Development of Cheap Real-Time HealthCare Monitoring System Using Locally Made Devices

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Abstract

Monitoring of triage parameters of a human being is very vital in healthcare; this research came up with a new innovative device which is suitable for measuring the triage parameters of both inpatients and outpatients. A device was developed which can be used in taking triage parameters of patients in real time remotely. With this developed device, patients triage parameters can be measured from various home, offices etc and such data will be transmitted wirelessly in real time to their care giver with the aid of the developed low-cost device. The research explores wireless sensor network technology in caring out the development of the device and a software layer of the work explores C- language. The device developed was tested, the analysis was done on the data gathered from the values of the triage parameters obtained (Temperature, pulse rate, and blood pressure)

Keywords: Temperature, Pulse, Heart Beat Rate, Monitoring, Sensor

1.0 INTRODUCTION

In the healthcare sector, there are diverse machines and apparatus used in monitoring patient's triage parameters and as such can be improved(King, Grazette et al. 2016). Technology is improving, and so the healthcare applications. Healthcare is a serious aspect in science which must be carefully deal with because it involves a human life which cannot be endangered for the absence of innovative healthcare devices(Black, Anandan et al. 2008).

The evolution of the health 4.0 was coined out from the concept of industry 4.0. Health 4.0 was well thought out from the health domain. It is aimed at exploring virtualization of healthcare services in real time. Health 4.0 is also aimed at meeting the needs of the patient's more effectively and efficiently, making interactions faster and easier and, consequently, increasing the patient's satisfaction and the likelihood of repeat visits, which is achieved via the use of internet of a Thing (IoT), use of wireless sensor networks, use of cloud computing, use of cyber-physical systems (CPS). CPS, software applications, algorithms, in terms of an object will be converted to a computer-generated simulation of reality via the use of the temporal matrix. This process is suitable for precision medicine as the virtualization process which is same as the simulation of the algorithms will enable the analysis to be visible in a pictorial pattern in real-time, which its application is useful in theragnostics**.**

In recent times, adoption of telemedicine is becoming more popular due to the advancement in technology. The word telemedicine refers to the act of making use of highly innovative technological inventions for diagnosing of some health challenges, administering treatments to patients as well as observing the triage parameters of patients in real time. It is aimed at ensuring an improved real time monitoring of patient's health conditions. In as much the composition of telemedicine is embedded with information system techniques, its relatively cheap because it deals with transfer of information unlike when patients will have to be at the hospital or at the nearest care giver. Due to advancement in telemedicine, the ratio and

percentage of the elderly one who are permanently on home health monitoring has increased significantly, except for few special cases, they may not visit hospital(Giuffrida, El-Wahab et al. 2009). Their triage parameters are monitored from their respective homes, and the device used as wirelessly enabled to send signals to their care givers in case of emergency(Wyne, Vitla et al. 2009). In a hospital, nurses are engaged periodically to conduct triage parameters such as temperature, heart rate, pulse oximeter, glucose levels reading on patients, a substantial amount of time is wasted in updating patient's medical records via measuring the triage parameters values and updating them on individual patient's files. The conventional method of monitoring patient's triage parameters is not efficient for real-time monitoring of the patient's health condition especially for patients in critical conditions. Also, attending to many patients at the same time pose a difficult challenge leading to inaccurate information about the physical state of all patients. Hence, real-time health monitoring has a great potential for the care of patients(Hossain, Muhammad 2016). The benefit of remote monitoring activities provides a viable option in addressing the increasing residents of patients who are incapable to contact clinics owing to any deficiency of funds, location, or disability(Suh, Evangelista et al. 2010). Because of this advantage, patients can be treated in an appropriate manner, before some terminal incident happens, by constantly monitoring the condition of patients and informing both the patients and medical professionals of any abnormalities, many abnormal scenarios are averted. In this pursuit, there are countless e-healthcare devices developed engaging various designs and techniques for public health establishments.

