Health Monitoring of Expecting Mothers using Multiple Sensor Approach: "Preg Care"

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***Abstract*— Maternal mortality ratio (MMR) of non-developing and developing countries stipulate that every year an enormous number of pregnant women succumbed to death due to lack of proper healthcare service. In the case of Bangladesh, maximum maternal deaths happen in the rural and hill-tracts area due to the communication gap during the emergency moments. To solve this situation, in this study, we have proposed multiple sensor-based systems that focus on the issue of complete health monitoring of an expecting mother. We envisioned to target the expecting mothers who are most of the time-deprived of complete health monitoring during the pregnancy time. Our developed system consists of non-invasive anemia and glucose rate detection, sudden fall detection, heart rate, and body temperature. We have also incorporated Wi-Fi and GSM modules in our device to make it viable for telemonitoring. To monitor all these physical parameters, we have also introduced a custom-made android application. These would allow the expecting mothers to assess their health conditions. The doctors and family members would also get notified through SMS if there is an emergency. The outcome of this research would help the health service providers to envision a different approach to give proper healthcare facilties to expecting mothers, specially in the rural areas.**

Keywords—Multi-sensor, non-invasive, telemonitoring, android application, mother healthcare, machine learning

I. INTRODUCTION

According to the World Health Organization (WHO), about 800 women succumb every day worldwide due to pregnancy-related risk [1]. Most of the cases arise in developing and under-developed countries due to poor healthcare systems. According to Fig. 1, it's evident that the highest MMR is found in under-developed or developing countries such as- Bangladesh, African nations, etc. [2]. In these countries, pregnant mothers don't get the proper healthcare facilities, especially, in rural and hill-tracts areas. Moreover, pregnant women face problems such as- overweight, sudden decrement of pulse rate and blood pressure, acute anemia or hypoglycemic/hyperglycemic conditions due to improper hygiene and healthcare systems [3].

Continuous monitoring of health parameters pregnant women is necessary to keep this MMR low and provide good healthcare to pregnant mothers. Nowadays, many researchers are trying to develop and introduce non-invasive healthcare devices which would allow us to monitor different physiological continuously [4]. As non-invasive devices are harmless, these devices could be used to monitor pregnant women's health. There have been numerous works focusing on continuous monitoring of pregnant mother's healthcare. Amala et al. developed an accelerometer sensor-based device to count the number of kicks onto the abdomen wall by baby to predict baby's growth which has the potentiality to reduce the usage of ultra-sonography. It might potentially reduce the cost of baby growth monitoring as an ultra-sonogram is expensive [5]. A group of researchers developed a system named "ASHA" which could be used to make a proper database for pregnant women. These kinds of databases would allow policymakers to make sustainable healthcare policies to increase the healthcare conditions for pregnant women [6].

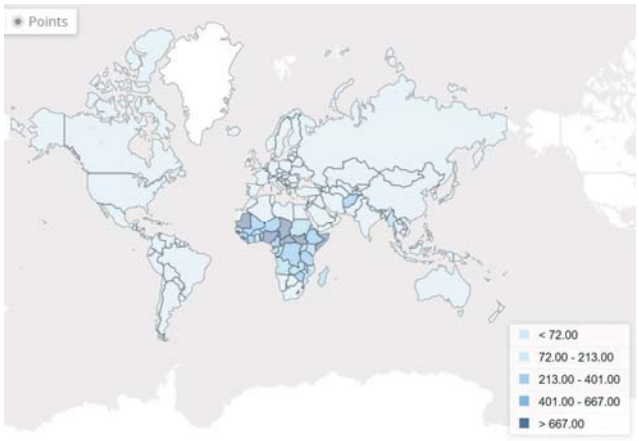

Fig. 1- Map displaying the maternal mortality ratios per 100,000 live births (2017) [2]

Most of the works related to non-invasive monitoring physiological parameters only focused on one parameter rather than focusing on holistic devices. For instance, an android application named "HemaApp" was developed to monitor the blood hemoglobin level which has the possibility to replace invasive hemoglobin measurement devices in the future [7]. The device could be useful to detect anemia patients among expecting mothers. Tamir et al. employed an android application-based system to take eye pallor images and detect anemic conditions [8]. Their system is easy to use and could be implemented in mass level as nowadays everyone uses smartphones. Glucose rate detection also important because pregnant women face problems such as as-Gestational diabetes [9]. Non-invasive blood glucose devices have been developed throughout the years which could be used to detect the blood glucose level of pregnant women [10, 11]. Fall detection is also another important aspect as expecting mothers sometimes experience falls which could prove to be fatal. Kukharenko et al. developed a wearable fall-detection system that can differentiate between the work-out fall, intentional fall or actual fall [12]. This device has the possibility of being used to track expecting mothers fall as it's wearable and non-invasive.

