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A Novel Framework of Health Monitoring Systems

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ABSTRACT

IoT plays an important role in the healthcare domain for improving the quality of patient care. To analyze the patients' healthcare data, a real-time health-monitoring system is required. The proposed framework in this work is cable of such monitoring and sending alerts on critical circumstances. In this framework, the use of IoT devices makes it possible. This is very helpful in taking care of especially old wards and children in the absence or their caretakers. The function of alerting the caretakers and to inform hospital in critical condition makes this system one of its kind. Readings of patient pulse rates are taken from the pulse rate sensor and the body temperature is measured by MAX30205, a temperature sensor. The data is collected through sensors and sent over the cloud servers. Linear regression is used for further analysis and prediction of pulse and temperature trend lines. Corresponding health repots will be sent to the nearby hospitals and registered mobile numbers. The framework is validated with real-time patient data, and prediction is made regarding the trends.

KEYWORDS

Cloud System, Diagnosis, Health Monitoring, Internet of Things, Machine Learning

1. INTRODUCTION

Healthcare is an important domain and there is a need for it to be updated with the recent and upcoming technology. Internet of Things or IoT has been developed by an amalgamation of Radio Frequency Identification (RFID)] and Wireless Sensor Network (WSN) technologies and an advanced integration with cloud computing. Thus it enables customers over the internet to communicate with the data, collect, store and interchange it. With the help of the IOT system one can track patient's health conditions and collect it on cloud.

This IoT based project intends to serve the patients as well as to aid the doctors with their diagnosis, thereby saving time. Since the system will be powered by commands and will capture the patient's data by using medical sensors, it makes the patient's data accessible to the doctor for review thereby reducing the doctor's labour time by about 15 hours. Moreover it helps reducing emergency room wait time because patient's medical history will be available to the doctor in prior for review.

It makes use of technologies like Machine Learning which uses diagnostic algorithms to derive some major conclusions about a patient's health from the data provided like pulse rate and body temperature. Cloud Computing is a technology used to store large amount of data over the internet. In this project, it is used to store the patient's diagnostic data into a large database. The readings from pulse rate sensor or temperature sensor are all put up on a cloud and made available to doctor,

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patient or can be provided to machine learning algorithms to perform diagnosis. With IOT, doctors and other medical associates may be able to know about the status of patient, and can save it on their database for further accessing and analysis.

2. STATE OF ART

In this era of Technology Internet of Things or popularly also known as IoT along with Cloud Computing play a very important role in monitoring the health condition of a person using various kinds of data collected using body sensors fitted in different types of wearable devices. It mainly uses Raspberry Pi board for this purpose. The collected data is processed using various machine learning algorithms and hence processed data is used to detect diseases and preventions that need to be taken. This data is then sent to the patients as well as concerned people and doctors to take recommended actions for precautionary purposes. As this data is kept on the cloud it can also be accessed anywhere and anytime around the world. It is very suitable in areas where medical facilities are not easily available, areas like villages or rough terrains. Body wireless sensor Network (BWSN) is used to transmit the patients' health parameters collected through Raspberry Pi microcontroller to the physicians and caretaker wirelessly. As we know that these devices are long ranged due to high bandwidths it is really easy and efficient to detect the patient's location in case of any emergency and timely intervention of responsible people, the server also rings alarm to nearby ambulance while itself performing various basic health care check-ups by continuously monitoring various body parameters and reporting the respective data. Use of smart devices increases the data accuracy and data protection on various parameters. The historical data uploaded on the cloud can also be used to perform various tests and at times infer data from family history's data or the health history of the patient himself.

Universal Health care concern and its solution has become crucial nowadays as it is necessary to pay attention to awareness on Healthcare. Mobile devices are available to us nowadays very easily. These devices help to collect data from the wearables and analyse it under a wireless sensor network. This reduces complications regarding location problems etc. We can also make use of Barcode Reader to verify and aid our patients.