The development of a patient-friendly medical equipment at a low price to provide the effective healthcare is a challenging task for medical service providers, although various system employing several technologies to provide great applications have been developed(Kokanuch, Tuntrabundit 2017). This issue entices several researchers to formulate a new development and deploy full patient monitoring way out for hospital healthcare scheme (Abdalla, Nubli et al. 2011, Sirisha, Sraddha et al. 2013). Monitoring of triage parameters such as body temperature, pulse and blood pressure on a regular basis ensures early awareness about any chronic clinical symptoms as well as for the effective treatment and management of illnesses(Appelboom, Camacho et al. 2014, Sirisha, Sraddha et al. 2013).

Several researchers have contributed to the attainment of telemedicine, there has been several scholars mentioned in the literature who has contributed towards adoption of technologies in the health sector. A lot of wearable has been developed and commercialized. The table 1 below shows the list of the commercialized products and their major applications as illustrated in the table below.

Table1. Commercialized products for patient's monitoring of triage parameters and activities

Product Name	Wireless Platform	Monitoring Parameters	Battery	
			Type	Life
Jawbone UP3™ Fitness Tracker	Bluetooth LE	Sleep stages (REM, light and deep), HR, food and liquid intake, number of steps, distance travelled, running.	Li-ion poly	7 days
Striiv® Fusion Bio Fitness Tracker	Bluetooth LE	HR, number of steps, distance travelled, calories burned, and sleep quality.	Li-ion	5 days
Garmin vivosmart® HR Fitness Tracker	BluetoothLE, ANT+	HR, calories burned, sleep quality, number of steps, climbing, running, swimming.	Li-ion	5 days
Microsoft® Band 2	Bluetooth	HR, calories burned, sleep quality, food, and liquid intake, number of steps, elevation, climbing, running, biking.	Li-poly	2 days
Fitbit Charge HR™ Fitness Tracker	Bluetooth LE	HR, calories burned, sleep quality, food, and liquid intake, number of steps, elevation, climbing, running	Li-poly	5–7 days

Many of the above listed devices are capable of monitoring and recording in real time, triage parameters of one's conditions as well as the body activities while in motion. There are other types of this devices made with sensors which can be incorporated into many things, there has been cases of sensors attached to textile fiber, clothes and even hand bands and it could even be attached directly to human body with the aid of a clip. The sensors are suitable for monitoring Heart rate denoted as HR, Electrocardiogram, as ECG, Blood pressure, popularly known as BP, Arteria oxygen saturation called SpO2, Body temperature (Pantelopoulos, Bourbakis 2010, Nemati, Deen et al. 2012).

The primary interest in this research is to make a low-priced, dependable, smart monitoring devide, capable of taking triage parameters or vital signs with the aid of the sensor heart rate sensor, blood pressure as well as temperature sensor used as one of the components in the device. The device is built in a way that readings can be transferred in realtime to the data base, before its been programmed to send alerts to the care giver.(Kioumars 2011). There is always a need to provide a more efficient and an intelligent system because of the limitations of the above developed systems.

2.0 SYSTEM COMPONENTS

This section focuses on the functionalities and the construction of the hardware mobile platforms. The mobile platform is basically a wearable device that would be worn by a patient to offer non-stop monitoring of the patient's vital signs.

The e-Health Sensor Shield shown in the Figure below is compatible with Arduino and Raspberry Pi users to accomplish biometric and medical applications schemes where triage parameters monitoring is needed(Maksimović, Vujović et al. 2015). The designed sensor node for each patient engaging three sensors temperature sensor, blood pressure and pulse meter as shown in Figure 2. AT mega 16 development board is used to embed the sensors and Wi-Fi module as a transmitter.

The following sensors were connected to this e-Health Sensor Shield: For body temperature measurement, LM35 temperature sensor is used in the designing of patient temperature sensor node that gives an analog output, this voltage reading is taking by microcontroller using analog converter to digital converter (ADC)(Fernández-López 2011, Manojprabu[1], Dhulipala). The LM35 gives its output in degree Celsius.

