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RESEARCH ARTICLE

Pre-eclampsia risk monitoring and alert system using machine learning and IoT

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After 20°weeks of gestation, pre-eclampsia is characterized by newly developing hypertension. Preventative interventions only moderately lower a woman's risk of pre-eclampsia due to its prevalence, the risk variables that have been found to be accurate in predicting its beginning, and the occurrence of pre-eclampsia. The signs and symptoms typically become visible toward the end of pregnancy (late second to early third trimester). Some of these tests are straightforward, while others are invasive; some have undergone significant research, while others are still being investigated in clinical settings. Pre-eclampsia has been linked, in particular, to cardiovascular sequelae in the fetus, such as hypertension and impaired vascular function. In our project, a system and an algorithm for evaluating the health status of pregnant women are proposed. Pre-eclampsia can cause major diseases and issues during pregnancy; thus, the system's goal is to diagnose the condition early and monitor its risk. Our research examines the diagnostic options for early risk assessment to identify pregnant women at high risk for pre-eclampsia and the possible advantages for the women, the unborn child, and health-care systems. A system like this will be widely used in clinical obstetric practice. It is designed to be implemented to monitor pregnant women's status updates through the Internet of Things based on machine learning.

Keywords: pre-eclampsia, hypertension, prediction, pregnant women, IoT, machine learning algorithm

Introduction

Pre-eclampsia is a health-related problem that occurs due to a sudden rise in the blood pressure (BP) level in the region of the blood vessels during the time of pregnancy. According to numerous studies, pre-eclampsia affects approximately 7% of pregnant women worldwide. This health problem contributes to maternal morbidity and mortality in pregnant women. There are some significant factors that lead to pre-eclampsia, including high stress and workload, mood swings, loss of physical movement, unhealthy eating habits, changes in environmental conditions, and, according to the research, the main factor is social class. Women from lower socioeconomic classes choose to get prenatal checkups less frequently, which increases the risk of pre-eclampsia or other issues.

It is possible to control this issue to prevent further health issues for the mother and fetus at 20°weeks of gestation, which can lower the risk and preserve both the mother's and the fetus' lives. One of the major parameters, such as blood pressure, and other health parameters, such as body temperature and heart rate, can be measured using sensors. In this case, we're using a non-invasive method for measuring BP that originated with the bracelet model. There are two stages of pre-eclampsia that occur during pregnancy (**Figure 1**).

Mild pre-eclampia

When the BP ranges higher than 140°mmHg for the systolic pressure and more than 90°mmHg for the

FIGURE 1 | Problems of pre-eclampsia.

diastolic pressure, mild pre-eclampsia occurs during or after 20°weeks of gestation.

Severe pre-eclampsia

When the BP ranges higher than 160°mm Hg for the systolic pressure and more than 110°mmHg for the diastolic pressure, severe pre-eclampsia occurs during or after 20°weeks of gestation. Some other symptoms to identify severe pre-eclampsia include pain in the upper right abdomen, sudden fatigue, and breathing issues.

The goal of the current study is to continuously monitor expectant mothers by taking their BP, heart rate, and temperature. This tool will be very useful for the ongoing supervision of expectant workers in both the public and private sectors. This device will continuously monitor these ladies because they do not have enough time to attend parental check-ups.

Pre-eclampsia diagnostic problems

In the Russian Federation, pre-eclampsia ranks second or third in the causes of maternal mortality and ranges from 11.8 to 14.8%. There is currently no concise theory or explanation for the development of pre-eclampsia. From the given range, the diagnosis of pre-eclampsia is difficult and needs a large number of tests. Pre-eclampsia prevention and conservative treatment are not possible or exist. But in this article, prevention of pre-eclampsia will be possible. The issues raised earlier appear reasonable, and obstetrics has identified pre-eclampsia diagnostic quality improvement as one of its top priorities. So, a pre-eclampsia risk monitoring and alert system using machine learning algorithms based on the Internet of Things (IoT) is implemented to predict pre-eclampsia in the early stage of pregnancy, at 20°weeks of gestation. Data from the hospital's pre-eclampsia registry are used in this study. We start with pre-processing before moving on to data cleansing, integration, and standardization. Furthermore, we use the KNN algorithm and decision tree technique to assess and forecast pre-eclampsia in its early stages.

