JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

AI-DRIVEN DEVELOPMENT OF NON-INVASIVE CHOLESTEROL MONITORING SYSTEM

[1]Mrs.ABIRAMEE.R, [2]Ms.SATHYAPRIYA.M, [3]Ms.SASIMITHA.A, [4]Mr.NARESH KUMAR.V.R

[1]Assistant Professor, [2]Biomedical engineering student, [3]Biomedical engineering student, [4]Biomedical engineering student
[1]Department of Biomedical Engineering,
[1]Sri Shakthi Institute of Engineering and Technology, Coimbatore, Tamil Nadu.

Abstract : The conception and creation of a non-invasive, AI-driven cholesterol monitoring system are presented in this study. Because high cholesterol is a major risk factor for cardiovascular illnesses, it must be regularly monitored in order to effectively manage and prevent these conditions. Invasive blood tests are a common component of traditional cholesterol monitoring techniques, which can be painful and inconvenient for patients. We suggest a brand-new, non-intrusive monitoring system that makes use of cutting-edge artificial intelligence methods to overcome this difficulty. Through AI(artificial intelligence) networking, data gathered by the NICMS(Non-invasive cholesterol monitoring system) is effortlessly sent to a secure cloud-based platform. This technology uses sophisticated machine learning algorithms to evaluate the data and provide accurate and real-time cholesterol level readings. A user-friendly mobile app or online interface gives users access to their cholesterol data, giving them a tailored and educational summary of their health state. Through the platform, medical personnel may also remotely monitor the condition of their patients, enabling prompt interventions and customized treatment regimens. The NICMS has a number of strong benefits. By doing away with the necessity for intrusive and painful blood tests, it improves user compliance with cholesterol monitoring. When cholesterol levels fluctuate, continuous monitoring makes it possible to identify them early and help people take proactive measures to lead healthier lives. AI connection makes data transfer secure and accessible from any location in the globe. To sum up, the Non-Invasive Cholesterol Monitoring System, which employs AI technology and the BPW34 pin photodiode, has the potential to completely transform the way cholesterol is managed. This novel method combines machine learning, Internet of Things connection, and non-invasive sensors to provide data-driven and user-centered cholesterol monitoring. This approach may lessen the prevalence of cardiovascular illnesses, which might enhance the standard of treatment generally and encourage preventative medical interventions.

Keywords: Artificial Intelligence, Non-invasive sensor, cholesterol monitoring, Machine learning

I.INTRODUCTION

Cardiovascular Disease : Bodily cells contain the waxy, fat-like substance known as cholesterol. It is necessary for the synthesis of vitamin D, the creation of hormones, and the digestion of dietary fat. Conversely, high blood cholesterol levels increase the risk of cardiovascular diseases including heart attacks and strokes by causing plaque to form in the arteries. Usually, high cholesterol has no outward signs. It is sometimes referred to as a "silent" ailment. On the other hand, symptoms like fatigue, shortness of breath, and chest discomfort might be brought on by the consequences of high cholesterol, such heart disease. It's important to keep in mind that these symptoms may be connected to other medical conditions, therefore a thorough medical assessment is necessary for an accurate diagnosis. In recent years, concerns about cholesterol have become increasingly severe health issues. Elevated risk of heart disease has been associated with elevated cholesterol levels, specifically elevated levels of low-density lipoprotein (LDL) cholesterol. Hereditary vulnerability, poor eating habits, and sedentary lifestyles are all contributing factors to the rise in cholesterol-related problems. One of the biggest problems is atherosclerosis, a condition in which chemicals and cholesterol build up in the arteries, causing plaques. Heart attacks and strokes are only a couple of the cardiovascular problems that these plaques may cause by reducing blood flow. Additionally, there is evidence connecting the prevalence of increased cholesterol to growing rates of diabetes and obesity, both of which increase the risk of cardiovascular illnesses. Cholesterol levels are raised by unhealthy diets high in trans fats, saturated fats, and processed carbs. The goal of developing a non-invasive cholesterol monitoring system is to provide individuals with a simple means of monitoring their cholesterol levels without requiring invasive procedures such as blood testing. This technology analyzes cholesterol levels using non-invasive methods including wearables or near-infrared sensors. The notion that particular physiological variables or biomarkers are related to cholesterol levels is the foundation of many of these monitoring systems. Based on these parameters, the system can determine cholesterol levels and provide consumers with instantaneous feedback regarding their cardiovascular health.

