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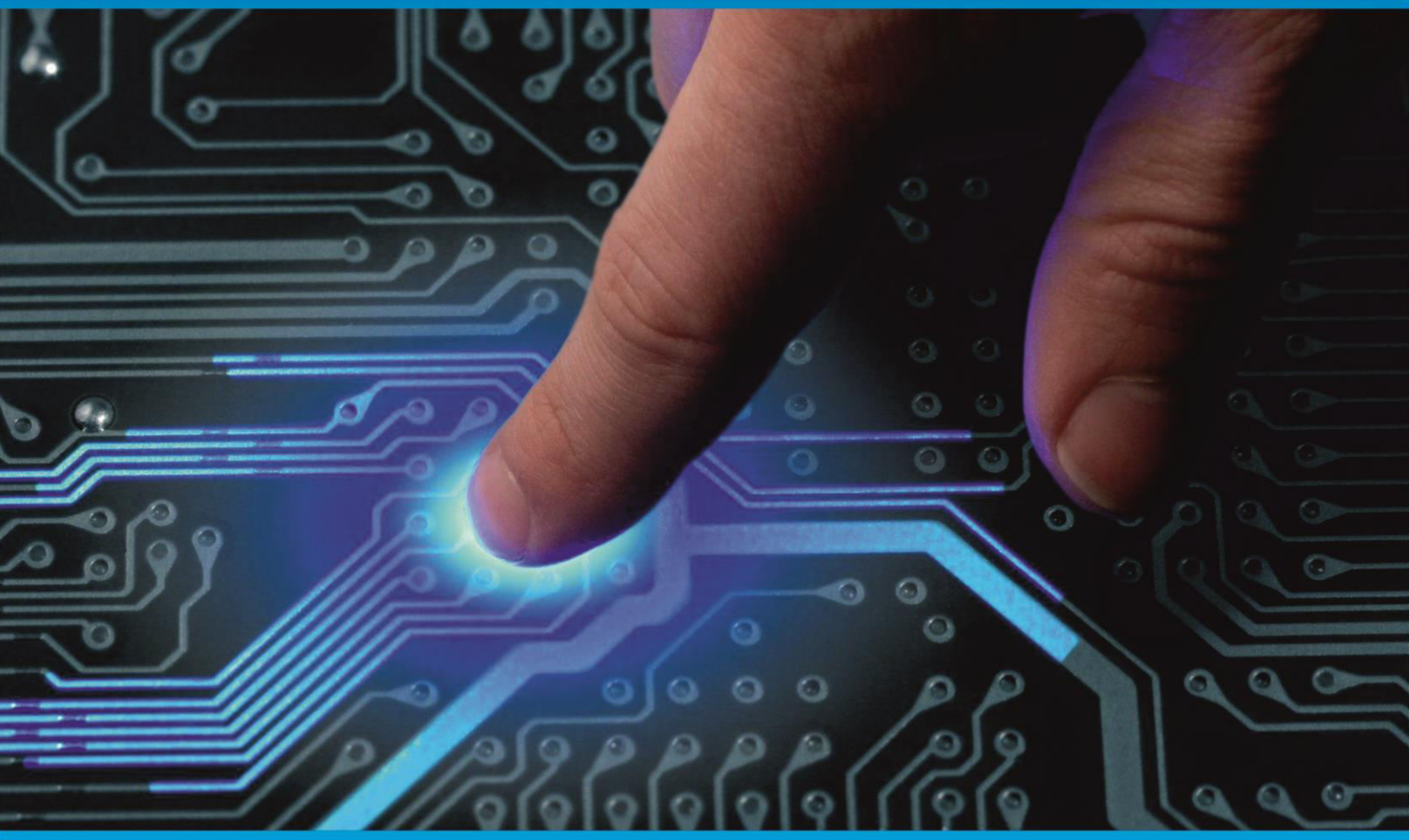

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Machine Learning Empowered PPG Based Blood Pressure Prediction System