Hypertensive disorder detection during the pregnancy period can be monitored using the machine learning-based technique developed by Moreira et al. [13]. Fetal heart rate is another important aspect which as addressed by Fanelli et al. [14]. Their device could monitor fetal heart rate and FECG all day long. Endo et al. developed a PPG based heart rate sensor to monitor pregnant women which only focused on heart rate data [15]. All these studies show a huge potential for the usage of non-techniques to monitor the physiological parameters of pregnant women. But there is still a lack of systems that have the capacity to cover multiple physiological parameters to monitor pregnant women's health.

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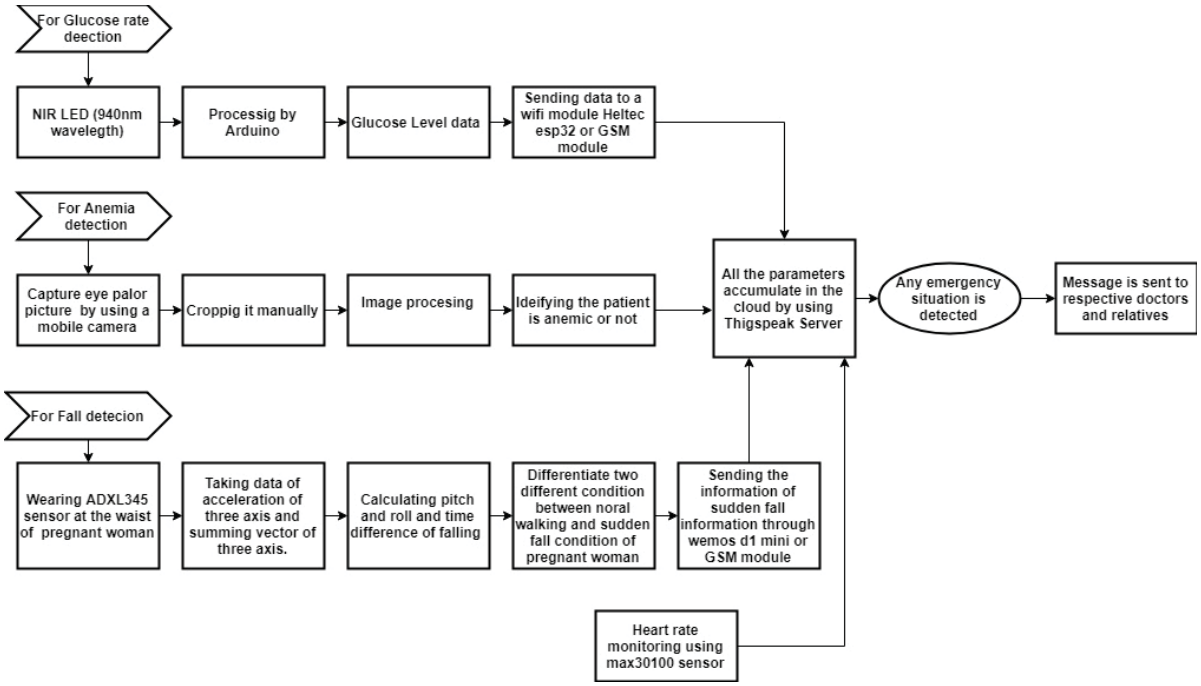

Fig. 2- Block diagram of our proposed device and system

To solve this problem, in our study, we approached in such a way so that we could present the feasibility of using multiple sensor-based systems to continuously monitor expecting mother's healthcare. Our goals for this study were to develop a cost-effective, completely non-invasive device which would allow us to monitor expecting mother's physiological parameter using android smartphones. The telemonitoring aspect of our study would increase the viability of this system as it would allow doctors to monitor the expecting mothers, even if expecting mother's life in rural and under-developed areas. Our primary aim was to show the feasibility of such systems rather than focusing too much on the accuracy of each individual parameter detection.