Artificial Intelligence : Artificial intelligence (AI) has become a disruptive force in a number of areas, including the medical field. Artificial Intelligence (AI) holds great promise to transform medical diagnosis, monitoring, and treatment through its capacity to handle massive amounts of data, identify patterns, and make predictions. AI has great potential in the creation of non-invasive monitoring systems for chronic illnesses like cardiovascular disorders. Elevated cholesterol levels provide a substantial risk for cardiovascular illnesses, which continue to be the primary cause of morbidity and death across the globe. In the past, intrusive blood tests have been used to check cholesterol levels. These procedures can be difficult and inconvenient, which may discourage patients from getting frequent checks. Consequently, there is an increasing demand for non-invasive techniques that may offer precise and ongoing cholesterol level monitoring. A potential solution to this issue is the creation of non-invasive, AI-driven cholesterol monitoring devices. These devices use wearable sensor technologies and sophisticated machine learning algorithms to scan physiological data in real-time and predict cholesterol levels without requiring blood samples. The use of artificial intelligence facilitates the derivation of significant insights from intricate information, hence permitting tailored and anticipatory cholesterol level control. Furthermore, by offering ongoing feedback and useful insights, AI-driven non-invasive monitoring devices may improve patient compliance and engagement. Patients can get individualized suggestions for medication or lifestyle changes, as well as real-time monitoring of their cholesterol levels and tracking of changes over time.

II.METHODOLOGY

There are many processes involved in non-invasively monitoring cholesterol levels with an AI-based system that uses an infrared sensor,

Selecting an Infrared Sensor: Pick a suitable sensor that can precisely measure cholesterol levels. Think about things like interoperability with AI devices, precision, and sensitivity.

Adjust the infrared sensor's calibration to guarantee precise measurements. To establish correlation and modify calibration settings appropriately, this may entail comparing sensor results with conventional blood tests.

Data Acquisition: To interact with the infrared sensor and gather data, develop software or firmware. Verify the stability and accuracy of the sensor readings.

Data Processing and Analysis: Put algorithms into place to handle and examine the gathered information. This might entail employing machine learning techniques for anomaly identification or predictive modeling, statistical analysis, and noise filtering.

User Interface: Provide a simple user interface so that cholesterol level measurements may be accessed. Users will be able to check their current cholesterol levels, follow trends over time, and receive notifications for problematic readings with this mobile app, web dashboard, or desktop program.

Connectivity with Medical Systems Integration: Connect the Artificial Intelligence-based cholesterol monitoring system to the current healthcare network. This might entail setting up a connection to electronic health record (EHR) systems so that medical professionals can access and keep an eye on patient data from a distance.

Security and privacy: To safeguard sensitive health data sent and stored by the Artificial Intelligence system, put strong security measures in place. For data privacy and to stop unwanted access, use access restrictions, authentication, and encryption.

Verification and Adherence to Regulations: Conduct tests and clinical studies to validate the non-invasive cholesterol monitoring system's accuracy and dependability. Assure adherence to pertinent laws, rules, and guidelines, such as the Health Insurance Portability and Accountability Act (HIPAA), which protects patient privacy.

Continuous Improvement: To enhance accuracy, dependability, and usefulness over time, the AI-based system should be continuously monitored and optimized. User and healthcare professional input should be incorporated.

These methods will help you create a functional, non-invasive cholesterol monitoring system that uses an infrared sensor within an Artificial Intelligence framework.

III.HARDWARE DESCRIPTION

BPW34 PIN PHOTODIODE : The BPW34 is a widely used silicon photodiode with excellent sensitivity to light in the visible and near-infrared spectrum. This photodiode is known for its high speed, reliability, and versatility, making it a popular choice in a wide range of applications, including light detection, optical communication, and medical devices. The BPW34 photodiode operates based on the principle of the photovoltaic effect, which allows it to convert light energy into electrical current.

Here's how the working of the BPW34 photodiode can be explained:

Photon Absorption: When photons (particles of light) with sufficient energy strike the semiconductor material of the BPW34, they are absorbed by the material. The energy from the absorbed photons causes electrons to move from the valence band to the conduction band, creating electron-hole pairs.

Generation of Electron-Hole Pairs: The absorbed photons create electron-hole pairs in the semiconductor material. Electrons are excited from the valence band to the conduction band, leaving behind positively charged holes in the valence band.

Flow of Current: The presence of electron-hole pairs results in the flow of electrical current through the BPW34. Electrons move towards the N-side of the photodiode (the anode), while the holes move towards the P-side (the cathode).

Amplification with Reverse Bias: To enhance the sensitivity and response of the photodiode, it is often operated under reverse bias conditions. This means that a reverse voltage is applied, making the anode more positive than the cathode. This reverse bias voltage creates an electric field that helps to accelerate the movement of charge carriers (electrons and holes) towards their respective terminals, thereby increasing the photodiode's response to incoming photons.