With the increased advancement of the sensors and wearables, it makes the health control and management system more powerful in remote areas. Now this needs to be secure. Our system designs are planted upon the WSN which is Wireless Sensor Networks. These systems have reduced the cost as the doctors can analyse the patient's health without actually visiting them for small health issues by collecting his data and sending the instructions to get cured.

An android app has been created for healthcare authority called ECG App, which provides the client with the Electro Cardiogram Waves and his/her data. This data gets uploaded to the cloud of the client which can be further analysed by the patients and doctors. This system is helpful for all whether they are at the hospital or at their home.

Gomez et al. (2016) showed that the Universal Health care concern and its solution has become crucial nowadays as it is necessary to pay attention to awareness on Healthcare. Mobile devices are available to us nowadays very easily. These devices help to collect data from the wearables and analyse it under a wireless sensor network. This reduces complications regarding location problems etc. We can also make use of Barcode Reader to verify and aid our patients.

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the client which can be further analysed by the patients and doctors. This system is helpful for all whether they are at the hospital or at their home.

Jorge Gomez et al. (2016) on the basis of evidence and symptoms of the patients, made analysis. By continuously monitoring the issues and the characteristics of the patient, and also of the improvement of the system, Franca told that these fruits of the innovations of the new generation devices and systems. He also focused on the use of wireless technologies which would help in increasing productivity. Tartarisco et al. (2012) inferred that lack of proper treatment on time, can lead to serious issues and sometimes death of the patients, that's why a health monitoring system with proper solutions of the problem is a need. Sivakanth et al. (2016) proposed the idea of collecting data based on various geographic locations. The data will be sent to the doctors nearby the patient's location and treatment could be done. Pustiek et al. (2015) showed that, IOT techniques which may be helpful in improving and to support healthcare. Data in heterogeneous formats will be helpful in creating real time applications. He also suggested that the patient should be made alert based on their fitness, past treatment and also heredity related issues.

Franca Delmastro et al. (2012) stated that the data transmitted in the monitoring systems by the wearables and sensors, needs to be in heterogeneous formats so that the user can access the data in the desired form and which in turn can be useful in building real time applications and time to time update is also necessary in the user's application. Nichal et al. (2015) discussed the important information of the software for healthcare and gave an suitable prototype for healthcare and IOT. He has taken the parameters like ECG, oxygen amount in blood, respiration, temperature etc. As there remains a lot many achievements and pros to this invention there are a very few factors that make this device a bit challenging. First being it's compulsory to have a running internet connection to efficiently run this device. Second challenge is the accuracy and validity of the data collected which can at very bleak chances can go wrong due to machine error or young training of the model at the start of this setup. Third could be the need for continuous wearing of this device for proper assessing of data and good amount of data to be collected for more accurate processing of the information.

But all in all these challenges have very less importance in front of the effectiveness, ease and feasibility that is offered by the device making the health care system more efficient and reachable by all people in the society.

New challenges and requirements need to be handled in the view to make the IoT future. Many challenges like the internet connectivity, the proper allowed distance between the sensors and the body parts etc. need to be focused upon. The system must be secure enough to handle absurd situations.

3. PREREQUISITE KNOWLEDGE

3.1 Linear Regression

Linear Regression, a well known supervised machine learning algorithm which has its slope constant and the predicted output continuous. This algorithm does not classify the values into categories but predict values within a specified continuous range. It works to find the relationship between dependent variables and set of independent variables. This means that when a set of one or more independent variables(x) changes, the values for dependent variables(y) may also be affected accordingly. There is a linear relationship between the independent(x) and dependent(y) variable. The red line in the graph is the best fit straight line. There are two main types:

- **Simple Regression:** Simple linear regression uses traditional slope-intercept form, where m and c are the variables, the algorithm will try to learn, x is the input data to be fed and y is the prediction:

$y = mx + c$

where:

y=a function of x
m=gradient, angle of the line to x-axis
c=is intercept on y-axis

- **Multivariable Regression:** A more complex, multi-variable linear equation might look like this, where w represents the coefficients, or weights, our model will try to learn:

f(x,y,z)=w1x+w2y+w3z

The variables x,y,zx,y,z represent the attributes, or distinct pieces of information, we have about each observation.