II. System Overview

In our proposed system, we incorporated different sensors for measuring different physical data of pregnant women. Fig. 2. displays the overall steps we applied to design our system. All the acquired values from the sensors are processed by Microcontroller. These sensor data are sent to the cloud server through a GSM module and an android app after processing is completed. The doctor or relatives of patients can get access to these data from both SMS and app. Any emergency condition is detected successfully by our designed system and alarm is given to the respective authority. As our proposed device is wearable, pregnant women can wear this device in their abdomen or hand.

A. System Components

Our proposed monitoring system consists of two parts: Hardware Part and Software Part. The components we used to design the system are discussed in the following sections.

1) Hardware Section:

Two main tasks are done in this section. The first one is data collection or acquisition from our multi-sensor device and the second one is data transmission in the cloud server. We used various sensors here for the different physical data acquisition process. For continuous glucose rate monitoring, we employed a NIR LED-Photodetector system (940nm) and GSM module for uploading the data in the server. There is a huge probability of sudden fall of a pregnant woman. In our designed device we also used ADXL-345 (Accelerometer) for detecting the sudden fall condition. WeMos D1 Mini1is used for transmitting data in the cloud and sending a message to relatives and respective doctors. We used the Max30100 sensor for estimating the amount of oxygen in the blood or measuring the percentage of hemoglobin and pulse rate concurrently. We measured the pulse oximetry in the blood. We used a mlx90614 sensor for measuring temperature. Max30100 is used for spo2 and pulse rate monitoring. Heltec esp32 OLED board is employed for uploading the SpO2, temperature value in the server. For processing all the data, we have used the Arduino microcontroller board before transmitting data in the cloud.

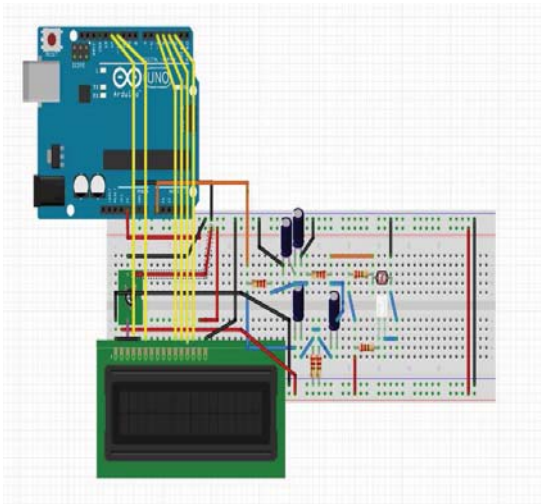

Fig. 3- Designed system in Fritzing. This particular design only cosists of non-invasive blood glucose detection system and temperature detection system

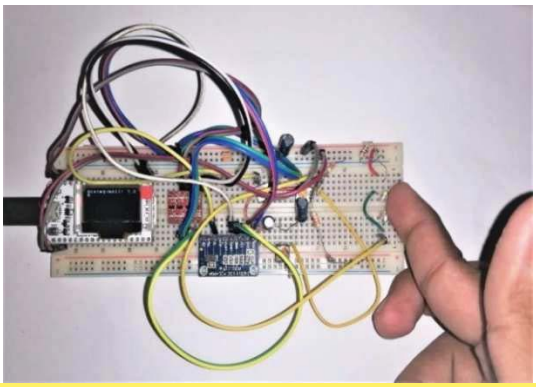

Fig. 4- Implemented non-invasive glucose measurement device. The figure shows that data is being collected from the finger and then being shown with the OLED monitor after processing

Fig. 3 shows overall designed system which includes all of the components expect fall detection system. In this circuit in Fig. 4 is designed for non-invasive glucose rate monitoring of expecting mothers. With a view to fulfilling this purpose, we used here IR (940nm) sensor. Finger, which is the hair-free organ of the body is placed upon this sensor, then the rate of glucose is measured. A notch filter is used in the circuit for reducing the noise from the measured value by an IR sensor. We have developed the circuit based on previously implemented design and conception [10].