Current Output: The generated photocurrent, which is proportional to the intensity of the incident light, flows from the anode to the cathode. This current can be measured and amplified for various applications.

Application-Specific Uses: Depending on the application, the output current from the BPW34 photodiode can be further processed. For example, in light sensing applications, it may be converted into voltage and used to measure light intensity. In other cases, it can be used in conjunction with amplifiers and analog or digital circuits for specific functions.

In summary, the BPW34 photodiode converts incident light into electrical current due to the photovoltaic effect. By applying a reverse bias voltage, this current can be optimized for various applications, including light sensing, proximity detection, and other applications that require the measurement of light intensity or radiation levels.

NodeMCU : NodeMCU is an open-source firmware and development kit based on the ESP8266WiFi module. The ESP8266 is a low-cost, highly-integrated wireless microcontroller that gained significant popularity for its ability to provide Wi-Fi connectivity to various electronics projects.
The NodeMCU project aims to make it easier for developers and hobbyists to work with the ESP8266 module by providing an easy-to-use firmware and development environment.
Lua Scripting: NodeMCU originally provided a Lua-based scripting environment, allowing developers to write code directly on the module using the Lua programming language. This made it accessible to those who were not familiar with embedded programming.
Wi-Fi Connectivity: The main purpose of the NodeMCU firmware is to enable Wi-Fi connectivity for AI (Artificial Intelligence) applications. The module can connect to local Wi-Fi networks and communicate with other devices over the internet.
Arduino Compatibility: While the original NodeMCU firmware was based on Lua, there are also Arduino-compatible firmware options available for the ESP8266. This allows developers to program the module using the Arduino IDE, which is a popular platform for creating embedded projects.
GPIO Pins: The ESP8266 module has a set of General-Purpose Input/Output (GPIO) pins that allow you to interface with external components such as sensors, actuators, LEDs, and more.
Here's a general overview of how the NodeMCU v1.0 works:
Microcontroller and CPU: The NodeMCU v1.0 is centered around the ESP8266EX microcontroller, which features a 32-bit RISC processor. This processor executes instructions, handles tasks, and manages I/O operations.
Voltage Regulation: The board's operating voltage is 3.3V, regulated by an onboard voltage regulator. This ensures that the components receive a stable voltage level for reliable operation.
Digital and Analog I/O: The NodeMCU provides 11 digital I/O pins (D0 - D10) for interacting with the digital world. These pins can be used as inputs or outputs to interface with various devices. Additionally, the A0 pin serves as an analog input with a 10-bit ADC, allowing you to measure continuous voltage levels from sensors.

LCD DISPLAY : A 16x2 LCD (Liquid Crystal Display) is a common type of alphanumeric display module that can display two lines of text, with each line containing up to 16 characters. These displays are widely used in various electronics projects, devices, and applications for displaying information to users.
Here are some details about a typical 16x2 LCD module:
Display Size: The LCD screen has 2 lines, and each line can display up to 16 characters (including letters, numbers, symbols, and spaces).
Character Size: The standard character size is typically 5x8 pixels, allowing the display of variety of characters and symbols. Backlight: Many 16x2 LCD modules come with a backlight that can be controlled to improve visibility in different lighting conditions. The backlight can be white, blue, green, or other colors.
Communication Interface: 16x2 LCD modules usually use the Hitachi HD44780 or a compatible controller, which is commonly interfaced with microcontrollers using a parallel interface.
Contrast Control: Many modules allow you to adjust the contrast of the characters on the screen using a built-in potentiometer.
Controller Commands: The HD44780 controller supports a set of commands that can be sent from a microcontroller to control the display, cursor position, clearing the display, and more.

I2C CIRCUIT : The I2C (Inter-Integrated Circuit) interface module, often referred to as I2C module or I2C controller, is a communication peripheral commonly found in microcontrollers and other integrated circuits.
I2C is a synchronous, multi-master, multi-slave communication protocol that allows multiple devices to communicate with each other using just two wires: a data line (SDA) and a clock line (SCL)
Pin Description SDA (Serial Data Line): This is the bidirectional data line used for transmitting and receiving data between devices on the I2C bus. Both master and slave devices use this line to send and receive data.
SCL (Serial Clock Line): This is the clock line that synchronizes the data transmission between devices on the I2C bus. It is generated by the master device and is used to control the timing of data transmission.
VCC (Power Supply Voltage): This pin provides the power supply voltage for the I2C module and the devices connected to it. The voltage level depends on the specific requirements of the devices and the I2C standard being used (e.g., 3.3V or 5V).
GND (Ground): This pin is connected to the ground reference of the system. Overall, the I2C module simplifies the process of interfacing with an LCD by abstracting low-level control and communication details. It allows microcontrollers to easily display text, graphics, and other visual information on the LCD panel without needing to manage the intricacies of the LCD's hardware interface directly. Specific commands, data formats, and features supported by the I2C module will depend on the manufacturer, model, and design of the module itself. For accurate details, refer to the datasheet and technical documentation provided by the manufacture.

