**AI and IoT Driven Heart Health Monitoring System**

**1.INTRODUCTION**

Cardiovascular diseases (CVDs) have now become the leading cause of mortality in India. These diseases contribute approximately 25% of the total mortality rate. Among all causes of heart diseases, Ischemic heart disease and heart strokes are responsible for 80% of deaths. The death rate due to CVD is higher in India than the average death rate across the globe. As per the figures reported in [], the average death rate is estimated to 272 per 100, 000 population in India whereas, it is 235 per 100,000 population at the global level.

Based on the severity, the heart diseases can be categorized into acute and chronic types. Acute heart failure is a condition in which the heart is not working properly. It either appears suddenly or worsens quickly and can be life threatening.Shortness of breath is the most common symptom of acute heart failure.The combination of Chest X-ray,Blood tests,Stress test,Electrocardiogram,Echocardiogram,Angiogram,CT scan and MRI scan are performed in case of acute heart failure. Chronic heart disease is a condition that develops gradually over time and affects the pumping power of heart muscle.High blood pressure,diabetes,faulty heart valves,coronary artery disease,inherited heart defects and damaged or inflamed heart are the conditions of chronic heart disease.Sometimes one of these chronic conditions leads to an acute event.Chronic conditions can be improved by a healthy diet , balanced weight, exercise under supervision, managing stress and quitting smoking. Conditions such as hypertension and diabetes can be controlled to minimize their effect on the heart. Heart failure often requires treatment with a low salt diet and diuretics to try to reduce the amount of fluid accumulating. Drugs such as digoxin improve the functioning of the heart muscle.

The shortage of a trained workforce is observed at all levels of health care, including specialists, primary care physicians, and frontline health workers.

Uneven distribution in numbers and in quality of the healthcare workforce in rural and urban India, but also within different regions and states is also the major reason . Improving the human resource capacity for the prevention and control of CVD should be a national priority, and efforts should be made to ensure equitable distribution of available resources in both rural and urban settings.Due to mounting hospital costs and shortage of qualified healthcare professionals it is difficult to continuously monitor the essential body parameters of the patients suffering from CVD.

These types of cardiovascular diseases need continuous monitoring of certain body parameters such as heart rate, cholesterol , blood pressure etc. which require hospital visits.

Internet of Things (IoT) is a network in which many devices are connected, and these devices can communicate by computer network . By this worldwide network, we can get information through sensors which relate to it. By using a computer network, we can access this information anywhere in this world. The Internet of things can connect physical objects to the Internet and can provide opportunities for building systems which are based on various technologies such as near field communication (NFC) and wireless sensor network (WSN). In wireless sensor networks, sensors sense the environment and send information to the base station.

In the modern era, patients are diagnosed by performing various tests in laboratories such as blood test, computerized tomography(CT)scan,Continuous ECG monitoring, magnetic resonance imaging(MRI), positron Emission Tomography(PET), radionuclide imaging, cardiac catheterization, coronary angiography, tilt table test etc.These instruments are bulky and immobile and thus keep patients stuck to the bed. Their wired connections are very uncomfortable to patients and medical staff .

Data captured by wearable, ingestible and embedded sensors, mobility patterns, device usage patterns allow to track user habits and can be effectively collected and processed to reveal critical conditions by using state of the art Artificial Intelligence (AI) and Machine/Deep Learning (ML/DL) based approaches.

**2. Related Literature**

An extensive analysis of existing literature in the field of disease diagnosis and visualization by using machine learning techniques gave insights about technological solutions. Various teams of researchers worked in the field of heart disease diagnosis using IoT and machine learning.

Kanchan Katake et. al [1] proposed a real time diagnostic system for remotely located heart prone patients to measure heart rate, blood pressure, and body temperature using biomedical sensors. They used the publicly available dataset at the UCI Machine Learning Repository [] and real time data collected via ECG sensor, temperature sensor, Pulse rate sensor etc. This system can simultaneously monitor multiple parameters onto a single chip integrated with wearable devices where. This data is sent to Arduino and a cloud server. The Recurrent Neural Networks ( RNN) based model was used to determine the local and temporal dependencies among data attributes and to accommodate variable sequence lengths. It can receive the values of parameters in a sequence as inputs and can produce corresponding sequences of values as outputs. The authors claimed that their system

achieved the highest accuracy of 92%. Thus, their approach is useful to analyze the data and to make predictions from the data. Also, it can send alerts to the patient in the form of SMS, Email etc. as soon as the value(s) of parameter (s) exceeds the preset threshold.