There is a huge probability of sudden fall of a pregnant woman. Fig. 5 shows our designed sudden fall detection system where we used ADXL-345 (Accelerometer) for detecting the sudden fall condition. We calculated the displacement along three normalized axes named as the azimuth, roll, pitch and then used the summing vector method. We applied the different conditions of fall by using three functions named:1) Free-like condition, 2) Increase in acceleration due to the impact of fall, 3) Senses a fall in any orientation by factoring pitch and roll (Sudden fall is detected in this condition). We used WeMos D1 Mini for sending the data to the cloud and emergency message to the respective persons

2) Software Section:

In the software segment, we used a Python-based image processing algorithm for the anemia detection process. Pictures of eye pallor were taken and then cropped them manually. Images were pre-processed to collect features. We have used 109 images from subjects. The dataset had both anemic and non-anemic subjects. All these data were used with permission from previous research [16] Among these subjects, 81 images were used for the training dataset and 28 images were used for testing the algorithm. We have used several machine learning algorithms which are shown in Fig. 6. Our study used Orange data mining software to carry on machine learning classifications [17]. Among those algorithms, the decision tree algorithm gave us the highest efficiency which was the reason behind the selection of the decision tree as our classification algorithm. The efficiency of different classification algorithms used in this study is presented in Table-I which is the basis of choosing the decision tree algorithm.

In the database part, we have employed the ThingSpeak cloud server for uploading all the sensor data [18]. Uploading data in the cloud provides data storage capacity and ease of decision making capability.

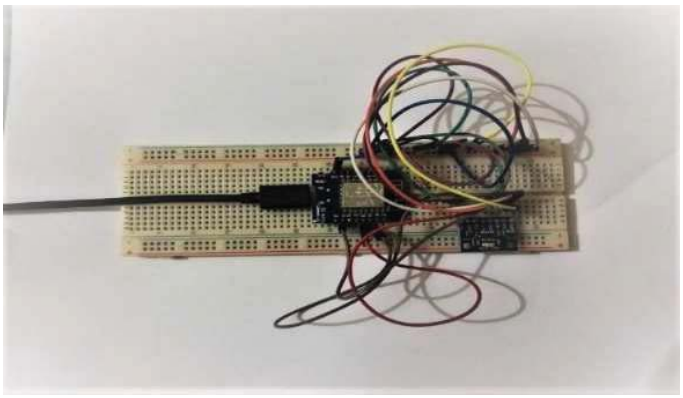

Fig. 5- Implemented circuit for sudden fall detection. The circuit is showing the circuitry used for fall detection.

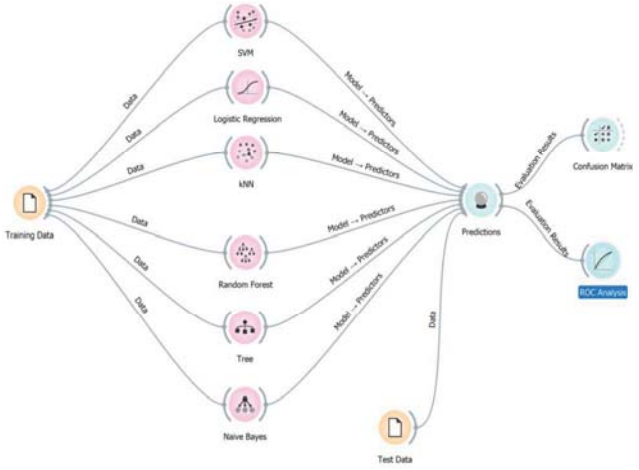

Fig. 6- Machine Learning Algorithms used in our study

Also, cloud integration with android applications provides more robustness and user-end data input capability which is being useful in different sectors, especially in health-care sectors [19, 20]. As a result of the supportive integration of Android smartphones, we designed this app named "Preg-Care" using the JAVA environment. All the physical data collected from pregnant women are sent to the server using both GSM and Wi-Fi module. One can easily observe all the uploaded data by using this app. An emergency notification system is also incorporated with this application.

Table I. Comparison Between Different Classifiers

Sl.	Model	Accuracy	Area under Curve
1	Tree	0.821	0.824
2	Random Forest	0.750	0.853
3	SVM	0.714	0.840
4	Logistic Regression	0.714	0.872
5	Naïve Bayes	0.679	0.818
6	kNN	0.643	0.668

III. Result and Discussion

After implementing the whole multi-sensor device, we collected data practically from our targeted patient. The output of different components of the system. All the data from individual components were continuously updated into the thingspeak server. All the presented data in the following section is collected from the things peak server.

