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Design of Cost-effective Wearable Sensors with integrated Health Monitoring System.

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***Abstract*—The present struggle with COVID 19 pandemic has necessitated strategic response in healthcare systems to decrease mortalities even with poor lab infrastructure. With improved disease surveillance, any country can handle health emergencies in a better manner. Combining wearable device technology with smartphone, self-testing can be improved and real time monitoring of various parameters such as temperature, oxygen levels and pulse rate reducing burden on healthcare and creating a vigilant environment. This also help us in contract tracing and also reduce death out of comorbities which has caused a heavy death toll out of pandemic. Here, the components of daily use are deployed with slight modification for creating real time monitoring along with auto alarm and warning transmission to local health ministry. Data collected from sensors are stored in Arduino memory and transmitted to smartphone through Wi-Fi module. Our proposed system is used to process, analyse and display patient's collected data with auto alarm. Our proposed system has been very reliable with average delay of 14s and low power consumption with standing time of nearly 4 hr.**

Keywords*— *COVID 19 pandemic, real time monitoring, sensors, comorbities, arduino.

I. INTRODUCTION

Corona virus disease has became a pandemic causing death toll around 3 lakhs and severe economic and political vaccum in major countries around the world [1, 2]. With fewer research done on pandemic since SARS to COVID symptoms has been common such as fever, cough, sneezing etc. Hence wearable health devices providing continuous monitoring of major symptoms aforesaid become potential life saver in this hour. Design of such wearable devices should be simple and affordable without much affecting everyday routine of our life. Moreover combining this with smart phone technology can save life of many persons even to remote location of our nation. As number of smartphone users crossed 2.5 billion this year the proposed method is possible creating revolution in Point of care diagnostics. Many researchers are working towards creating an innovative real time health monitoring tools with ubiquitous connectivity devices and simple smartphone as it enters into 5G [3-5].Remote monitoring also help elderly people in improving their health condition and reduce death with major changes in geriatric care. When all these parameters combined with telemedicine and mhealth through Artificial Intelligence and Blockchain technology as shown in Fig will easily achieve our SDG on health creating Smarter and Healthier India.

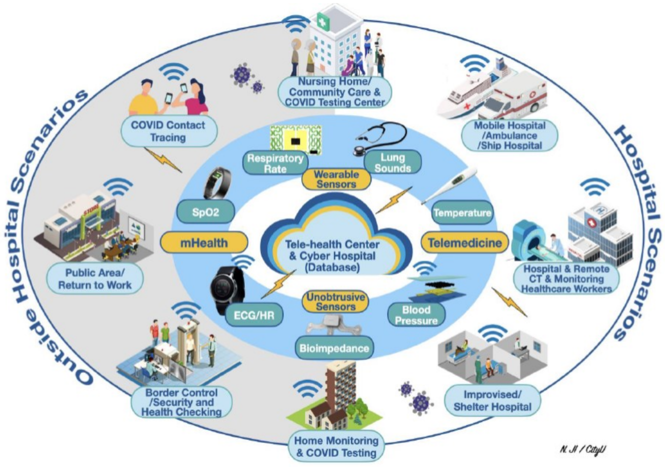


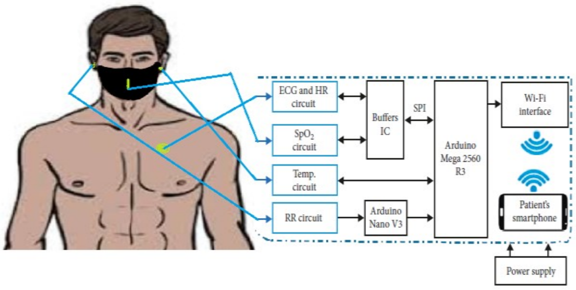
Fig 1. Integrated Real time monitoring and telemedicine borrowed from Dr. R. Pettigrew's presentations [6]

The proposed project have considered critical physiological parameters such as temperature, respiratory rate(RR), blood oxygen saturation (SpO_2) and Heart rate (HR).With sensors, it gathers information and process it with Arduino and based on threshold values it is provided with auto alarm feature that send warning through Internet and SMS to concerned local health ministry. It is also with two modes of data transfer either continuous or specific. Adequate importance is also given to the protection of patient data and for power support special power module is used. Section II provides system overview, Section III provides result and discussion of our proposed system. Finally section IV concludes our paper.