Md.Milon Islam et. al [2] proposed a system for continuous monitoring of patients and her or his room conditions. It comprises a sensor module, data processing module and web user interface. The sensor module comprises a heart beat sensor to measure change in blood volume, ‘LM35’ sensor for monitoring the body temperature, ‘DHT11’ for sensing the room temperature and humidity level, ‘MQ-9’ sensor for detection of gases viz. Liquified Petroleum Gas(LPG), Carbon Mono-Oxide (CO), and methane (CH4), and ‘MQ-135’ sensor for testing the air quality. The sensor module collects the data and transfers it to the data processing module comprising ESP32 with an inbuilt Wi-Fi module. The ESP32 module processes the data and sends it to the gateway server. The third module of the system involves the web user interface. It usesThingSpeak for the graphical interpretation, display of results, and process of transactions. The authors claimed that their system reported the highest error rate of 4.28%, 0.81%, and 3.07% in monitoring of heart rate, body temperature and room humidity respectively. Although the system is easy to use for a medical staff, it does not provide the option for tele-consultation. Also, the bulkiness of the system works as a hindrance in its use for real-time monitoring. Further, the password protected access of data does not ensure the security of the data collected at the server.

Chao Li along with Xiangpei Hu et. al [3]proposed a health monitoring system for the data acquisition and transmission. The system continuously monitors the physical parameters viz.blood pressure, ECG, SpO2, heart rate, pulse rate, blood fat, blood glucose and environmental indicators viz. Room temperature, humidity etc. Further, it provides four modes for data transmission. Its first mode facilitates the real-time transmission of data, second mode supports the periodic transmission, third mode allows the event triggered transmission and the fourth mode transmits the data only on the demand of patients. However, the system is efficient in real-time data collection and transmission but it does not provide any mechanism for the data interpretation and decision making.

Shubham Banka et. al [4]proposed a remote system that gathers the values of heart rate, and blood pressure via the wearable devices connected wirelessly to the Raspberry pi and sends the collected values to a cloud server. The system also employs artificial intelligence based algorithms for data interpretation and decision making.Although the system is effective in health Monitoring and emergency alert generation, and prediction of health status, it is challenging to correctly identify the consistent patterns and their impact on the status of health.

Priyanka Kakria et. al [5] proposed a real-time diagnostic system that can remotely monitor heart disease prone patients. The system makes use of wearable sensors to collect the values of heart rate, blood pressure, and body temperature. Now, it employs the Fuzzy logic algorithms to interpret the data and diagnose the diseases such as bradycardia, tachycardia, hypertension, hypotension, fever, and hypothermia. Further, it provides an interface to patients via an android handheld device and a web portal. The system also sends the alert when the values of parameters exceed the pre-set threshold. But, the system is prone to generate false alarms due to the battery issues of sensors and smartphones. Also, the poor signal strength can lead to delay in alert generation and transmission.

Udit Satija el. al [6] proposed a Internet of Things (IoT)-enabled Electrocardiogram Graph (ECG) telemetry system for continuous monitoring of cardiac health. The system comprises the ECG signal sensing module; automated signal quality assessment (SQA) module; and signal-quality aware (SQAw) ECG analysis and transmission module. The system collects the ECG signals and divides them into three classes namely good; intermediate; and bad based on their quality. Although the system is effective in automatic classification of ECG signals into acceptable or unacceptable class, the limitation of bluetooth connectivity restricts its distance from the server as well as patient. Also the working of the setup is dependent on the battery of smartphone and bluetooth connectivity.

