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Systolic Blood Pressure Measurement from Heart Rate using IoT

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***Abstract**: Hybrid Sensors and Vehicular Networks (HSVN) represent an architecture which creates a framework of collaboration between Wireless Sensors Networks (WSN) and Vehicular Ad Hoc Networks (VANET). The goal of this collaboration is the improvement of the road safety. The coverage and connectivity problems (deployment models) of wireless sensors networks represent a big challenges studied by many searchers. The environment and application requirements have a relationship with the aspects used to create a deployment model. In this paper, we have proposed a deployment model of WSN used in HSVN basing on the roads network and application of road safety. This model uses an algorithm which has for purpose ensuring the sensing of any road event and allows the connectivity between sensors. The results proven that our proposition is more reliable than others works.*

***Index Terms**: Coverage, Connectivity, Deployment models HSVN, VANET, WSN.*

I. INTRODUCTION

High blood pressure known as the hypertension increases the chance of mortality for the adults. However, a recent study in China shows, peoples who have the pre-high heart rate in between 80 to 90 bpm have a short life compare to who have the heart rate in between 60 to 69 bpm. So, there is a linear relationship between the heart rate and blood pressure [1]. Some related key factors to blood pressure like headaches, dry eye, stress, sleep, emotion etc., are also related to the heart rate. Another study from African-American teenagers shows, there is a positive relationship between the heart rate and blood pressure [2].

In this paper, an IoT (internet of things) based systolic blood pressure (SBP) monitoring system from heart rate (HR) is proposed. LM358 sensor and NRF module are used to measure HR and calculate SBP via using regression techniques. During the experiment, the extracted results of SBP are compared with the measured SBP data of a sphygmomanometer at same time. The experimental results of the designed system are also compared with the other state-of-the-art methods to calculate the accuracy of proposed method.

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II. PREVIOUS WORK

Hassan et al. [3] proposed a regression method to measure systolic blood pressure from heart rate via ECG signal and the sphygmomanometer. In their experiment, they observed the HR and the corresponded SBP for persons aged between 19-30 years. They proposed 10 regression equations based on different pattern between HR and SBP. A recent study in [4] discussed the validity of different devices which can measure blood pressure. The automated and semi-automated devices which can measure blood pressure use only 2 or 3 protocols. In that study, authors discussed many international protocols related to blood pressure. They observed the blood pressure by sphygmomanometer for different subjects and compare with other devices in order to find out the accuracy. Ramsey et al. [5] discussed an Oscillometric device which can automatically measure the arterial blood pressure. Their proposed device uses a cuff to send an external pressure in the artery. When the cuff pressure is increased, it considers as the systolic blood pressure. Even though, their system required a long to time to measure the blood pressure and sometimes system needed many cardiac cycles.

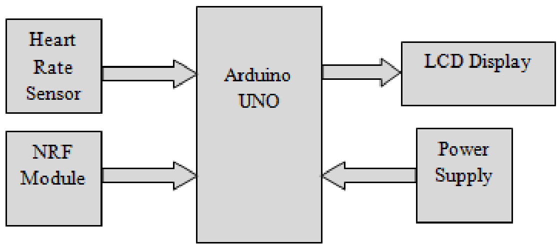

Fig. 1 HR Measure by using Device

III. DEVICE & COMPONENTS

The aim of this project is to measure the heart rate and calculate the systolic blood pressure from the heart rate. The Arduino Uno (ATmega328) is working as a CPU for measuring the heart rate of a person. Fig. 1 shows the block diagram of our device which can measure HR. The list of main sensors and components of the proposed heart rate measuring device are

given below-

Arduino Uno (ATmega328)

Heart Rate Sensor (LM358)

NRF Module (nRF24L01)