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ABSTRACT: The dynamic world is running after technologies which are far beyond for human to imagine. As a result of this hectic environment, people are supposed to suffer from stress, anxiety and many more health problem. Stress plays an important role in all human beings. All this lead to Hypertension which is a prevalent chronic disorder. For most hypertensive cases there will not be any signs or warnings in the body. It may contribute to severe health issues and can often lead to loss of life. Early detection and prediction of blood pressure is a boon to those patients who suffer from hypertension. Hence a Machine learning empowered, PPG based blood pressure prediction system is proposed. The proposed method uses the PPG technique to obtain pressure values from the fingertip. The microcontroller converts the signal to pressure values and machine learning algorithm predicts the future values. The pres sure values are calculated from an embedded device and these values are used to construct a database which is then served to machine learning algorithm. The ideal approach is to monitor the pressure values and to predict its future variation and get rid of the downsides of traditional methods, as well as reinforce the bright sides that are functionally needed for the treatment. More clearly, on one hand, to make up for the shortage of therapists which may indirectly compromise the eventual efficacy to the patients. On the other hand, to offer them individually self-usable device that is technically substantial for a blood pressure treatment.

KEYWORDS: Blood Pressure, Hypertension, Machine Learning Prediction.

I. INTRODUCTION

Each organ in our body requires oxygen for proper working. Oxygen is delivered by arteries as the blood flows through each and every portion of the body. Factors like smoking, caffeine, discomfort, extra fat in the diet will render the artery wall thinner. As a result, the blood cannot circulate through the vital tissue and thereby organs of the body can't function properly. All these factors leads to increase blood pressure inside the arteries. This situation may cause a cardiac attack, coronary artery disease, chronic kidney disease, loss of hearing, etc. Blood pressure is a direct indicator of Hypertension which is prevalent chronic disease. It is also referred as "Silent Killer" in medical field. It is estimated that one billion among the world population is seriously affected by Hypertension. This number would rise by the year 2025. Hypertension impacts mainly the aged and often residents in rural areas who are ignorant of it. Although instruments such as the blood pressure cuff enable them to monitor their blood pressure regularly. This would provide a lengthier and safer lifestyles.

Now a days people are more conscious about their health condition. Routine check-ups and clinical trials have become a habit for many people. Living a healthy lifestyle is the only solution to avoid any sever e health problem. But the truth is that, the food we consume also contribute to many health problems since the adulteration content is very high. Even though we cannot stop these consequences but can prevent them by taking successive measures. Data science has emerged as a new technology that became an inevitable part of everyone's life. The world has been changing and much more predictive for human by data analysis. From the stock market to weather forecasting, the prediction plays an important role. Hence this same mechanism can be also adopted in medical science. If the changing nature of vital parameters in the body can be predicted in advance, it will be boon to those patients who are suffering from severe health issues.

The novelty in this work is the combination of Photoplethysmography and Machine learning. Here machine learning technique is used to pre-predict a future health parameter. There are several self-monitoring devices are hitting the market, such as Apple watch, smart watches etc. which can track heart rate , blood pressure, etc. But these devices lacks the ability to pre predict the future health status. High blood pressure fluctuations are unstable for those who are at critical conditions and others who have recovered from strokes. For them, continuous monitoring of blood pressure is necessary for proper diagnosis. If the future health condition of a person is known prior, then proper health

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measurements can be taken in order to tackle them. This work focuses on the prediction of only two parameters that is blood pressure and heart pulse variations. All the health parameters can be analysed in this way which is an innovative feature that can be added into the medical stream.

For the standard measurement of blood pressure two techniques are used, they are the auscultatory method and oscillometric method [2]. This paper deals with a method that uses the PPG technique to monitor the blood pressure apart from other techniques. Hence a non-invasive, low-cost blood pressure monitoring and prediction system can be developed. For the prediction of future blood pressure value, machine learning plays an important role. The best algorithm is also proposed based on their performance analysis. This device is very simple and can be used by any person without any assistance. The obtained pressure values are collected and a database is created. The database is given to a machine learning algorithm which predicts the future blood pressure values. The main advantage is that it's not a static measurement system but provides continuous pressure values. Hence we can accurately predict future pressure values. If the future health condition of a person can be predicted like this way, early disease prediction and prevention is possible [3].

Fig1. Blood Pressure monitoring

II. RELATED WORK

Nath, et.al, [4] proposed a novel blood pressure classification model using Phototplethysmogram (PPG).The proposed model uses algorithms for signal processing and machine learning to classify blood pressure into four phases: normal, elevated, phase 1 and stage 2. A total of 83 features have been derived from the PPG signal including 71 statistical features and 12 characteristics. Here random forest classifier is used to train and test the predictive model. The suggested approach is tested with 20 different individuals on the publicly available MIMIC website. The software includes raw PPG data for various users and Arterial Blood Pressure (ABP) to measure the systolic and diastolic blood pressure for testing and evaluation purposes to be used as the ground truth. Here an overall accuracy of 90.8 percent over the four classes of blood pressure levels was obtained. The results indicate that the proposed model will be ideal for integration into a non-invasive blood pressure monitoring system with significant accuracy.