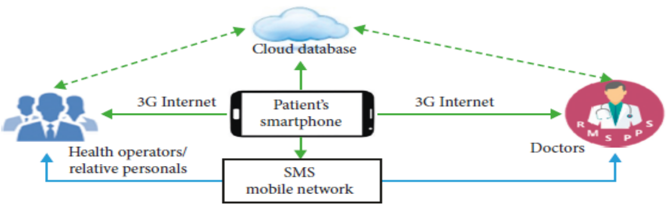
II. SYSTEM OVERVIEW

A. Proposed Architecture

First, the proposed system is discussed with various sensors fitted to various body parts and processing collected data with Arduino transferring data to the cloud as shown in Fig 2.All the hardware modules of our proposed system overview were selected considering their power dissipation, affordability and reliability. Various wearable sensors in use are shown in Table 1.But fabrication of such sensors are costlier to support our population, hence existing gadgets such as earphones are modified to suite our application without compromising on quality and accuracy of diagnosis.



(a)



(b)

Fig 2. System overview with various module

B. *Headset module integrated to mask*

Here, a simplest sensor mobile headset is used with slightly modified microphone. Fig 3 shows us the modified form of headset integrated to mask. Post COVID wearing mask became inseparable part of human life and hence this integration is selected. Here, JAVA based online application is used for designing autonomous gadget suiting our need. Earphone is modified in such a way that thermistor for measuring temperature either PTC or NTC are fixed on to one side while on the other side PPG earclip for detecting Heart rate is placed as shown in Fig 3.The sensor in microphone records the audio signal with aid from mobile application and is imported as wav file for further processing. It is processed in all domains time and frequency to analyze breathing pattern/lung sound and cough nature. The mask itself act as amplifier.PPG for heart rate detection is only standalone part of this module.

TABLE I .VARIOUS WEARABLE SENSORS

Parameters	Measurements	Warning levels	*Sensors*
RESPIRATORY ASSESMENT	Respiratory Rate (RR)	≤20 bpm	Straps on chest,Belts,flexible Patches, Masks,Vests,Tatoo,Earbud,Ring patch
	Lung sound	Cracking sound	
	Oxygen Saturation (Spo_2)	≤94%	
CARDIO ASSESMENT	Heart Rate (HR)	> 100 beat per minute	Watch,wrist band, ring patch,tatoo,flexible patch
OTHER ASSESMENT	FEVER	≥ 38 °C	Thermal sensing and piezoelectric sensing
	COUGH	Dry	

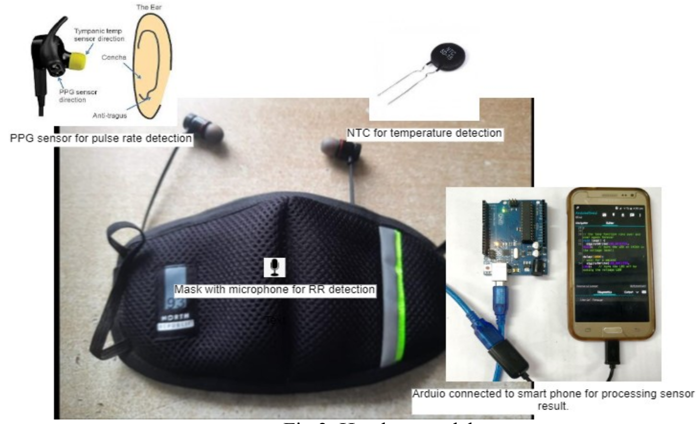


Fig 3. Headset module

C. *Arduino module connecting smartphone*

For improving accuracy of detection and remove noise, the captured audio signal is processed with Arduino Mega 2560 module through Arduino Nano.ECG signal is also calculated from Heart rate measured with PPG using MAX3003 module. Before feeding signals to Arduino they are amplified with circuit module as shown in Fig 5.