A pulse sensor is used to measure the rate of flow of blood in a patient's body per minute which is also called as heartbeat(McArdle, Katch et al. 2010). Pulse sensor works on the principle of near-infrared spectroscopy (NIR)(Ferrari, Quaresima 2012).

NIR encompasses using light in the wavelength of 700-900nm to measure blood volume(Luo, Nioka et al. 1997). Looking at the wavelengths, greatest sum of tissues do not absorb light compare to hemoglobin necessary to monitor the pulse rate(Kamat 2002, Gupta, Mukhopadhyay et al. 2007). It measures the volume hange in the flow of blood using an infra-red LED(Bagha, Shaw 2011). An Accelerometer (ADXL 213) was used to detect the body position. Its gives output in two-axis response horizontal vales and vertical values. It provides a digital voltage; the amplitude of the voltage is directly proportional to the acceleration(Deepa, Kumar 2013).

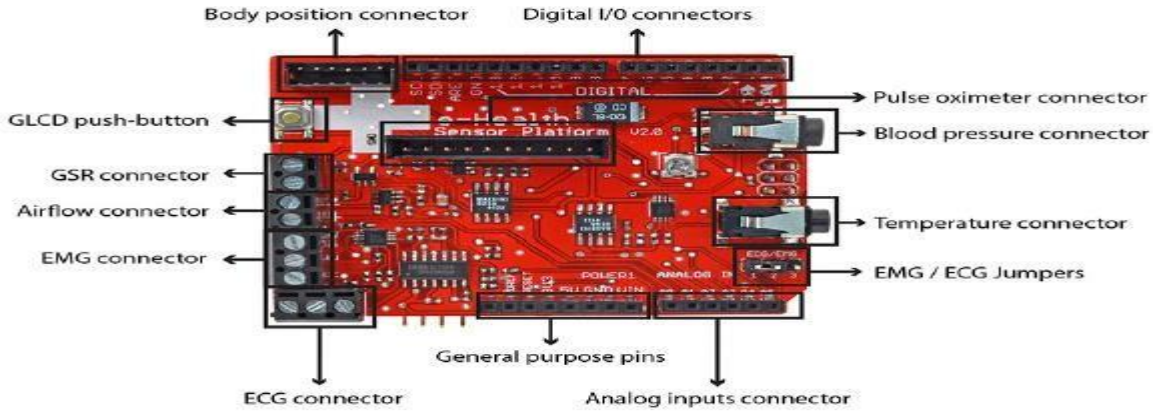

Figure1. The E- health sensor shield

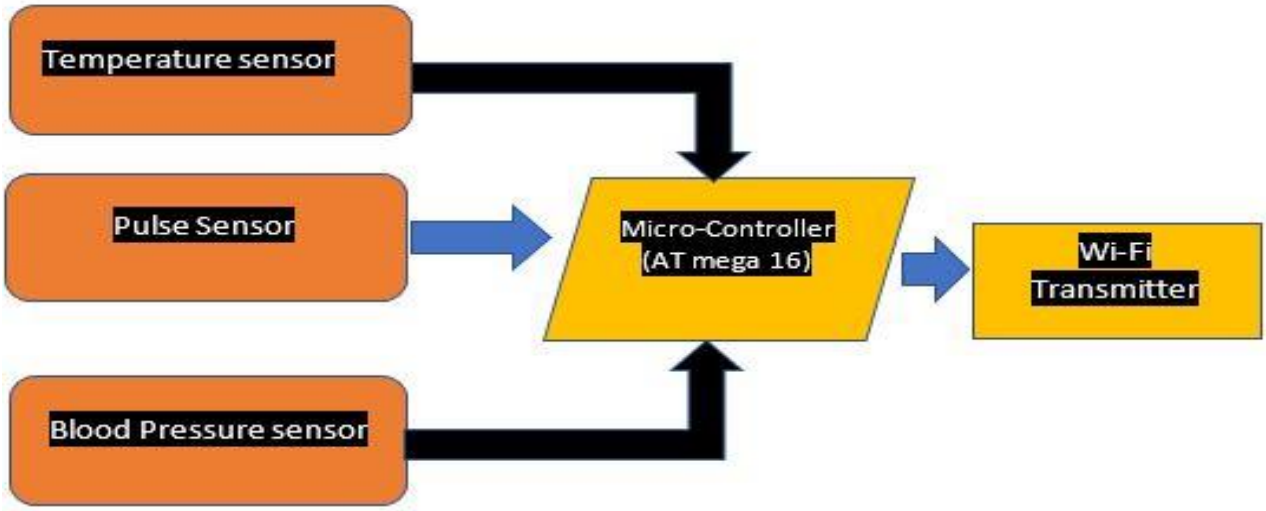

Figure 2. Block diagram of the Patient's sensor node

Figure 3 below is the developed device which is constantly powered by a 9 Volt battery. The prototype is comprised of one pulse sensor, one temperature sensor, blood pressure sensor and one Wi-Fi module. The system is developed on ATmega-16/32(microcontroller) development board. At port A all three sensors are interfaced and at port-D Wi-Fi module is attached using USART. After initializing the Wi-Fi module, the server-client model is created where a central hub works as a server and both sensor nodes worked as clients.

Figure 3. A prototype of system hardware unit

3.0 SYSTEM OPERATIONS, RESULTS, AND VALIDATIONS

A circuitry was formed which is enhanced with analog display coupled with sensors assembled on the PCBs which is placed on the wrist strap. Initial analysis of the accelerometer indicators and the better-quality signal processing algorithm showed very promising results for real-time discovery and intervention. Though the initial signal processing algorithm in which this research is obtained make use of a long window from which this work is derived