Kao, et.al [5] proposed a new portable PPG-BP device designed for continuously measuring blood pressure (BP) without a cuff. This continuous and long-time BP monitoring enabled herein by the portable cuffless BP sensor. Towards the aforementioned goal, the sensor is designed capable of detecting in real-time, non-invasively and continuously the temporal intravascular blood volume change based on the principle of a photoplethysmograph (PPG) for estimating BP. The hardware of the sensor consists mainly of light emitting diodes (LEDs) in wavelengths of 660 nm, a photodetector (PD), and also signal processing chips to read output signals of the PD. The PD readout circuit includes a PD pre-amplifier, a band-pass filter, a programmable gain amplifier (PGA), a microcontroller unit for calculation and a wireless module for communication. A laptop is also used for a continuous view of BPs and mathematical review and test tests. 27 participants engaged in the experimental testing, in which the BPs collected was measured by OMRON's consumer blood pressure monitor and then compared. The resultant signal-to-noise ratio (SNR) is capable of rising more than 15 percentage, correlation coefficient, R2, for systolic blood pressure (SBP) and diastolic blood pressure (DBP) are 0.89 and0.98, respectively.

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Ghosh, Shrimanti, et al [6] proposed a non-invasive method for continuous blood pressure monitoring. Pulse transit time (PTT) has been documented to be highly correlated with the blood pressure but there are very limited data to investigate the impact of attitude and movement on PTT-based BP calculation. PTT has been calculated in this paper using the windowed association between the ECG and PPG signals. A previously published linear regression algorithm was used to measure constant blood pressure. For fourteen healthy subjects, according to a standardized procedure, BP was measured using PTT for 5 different positions (recumbent, sitting, standing, walking, and cycling) for each subject. Accuracy was increased when the pre-processed PPG signals were used. Furthermore, the observed errors of PTT measurement were within 1 percentage of manual PTT measurement. In systolic and diastolic blood pressure, the root-mean-squared errors (RMSE) between the reference model oscillometric cuff based device and the approximate PTT BP were lowest when sitting or standing and maximum when walking or cycling. Therefore, the estimation of PTT-based BP was reasonably accurate while stationary but not during motion, and further improvements in estimation are required before its use for the estimation of ambulatory BP.

Tony Hao, et.al [7] proposed a new study based on machine learning technique, specifically artificial neural network, is investigated to predict the systolic blood pressure by correlated variables (BMI, age, exercise, alcohol, smoke level etc.). The raw data are split into two parts, 80 percentage for training the machine and the remaining 20 percentage for testing the performance. To construct and test the prediction method, two neural network architectures, back-propagation neural network and radial base function network, is used. An innovative form of estimating systolic blood pressure helps give early warnings to young and middle-aged people who may not be taking daily measures of blood pressure. As it is also known that an isolated measurement of blood pressure is sometimes not very accurate due to the daily fluctuation, this predictor device can provide the medical staff with another reference value. Additionally, since an independent calculation of blood pressure is sometimes not quite accurate due to the regular fluctuation, this prediction system can provide the medical staff with a further reference value. The experimental results indicate that artificial neural networks are ideal for systolic blood pressure simulation and prediction.

III. METHODOLOGY

A. *Photoplethysmography*

Blood volume variations within the microvascular bed of tissue can be detected by Photoplethysmography (PPG), which is a simple and low-cost optical technique. PPG is a non-invasive technique that utilizes a light source and a photodetector on the skin surface to calculate the volumetric differences in blood circulation. The light source emits light from one end of the fingertip and the photodetector analyses the transmitted light. A typical PPG setup is shown in the Figure: 2. The light that is transmitted is equal to differences in blood flow. There are other LED sensors with different colours are available to measure haemoglobin, but an IR LED is considered as the most commonly used. That is mainly because it penetrates deeper into the tissue, which will have more precise measurements.