The formulas related to linear regression are as follows:

Slope $b = \sum(Y_i - \bar{Y})(X_i - \bar{X}) / \sum(X_i - \bar{X})^2$
Variance $\sigma^2 / \sum(X_i - \bar{X})^2$
Intercept $a = \bar{Y} - b\bar{X}$
Variance of a $[\frac{1}{n} + \frac{X^2}{\sum\left(Xi - \bar{X}\right)^2}]\sigma^2$
Estimated mean at X_0 $a + bX_0$
Variance $[\frac{1}{n} + \frac{\left(X0 - \bar{X}\right)^2}{\sum\left(Xi - \bar{X}\right)^2}]\sigma^2$
Estimated individual at X_0 $a + bX_0$
Variance $[1 + \frac{1}{n} + \frac{\left(X0 - \bar{X}\right)^2}{\sum\left(Xi - \bar{X}\right)^2}]\sigma^2$
Total SS $= \sum(Y_i - \bar{Y})^2$
Regression SS $= [\sum(Y_i - \bar{Y})(X_i - \bar{X})]^2 / \sum(X_i - \bar{X})^2$
Error SS = Total SS – Regression SS
R^2 = Regression SS / Total SS = "proportion explained"
MSE = error mean square = estimate of σ^2 = Error SS/df
df = degree of freedom = n-2 for sample linear

4. PROPOSED FRAMEWORK

The project focuses to resolve one of the pressing problem we face in the health care system that is of diagnosis and critical time management. It uses a healthcare system developed around the latest technology of IoT. The proposed framework is mentioned in Figure 1.

Readings of patient's pulse rate are taken from the pulse rate sensor and the body temperature is measured by MAX30205, a temperature sensor. Temperature sensor and pulse rate sensor are external devices used to measure the patient's details. These send out the data to NodeMCU. NodeMCU is an open source LUA based firmware developed for ESP8266 wifi chip. It is an open source platform which means that its hardware is open for editing, modifying and building. NodeMCU Development board is featured with wifi capability, analog pin, digital pins and serial communication protocols. This healthcare device is connected to an IoT cloud server. The data stored in the cloud server can be reused in the future for reference and analysis as well. A summary report of the patient will be sent to the registered email id. Alerts in the critical conditions will be sent to the registered phone numbers.

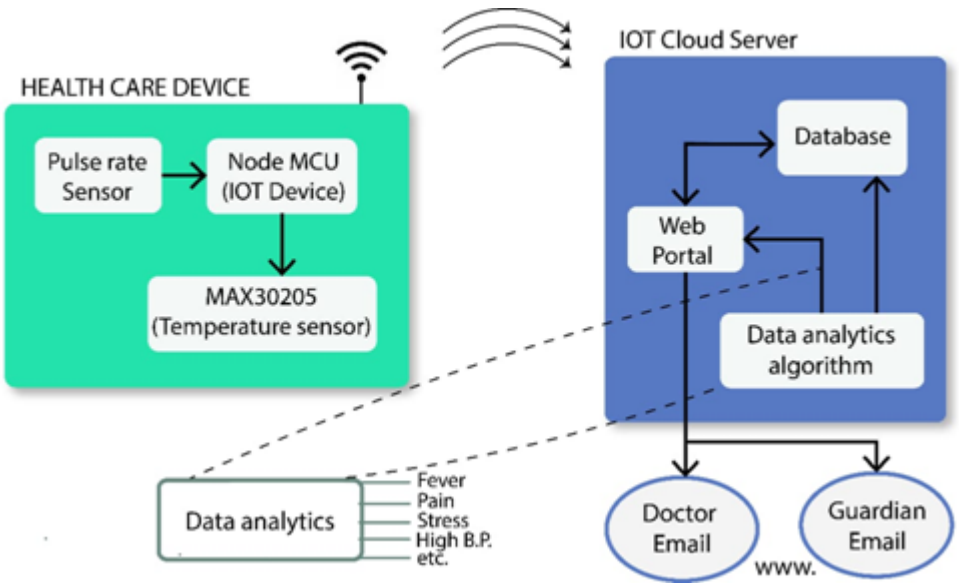
The results received by NodeMCU are then analysed using some strict and unique algorithms. Linear Regression is used to determine the trend line. The trend of the patients pulse rate and temperature is used to generate reports for the user and doctor. They reduce the labour work and time of doctors as well as hospital management. The IoT cloud server has a database in connection with a web portal. With unique data analytics algorithm which is capable of diagnosing ailments from the statistical data provided to them through the external healthcare device system. The web portal gathers all the data, stores stored at same place and is responsible for generating and sending out a copy of the report through email to the doctor as well as the guardian/patient.