IV.SOFTWARE DECRIPTION:

NodeMCU is an open-source firmware and development kit based on the ESP8266 WiFi module. The ESP8266 is a low-cost, highly-integrated wireless microcontroller that gained significant popularity for its ability to provide Wi-Fi connectivity to various electronics projects.
The NodeMCU project aims to make it easier for developers and hobbyists to work with the ESP8266 module by providing an easy-to-use firmware and development environment. The NodeMCU v1.0 is a development board that utilizes the ESP8266 microcontroller module, allowing for Wi-Fi connectivity and versatile digital and analog input/output capabilities
How the NodeMCU v1.0 works:
Microcontroller and CPU: The NodeMCU v1.0 is centered around the ESP8266EX microcontroller, which features a 32-bit RISC processor. This processor executes instructions, handles tasks, and manages I/O operations.

Voltage Regulation: The board's operating voltage is 3.3V, regulated by an onboard voltage regulator. This ensures that the components receive a stable voltage level for reliable operation.
Digital and Analog I/O: The NodeMCU provides 11 digital I/O pins (D0 - D10) for interacting with the digital world. These pins can be used as inputs or outputs to interface with various devices. Additionally, the A0 pin serves as an analog input with a 10-bit ADC, allowing you to measure continuous voltage levels from sensors.
Wi-Fi Connectivity: One of the standout features of the NodeMCU is its Wi-Fi connectivity. The ESP8266 module supports a range of Wi-Fi modes, including Station mode for connecting to existing networks and SoftAP mode for creating its own access point. This enables the board to communicate over the internet and with other Wi-Fi-enabled devices.
Programming and Communication: To program the NodeMCU, you can use different Integrated Development Environments (IDEs) like the Arduino IDE or the NodeMCU firmware with Lua scripting. The USB-to-Serial chip (CH340G) facilitates the connection between your computer and the board, allowing you to upload code, monitor output, and debug.
GPIO and Communication Protocols : The General-Purpose Input/Output (GPIO) pins are versatile and can be configured for various communication protocols. PWM(pulse width modulation) allows you to modulate the duty cycle of digital signals, I2C lets you connect multiple devices with just a few wires, SPI (Serial peripheral interface) enables high-speed communication, and 1-Wire simplifies data exchange with sensors.

V. BLOCK DIAGRAM

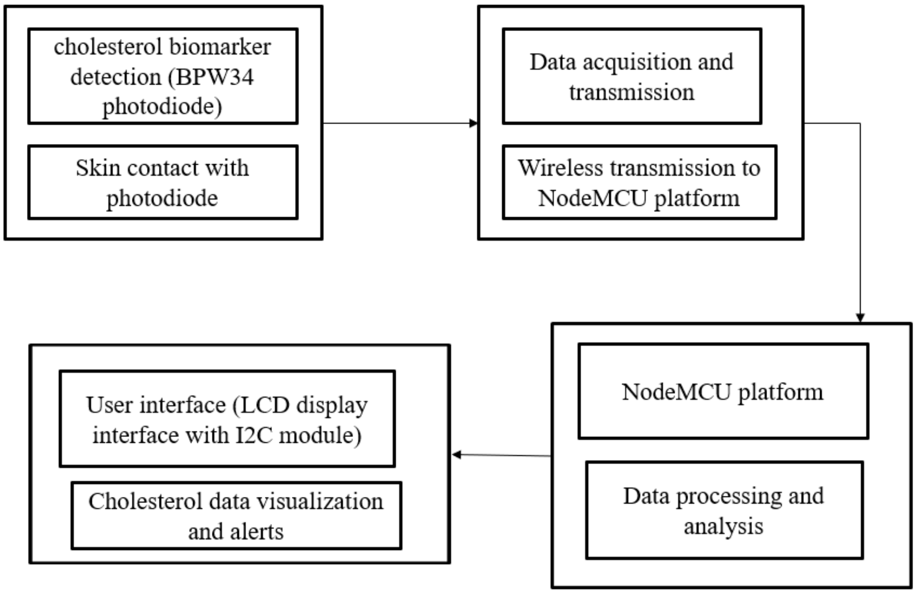

Fig no :1 Block diagram AI-driven development of non-invasive cholesterol monitoring system.