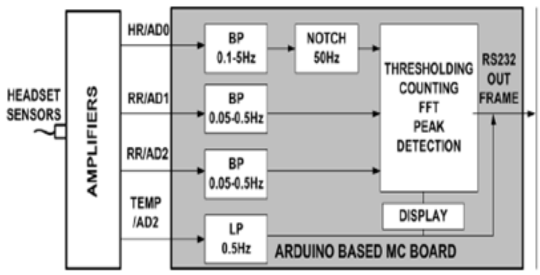


Fig 4. Arduino module connecting mobile phone

After preprocessing with simple LM324 amplifier, signals are passed through various filters and thresholding, signal leveling along with FFT is performed to detect heart rate and ECG.

$$HR(bpm) = \frac{1000 * 60}{\mathrm{R - Rinterval\ (ms)}} \quad (1)$$

Analog signals given to Arduino is processed and converted to low frequency signal of about 25Hz. The proposed power supply circuit with various components is shown in Fig 5.

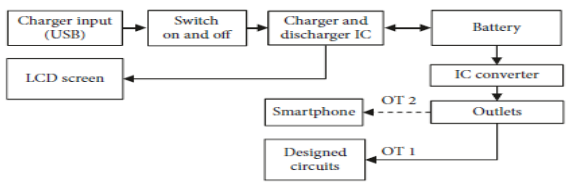


Fig 5. Power circuit module

D. *Smartphone Application Module*

Data transmitted from Arduino is sent to mobile using wifi module ESP8266 through serial communication links. It has been chosen due to low power dissipation. Further, it is designed to operate in two modes namely continuous mode and alarming mode. In the continuous mode all the parameters recorded are sent in real time through smartphone and in alarming mode when the recorded value cross normal value as assigned it is transmitted since it saves our time in monitoring. It also has feature for getting GPS location of patients whose recorded parameters cross the normal values. Health application with essential privacy protection feature is designed in Android with easy user interface as shown in Fig 6.

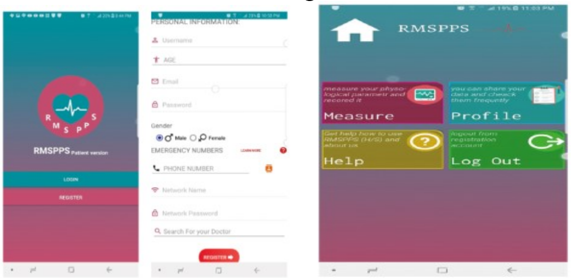


Fig 6. Developed Health application with user interface

Wifi connection interface for sending recorded parameters from Arduino to local health ministry is as shown in Fig 7. Since 3G module is available throughout the location, the module is tested with it, however it can be extended to use in 4G also. Wi-Fi is reconnected for 832μs to get processed information from Arduino to be sent to developed doctor application. Even SMS is sent to local health ministry if recorded values are greater than normal through RMSPPS servers. The working principle is as shown as Fig 8 to calculate threshold values for further processing. Auto alarm module of this project is fully dependent on the threshold value calculation.HR and ECG threshold value calculation is based on the estimation principle [7].Similarly, RR rate calculation is done comparing data collected with the age factor and pathological values as explained in [8]. SpO_2 and temperature estimation is done comparing with other values collected as shown in Table 2.