5. RESULT

The pulse and the temperature data values as recorded by the IOT system is tabulated in Table 1. Figure 2 and 3 plots its corresponding pulse and temperature graphs. The predicted trends of pulse and temperature values are tabulated in Table 2 and 4 respectively. Table 3 and Table 5 states the statistical values of Linear Regression on Pulse and Temperature data values. Figure 4 and 5 are the prediction trends of pulse and temperature respectively. Figure 6 is the sample diagnosis report of the patient which will be available on his/her login. This report can be mailed to the doctor as well so that during emergency the basic tests of the patient need not to be done again and again.

The following observations are made:

Figure 1. The framework



- As time interval and Pulse/Temperatur data points are independent, we should not be predicting the pulse/temperature values based on time intervals;
- As data points are independent, we should not be driven any reference point of Sign. F/P-values based on time interval, as the statistical outcomes are not up to the mark to describe it as a good model;
- We are using linear regression to see the trend of data to get the tentative idea of the trend of values along with the time interval;
- It is looking similar to moving average of data values, where the trend can be plotted based on initial benchmarks, like based on initial 5 timelines, subsequent data trendline can plot similar to the linear regression trend line.

6. THREATS TO VALIDITY

In this paper, the treats to validity is discussed under the following threats:

- Threats to internal and external validity
- Threats to reliability validity
- Threats to conclusion validity

The experimental errors are considered under the treats to internal validity. There might be some unnoticed errors although the datasets and the experiment have been examined carefully. The machine learning includes many algorithms. We have used Linear Regression in our experiment. The usage of limited classifier for prediction and modeling can affect the internal validity. The external validity generates due to generalization of the results. On consideration of more datasets from different sources and patients may reduce the threat of external validity.

The stated work has the probability of replication thereby causing the threat to reliability validity.

The threat to conclusion validity is that we have analysed our outcomes of the experiment on the basis of trend line plotted using Linear Regression The proposed model can be also compared with the other baseline framework in the state of art of CPDP.

7. CONCLUSION

Healthcare is an important domain and there is a need for it to be updated with the recent and upcoming technology. The IOT based health monitoring system is an emerging service in the healthcare domain. It has the potential to bring revolution in the healthcare and medical industry. It improves the availability of the patients healthcare data. Continuous monitoring and real time analysis for tracking the patients health is made easy through IOT and Machine Learning.

This is very helpful in taking care of especially old wards and children in the absence or their caretakers. Health Data management of patient at cloud server can make it paperless, which is the need of the hour. Its added advantage is that it will reduce hospital's management cost with the help of an IOT based mobile app and we can expect this to reduce the patient's treatment charges making healthcare sector affordable to many.

Moreover it helps reducing emergency room wait time because patient's medical history will be available to the doctor in prior for review.

Future work will involve implementation of GPS sensor on the framework so that the current location of the patient can be tracked. Immediate actions can be taken in catastrophic conditions. Moreover, usage of the GPS sensor will enable to locate the nearby hospitals. This in turn will assist in critical and emergency situations.