Literature review

An IoT-based health assessment framework is being proposed by Rydhm Beri, Mithilesh Kr. Dubey, Anita Gehlot, and Rajesh Singh to continually record pregnant women's BP and other health-related indicators. Fog nodes then process and evaluate the recorded data. The patient is then given immediate recommendations from these fog nodes for enhancing their health. Yuliya A. Zhivolupova has conducted research on the early identification and remote management of pre-eclampsia. The suggested method's main distinctions are its reliance on a standard diagnostic framework, its type-specific data analysis, its integrated approach to estimating the maternal condition, and its potential for emergency communication with a doctor. The application of a soft voting-based ensemble approach and recommendation system for women at high risk of pre-eclampsia has been studied by Nurul Widooyawati. For women at high risk of pre-eclampsia, we created a mobile application with two pre-eclampsia prediction and recommendation features. Glenda Puco, Cesar Granizo, Carlos Nunez, Patricio Encalada, and Carlos Gordon have undertaken studies on keeping a regular watch on pregnant women in an effort to lower maternal mortality by spotting potential issues in their early stages. The suggested electronic system enables the following functions: measuring the pressure variables (mmHg), recording the measured variables, visualizing the data via an interface, and producing reports using the stored data. Researchers Tessey Badriyah, Muhlis Tahrir, and Iwan Syarif compared two data mining techniques—logistic regression and naive Bayes—in order to forecast the risk level of pre-eclampsia based on the data from 17 existing variables.

Methodology

Methodology is the general description of the project and the steps involved to complete it in a sequential manner. Throughout the study process, data is gathered and evaluated using a theoretical and systemic approach. It enables researchers to confirm the accuracy of a study in order to gather new data. The goal of research methodology is to evaluate a chosen research method's reliability, validity, and credibility.

The main steps involved in the methodology include the following (**Figure 2**):

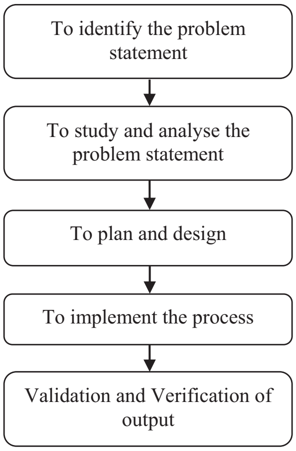

FIGURE 2 | Flow diagram of general methodology.

1. Pre-eclampsia is diagnosed and supported by indicators that are similar to those used to predict pre-eclampsia.
2. Analyze and evaluate the indicators used in the pre-eclampsia prediction.
3. Study the principles and construction of an algorithm to predict pre-eclampsia at an early stage.
4. Developing the algorithm for the prediction of pre-eclampsia.
5. Validation and verification will be processed in the next step.

Proposed system

In this project, a wireless transmission module, an electronic module, and a sensor module are utilized to create a smart bracelet. The software application supports data exchange, acquisition, and processing and also operating the system. The waveforms of the BP, heart rate, and body temperature are picked up by the sensors. Based on the input data generated by the BP sensor, the electronic module integrates features for conditioning and processing. The output data is then wirelessly sent to a connected smartphone in the following stage. The data is processed by a special algorithm, which then offers numerical and graphical representations of the pertinent physiological characteristics. When the BP exceeds the normal range, an alert signal is sent. The smart wristband used by the system, which checks BP once every 15°min, provides the input data (**Figure 3**).

Block diagram

To detect events or changes in the environment and transmit the information to other electronics, typically a computer processor, a sensor is a module, device, subsystem, or machine. Three different types of sensors, including BP, heart rate, and temperature sensors, are used in this instance to measure various health factors. The electronic module is an assembly of various power components, primarily power semiconductor devices that are internally coupled to perform a power conversion function. Every user who wishes to create his/her own projects must have access to these modules. A wireless transmission module is a tiny electrical gadget that connects two devices by transmitting and receiving radio signals. The ability to wirelessly interact with another device is frequently desirable. Both optical and radio-frequency communication can be used to carry out this wireless communication (**Figure 4**).