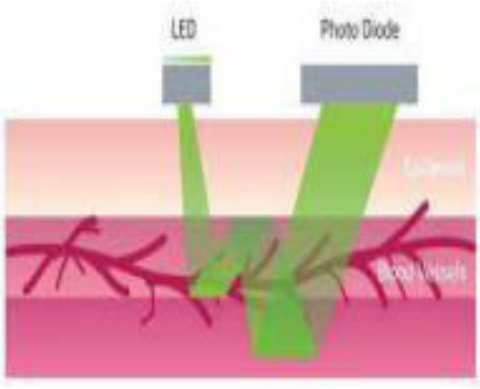

Fig 2. PPG Technique.

B. *Machine Learning*

Machine learning has been one of the pillars of information technology over the past two decades and became a very integral part of our existence. Machine learning is gradually being used to simplify the task of creating a successful search engine, rather than guesswork and creative technologies. The machine learning (ML) techniques are

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used to create a custom model to predict regular BP by using the historic BP values and health behaviour of a person which is used estimate the impact of the individual's health behaviour on his or her BP. The proposed method uses the PPG technique to monitor the blood pressure apart from other techniques. The obtained pressure values are collected and a database is created. The database is given to a machine learning algorithm which predicts the future blood pressure values. There are many machine learning algorithms were available based on the nature of database in which the algorithm is being performed. Among them selecting the appropriate one for our prediction is a tedious task. Because each algorithm provides different values for different algorithm. So here the task to select the best prediction which gives the highest accuracy.

C. Block Diagram of the proposed model

The functional block diagram can be divided into two sections; hardware and software sections. The block diagram of the whole system is shown in Figure: 3. Software section mainly includes the machine learning algorithms for prediction of blood pressure values. The hardware section consists of sensor based on PPG technique and a microcontroller or processing the signal to pressure values. The sensor includes LEDs and photodetector which works on the principle of photoplethysmogram.

Later the signal obtained from the fingertip will be amplified since it will be in few mV. The signal conditioning circuits will amplify and filter out the required signal to the microcontroller. The signal will be processed by the microcontroller and obtain the systolic pressure.

In machine learning part, a database is given as the input to the model. Data is been cross-validated to ensure better accuracy and efficiency of the algorithm used in the training the machine. Finally these values are given to the machine learning algorithm where future value is predicted. Both the hardware and software sections are combined to check the correct functioning of the system.

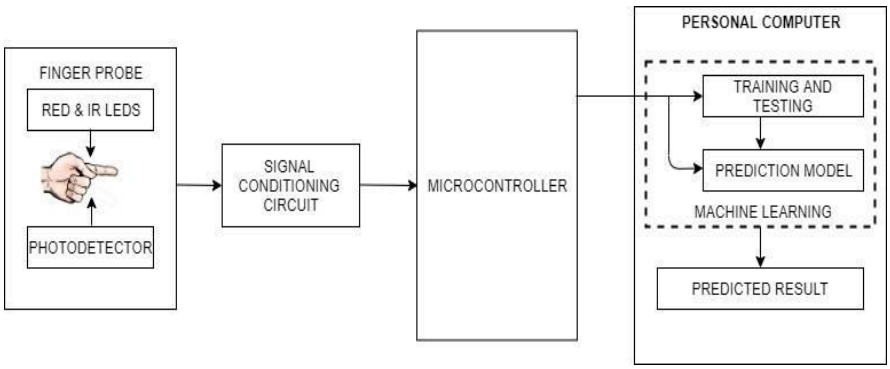

Figure 3: Block diagram of proposed system

IV. FINDINGS AND RESULTS

The hardware includes a sensor section, signal conditioning and processing section. The sensor consists of an IR Led and photodiode. The circuit wired on a dot board is shown in Figure: 4. The finger can be placed in both transmittance and reflectance mode.

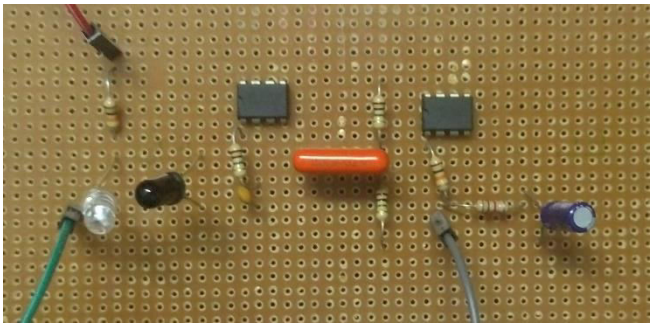

Figure 4: Setup for PPG signal generation

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The current obtained from the photo diode is converted to a voltage value by a transimpedance amplifier. Then the signal is amplified since it is in the range of millivolt. The low-frequency signals were removed by using a high pass filter. The circuit is completed by using active and passive components only. The circuit is powered with 5 V by an Arduino. The PPG signal obtained from the hardware is plotted by using serial plotter available within the Arduino IDE.