Table 1. Pulse and temperature data values

Interval	Pulse	Temp	Interval	Pulse	Temp
1	73	36	30	75	33
2	78	37	31	87	32
3	74	32	32	90	30
4	63	36	33	86	32
5	69	30	34	85	40
6	77	37	35	70	35
7	66	31	36	72	30
8	72	36	37	78	35
9	85	37	38	69	34
10	65	35	39	66	37
11	84	34	40	82	32
12	66	37	41	66	38
13	72	37	42	60	34
14	75	37	43	86	40
15	67	40	44	61	38
16	89	38	45	74	36
17	73	37	46	85	40
18	80	32	47	60	37
19	88	30	48	81	38
20	90	36	49	90	36
21	90	37	50	83	31
22	61	32	51	80	34
23	87	36	52	85	32
24	61	40	53	62	34
25	62	39	54	77	39
26	77	40	55	82	39
27	64	31			
28	64	30			
29	88	31			

ACKNOWLEDGMENT

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Figure 2. Graphical plot of the pulse data values

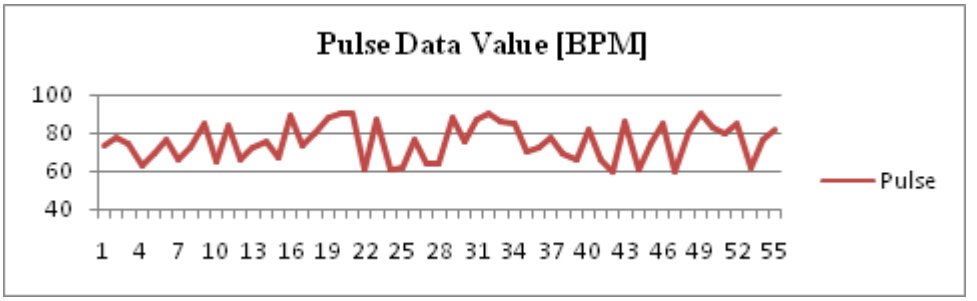


Figure 3. Graphical plot of the body temperature data values

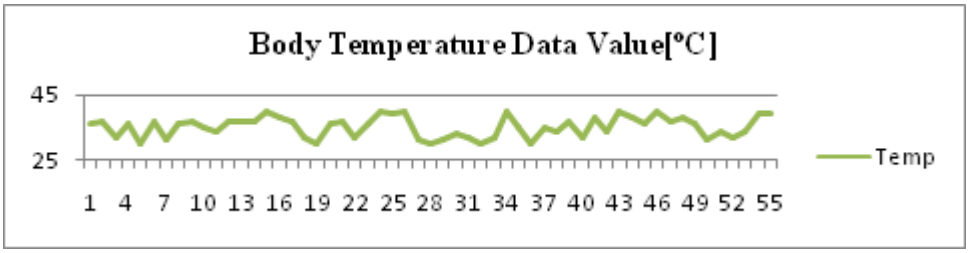


Table 2. Predicted trends of the pulse data values

Interval	Pulse	Predicated Trends	Interval	Pulse	Predicated Trends
1	73	73.8525974	31	87	75.67294372
2	78	73.91327561	32	90	75.73362193
3	74	73.97395382	33	86	75.79430014
4	63	74.03463203	34	85	75.85497835
5	69	74.09531025	35	70	75.91565657
6	77	74.15598846	36	72	75.97633478
7	66	74.21666667	37	78	76.03701299
8	72	74.27734488	38	69	76.0976912
9	85	74.33802309	39	66	76.15836941
10	65	74.3987013	40	82	76.21904762
11	84	74.45937951	41	66	76.27972583
12	66	74.52005772	42	60	76.34040404
13	72	74.58073593	43	86	76.40108225
14	75	74.64141414	44	61	76.46176046
15	67	74.70209235	45	74	76.52243867
16	89	74.76277056	46	85	76.58311688
17	73	74.82344877	47	60	76.64379509
18	80	74.88412698	48	81	76.7044733
19	88	74.94480519	49	90	76.76515152
20	90	75.00548341	50	83	76.82582973
21	90	75.06616162	51	80	76.88650794
22	61	75.12683983	52	85	76.94718615
23	87	75.18751804	53	62	77.00786436
24	61	75.24819625	54	77	77.06854257
25	62	75.30887446	55	82	77.12922078
26	77	75.36955267	56	84	77.18989899
27	64	75.43023088	57	82	77.2505772
28	64	75.49090909	58	86	77.31125541
29	88	75.5515873	59	85	77.37193362
30	75	75.61226551	60	85	77.43261183