TABLE II .THRESHOLD VALUE ESTIMATION

Parameter	Rhythm/pathology	Threshold values
SpO_2 (%)	Normal	96 to 99
	Pulmonary or cardiovascular chronic diseases	Drop rapidly
	Acute respiratory failure	<90% + 3 to 4%
RR (breaths per minute (bpm))	Normal	12-16
	Cardiac arrest	≥27
	Lower respiratory tract infections	>24
	Tachypnea	>12-16
	Bradypnea	<12-16
Temperature (°C)	Normothermia or euthermia	37.0
	Fever	≥37.8
	Hypothermia	≤35.0
HR (beats per minute (bpm))	Normal	60 to 100
	Bradycardia	<60
	Tachycardia	>100

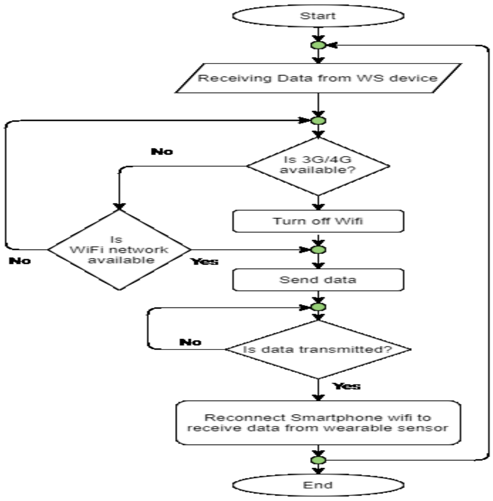


Fig 7. Wifi module for data transmission

III. RESULTS AND DISCUSSION

The audio signal from mic is recorded in wav format is processed with Hilbert transform as shown in Fig 9.From the original value of Hilbert transform RR and HR are calculated with envelope detection and Fourier transform. From the graph, the normal breathing pattern and its variation is observed. With noise removal and filtering mechanism, HR and RR are assigned as shown in Fig 10. Moreover the proposed system shows time delay of 14 seconds and power standby of around 4 hour which is better one till today comparing others. Recorded values is also checked for accuracy by comparing with normal values and displayed in Table III. Monitoring parameters in mobile is shown in Fig 11.Average time delay is shown in Table IV.

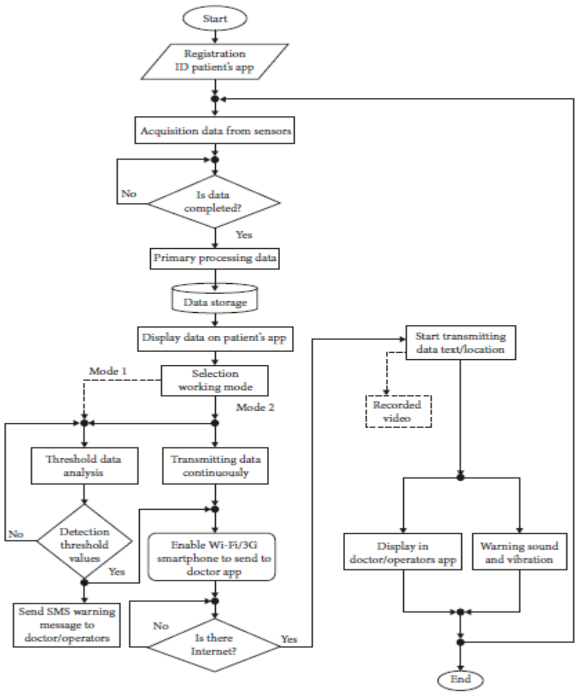
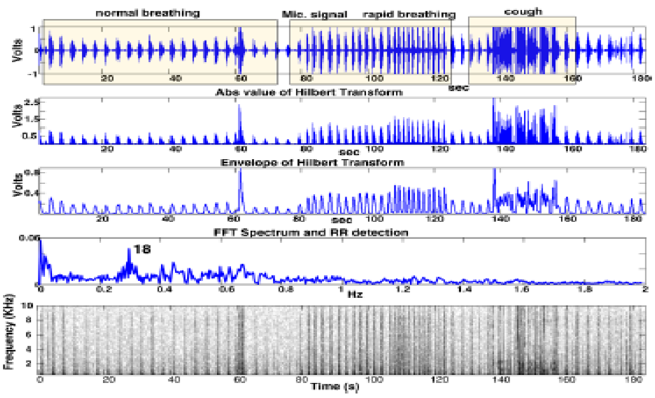