Fig. 7- Continuous Glucose rate measurement

Fig. 8 - Temperature value is uploaded in the ThingSpeak cloud

Fig. 9- Sudden Fall condition is uploaded in the ThingSpeak cloud

Fig. 10- Anemic condition detection and monitoring in server

A. The output from the different component of the system

For glucose rate detection part, one need not prick a finger for blood testing purpose here. Rather only by placing a finger, one can easily know the glucose level. This non-invasive aspect can reduce the pain of many. The glucose rate is shown in Fig. 7. By setting personalized appropriates level for hypoglycemia and hyperglycemia, anyone can get notification in their mobile phone during these mentioned complications. Fig. 8 shows the temperature value of a person. The temperature was also collected using a non-invasive infrared temperature sensor. The data collected from the server shows that data were uploaded continuously.

Fig. 9 shows the fall detection system. If there is any fall happens, then it would get uploaded on the server. Otherwise, the value would always below. We simulated fall like conditions and the data is presented in Fig, 9. If there is fall it's going to register a defined number and give notification fo fall.

Fig. 10 shows whether a patient is anemic or not-anemic. If any patient or expecting mother takes a picture of the eye pallor. Our system would automatically process the image based on machine learning algorithms and upload the result in the server. Fig. 11 shows the confusion matrix which indicates the accuracy of our proposed non-invasive image-based anemia detection system. The decision tree algorithm provided us 82.1% accuracy which is evident from Fig. 11.

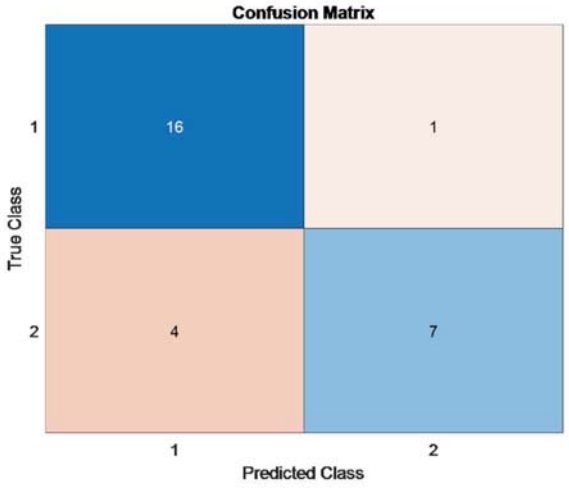

Fig. 11- Confusion matrix showing the accuracy level of the anemia detection system

Fig. 12 represents the ROC curve from the tested dataset. The value of AUC was found to be 0.824 which indicates that our device provides a decent amount of accuracy.

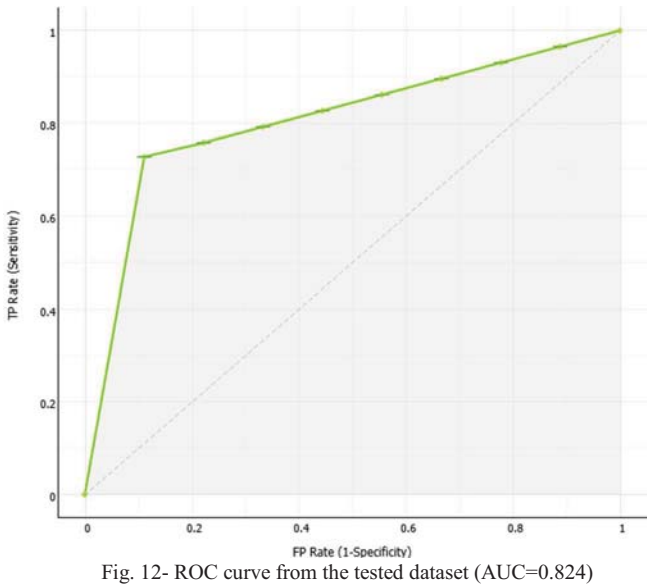

Fig. 12- ROC curve from the tested dataset (AUC=0.824)

Fig. 13 – Our designed Android Application for complete care of Pregnant

Fig. 13 shows the interface of our developed android application "Preg-Care". This android application would introduce convenience to monitor expecting mothers because it would allow both the mother and her family members to access the current physiological conditions.
In case of emergency conditions, an SMS would be delivered to the expecting mother's family members so that they could take immediate actions and it would hopefully reduce the current fatality rate. As all these data would be stored in the database, it would allow the doctors to take much more fruitful decision making in the future.