Table 3. Statistical values of linear regression on pulse data

Regression Statistics								
Multiple R	0.100091							
R Square	0.010018							
Adjusted R Square	-0.00866							
Standard Error	9.754259							
Observations	55							
ANOVA								
	df	**SS**	**MS**	**F**	**Significance F**			
Regression	1	51.03038	51.03038	0.53634	0.467179944			
Residual	53	5042.715	95.14557					
Total	54	5093.745						
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	73.79192	2.666813	27.67045	3.53E-33	68.44297	79.14087	68.44297	79.14086843
X Variable 1	0.060678	0.082854	0.732352	0.46718	-0.10551	0.226862	-0.10551	0.226861978

Figure 4. Pulse data values prediction trends

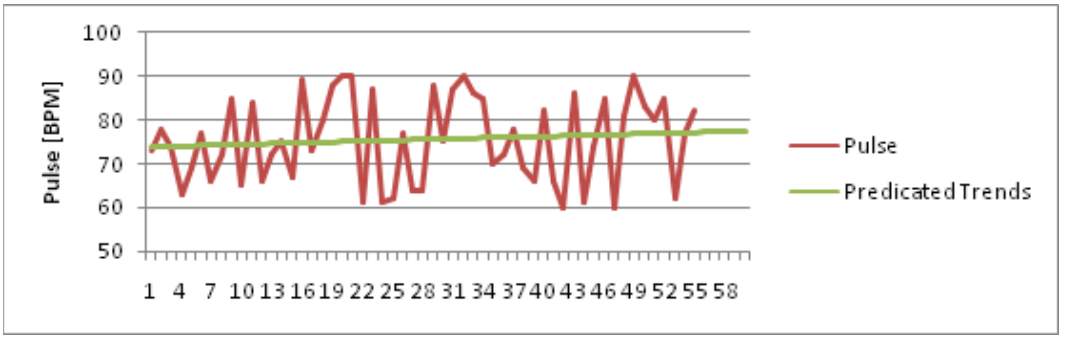


Table 4. Predicted trends of the temperature data values

Interval	Temp	Predicated Temp	Interval	Temp	Predicated Temp
1	36	34.84220779	31	32	35.25996
2	37	34.85613276	32	30	35.27388
3	32	34.87005772	33	32	35.28781
4	36	34.88398268	34	40	35.30173
5	30	34.89790765	35	35	35.31566
6	37	34.91183261	36	30	35.32958
7	31	34.92575758	37	35	35.34351
8	36	34.93968254	38	34	35.35743
9	37	34.9536075	39	37	35.37136
10	35	34.96753247	40	32	35.38528
11	34	34.98145743	41	38	35.39921
12	37	34.9953824	42	34	35.41313
13	37	35.00930736	43	40	35.42706
14	37	35.02323232	44	38	35.44098
15	40	35.03715729	45	36	35.45491
16	38	35.05108225	46	40	35.46883
17	37	35.06500722	47	37	35.48276
18	32	35.07893218	48	38	35.49668
19	30	35.09285714	49	36	35.51061
20	36	35.10678211	50	31	35.52453
21	37	35.12070707	51	34	35.53846
22	32	35.13463203	52	32	35.55238
23	36	35.148557	53	34	35.56631
24	40	35.16248196	54	39	35.58023
25	39	35.17640693	55	39	35.59416
26	40	35.19033189	56		35.60808
27	31	35.20425685	57		35.62201
28	30	35.21818182	58		35.63593
29	31	35.23210678	59		35.64986
30	33	35.24603175	60		35.66378