An IR LED and the corresponding photodetector is used to obtain the PPG signal. The wavelength of IR LED is 940 nm. A wavelength comparison study has been carried out using red, green and blue LEDs in order to find out which light penetrates more into the skin. The Figure: 5 shows the setup for comparison. According to the results obtained from study, as the wavelength decreases the output voltage also decreases. This shows that the light with higher wavelength can penetrate from one end to another end of the finger. That is why IR LED is used in the sensor for generating PPG signal. The comparison of wavelength and voltage is shown in Table: 1.

The dataset has been collected by using digital blood pressure sensor from several individuals. At the same time, corresponding values from the PPG sensor is also collected. A graph has been plotted which shows the variation between the blood pressure collected from both the sensors. The graph is shown in Figure: 6 below.
After collecting the database, real time pressure values were given as input to the machine learning code. After processing the algorithms, the pressure has been predicted for next time period. The variation between the predicted and actual value is shown in Figure: 7.

The variation of trend in blood pressure changes from person to person. For normal and young people the blood pressure values usually lies in normal range. But for middle aged and old people, the pressure value lies in either elevated or high blood pressure category. For a person who is suffering from critical illness, the blood pressure will be a random value which can fall in any category. The data has been collected from three people belonging to three different age groups is plotted in Figure: 8.

The algorithms used here are Knn Classifier, Support Vector Machine, Random Forest, Naive Bayes, Linear Regression and Decision Tree. Knn classifier performs better for clustering of data based on a particular feature. Support Vector Machines provide a highly accurate result for data prediction. Random Forest is mostly suitable for large data sets and it helps to find the significant feature from the input features. Naive Bayes is a simple algorithm that also works for a huge amount of data. Linear Regression is the simplest machine learning algorithm that predicts the future value of a process for a continuous value. Decision tree algorithms are mainly used for feature interactions and can be operated over the data regardless of their linearly separable basis since they are non- parametric.

It is necessary to do a comparison among different machine learning algorithms to check their consistency. A method to do this is to calculate average variance, accuracy and precision of distribution models. The comparison among machine learning is said to be fair if each algorithm evaluates on the same data on the same way. Python IDLE is used to run all these machine learning algorithms and the graphs were plotted by using matplot.lib function. The percentage of accuracy is shown in Table: 2.

Even though the decision tree provides 93% percent accuracy it can't be selected as the best one since it predicts the result based on the branching technique. It might be true or false depending upon the splitting threshold. Hence Random Forest is selected as the best prediction algorithm.

