II shows the values of the parameters used in evaluation of the experiment.

TABLE II: *RESULT OF THE PROPOSED ALGORITHM*

Parameter	Value
True Positive	58
True Negative	24
False Positive	1
False Negative	17
Sensitivity	0.77
Specificity	0.96
Accuracy	**82%**

Graphical representation of the clusters formed has been illustrated in table III.

TABLE III: *REPRESENTATION OF CLUSTER FORMATION*

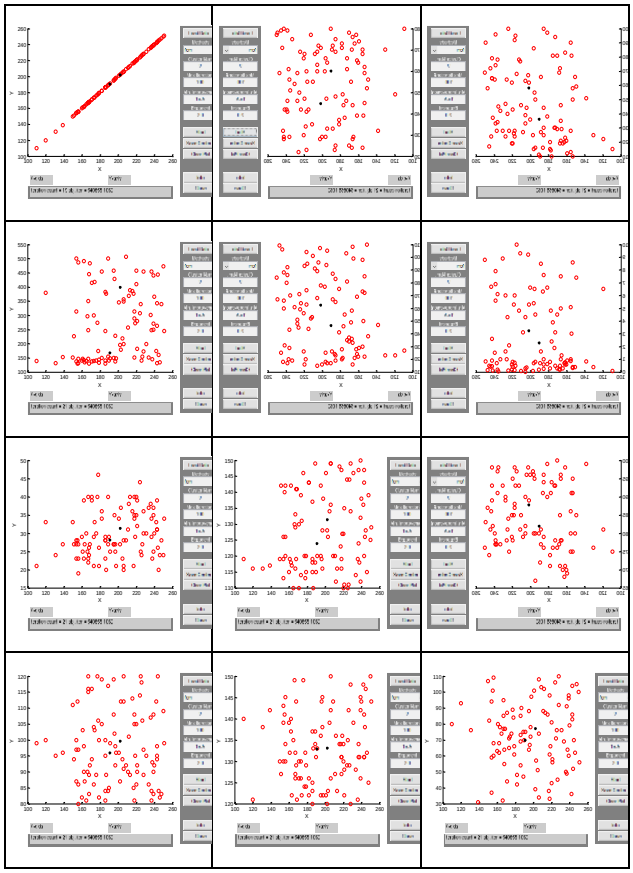

Table IV shows the comparison of the existing papers with the proposed algorithm based on their accuracies.

TABLE IV: *COMPARITIVE STUDY*

Reference	Accuracy
Srinivas et al. [3]	82%
Satapathy et al. [4]	30.5%
Costin et al. [18]	75.76%
Raihan et al. [5]	49.6%
Proposed Algorithm	**82%**

It can be seen from the table that the accuracy of proposed algorithm is 82% which is of high competency as compared to existing literature.

V. CONCLUSION AND FUTURE WORK

This paper presents an automated mathematical model for detecting a heart attack. The main objective of this paper is to detect a heart attack accurately and warn the patient through a message or email in their phone. The proposed algorithm uses fuzzy c-means clustering for prediction of heart attack in human beings. The accuracy of the result is 82% which is quite competent as compared to present day techniques. According to the results, it was seen that with fuzzy c-means algorithm the accurate detection of heart attack could be achieved and with the help of IoT the patient and the registered user will be informed in time and save their life from getting an unexpected heart attack. In future, the emphasis will be to achieve the higher accuracy.

ACKNOWLEDGMENT

We are thank full to Dr. Anil Mathur, physician doctor at Pharmacological Consultant in Saharanpur (U.P., India) for his selfless help and support in enlightening us about the complete knowledge of the heart attack causes and factors.

We also thank Dr. Pankaj Gupta and Dr. Veenika Gupta of Gupta Nursing Home in Saharanpur (U.P., India) for providing us the required knowledge in medical field related to heart attack, it's causes, effects and prevention.

REFERENCES

[1] Bernard Chiu, Micaela Egger, J. David Spence, Grace Parraga, Aaron Fenster, "Quantification of progression and regression of carotid vessel atherosclerosis using 3D ultrasound images", Proceedings of the 28th IEEE EMBS Annual International Conference, 2006, IEEE, pp. 3819-3822.

[2] Xu Huang, Raul Fernandez-Rojas, Kengliang Ou, Allan C. Madoc, "Novel signal processing of brain activity based on ant colony optimization and wavelet analysis with near infrared spectroscopy", 8th IEEE International Conference on Communication Software and Networks, 2016, IEEE, pp. 81-85.