Figure 5. Temperature data values prediction trends

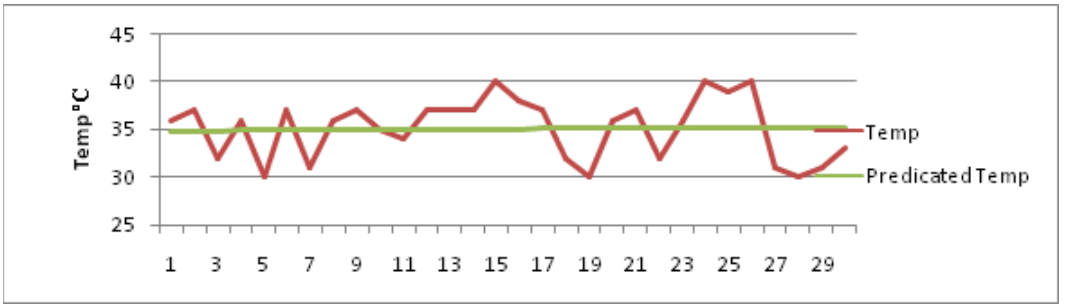
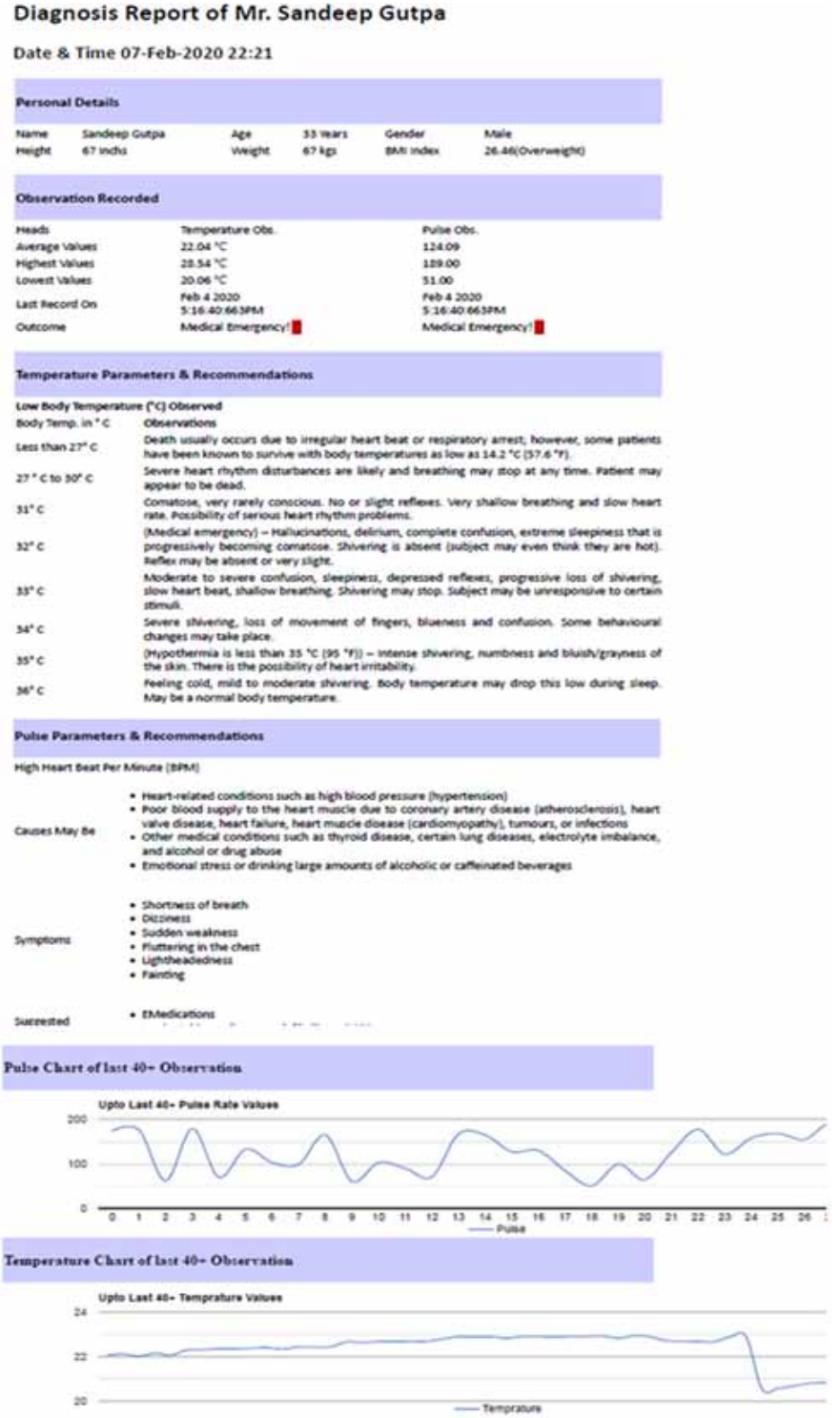