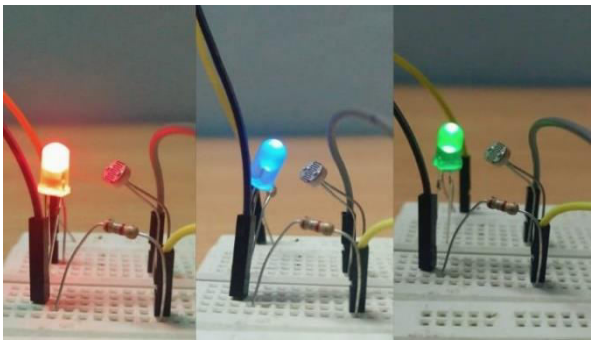

Figure 5:Comparison of output voltage

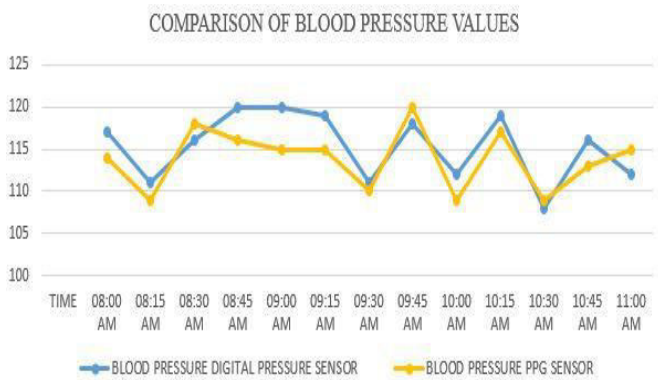

Figure: 6 Comparison of blood pressure values using red, blue and Green leds

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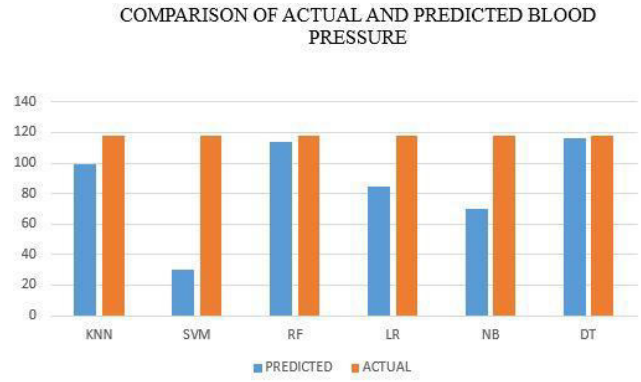

Figure: 7 Comparison of predicted and actual pressure values from different age groups

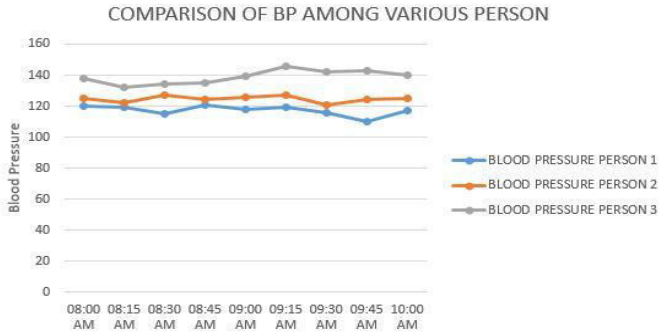

Figure: 8 Comparison of blood pressure values

No:	LIGHT	WAVELENGTH	OUTPUT VOLTAGE
1	Infra-red	>940 nm	2.49 mV
2	Red	700-635 nm	1.70 mV
3	Green	560-520 nm	1.66 mV
4	Blue	490-450 nm	1.54 mV

Table: 1 Wavelength and Voltage comparison

ALGORITHMS	ACCURACY PERCENTAGE
K NEAREST NEIGHBOR	70%
SUPPORT VECTOR MACHINE	11%
RANDOM FOREST	88%
LINEAR REGRESSION	25%
NAÏVE BAYES	17%
DECISION TREE	93%

Table: 2 Accuracy percentage of each algorithms

V. RESULT AND DISCUSSION

A PPG based blood pressure prediction method is proposed here. The hardware for obtaining PPG signals was developed and thereby created a private database. This simply enhanced the prediction of future blood pressure values using machine learning. This recommended solution helps to reduce the difficulty that a patient experiences while calculating blood pressure. The key aim of this work is to reduce the need for any doctor or specialized staff in the process of calculating blood pressure with a fairly inexpensive and user-friendly tool. Data that can be used by doctors is easy to store for further study. PPG based blood pressure monitoring system has been successfully developed and tested using a micro-controller at a lower cost. In future, this concept can be expanded to predicting many more health indicators such as sodium, insulin, creatine, urea concentration, etc. Using electronic method in combination with the machine learning technique, a lot of diseases can be pre-predicted. Hence personalized actions can be recommended to improve and control the health of a person in advance.

VI. CONCLUSION AND FUTURE WORK

Nowadays this dynamic world is running after technologies which are far beyondfor human to imagine. As a result of this hectic environment, people are supposed tosuffer from stress, anxiety and many more health problem. The food that we consumealso contribute to many health problems since the adulteration content is very high. Eventhough we cannot stop these consequences but can prevent them by taking successivemeasures. Data science has emerged as a new technology that became an inevitable part of everyone's life. The world has been changing and much more predictive for humanby data analysis. From the stock market to weather forecasting, the prediction plays animportant role. Hence this same mechanism can be also adopted in medical science. Ifthe changing nature of vital parameters in the body can be predicted in advance, it will beboon to those patients who are suffering from severe health issues. In future, this conceptcan be expanded to predicting many more health indicators such as sodium, insulin, creatine,urea

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BIOGRAPHY

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