Fig 8. Working Principle of automated transmission



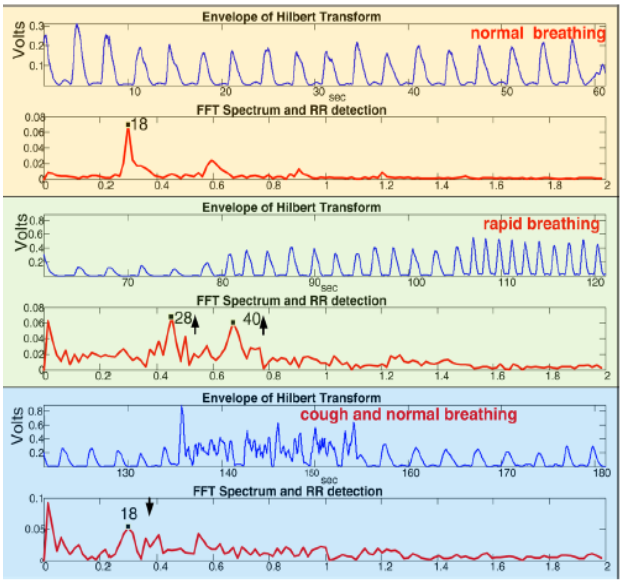


Fig 9. Detection RR rate from audio signal

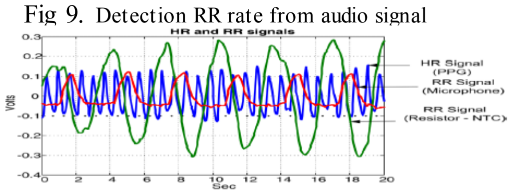


Fig 10. Arduino processing result

Proposed system displays various physiological parameters in graphic and numeric form which makes it more preferred compared to previous approaches. Autoalarm module adds to additional advantage to track multiple patients simultaneously along with their GPS location.3G mobile network is used as it can provide long range with real-time monitoring with acceptable power consumption of nearly 4 hours that distinguishes our proposed approach. Use of less time for data transmission and efficiency improvements in terms of real time monitoring, power consumption, compatibility and affordability makes our proposed system a remarkable one.

TABLE III.ACCURACY MEASUREMENT

Subject	Parameters									
	SpO2 %		HR rate(bpm)		RR rate(rpm)		Temperature (°C)		ECG (R-R ms)	
	Measured Value(MV)	True Value(TV)	MV	TV	MV	TV	MV	TV	MV	TV
1	96	96	46	44	14	14	32	33	627	632
2	95	94	88	87	16	16	35	34	563	566
3	98	97	79	78	15	14	35	33.5	581	585
4	97	97	100	99	14	15	36	35	627	632
5	99	98	67	66	15	15	34.5	35.5	632	630
Accuracy	98.23%		98.32%		100%		99.11%		99.3%	

TABLE IV. PERFORMANCE ANALYSIS

No	Performance Parameters	Wifi	3G
1	*Average connecting time (s)*	*71*	*117*
2	*Average transmitting time to doctor app (s)*	*18*	*70*
3	*Average time loss ratio (s)*	*4*	*2*
4	*Average time delay (s)*	*14*	*68*

IV. CONCLUSION

Real time monitoring systems with smart phone technology becomes need of the hour to combat this COVID 19.It has potential to create revolution in health and geriatric care. Since proposed project have used components of daily use, it doesn't require huge investment and can be integrated into our life very easily. It is also observed that the proposed approach also comes with higher accuracy and lower power dissipation. It will also be more economically beneficial when implemented across the country. Our future work will concentrate on including other parameters such as Blood Pressure, Sugar which has seen rise now a days. Now, this design is implemented in Android mobile that has to be extended to iPhone. So that the proposed system of real time monitoring can be made universal.

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