B. The cost of different components of the system

The cost of our total system is USD 93.4. The breakdown of cost is exhibited in Table II. The cost of overall device can be reduced using single Wi-Fi modules for all of the system components.

Table II. Cost Analysis of Our Proposed System

Sl.	Name	Quantity	Price(USD)
1	ADXL-345(Accelerometer sensor)	1	18.95
2	Wemos D1 Mini	1	3.5
3	MLX90614 Infrared thermometer	1	12
4	ESP 32 Module	3	31.2
5	MAX30100 Pulse Oximeter	1	9.8
6	Logic Level Converter	1	2.95
7	Miscellaneous		15
	Total		93.4

C. Lackings of our deigned system

Our designed app is designed is very trivial and less efficient. Our system takes the value of BP manually and then send that in server. In this system, we used individual Wi-Fi module for each parameters which increased the total cost. Here, we have used the Thingspeak cloud which server provides less data security. Also, the accuracy level of each individual parameter is not perfect which is another pitfall of our current system. There is a possibility that accuracy in this study might have been impacted by calibration issues.

D. Future Works

In the future, we would try to increase the accuracy of every component of this system. More validation studies are required before claiming this system would work in root level. We would try to make it more modular to make easier to use at the root level. We will add more features in our module like fetal ultrasound. We will update our app in that way so that individual users can interface through this app. We will replace Thingspeak cloud by Firebase or amazon paid cloud service which will ensure our data security and quality will also be upgraded. We will add a machine learning algorithm which might help us in prediciting an expecting mother's health issues. We will reduce the cost as our target people are the deprived people of hill-tracks and rural areas. We will also try to learn our app so that it can also verify the emotion of the pregnant women by NLP (Natural Language Processing). Overall, we would try to make a reliable system to improve the current maternal healthcare condition.

IV. HUMANITARIAN IMPACT

Though this system lacks robustness issue in few things, still this system can have a vital impact in the direction of wearable health for expecting mother's in rural areas. This system provides a non-invasive approach to take care different physiological parameters which would ease the current situation of monitoring. Both cloud and android application based approach would provide robustness in the data storage and going to increase decision making capabilities for doctors and relatives in case of emergency.

V. CONCLUSION

In this study, we have developed a cost-effective system to monitor expecting mother's healthcare. The device is modular and consisted of multiple sensors to cover several physiological parameters. We have developed this study to see the feasibility of such a system. In this way, we may have overlooked the efficiencies of several components. We would try to improve the overall efficiencies of these components in the future study. The non-invasiveness of this system would make this system more acceptable to everyone. Also, the telemonitoring aspect would introduce a more reliable monitoring system with respect to expecting mother's families. All of these aspects indicate that our developed device would really help to lower the complications of expecting mothers by imposing a more reliable monitoring system.

REFERENCES

[1] WHO Media Centre, "Maternal mortality fact sheet," pp. 2–5, 2012.

[2] WHO, UNICEF, UNFPA, World Bank Group, and the United Nations Population Division. Trends in Maternal Mortality: 2000 to 2017, https://data.worldbank.org/indicator/SH.STA.MMRT?view=map,(Accessed-28/05/2020)

[3] Valentina Zharkova, Lakhmi C. Jain (Eds.) , "*Artificial Intelligence in Recognition and Classification of Astrophysical and Medical Images*", Springer, 2007.

[4] R. Paradiso, A. Alonso, D. Cianflone, A. Milsis, T. Vavouras and C. Malliopoulos, "Remote health monitoring with wearable non-invasive mobile system: The Healthwear project," *2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Vancouver, BC, 2008, pp. 1699-1702.

[5] S.S.Amala and S.Mythili , "IoT Based Health Care Monitoring System For Rural Pregnant Women,'' *International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)* Volume 6, Issue 11, November 2017

[6] N.D.Valakunde,S.Kumarni,P.S.Kulkarni,S. B. Jumbad, S. S. Chavan,P.B.Shah andA. J. Ustad, "Smart ASHA Pregnancy Monitoring System,'' *International Conference on Big Data, IoT and Data Science (BID) Vishwakarma Institute of Technology*, Pune, Dec 20-22, 2017

[7] Edward Jay Wang, William Li, Doug Hawkins, Terry Gernsheimer, Colette Norby-Slycord, and Shwetak N. Patel. 2016. HemaApp: noninvasive blood screening of hemoglobin using smartphone cameras. *In Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '16).* ACM, New York, NY, USA, 593-604.