FLOWCHART

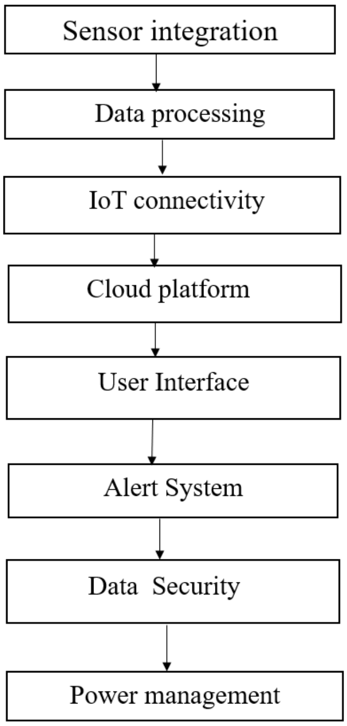

Fig no:2 Flowchart of AI-driven development of non-invasive cholesterol monitoring system.

VI DISCUSSION

EXISTING SYSTEM

While there were a number of new AI-driven advancements in non-invasive cholesterol monitoring devices, the industry was not controlled by a single, widely used system. I can, however, list the broad elements and capabilities that these kinds of systems usually include:

BPW34 Pin Photodiode Sensor: The core of the system is the BPW34 pin photodiode sensor, known for its effectiveness in non-invasive cholesterol monitoring. This sensor is integrated into the system to detect and analyze key biomarkers associated with cholesterol levels.

Wearable Device: The BPW34 sensor is incorporated into a discreet and user-friendly wearable device. This device can be worn on the skin, ensuring continuous monitoring without causing discomfort to the users.

Internet of Things (IoT) Connectivity: The wearable device is equipped with IoT connectivity capabilities, allowing it to transmit data securely to a cloud-based platform in real time. IoT ensures seamless data transfer and accessibility from anywhere in the world

Cloud-Based Data Platform: The cloud-based platform is the central hub for data storage and analysis. It employs advanced machine learning algorithms to process the data received from the wearable device.

Mobile Application and Web Interfaces Users can access their cholesterol data through a user-friendly mobile application or a web-based interface. These interfaces provide personalized insights into their cholesterol levels, trends, and actionable recommendations for lifestyle modifications.

Healthcare Professional Access: Healthcare professionals, such as doctors and clinicians, have secure access to the platform. They can remotely monitor patient health, receive alerts for critical changes, and formulate personalized treatment plans based on real-time data.

Key Advantages: The proposed system offers several advantages:

Non-Invasive Monitoring: By using the BPW34 sensor, the system eliminates the need for invasive blood tests, enhancing user compliance with cholesterol monitoring

Continuous Monitoring: Users benefit from continuous monitoring, enabling the early detection of cholesterol level fluctuations and empowering them to make proactive health decisions.

Data-Driven Insights: Advanced machine learning algorithms process data to provide realtime and accurate assessments of cholesterol levels, ensuring the reliability of health insights.

Remote Healthcare: Healthcare professionals can monitor patient health remotely, enabling timely interventions and personalized treatment plans.

User-Centric Approach: The mobile app and web interface provide a user-centric experience, giving individuals the tools to actively engage in their health management. In conclusion, the proposed Non-Invasive Cholesterol Monitoring System using IoT and the BPW34 sensor represents a pioneering solution to cholesterol management. By combining noninvasive sensing, IoT connectivity, machine learning, and user-centric interfaces, it aims to provide a convenient and effective means of monitoring cholesterol levels, ultimately contributing to better cardiovascular health and overall well-being.

VII.RESULTS

Non-invasive cholesterol monitoring systems with AI-driven advancements have shown encouraging results, but it's crucial to remember that precise findings might differ based on the technology, approach, and stage of development.
The following are some overarching patterns and possible outcomes connected to these systems:

Accuracy: Using information from non-invasive sensors, AI systems have proven to be able to estimate cholesterol levels with accuracy. Correlations between sensor data and conventional blood tests have been demonstrated in studies, suggesting the possibility of accurate cholesterol monitoring without intrusive procedures.

Real-time Monitoring: AI-enabled non-invasive cholesterol monitoring devices can provide users immediate feedback on their cholesterol levels, enabling them to keep a closer eye on their cardiovascular health. The capacity to monitor in real-time facilitates prompt intervention and lifestyle modifications for the purpose of efficiently managing cholesterol levels.

Personalized Insights: AI systems are capable of sifting through enormous databases to find specific patterns and trends in cholesterol levels. This makes it possible to generate individualized insights and suggestions based on each user's own health profile, allowing people to make knowledgeable decisions about their food and way of life.

Convenience and accessibility: By doing away with the necessity for uncomfortable venipuncture procedures and recurrent trips to medical institutions, non-invasive monitoring devices provide a handy substitute for conventional blood testing. This accessibility facilitates proactive treatment of cardiovascular health and increases adherence to cholesterol monitoring programs.