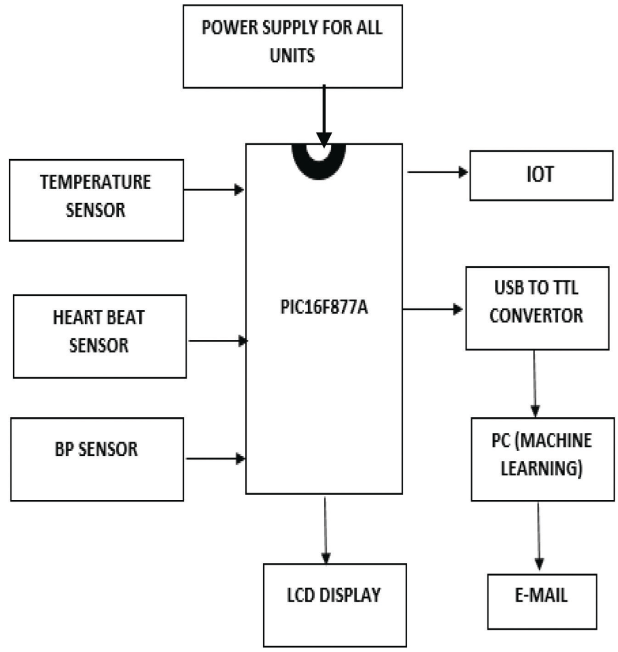

FIGURE 3 | Block diagram of proposed system.

Data communication

Data communication is the process of sending data or information between two devices across a transmission medium, as in computer networks. A hardware- and software-based communication system is used in this procedure (**Figure 5**).

It is the transmission and reception of data via a point-to-point or point-to-multipoint communication channel as a digital stream or digitalized analogue signal.

Data acquisition

The sea surface sensors used in this data collection are in charge of measuring the health metrics in a real-time environment. Utilizing BP sensors, temperature sensors, and heart beat sensors, our proposed system assists in

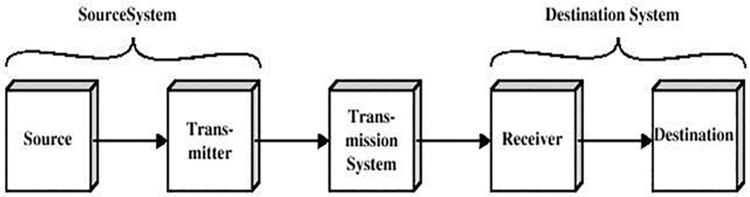

FIGURE 4 | Flow diagram of proposed system.

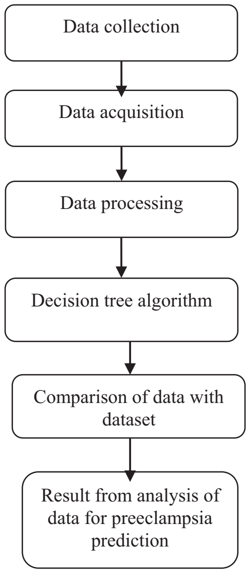

FIGURE 5 | Block diagram of data communication.

capturing health metrics, including BP, temperature, and heart rate. In accordance with the size and requirements, this acquisition is carried out utilizing the various sensors indicated with the peripheral interface controller (PIC) microcontroller (**Figure 6**).

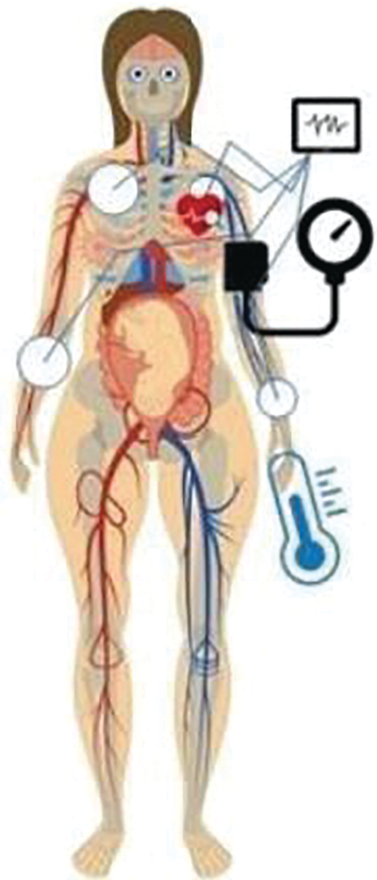

FIGURE 6 | Data acquisition.

Data processing

Data processing wirelessly captures and collects data from data gathering processes in order to process the data for real-time analysis and suggestions. Lesser latency and lower bandwidth are important advantages for data processing. Through this data processing, large amounts of data can be processed in a matter of seconds. The PIC microcontroller, which is in charge of handling data processing, was used in the suggested system.