[8] A.Tamir,C.S.Jahan,M.S.Saif,S.U.Zaman,M.M.Islam,A.I.Khan,S.A.Fattah,C.Shahnaz, "Detection of Anemia from Image of Anterior Conjunctiva of the Eye by Image Processing and Thresholding," *IEEE Region 10 Humanitarian Technology Conference(R-10-HTC)*,21-23 December,2017

[9] Mirghani Dirar, Abdel Hameed, and John Doupis. "Gestational diabetes from A to Z." *World journal of diabetes* vol. 8,12 (2017): 489-511.

[10] M. S. Arefin, A. H. Khan and R. Islam, "Non-invasive Blood Glucose Determination using Near Infrared LED in Diffused Reflectance Method," *2018 10th International Conference on Electrical and Computer Engineering (ICECE)*, Dhaka, Bangladesh, 2018, pp. 93-96.

[11] J. Yadav, A. Rani, V. Singh and B. M. Murari, "Near-infrared LED based non-invasive blood glucose sensor," *2014 International Conference on Signal Processing and Integrated Networks (SPIN)*, Noida, 2014, pp. 591-594.

[12] I. Kukharenko and V. Romanenko , "Picking a Human Fall Detection Algorithm for WristWorn Electronic Device," *IEEE First Ukraine Conference on Electrical and Computer Engineering (UKRCON)*,2017

[13] M. W. L. Moreira, J. J. P. C. Rodrigues, A. M. B. Oliveira and K. Saleem, "Smart mobile system for pregnancy care using body sensors," *2016 International Conference on Selected Topics in Mobile & Wireless Networking (MoWNeT)*, Cairo, 2016, pp. 1-4,

[14] A. Fanelli, M. Ferrario, L. Piccini, G. Andreoni, G. Matrone, G. Magenes and M. G. Signorini, "Prototype of a wearable system for remote fetal monitoring during pregnancy," *32nd Annual International Conference of the IEEE EMBS*, Buenos Aires, Argentina, August 31 - September 4, 2010.

[15] G. K. Endo, I. Oluwayomi, V. Alexandra, Y. Athavale and S. Krishnan, "Technology for continuous long-term monitoring of pregnant women for safe childbirth," *2017 IEEE Canada International Humanitarian Technology Conference (IHTC)*, Toronto, ON, 2017, pp. 6-10.

[16] N. B. Noor, M. S. Anwar and M. Dey, "Comparative Study Between Decision Tree, SVM and KNN to Predict Anaemic Condition," *2019 IEEE International Conference on Biomedical Engineering, Computer and Information Technology for Health (BECITHCON)*, Dhaka, Bangladesh, 2019, pp. 24-28,

[17] Demsar J, Curk T, Erjavec A, Gorup C, Hocevar T, Milutinovic M, Mozina M, Polajnar M, Toplak M, Staric A, Stajdohar M, Umek L, Zagar L, Zbontar J, Zitnik M, Zupan B (2013) Orange: Data Mining Toolbox in Python, *Journal of Machine Learning Research* 14(Aug): 2349−2353.

[18] Thingspeak server, https://thingspeak.com/ [Accessed- 20/02/2020]

[19] A. Jayed Islam, M. Mehedi Farhad, S. Shahriar Alam, S. Chakraborty, M. Mahmudul Hasan and M. Siddat Bin Nesar, "Design, Development and Performance Analysis of a Low-Cost Health-Care Monitoring System using an Android Application," *2018 International Conference on Innovations in Science, Engineering and Technology (ICISET)*, Chittagong, Bangladesh, 2018, pp. 401-406,

[20] S. Chowdhury, M. S. Islam, M. K. Raihan and M. S. Arefin, "Design and Implementation of an IoT Based Air Pollution Detection and Monitoring System," *2019 5th International Conference on Advances in Electrical Engineering (ICAEE)*, Dhaka, Bangladesh, 2019, pp. 296-300