LCD Display

Power Supply

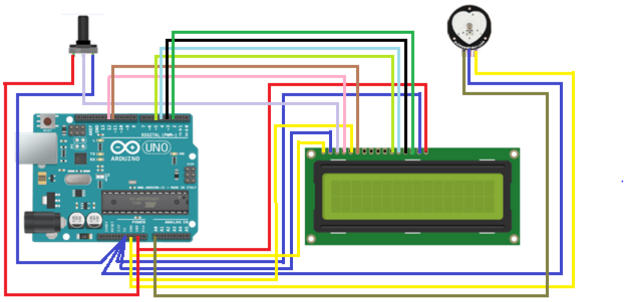

Fig. 2 Circuit Diagram for HR and SBP Measurement

The schematic circuit diagram of the designed system is depicted in. Fig. 2. As observed, the device will receive the power supply through the power supply block. The heart rate sensor captures the HR data and sends it to the Arduino Uno. Then, the transmitted information sends serially through NRF module, and finally, the measured heart rate is shown on the LCD.

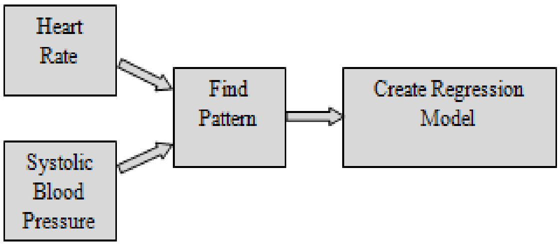

Fig. 3 Regression Model Flow

IV. METHODOLOGY

In this experiment, more than 250 data of SBP and HR from university students aged between 20 to 28 were collected. The corresponding data on heart rate and SBP for each individual are collected through HR sensor via Arduino Uno and sphygmomanometer at a time. Fig. 3 illustrates the flow of proposed regression model. At first, the data of HR and its' corresponded SBP are collected and then divided the dataset into 3 categories including high SBP, pre-high SBP, normal SBP. The ranges for each category are given in Table 1.

Table 1. Categories and Ranges of SBP

Category	Systolic Blood Pressure	Range
Category 1	High SBP	SBP ≧140
Category 2	Pre-High SBP	120≦ SBP <140
Category 3	Normal SBP	SBP <120

Table 2. Regression Model for SBP using HR

Category	Proposed Regression Model
Category 1	Y= 0.383X + 108.222
Category 2	Y= 0.2411X +106.27
Category 3	Y= 0.2481X + 98.0867

Table 3. Calculated SBP Considered Status

Difference of original SBP and calculated SBP	Status
0 —2 mmHg	Very accurate
3 —4 mmHg	Slightly inaccurate
5 —6 mmHg	Moderately inaccurate
>6 mmHg	Very inaccurate

Based on these patterns, a regression model for each category is developed. Table 2 shows the regression model for each category. Finally, the developed regression equations are implemented in the device to measure the SBP from heart rate. The corresponding status based on the difference between the original and calculated SBP status are presented in Table 3.

Table 4. SBP Data for Category 1 in Our Method

HR (BPM)	Original SBP (mmHg)	SBP via proposed model (mmHg)	Difference (mmHg)
105	148	148.437	0.437
94	146	144.224	1.776
104	148	148.054	0.054
105	150	148.437	1.563
86	142	141.16	0.84
84	141	140.394	0.606
94	145	144.224	0.776
97	144	145.373	1.373
83	140	140.011	0.011
83	141	140.011	0.989

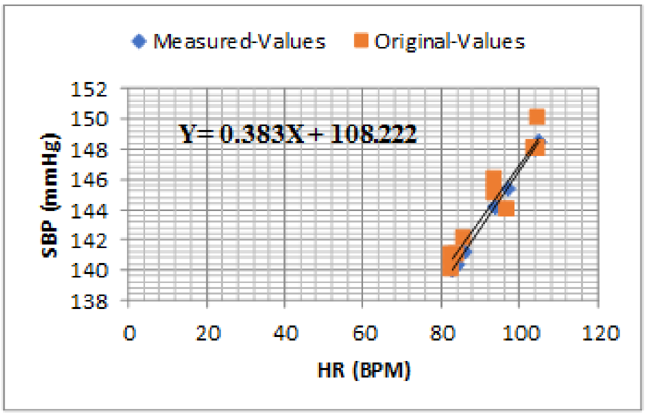

Fig. 4 Original SBP and SBP measured through proposed model (Category 1)

V.RESULT ANALYSIS

Table 4 shows the comparative study between the original SBP measured by sphygmomanometer and SBP measured by the proposed model for category 1 (High SBP). According to the status provided in Table 3, the results of Table 4 prove the effectiveness of the proposed model. Fig. 4 graphically validates the accuracy of the designed system via showing linear regression line for both original and measured SBP values.