uses a very long window which is approximately seven seconds, at the end of the day, we obtained some progressive results with a reasonable window of about three hundred and twenty milli seconds. The device was tested on five patients pregnant women who were experiencing early stage contration of their pregnancy and it becomes highly imperative for the doctors and nurses to monitorntheir vital signs. This was done in a private hospital in Ado Ekiti, Nigeria, the patients vital signs reading is imdicated in the table below. The readings were taken to validate the sensitivity of the developed device by comparing its reading with the conventional ones used in the hospital.

The outputs of the device when tested on five (5) different patients for three (3) days as presented in the table below

Table: Data Obtained from comparison between the Developed device and the conventional measuring tools

	Device Developed			Conventional or Control			Error Percetage	
S/N	Temperature	Blood Pressure	Pulse rate	Temperature	Blood Pressure	Pulse rate	Temperature	Pulse rate
Day 1/ Patient 1	36.6^{0C}	120/80mmHg	70	36.5^{0C}	120/70mmHg	72	0.27	2.56
Day 2/ Patient 1	36.9^{0C}	110/80mmHg	76	37^{0C}	114/80mmHg	78	0.27	2.56
Day 3/ Patient 1	36.6^{0C}	120/70mmHg	80	36.7^{0C}	120/70mmHg	80	0.27	0
Day 1/ Patient 2	37^{0C}	100/80mmHg	72	36.5^{0C}	110/80mmHg	72	1.37	0
Day 2/ Patient 2	36.3^{0C}	110/80mmHg	70	36.4^{0C}	108/70mmHg	70	0.27	0
Day 3/ Patient 2	37^{0C}	110/80mmHg	76	36.9^{0C}	120/88mmHg	76	0.27	0
Day 1/ Patient 3	37.3^{0C}	120/80mmHg	72	36.9^{0C}	120/90mmHg	72	1.08	0
Day 2/ Patient 3	36.6^{0C}	110/70mmHg	84	37^{0C}	110/80mmHg	84	1.08	0
Day 3/ Patient 3	36.2^{0C}	110/60mmHg	88	37^{0C}	110/80mmHg	88	2.16	0
Day 1/ Patient 4	37.5^{0C}	100/60mmHg	80	37.2^{0C}	110/80mmHg	80	0.80	0
Day 2/ Patient 4	37^{0C}	110/80mmHg	82	37^{0C}	110/60mmHg	84	0	2.38
Day 3/ Patient 4	36.8^{0C}	110/80mmHg	80	36.6^{0C}	110/70mmHg	83	0.55	3.61
Day 1/ Patient 5	37^{0C}	120/70mmHg	68	36.8^{0C}	116/80mmHg	70	0.54	2.86
Day 2/ Patient 5	36^{0C}	110/60mmHg	73	36.2^{0C}	114/80mmHg	70	0.29	3.61
Day 3/ Patient 5	36.8^{0C}	112/70mmHg	71	36.4^{0C}	110/80mmHg	73	1.09	2.74