Table 5. Statistical values of linear regression on temperature data

Regression Statistics								
Multiple R	0.070587							
R Square	0.004983							
Adjusted R Square	-0.01379							
Standard Error	3.182186							
Observations	55							
ANOVA								
	df	**SS**	**MS**	**F**	**Significance F**			
Regression	1	2.687518	2.687518	0.2654	0.608577			
Residual	53	536.6943	10.12631					
Total	54	539.3818						
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept	34.82828	0.870009	40.03209	2.73E-41	33.08327	36.5733	33.08327	36.5733
X Variable 1	0.013925	0.02703	0.515169	0.608577	-0.04029	0.06814	-0.04029	0.06814

Figure 6. Sample diagnosis report



Diagnosis Report of Mr. Sandeep Gutpa

Date & Time 07-Feb-2020 22:21

Personal Details

Name	Sandeep Gutpa	Age	33 Years	Gender	Male
Height	67 inchs	Weight	67 kgs	BMI Index	26.46(Overweight)

Observation Recorded

Heads	Temperature Obs.	Pulse Obs.
Average Values	22.04 °C	124.09
Highest Values	28.54 °C	189.00
Lowest Values	20.06 °C	51.00
Last Record On	Feb 4 2020 5:16:40.663PM	Feb 4 2020 5:16:40.663PM
Outcome	Medical Emergency!	Medical Emergency!

Temperature Parameters & Recommendations

Low Body Temperature (°C) Observed

Body Temp. in ° C	Observations
Less than 27° C	Death usually occurs due to irregular heart beat or respiratory arrest, however, some patients have been known to survive with body temperatures as low as 14.2 °C (57.6 °F).
27 ° C to 30° C	Severe heart rhythm disturbances are likely and breathing may stop at any time. Patient may appear to be dead.
31° C	Comatose, very rarely conscious. No or slight reflexes. Very shallow breathing and slow heart rate. Possibility of serious heart rhythm problems.
32° C	(Medical emergency) – Hallucinations, delirium, complete confusion, extreme sleepiness that is progressively becoming comatose. Shivering is absent (subject may even think they are hot). Reflex may be absent or very slight.
33° C	Moderate to severe confusion, sleepiness, depressed reflexes, progressive loss of shivering, slow heart beat, shallow breathing. Shivering may stop. Subject may be unresponsive to certain stimuli.
34° C	Severe shivering, loss of movement of fingers, blueness and confusion. Some behavioural changes may take place.
35° C	(Hypothermia is less than 35 °C (95 °F)) – Intense shivering, numbness and bluish/grayness of the skin. There is the possibility of heart irritability.
36° C	Feeling cold, mild to moderate shivering. Body temperature may drop this low during sleep. May be a normal body temperature.

Pulse Parameters & Recommendations

High Heart Beat Per Minute (BPM)

Causes May Be	• Heart-related conditions such as high blood pressure (hypertension) • Poor blood supply to the heart muscle due to coronary artery disease (atherosclerosis), heart valve disease, heart failure, heart muscle disease (cardiomyopathy), tumours, or infections • Other medical conditions such as thyroid disease, certain lung diseases, electrolyte imbalance, and alcohol or drug abuse • Emotional stress or drinking large amounts of alcoholic or caffeinated beverages
Symptoms	• Shortness of breath • Dizziness • Sudden weakness • Fluttering in the chest • Lightheadedness • Fainting
Suggested	• EMedications

Pulse Chart of last 40+ Observation

Temperature Chart of last 40+ Observation

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