Early Detection and Prevention: AI-driven systems make it possible to continuously monitor cholesterol levels, which helps with the early detection of irregularities and cardiovascular disease risk factors. Then, early intervention techniques can be used to reduce these risks and stop the development of problems associated to the heart.

Research and Validation: The effectiveness and dependability of AI-driven non-invasive cholesterol monitoring systems are validated in large part through scientific investigations and clinical trials. The increasing amount of data that supports the use of these technologies in clinical practice and public health efforts is bolstered by research findings

Cholesterol type	Male (age 20 or older)	Female (age 20 or older)	Male or female (Anyone 19 or younger)
Total Cholesterol	125 – 200 mg/dL	125 – 200 mg/dL	Less the 170 mg/dL
HDL	40 mg/dL or hinger	50 mg/dL or hinger	More the 45 mg/dL
LDL	Less the 100 mg/dL	Less the 100 mg/dL	Less the 100 mg/dL

Fig no:3 Normal range of standard cholesterol level

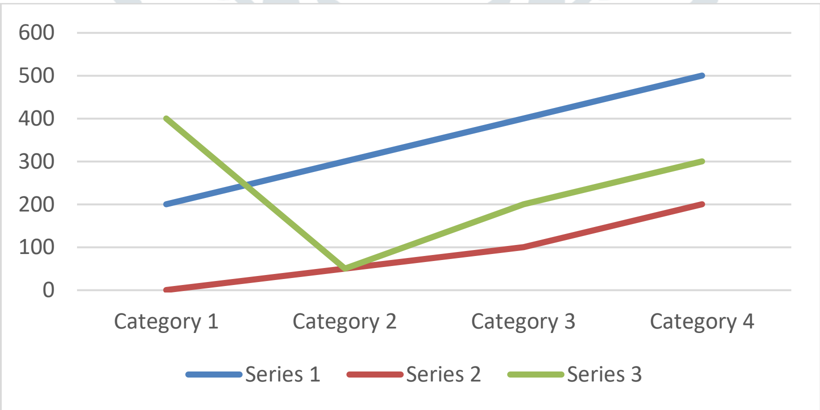

Fig no:4 Graphical representation of normal cholesterol values.

Subject	Invasive measurement value in mg/dl	Non-Invasive measurement value in mg/dl	Non-Invasive measurement value accuracy in percentage
A	150	140	75%
B	180	175	73%
C	143	131	69%
D	210	180	60%
E	190	181	81%
F	178	164	79%
G	236	220	76%
H	183	174	80%
I	246	236	75%
J	296	283	75%
K	315	296	80%

Fig no:5 Measurement of Invasive and Non-invasive cholesterol monitoring system

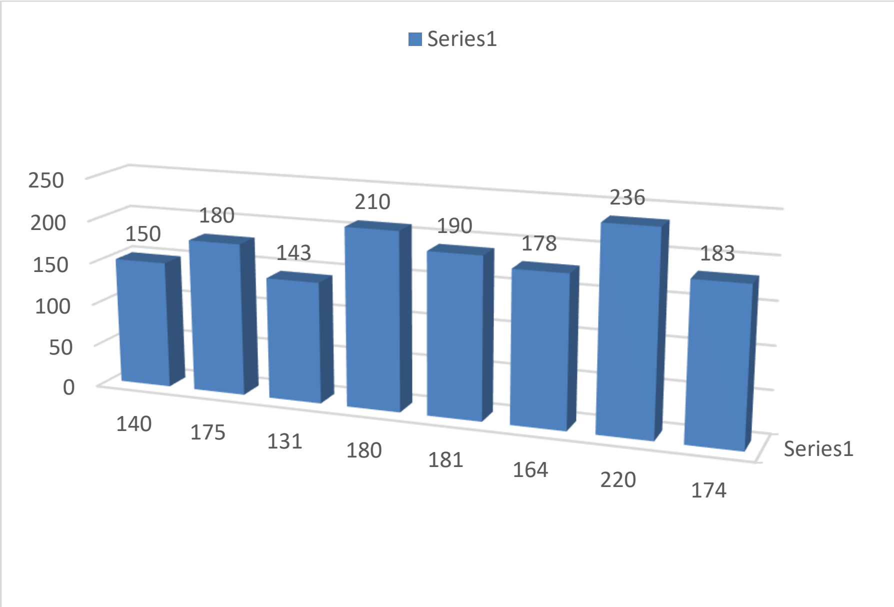

Fig no:6 Graphical representation of above cholesterol ranges listed in the model

VIII.CONCLUSION

The results of the non-invasive cholesterol monitoring system's AI-driven development demonstrate the exciting possibilities of fusing AI with medical technology. Significant progress has been achieved in improving patient outcomes and healthcare accessibility because to this invention. The technology is a significant development in preventive medicine since it can simply and reliably monitor cholesterol levels without requiring intrusive treatments. Furthermore, real-time analysis and individualized insights are made possible by the integration of AI algorithms, which promotes proactive treatment of cardiovascular health. It is projected that these AI-driven solutions will become more and more important in transforming healthcare delivery and enabling people to take proactive steps toward improved health as research and development in this area continue.