Uttara Gogate el.[7] al proposed paper presenting 3 - tier architecture of their prototype healthcare monitoring system using wireless sensor network (WSN) monitoring certain body parameters of patients. Different biosensors available to measure heart rate, body oxygen level and temperature are attached to Arduino Nano board and recorded signals are sent to the server using Node MCU ESP8266 wireless communication. Data is made available on remote servers for doctors and caregivers using ThingSpeak, an internet of things (IOT) application. This wearable device consists of different sensors such as temperature sensor and heart rate sensor. The device will collect the data in form of bio signals from sensors and send it to hospital server for further storage and processing using wireless communication. The proposed system architecture consists of three tiers. Tier-1 consists of wireless sensor nodes attached to the patient’s body for sensing vital body parameters. The data acquired through the sensors is processed and transmitted through control unit. Tier-2 is the intermediate receiving unit which acquires the forwarded data. It is also responsible for storage, processing and displaying the data. Tier-3 is concerned with alert systems and data transmission to longer distances through appropriate internet services. Different wireless communications such as ZigBee, Wi-Fi and Bluetooth are available for tier I, tier II and tier III communication. Different sensors are attached or induced to the patient’s body to collect vital body parameters like temperature, SPO2, heart rate, pulse rate etc. to be monitored. Heart rate and ECG sensor probes are also attached to the patient's body. Sensor data is in the form of analog signals and to be converted into digital form using inbuilt circuits of Arduino board which collects & processes sensor data for further communication. For further use and storage it is then sent to the server using ESP 8266. They used ThingSpeak which channels data , available to authorized users like experts, doctors and caregivers who can remotely monitor patient’s data over the internet and can get alert messages in any emergency situation. Accuracy of the system is found 95% with the response time of 10 seconds. Challenges : The communication can be made collaborative by adding two way communication protocols for IOT so that doctors can monitor and advise patients online. Similarly, patients can ask their queries to remote doctors as well. Some more efforts are required to achieve 100% correctness in the system.

Kumar et.al [8]proposed a project which uses Raspberry Pi along with sensors to track Patient’s Body temperature, heart beat Rate, body movement and Respiration Rate. Here IR transmitter and receiver is used to monitor Heart beat rate. In this system he has used general circuitry or basic electronics system for the conditioning of the system like amplifier to increase the gain of the system as transference of the signal from range may lead to attenuation for that part used amplifier. Transformer specifically step down transformer is used to bring the input voltage of 230 V to convert into 9 volt and 5 volt and here SMPS\* Switched Mode Power Supply is also used because every sensor has a different input. The challenges which this system faces is loss of energy due to attenuation , which can be made more efficient and useful by reducing the effect of attenuation by using certain technologies and newer versions of transformers and amplifiers which are more efficient. With the deep study of these researches the perfect cloud for these kinds of applications is Amazon Web services because of its security as well as the easy technique of usage.

Niket Patil et.al [9]worked on the fitness monitoring and apprehending system for soldiers using IoT. Patil proposed the monitoring using sensors like LM35, Pulse Rate Sensor and Oxygen spotter. This total sensing system and for tracking purposes, they are using GPS SIM28M which is very precise to track the location of soldiers. This whole system is connected to the internet using Node MCU ESP 8266 wifi module and it also comes with a panic button to get help in an emergency situation. And the whole system is low cost and sensors are connected with Arduino Uno (ATMega 328p) as the MCU Board. In the proposed project heartbeat sensor , Pulse sensor , ECG sensor , Temperature sensor are connected to Raspberry Pi as per given flowchart from which the data is transferred to doctors through servers and through sms directly in case of emergency.A precaution notification is sent to patient after further proceedings. Though the system is a perfect example of an IoT and AI based system , still it can be improved a lot by replacing some of the outdated sensors and cloud servers with new and advanced ones with more security promises.

Khan et al.[10] proposed Healthcare Monitoring System and transforming Monitored data into Real time Clinical Feedback based on IoT using Raspberry Pi. He worked on a system with a combination of Arduino Uno and Raspberry Pi. They collected all the data with arduino from all the sensors and then used a raspberry pi to shoot a video. Using a local server, they created a hub of reading that was updated every 2 minutes. This system was proposed to resolve the issues for aged groups & patients who do not regularly visits the doctors.Heartbeat sensor , ECG sensor and Temperature sensor is been connected with arduino UNO ←→ Raspberry Pi , further Raspberry Pi is connected with keyboard and Pi camera , which in turn Raspberry Pi proceeds in two ways , towards WiFi dongle and HDMI to VGA converter , which in turn displays on monitor/ LCD screen. Though the system is a perfect example of IoT and AI based systems , still it can be improved a lot by replacing some of the outdated sensors and cloud server with new and advanced ones with more security promises.Replacement of servers with Amazon Web services because of its security as well as the easy technique of usage.