Hardware requirements

Peripheral interface controller microcontoller

One of the best-known microcontrollers in the business is the PIC microcontroller (PIC16F877A). It is quite easy to code or program this microcontroller, and it is also very convenient to use. Due to the usage of FLASH memory technology, one of the primary benefits is that it can be written to as many times as possible. There are 33 input and output pins out of a total of 40 pins on it. PIC16F877A are widely used in digital electrical circuits as well. It operates at a maximum frequency of 20 MHZ and has a reduced 35-instruction set (**Figure 7**).

Blood pressure sensor

The essential indication of BP is one of the most significant. It is the force that flowing blood applies to the blood vessel walls. It is used as a non-invasive method of measuring BP. This sensor is secure to use because it is non-invasive. It is simpler to operate, and anyone can keep an eye on it. By

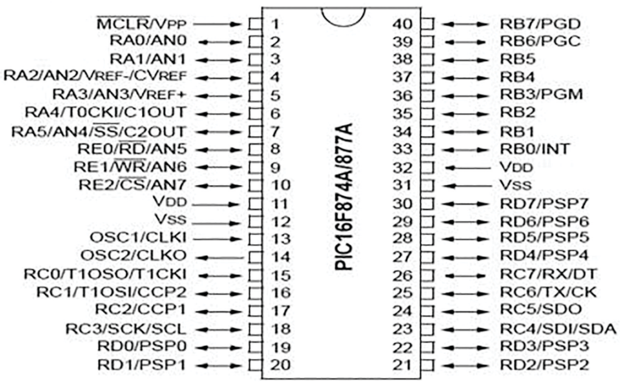

FIGURE 7 | Pin diagram of PIC microcontroller.

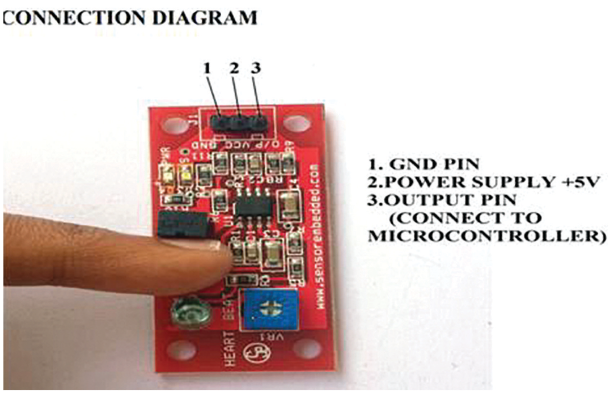

FIGURE 8 | Heartbeat sensor.

providing findings automatically, this sensor simplifies the work of calculating pressure and monitoring mercury levels.

Heartbeat sensor

An extremely bright red light-emitting diode (LED) and a light detector make up the heartbeat sensor. It is positioned in the index finger, and the heart sensor's output is connected to a PIC microprocessor (**Figure 8**).

Temperature sensor

The precision integrated circuit of the LM35 series has an output voltage that is linearly proportional to Celsius. It is applied to the skin's surface to monitor body temperature (**Figure 9**).

Internet of things module

An open source IoT platform is the node MCU. It consists of hardware based on the ESP-12 module and firmware that runs on Espressif Systems' ESP8266 Wi-Fi SoC. By default, "node MCU" refers to the firmware rather than

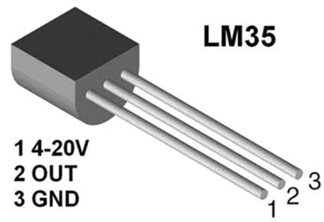

FIGURE 9 | Temperature sensor.

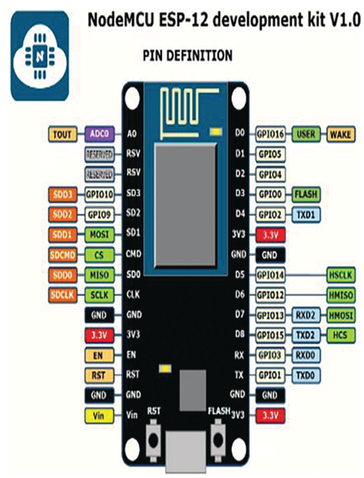

FIGURE 10 | Internet of Things (IoT) module.