Both, Table 5 and Table 6 also shows SBP data measured by sphygmomanometer and the proposed model for category 2 (Pre-High SBP) and category 3 (Normal SBP), respectively. In these two cases, all the extracted data shows the effectiveness of the proposed SBP measurement technique

except few inaccuracies (higher than 2) highlights in the tables. Fig. 5 and Fig. 6 also show the linear regression line for both original SBP value and measured SBP via proposed model for category 2 and category 3, respectively.

Table 5. SBP Data for Category 2 in Our Method

HR (BPM)	Original SBP (mmHg)	SBP via proposed model (mmHg)	Difference (mmHg)
73	122	123.8703	1.8703
57	122	120.0127	1.9873
104	**134**	**131.3444**	**2.6556**
105	133	131.5855	1.4145
94	128	128.9334	0.9334
73	123	123.8703	0.8703
94	127	128.9334	1.9334
67	121	122.4237	1.4237
70	123	123.147	0.147
70	124	123.147	0.853

Table 6. SBP Data for Category 3 in Our Method

HR (BPM)	Original SBP (mmHg)	SBP via proposed model (mmHg)	Difference (mmHg)
67	116	114.7094	1.2906
58	111	112.4765	1.4765
61	113	113.2208	0.2208
77	119	117.1904	1.8096
88	118	119.9195	1.9195
79	117	117.6866	0.6866
81	118	118.1828	0.1828
60	114	112.9727	1.0273
74	118	116.4461	1.5539
84	**116**	**118.9271**	**2.9271**

From the above Fig. 4, Fig. 5 and Fig. 6, it is observed that, both the measured blood pressure using the sphygmomanometer and the designed system are approximately same with some little discontinuity. Table 7 shows the accuracy percentage for each proposed category.

Table 7. Accuracy Table for Proposed Category

Category	Accuracy (%)	Inaccuracy (%)
Category 1	100%	0
Category 2	90%	10%
Category 3	90%	10%

TABLE 8. Regression Model for [3]

Subject	Regression Model
Subject 1	Y= -0.41482X + 256.15
Subject 2	Y= -0.41482X + 159.15
Subject 3	Y= -0.41482X + 233.58

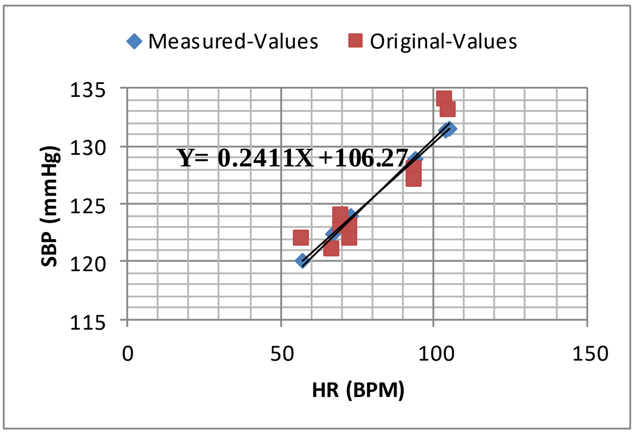

Fig. 5 Original SBP and SBP measured through proposed model (Category 2)

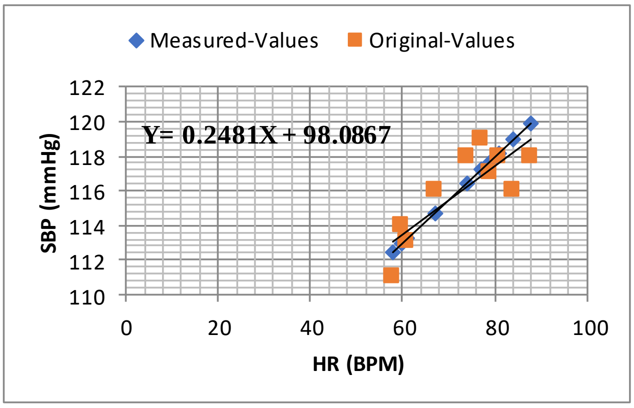

Fig. 6 Original SBP and SBP measured through proposed model (Category 3)