IX.ACKNOWLEDGMENT

The authors are very thankful to the principal ,Dr. Ravi Kumar, Dr.R.V.Shalini, Mrs.Abiramee.R for providing the proper knowledge about the research facilities.

X.REFERENCES

1. J. Luo, H. Yang, and B.L. Song, “Mechanisms and regulation of cholesterol homeostasis,” Nat. Rev. Mol. Cell Biol., vol. 21, pp. 225-245, 2020.
2. W.Y. Ho, H. Hartmann, and S.C. Ling, “Central nervous system cholesterol metabolism in health and disease,” IUBMB Life, vol. 74, pp. 826-841, 2022.

3. E. Jung, S.Y. Kong, Y.S. Ro, H.H. Ryu, and S.D. Shin, "Serum Cholesterol Levels and Risk of Cardiovascular Death: A Systematic Review and a Dose-Response Meta Analysis of Prospective Cohort Studies," Int. J. Environ. Res. Public Health, vol. 19, p. 8272, 2022.
4. L. Liu, J. Wang, J. Wang, J. Wu, S. Wu, and L. Xie, "Colorimetric Detection of Cholesterol Based on the Peroxidase-Like Activity of Metal-Organic Framework MIL101 (Cr)," Chemistry Select, vol. 6, pp. 7143-7149, 2021.
5. L. Rastogi, K. Dash, and R.B. Sashidhar, "Selective and sensitive detection of cholesterol using intrinsic peroxidase-like activity of biogenic palladium nanoparticles," Curr Res. Biotechnol., vol. 3, pp. 42-48, 2021.
6. M. Briones, C. Busó -Rogero, S. Catalán-Gómez, T. García-Mendiola, F. Pariente, A. Redondo-Cubero, and M.E. Lorenzo, "ZnO nanowire-based fluorometric enzymatic assays for lactate and cholesterol," Microchim. Acta, vol. 187, p. 180, 2020.
7. K. Murakami, A. Harada, R. Toh, T. Kubo, K. Miwa, J. Kim, M. Kiriyama, T. Iino, Y. Nishikawa, S. Uno, et al., "Fully automated immunoassay for cholesterol uptake capacity to assess high-density lipoprotein function and cardiovascular disease risk," Sci. Rep., vol. 13, p. 1899, 2023.
8. V. Narwal, R. Deswal, B. Batra, V. Kalra, R. Hooda, M. Sharma, and J.S. Rana, "Cholesterol biosensors: A review," Steroids, vol. 143, pp. 6-17, 2019.
9. B. Batra, V. Narwal, J. Ahlawat, and M. Sharma, "An amperometric cholesterol biosensor based on immobilization of cholesterol oxidase onto titanium dioxide nanoparticles," Sens. Int., vol. 2, p. 100111, 2021
10. V. Hooda and A. Gahlaut, "Amperometric cholesterol determination using HRP incorporated carbon paste electrode," Biosci. Biotechnol. Res. Asia, vol. 17, pp. 53-64, 2020.
11. A. Kumari, R. Rajeev, L. Benny, Y.N. Sudhakar, A. Varghese, and G. Hegde, "Recent advances in carbon nanotubes-based biocatalysts and their applications," Adv. Colloid Interface Sci., vol. 297, p. 102542, 2021.
12. Q. Yan, R. Wu, H. Chen, H. Wang, and W. Nan, "Highly sensitive cholesterol biosensor based on electron mediator thionine and cubic-shaped Cu2O nanomaterials," Microchem. J., vol. 185, p. 108201, 2023.
13. V.S. Haritha, S.S. Kumar, R.B. Rakhi, "Amperometric cholesterol biosensor based on cholesterol oxidase and Pt-Au/MWNTs modified glassy carbon electrode," Mater.Proc., vol. 50, pp. 34-39, 2022.
14. E. Cevik, A. Cerit, N. Gazel, and H.B. Yildiz, "Construction of an amperometric cholesterol biosensor based on DTP (aryl) aniline conducting polymer bound cholesterol oxidase," Electroanalysis, vol. 30, pp. 2445-2453, 2018.
15. D.P. Silva, C.M. Miyazaki, D.B. Mascagni, and M. Ferreira, "Layer-by-layer films of gold nanoparticles and carbon nanotubes for improved amperometric detection of cholesterol," J. Nanosci. Nanotechnol., vol. 19, pp. 5483-5488, 2019.