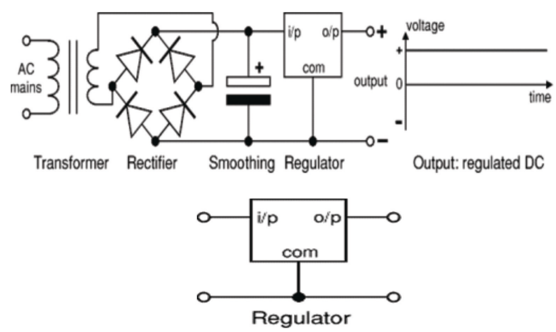

FIGURE 11 | Power supply unit.

the development kits. The Lua programming language is employed by the firmware. It is constructed using the Espressif Non-OS SDK for ESP8266 and is based on the eLua project (**Figure 10**).

Power supply

How do voltage regulators, rectifiers, and filters work together to power supply circuits? An alternating current (AC) voltage is converted to a continuous direct current (DC) voltage by rectifying it, filtering it to a DC level, and then regulating it to the required fixed DC value. a fullwave rectified voltage from a diode rectifier that is first filtered to create a DC voltage by a basic capacitor filter (**Figure 11**).

Software requirements

- MPLAB IDE - PIC IC programming software
- PICKIT 2 - PIC programmer kit
- Sketch IDE - ESP module (IoT module) programming IDE
- Personal computer (PC) with machine learning based decision tree algorithm

Hardware specification

SYSTEM: PC OR laptop

PROCESSOR: INTEL i3

RAM: 2 GB recommended **ROM:** 1 GB

Software specification

OPERATING SYSTEM: WINDOWS 8, 10, 11

LANGUAGE USED: PYTHON

FRONT END: PYTHON SHELL

BACK END: PYTHON SCRIPT WINDOW

Decision tree algorithm

Discrete and continuous properties can both be predicted using the classification and regression method known as the DT method. The algorithm makes predictions about discrete qualities based on the relationships between input columns in a dataset. The approach specifically identifies the input columns linked to the predicted column. Since it mimics the steps a person takes when making a real-life decision, the decision tree is simple to understand. Dealing with challenges involving decision-making may make use of it. It is a good idea to consider all options for resolving a problem. Data cleaning is not as crucial as it is with other techniques (**Figure 12**).

Result and discussion

According to the concept, hardware designs were made and circuit connections were made by interfacing all the sensors with the PIC microcontroller. Temperature sensors were interfaced with the PIC16F877A at the A0 pin, and the analog outputs of the temperature sensor were measured and displayed in the liquid crystal display (LCD) module. The heartbeat sensor was digitally connected with the PIC16F877A. The pulse rates from the heartbeat sensor were calculated for 30°s and displayed in the LCD module.

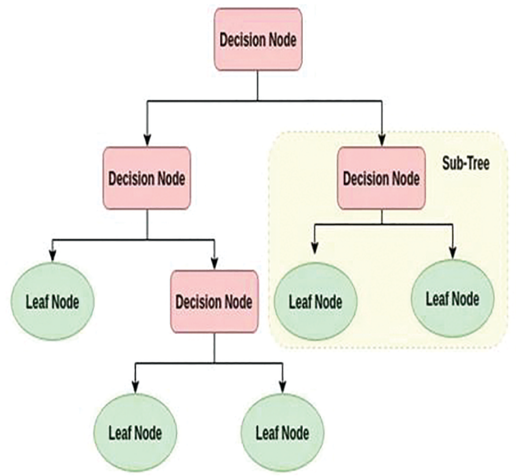

FIGURE 12 | Decision tree algorithm.

The BP sensor was interfaced with the PIC microcontroller through the UART protocol. BP data were received serially and displayed in the LCD module. All the sensors were successfully interfaced, programmed, displayed on the LCD for visualization, and transmitted to the PC for further artificial intelligence processing for the prediction of pre-eclampsia.

Conclusion

A group of indications useful for diagnosing pre-eclampsia was developed and supported. It contains both the outcomes of scientific testing and quality indicators that represent the pregnant woman's subjective state of health. The accuracy of the diagnosis will increase as a result of the information about indicators changing that is gathered throughout the monitoring. It may also be used to calculate the risk of pre-eclampsia, the goal of monitoring, while maintaining the diagnostic use of the discovered results. The fundamentals of building an algorithm to detect pre-eclampsia using a long-term remote monitoring system are outlined. One of the main benefits of incorporating the system into medical practice is the fundamental idea of employing currently used medical protocols, which will greatly boost doctors' loyalty.

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