4.0 CONCLUSION

As earlier stated at the beginning of this study, the main interest of engaging in this research is to develop a real-time healthcare monitoring system using a locally made device which will be relatively cheap compared to what has been in existence, which will be used to take readings of triage parameters and transmit them remotely to the stationed computer server or the appointed healthcare carer.

The research mission was successfully carried out, a wireless sensor network technology, C- language software was used with another component to develop a locally made device suitable for taking triage parameters in healthcare applications. The locally made measuring gadget is completely suitable for taking triage parameter in various health establishments to ensure prompt and real-time monitoring of patient temperature, heart rate as well as the blood pressure. TMP36 analog sensor explored in taking the reading of body temperature gives a virtuous estimate of a patient's mean body temperature using Burton's equation with a maximum error of less than 0.27 °C. The sensor deplored for the reading of heart rate explores both infra-red LED and a phototransistor in its operations. An estimate of heart rate with a maximum error between 0 and 3.61 beats per minute was obtained.

The valuess derived, from the sampled patient's using the developed device indicate that the sensors deployed worked perfectly. The locally developed real-time monitoring device be improved over time to handle the capabilities of traditional electro-cardiograms.

REFERENCES

ABDALLA, A.N., NUBLI, M., SIONG, T.C., KHAIRI, F. and NORAZIAH, A., 2011. Enhancement of real-time multi-patient monitoring system based on wireless sensor networks. *International Journal of Physical Sciences,* **6**(4), pp. 664-670.

APPELBOOM, G., CAMACHO, E., ABRAHAM, M.E., BRUCE, S.S., DUMONT, E.L., ZACHARIA, B.E., D'AMICO, R., SLOMIAN, J., REGINSTER, J.Y. and BRUYÈRE, O., 2014. Smart wearable body sensors for patient self-assessment and monitoring. *Archives of Public Health,* **72**(1), pp. 28.

BAGHA, S. and SHAW, L., 2011. A real time analysis of PPG signal for measurement of SpO2 and pulse rate. *International journal of computer applications,* **36**(11), pp. 45-50.

BLACK, A., ANANDAN, C., CRESSWELL, K., PAGLIARI, C., MCKINSTRY, B., PROCTER, R., MAJEED, A. and SHEIKH, A., 2008. The Impact of eHealth on the Quality & Safety of Health Care. *London: Imperial college of London,* .

DEEN, M.J., 2015. Information and communications technologies for elderly ubiquitous healthcare in a smart home. *Personal and Ubiquitous Computing,* **19**(3-4), pp. 573-599.

DEEPA, A. and KUMAR, P.N., 2013. Patient health monitoring based on ZigBee Module, *Optical Imaging Sensor and Security (ICOSS), 2013 International Conference on* 2013, IEEE, pp. 1-4.

FERNÁNDEZ-LÓPEZ, H., 2011. Remote vital signs monitoring based on wireless sensor networks.

FERRARI, M. and QUARESIMA, V., 2012. A brief review on the history of human functional near-infrared spectroscopy (fNIRS) development and fields of application. *NeuroImage,* **63**(2), pp. 921-935.

GIUFFRIDA, A., EL-WAHAB, S. and ANTA, R., 2009. *Mobile health: the potential of mobile telephony to bring health care to the majority,* .