[3] K. Srinivas, Dr. G. Raghavendra Rao, Dr. A. Govardhan, "Analysis of coronary heart disease and prediction of heart attack in coal mining regions using data mining techniques", 5th International Conference on Computer Science and Education, 2010, IEEE, pp. 1344-1349.

[4] S. Satapathy, S. Chattopadhyay, "Mining important predictors of heart attack", Proceedings of International Conference on Advances in Recent Technologies in Communication and Computing, 2011, IET, pp. 143-147.

[5] M. Raihan, Saikat Mondal, Arun More, Md. Omar Faruque Sagor, Gopal Sikder, Mahbub Arab Majumder, Mohammad Abdullah Al Manjur, Kushal Ghosh, "Smartphone based ischemic heart disease (heart attack) risk prediction using clinical data and data mining approaches, a prototype design", 19th International Conference on Computer and Information Technology, 2016, IEEE, pp. 299-303.

[6] S. Sapna, Dr. A. Tamilarasi, "Fuzzy relational equation in preventing diabetic heart attack", International Conference on Advances in Recent Technologies in Communication and Computing, 2009, IEEE, pp. 635-

637.
[7] R. Kumar, Dr. M. Pallikonda Rajasekaran, “An IoT based patient monitoring system using raspberry pi”, International Conference on Computing Technologies and Intelligent Data Engineering, 2016, IEEE, pp. 1-4.
[8] Suman Sankar Bhunia, Sourav Kumar Dhar, Nandini Mukherjee, “iHealth: a fuzzy approach for provisioning intelligent health-care system in smart city”, 10th International Conference on Wireless and Mobile Computing, Networking and Communications, 2014, IEEE, pp. 187-193.
[9] Kala John Kappiarukudil, Maneesha Vinodini Ramesh, “Real-time monitoring and detection of “heart attack” using wireless sensor networks”, 4th International Conference on Sensor Technologies and Applications, 2010, IEEE, pp. 632-636.
[10] Punit Gupta, Deepika Agrawal, Jasmeet Chhabra, Pulkit Kumar Dhir, “IoT based smart healthcare kit”, International Conference on Computational Techniques in Information and Communication Technologies, 2016, IEEE, pp. 237-242.
[11] Georg Wolgast, Casimir Ehrenborg, Alexander Israelsson, Jakob Helander, Edvard Johansson, Hampus Manefjord, “Wireless body area network for heart attack detection”, Antennas and Propagation Magazine, vol. 58, No. 05, 2016, pp. 84-92.
[12] P. Prittopaul, S. Sathya, K. Jayasree, “Cyber physical system approach for heart attack detection and control using wireless monitoring and actuation system”, 9th International Conference on Intelligent Systems and Control, 2015, IEEE, pp. 1 – 6.
[13] Abdallah Kassem, Mustapha Hamad, Chady El Moucary, Elie Fayad, “A smart device for the detection of heart abnormality using R-R interval”, 28th International Conference on Microelectronics, 2016, IEEE, pp. 293-296.
[14] Shrinivas B Mudigoudar, Abdul Imran Rasheed, “Design and implementation of image processing algorithms for cardiac blockage detection on FPGA”, IEEE Annual India Conference, 2016, IEEE, pp. 1-5.
[15] A. M. Khairuddin, Ku Azir K. N. F, P. Eh Kan, “Limitations and Future of Electrocardiography Devices: A Review and the Perspective from the Internet of Things”, 5th International Conference on Research and Innovation in Information Systems (ICRIIS), 2017, IEEE, pp. 1-7.
[16] Arbish Akram, Maria Anjum, Mariam Rehman, Hafsah Bukhary, Hifza Amir, Rafia Qaisar, “Life Savior: An Integrated Emergency Response System”, 8th Inernational Conference on Information Technology (ICIT), 2017, IEEE, pp. 1002-1006.
[17] Eugene Braunwald, Douglas P. Zipes, Peter Libby, “Diagnosis and management of acute heart failure” in Heart Disease: A Textbook of Cardiovascular Medicine, 6th ed., vol. 1, W. B. Saunders, 2001, pp. 156-170.
[18] Hariton Costin, Cristian Rotariu, Alexandru Pasarica, Mental stress detection using heart rate variability and morphologic variability of ECG signals”, International Conference and Exposition on Electrical and Power Engineering (EPE), 2012, IEEE, pp. 591-596.