**3.PROPOSED WORK**

This manuscript focuses on designing and developing an AI and IoT based Health Health Screening System (HHSS). The system will monitor the body parameters such as blood pressure, blood glucose level, temperature and heart rate using IoT sensors and send the collected data to the cloud. Machine learning algorithms make predictions of heart health.Algorithm used in our proposed system is Convolutional Neural Network [CNN] . These algorithms perform automatic preprocessing, feature extraction, multi class classification and evaluation. Thus, minimizes human intervention. It will notify the person in case of deviation from the standard values of body parameters. The degree of emergency will be decided by setting a threshold for different body parameters on consulting the specialist doctors for respective diseases.

The sensor module comprises a heart beat sensor to measure change in blood volume, ‘LN35’ sensor for monitoring the body temperature,ECG sensor to evaluate cardiac rate and rhythm. The sensor module collects the real time data and transfers data to the bolt cloud server. Different machine learning models are trained on this data and the one with highest accuracy is used . Authenticated dataset from kaggle was used for training models. We trained multiple regression models and acquired the highest accuracy of the Xgboost supervised classifier for making the ranking based predictions. It reported approximately 97% accuracy. We are working on further improving its accuracy.Flask was used to connect it with a user friendly web application. Users have the option to enter their health parameters if they have reports from the laboratory or it can be checked by your hardware. The person can log in our web app and can enter the details. Machine learning model analyses this data and makes the predictions into five classes viz. low risk, moderate risk, high risk, healthy or diseased heart.

**4. Materials and Methods**

In this section, we present the dataset preparation and methodology adopted for carrying out this research.

**Dataset:** We used dataset available online at the Kaggle platform and real time data collected at bolt cloud using ECG sensor, temperature sensor,heart beat sensor, pulse rate sensor etc. Dataset comprises of various parameters such as age,sex,chest pain type,resting blood pressure,cholesterol,fasting blood sugar, rest ecg,max heart rate achieved, exercise indused angina etc which help in determining the heart health.

**IoT devices:** The Internet of Things (IoT) refers to the billions of physical objects or "things" that are all connected to the Internet and gathering and sharing data with other devices and systems. IoT devices are hardware devices that capture and share data over the Internet, such as cameras, gadgets, appliances, and other machines. They're pre-programmed for specific uses and can be integrated into other IoT products. Small household cooking appliances to advanced manufacturing equipment are all examples of IoT products. Each IoT component has a unique identifier (UID) and can send data without the need for human intervention.

**Heartbeat sensor:** A heartbeat sensor is an electronic system that measures the heart rate, or the rate at which the heart beats.We have used KY039 heartbeat sensor in our system. It comes in a variety of shapes and sizes and can be used to calculate the pulse in real time. Wrist watches (Smart Watches), smart phones, chest belts, and other devices all have heartbeat sensors.The pulse is counted in beats per minute (bpm), which shows how many times the heart contracts or expands in a minute.Photoplethysmograph is the concept behind the Heartbeat Sensor's operation. The changes in the amount of blood in an organ are determined by the changes in the strength of light moving through that organ, according to this theory.In most heartbeat sensors, the light source is an IR LED, and the detector is a Photo Detector such as a Photo Diode, an LDR (Light Dependent Resistor), or a Photo Transistor.

We may arrange these two elements, a light source and a detector, in two ways: a Transmissive Sensor and a Reflective Sensor.

**Temperature sensor:** The LM35 series are precision integrated-circuit temperature devices with a linearly proportional output voltage to the temperature in degrees Celsius. In comparison to linear temperature sensors tuned in Kelvin, the LM35 unit has the advantage of not requiring the consumer to subtract a significant constant voltage from the output to obtain convenient Centigrade scaling. The LM35 system needs no external calibration or trimming to achieve standard accuracies of ±¼°C at room temperature and ±¾°C over a temperature range of 55°C to 150°C.