GUPTA, G.S., MUKHOPADHYAY, S., DEVLIN, B. and DEMIDENKO, S., 2007. Design of a low-cost physiological parameter measurement and monitoring device, *Instrumentation and Measurement Technology Conference Proceedings, 2007. IMTC 2007. IEEE* 2007, IEEE, pp. 1-6.

HONG, Y., KIM, I., AHN, S.C. and KIM, H., 2010. Mobile health monitoring system based on activity recognition using accelerometer. *Simulation Modelling Practice and Theory,* **18**(4), pp. 446-455.

HOSSAIN, M.S. and MUHAMMAD, G., 2016. Cloud-assisted industrial internet of things (iiot)–enabled framework for health monitoring. *Computer Networks,* **101**, pp. 192-202.

KAMAT, V., 2002. Pulse oximetry. *Indian J.Anaesth,* **46**(4), pp. 261-268.

KING, K.R., GRAZETTE, L.P., PALTOO, D.N., MCDEVITT, J.T., SIA, S.K., BARRETT, P.M., APPLE, F.S., GURBEL, P.A., WEISSLEDER, R., LEEDS, H., ITURRIAGA, E.J., RAO, A.K., ADHIKARI, B., DESVIGNE-NICKENS, P., GALIS, Z.S. and LIBBY, P., 2016. *Point-of-Care Technologies for Precision Cardiovascular Care and Clinical Research: National Heart, Lung, and Blood Institute Working Group.*

KIOUMARS, A.H., 2011. *Wireless data acquisition and monitoring for healthcare services systems: a thesis in the partial fulfillment of the requirement for the Masters of Engineering (Electronics and Computer Systems), Massey University, Palmerston North, New Zealand,* .

KOKANUCH, A. and TUNTRABUNDIT, K., 2017. Knowledge sharing capability in healthcare organizations. *Journal of Asia Business Studies,* **11**(2), pp. 135-151.

LUO, Q., NIOKA, S. and CHANCE, B., 1997. Functional near-infrared imager, *Optical Tomography and Spectroscopy of Tissue: Theory, Instrumentation, Model, and Human Studies II* 1997, International Society for Optics and Photonics, pp. 84-94.

MAJUMDER, S., MONDAL, T. and DEEN, M.J., 2017. Wearable sensors for remote health monitoring. *Sensors,* **17**(1), pp. 130.

MAKSIMOVIĆ, M., VUJOVIĆ, V. and PERIŚIĆ, B., 2015. A custom Internet of Things healthcare system, *Information Systems and Technologies (CISTI), 2015 10th Iberian Conference on* 2015, IEEE, pp. 1-6.

MANOJPRABU[1], M. and DHULIPALA, V.S., Wireless Physiological Parameter Monitoring and Recording System.

MCARDLE, W.D., KATCH, F.I. and KATCH, V.L., 2010. *Exercise physiology: nutrition, energy, and human performance.* Lippincott Williams & Wilkins.

NEMATI, E., DEEN, M.J. and MONDAL, T., 2012. A wireless wearable ECG sensor for long-term applications. *IEEE Communications Magazine,* **50**(1),.

PANTELOPOULOS, A. and BOURBAKIS, N.G., 2010. A survey on wearable sensor-based systems for health monitoring and prognosis. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews),* **40**(1), pp. 1-12.

SIRISHA, B., SRADDHA, T. and VIJAYANAND, K., 2013. Real-time multi-patient monitoring system using ARM and wireless sensor network. *International Journal of Communication Network Security,* **2**(2), pp. 41-47.

SUH, M., EVANGELISTA, L.S., CHEN, C., HAN, K., KANG, J., TU, M.K., CHEN, V., NAHAPETIAN, A. and SARRAFZADEH, M., 2010. An automated vital sign monitoring system for congestive heart failure patients, *Proceedings of the 1st ACM International Health Informatics Symposium* 2010, ACM, pp. 108-117.

WYNE, M.F., VITLA, V.K., RAOUGARI, P.R. and SYED, A.G., 2009. Remote patient monitoring using GSM and GPS technologies. *Journal of computing sciences in colleges,* **24**(4), pp. 189-195.

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