VI. RESULT COMPARISON & DISCUSSION

In this section, the proposed method is compared with the technique describe in [3] to testify the accuracy of the designed system. Table 8 presents the regression model described in [3] for three different subjects. Table 9 shows the comparison between the proposed regression model and the model described in [3]. Here, the subject 1 data from [3] for the equation Y= -0.41482X + 256.15, is used. On the same data line, the proposed category 2 equation Y= 0.2411X +106.27, is applied. As observed, the difference between the original SBP and the calculated SBP through the proposed model is less as compare to the difference found via model in [3]. Similarly, subject 2 data for the equation Y= -0.41482X + 159.15 from [3] is compared with the data category 1 of the proposed model with equation Y= 0.383X + 108.222, shows in Table 10. The result shows the much more improvement in the differences on SBP values compare to the model given in [3].

Table 11 shows the percentage accuracy of the two methods in terms of measuring the SBP. As shown, the proposed regression model based SBP monitoring system provides 80% of very accurate result compared to the 35% provided by the method in [3].

Table 9. Data Comparison Between The Proposed Method and [3] Subject 1

HR (BPM)	Original SBP (mmHg)	SBP in [3] (mmHg)	SBP via proposed model (mmHg)	Difference with [3] (mmHg)	Difference with proposed model (mmHg)
66.96492	121	121	122.4152	0	1.415242
73.08161	122	124.4821	123.89	2.4821	1.889976
69.93007	123	122.6882	123.1301	0.3118	0.13014
58.82353	**123**	**116.3662**	**120.4524**	**6.6338**	**2.547647**
105.6338	132	143.0113	131.7383	11.0113	0.261691
105.6338	132	143.0113	131.7383	11.0113	0.261691
94.78673	128	136.837	129.1231	8.837	1.123081
94.78673	**127**	**136.837**	**129.1231**	**9.837**	**2.123081**
73.3126	123	124.4821	123.9457	1.4821	0.945668
70.42254	124	122.9685	123.2489	1.0315	0.751126

TABLE 10. Data Comparison Between Our Method and [3] Subject 2

HR (BPM)	Original SBP (mmHg)	SBP in [3] (mmHg)	SBP via proposed model (mmHg)	Difference with [3] (mmHg)	Difference with proposed model (mmHg)
76.92308	128	128	129.6835	0	1.68354
75.94937	**127**	**127.4457**	**129.3106**	**0.4457**	**2.310609**
73.17073	128	125.8641	128.2464	2.1359	0.24639
74.07407	128	126.3783	128.5924	1.6217	0.592369
107.5269	150	145.4202	149.4048	4.5798	0.595197
105.4482	150	144.2369	148.6087	5.7631	1.391339
90.63444	**146**	**135.8047**	**142.935**	**10.1953**	**3.065009**
94.93671	146	138.2536	144.5828	7.7464	1.41724
86.95652	142	133.7112	141.5263	8.2888	0.473653
85.59201	142	132.9345	141.0037	9.0655	0.99626

TABLE 11. Accuracy Table for [3] and Our Method

Accuracy	Hassan et al. [3]	Our Method
Very Accurate	35%	80%
Slightly Inaccurate	10%	20%
Moderately Inaccurate	10%	0
Very Inaccurate	45%	0

VII. CONCLUSION

In this paper, a novel method for systolic blood pressure measure from heart rate via IoT has been proposed. The experimental analysis was conducted for 30 datasets into 3 categories, and the proposed regression model provides nearly acceptable result with good accuracy. Also, a comparison study with another existence model validates the effectiveness of the proposed low-cost design. In future, the accuracy of the SBP monitoring system can be further improved with the inclusion of other parameter related to human body e.g. skin moisture, body temperature etc.

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