**ECG sensor:** We have used AD8232 ECG sensor in our system.This sensor is a low-cost board that measures the heart's electrical activity. This electrical activity can be visualised as an ECG (Electrocardiogram) and read as an analogue reading. Since ECGs can be very noisy, the AD8232 Single Lead Heart Rate Monitor functions as an op-amp to make it easier to get a consistent signal from the PR and QT Intervals.For ECG and other biopotential measurement applications, the AD8232 is an integrated signal conditioning block. It's made to isolate, amplify, and filter tiny biopotential signals in noisy environments like those caused by motion or remote electrode placement.The AD8232 module exposes nine pins, cables, or other connectors on the IC that can be soldered to. The pins SDN, LO+, LO-, OUTPUT, 3.3V, and GND are needed for use with an Arduino or other development board.There is also an LED warning light that will pulsate in time with a heartbeat.

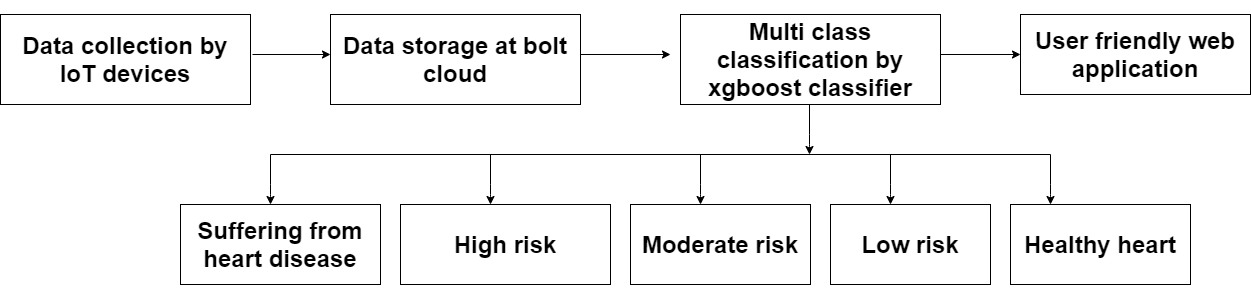
**Bolt wifi module:** Bolt is a fully integrated IoT platform for developers that enables them to quickly and easily create IoT projects and products. It's a forum for Makers and Developers to build Internet of Things (IoT) projects.Bolt has a cloud network and a Wi-Fi module. The Bolt cloud allows you to store data, run analytics on it, and visualise it in the form of graphs both directly and through APIs. When the calculated values exceed certain thresholds, you will receive notifications via SMS and email.The Bolt cloud also includes a powerful system management dashboard, as well as online setup and a code editor. This allows users to link simple hardware and graph their data almost instantly, allowing for fast prototyping of IoT use cases. Bolt also allows you to quickly run Machine Learning Algorithms to predict and detect anomalies in your IoT data.

**Arduino:** We have used Robokits india ARDUINO UNO R3 SMD BOARD, A Type, Model Name/Number: Rki-1672 in our system. The Arduino Uno is an ATmega328-based microcontroller module. It has a 16 MHz resonator, a USB connection, a power jack, an in-circuit device programming (ICSP) header, and a reset button. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as analogue inputs), a 16 MHz resonator, a USB connection, a power jack, an ICSP header, and a reset button. The Arduino Uno is programmed with the Arduino Software (IDE), which is the same IDE that runs on all of our boards and can be used both online and offline.

**Pulse rate sensor:** The Pulse Sensor is an Arduino-compatible heart-rate sensor. We have used SEN 11574 in our system. Students, musicians, athletes, makers, and game and mobile developers who want to integrate live heart-rate data into their projects may use it. An integrated optical amplifying circuit and a noise-reducing circuit sensor are at the heart of the system.You can now read heart rate by clipping the Pulse Sensor to your earlobe or fingertip and plugging it into your Arduino. It also comes with an Arduino sample code, making it simple to use. VCC, GND, and Analog Pin are the three pins on the pulse sensor.

**5. Proposed Method**

In this research, we proposed the system for diagnosis of heart health. The working of the proposed system is demonstrated in figure

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**6. Classification**

**7. Conclusions**

**8. References**