16. M. Alagappan, S. Immanuel, R. Sivasubramanian, and A. Kandaswamy, "Development of cholesterol biosensor using Au nanoparticles decorated f-MWCNT covered with polypyrrole network," Arab. J. Chem., vol. 13, pp. 2001-2010, 2020.
17. T.T.N. Anh, L.T. Tam, V. Van Thu, A.T. Le, V.P. Hung, and P.D. Tam, "Nano-rods structured cerium oxide platform for cholesterol biosensor," J. Inorg. Organomet. Polym. Mater., vol. 30, pp. 3886-3893, 2020.
18. C. Kaçar, P.E. Erden, B. Dalkiran, E.K. Inal, and E. Kiliç, "Amperometric biogenic amine biosensors based on Prussian blue, indium tin oxide nanoparticles and diamine oxidase– or monoamine oxidase–modified electrodes," Anal. Bioanal. Chem., vol. 412, pp. 1933-1946, 2020.
19. N. Stasyuk, O. Demkiv, G. Gayda, A. Zakalskiy, H. Klepach, N. Bisko, M. Gonchar, and M. Nisnevitch, "Highly porous 3D gold enhances sensitivity of amperometric biosensors based on oxidases and CuCe nanoparticles," Biosensors, vol. 12, p. 472, 2022.
20. O. Demkiv, G. Gayda, N. Stasyuk, O. Brahinetz, M. Gonchar, and M. Nisnevitch, "Nanomaterials as redox mediators in laccase-based amperometric biosensors for catechol assay," Biosensors, vol. 12, p. 741, 2022.
21. W. Sibirnyj, D. Grabek-Lejko, and M. Gonchar, "The use of enzymes for ethanol, methanol and formaldehyde determination in food products," J. Microbiol. Biotechnol. Food Sci., 2021, pp. 393–397.
22. J. Liu, H. Cheng, H. Xie, G. Luo, Y. Niu, S. Zhang, and W. Sun, "Platinum nanoparticles decorating a biomass porous carbon nanocomposite-modified electrode for the electrocatalytic sensing of luteolin and application," RSC Adv., vol. 9, pp. 33607–33616, 2019.
23. R. Doaga, T. McCormac, and E. Dempsey, "Functionalized magnetic nanomaterials for electrochemical biosensing of cholesterol and cholesteryl palmitate," Microchim. Acta, vol. 187, 2020, pp. 225.
24. K. S. Eom, Y. J. Lee, H. W. Seo, J. Y. Kang, J. S. Shim, and S. H. Lee, "Sensitive and non-invasive cholesterol determination in saliva via optimization of enzyme loading and platinum nano-cluster composition," Analyst, vol. 145, pp. 908–916, 2020.
25. X. R. Li, J. J. Xu, and H. Y. Chen, "Potassium-doped carbon nanotubes toward the direct electrochemistry of cholesterol oxidase and its application in highly sensitive cholesterol biosensor," Electrochim. Acta, vol. 56, pp. 9378–9385, 2011.
26. N. Thakur, D. Gupta, D. Mandal, and T. C. Nagaiah, "Ultrasensitive electrochemical biosensors for dopamine and cholesterol: recent advances, challenges and strategies," Chem. Commun., vol. 57, p. 13084, 2021.
27. N. Thakur, D. Mandal, and T. C. Nagaiah, "A novel NiVP /Pi-based flexible sensor for direct electrochemical ultrasensitive detection of cholesterol," Chem. Commun., vol. 58, p. 2706, 2022.
28. Y. Ning, F. Lu, Y. Liu, S. Yang, F. Wang, X. Ji, and Z. He, "Glow-type chemiluminescent hydrogels for point-of-care testing (POCT) of cholesterol," Analyst, vol. 146, p. 4775, 2021.
29. N. M. Galdino, V. S. Souza, F. S. Rodembusch, R. Bussamara, and J. D. Scholten, "Biosensors Based on Graphene Oxide Functionalized with Benzothiadiazole-Derived Ligands for the Detection of Cholesterol," ACS Appl. Bio Mater., vol. 6, p. 2651, 2023.
30. N. Tiwari, S. Chatterjee, K. Kaswan, J. Chung, K. Fan, and Z. Lin, "Recent advancements in sampling, power management strategies and development in applications for non-invasive wearable electrochemical sensors," J. Electroanalytical Chem., vol. 907, p. 116064, 2022.