Coronary Heart Disease Risk Prediction Using Combined Expert System and Deep Learning Methods

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Abstract

Coronary Heart Disease (CHD) encompasses several conditions such as chest pain, heart attack, and cardiac arrest. It is a major form of cardiovascular disease and a leading cause of death. CHD has become increasingly common and occurs when plaque builds up along the inner walls of the heart's arteries, restricting normal blood flow. This study presents a web-based expert system designed to estimate an individual's likelihood of developing CHD based on key risk factors such as cholesterol level, diabetes status, and smoking habits. The system integrates two artificial intelligence techniques: a rule-based expert system and a deep learning model. The rule-based component is implemented using CLIPS, while the deep learning model is developed using the TensorFlow framework to train and evaluate the dataset. The primary objective of this project is to assess the risk of heart disease early, enabling individuals to take preventive measures before serious complications occur.

Key words: *Coronary, Heart Disease, Prediction, Expert System and Deep Learning,*

1.0 INTRODUCTION

In recent times, health problems have become increasingly prevalent, largely due to lifestyle changes and limited awareness of proper healthcare practices. Numerous illnesses can lead to severe complications or even death, making it beneficial to identify the likelihood of such diseases early (Amosa et al., 2017). As health challenges continue to rise, the medical field has likewise expanded, adopting advanced technologies to enhance healthcare delivery.

Artificial Intelligence (AI) refers to intelligent systems capable of performing tasks in ways that resemble human reasoning. An AI system observes its environment and makes decisions that increase the likelihood of achieving successful outcomes (Wikipedia Review, 2025). In medicine, AI represents a growing research field that integrates advanced computational and representational techniques with expert medical knowledge to create tools that enhance patient care. AI has evolved to the point where it can meaningfully support both healthcare professionals and patients in diagnosis, treatment, and disease management. AI-based systems may rely on rule-based logic or machine-learning algorithms. Through these approaches, AI has been used to predict, diagnose, and support treatment for diseases affecting various organs such as the heart, lungs, and kidneys, including conditions like cancer, kidney stones, and cardiovascular events.

Coronary Heart Disease (CHD) also referred to as Ischemic Heart Disease (IHD) or Coronary Artery Disease (CAD) is a cluster of conditions that includes stable angina, unstable angina, myocardial infarction, and sudden cardiac death. It is the most common form of cardiovascular disease. CHD occurs when plaque accumulates in the coronary arteries, restricting blood flow and potentially leading to heart attacks. Major risk factors for CHD include elevated LDL cholesterol, low HDL cholesterol, hypertension, family history, diabetes, smoking, obesity, post-menopausal status in women, and age above 45 in men (Amosa et al., 2017)

1.2 Statement of Research Problem

According to WHO/UNICEF, Coronary Heart Disease (CHD) also known as Ischemic Heart Disease (IHD) or Coronary Artery Disease (CAD) refers to a group of conditions that include stable angina, unstable angina, myocardial infarction, and sudden cardiac death. It is the most common form of cardiovascular disease and results from the accumulation of plaque within the coronary arteries, which can impair blood flow and potentially trigger a heart attack.

Major risk factors associated with CHD include elevated LDL cholesterol, reduced HDL cholesterol, high blood pressure, a family history of heart disease, diabetes, smoking, obesity, menopause in women, and age above 45 in men.

Deep learning approaches have shown remarkable success in medical prediction tasks by automatically extracting complex patterns from patient data. However, despite their high accuracy, these models are often criticized for their limited transparency, lack of interpretability, and minimal alignment with medically validated expert knowledge. These shortcomings contribute to a lack of trust among healthcare professionals, slowing the adoption of AI-based diagnostic tools.

Furthermore, many existing CHD prediction models are trained on datasets originating from non-local populations, which may not accurately capture regional variations in genetics, lifestyle, environment, and health behavior. Consequently, their predictive performance may be inconsistent or unreliable when applied to diverse or underrepresented populations.

These challenges emphasize a significant gap: the need for a reliable, interpretable, and adaptable CHD prediction system that integrates the structured knowledge of expert systems with the high predictive power of deep learning. Without such a combined framework, early detection efforts will remain inadequate, leading to preventable complications, higher healthcare costs, and increased mortality

1.3 Objective of the Study

The specific objectives of this study are;

1) To design an intelligent system for diagnosis of Coronary Heart Disease in patient.
2) To implement the system where the user can interact with the system website anywhere, anytime to manage or diagnose various Coronary Heart Disease in patient.
3) To evaluate the performance of the developed system in managing this disease.

2.0 LITERATURE REVIEW

2.1 Artificial Intelligence

Intelligence refers to the capacity to learn, understand, solve problems, and make informed decisions. Artificial Intelligence (AI), on the other hand, involves the demonstration of intelligence by machines, with its primary aim being to enable machines to perform tasks that would normally require human intelligence. Core challenges in AI include reasoning, knowledge representation, planning, learning, communication, perception, and the ability to manipulate and interact with objects. By the early 1990s, AI had made notable progress in practical applications despite earlier setbacks, finding success in areas such as logistics, data mining, and medical diagnosis. The resurgence of AI's popularity during this period was largely driven by the commercial adoption of expert systems (Russell and Norvig, 2018).

Artificial Intelligence is a branch of computer science dedicated to creating systems capable of exhibiting behaviors considered intelligent by human standards. It involves studying human cognitive processes and replicating these processes through computational models. Expert Systems (ES), one of the major subfields of AI, emerged in the mid-1960s within the AI research community. As described by Darlington (2018), an expert system is a computer program designed to emulate human expertise by applying inference techniques to a specific domain of knowledge. Similarly, Turban, Aronson, and Liang (2015) define an expert system as an intelligent program that reproduces the problem-solving abilities of human experts.

2.1.2 Expert System

An expert system is a type of Artificial Intelligence (AI) program designed to replicate the knowledge and analytical abilities of one or more human specialists. Traditional expert systems are typically developed for highly specific domains with clearly defined expertise, making their performance heavily reliant on selecting the right expert during system development. While many systems rely on a single expert, more complex applications or those involving broader or less-defined knowledge domains may require input from multiple experts (Negnevitsky, 2017).

The rapid expansion of Internet technologies has also significantly contributed to the advancement of expert systems (Li, Fu, and Duan, 2017). Early expert systems operated as standalone applications on mainframes, AI workstations, or personal computers. Over time, these systems transitioned into web-based platforms, transforming information technology, enabling distributed solutions, and greatly enhancing the capabilities of traditional expert systems.

A knowledge-based or expert system is essentially a decision-making and problem-solving tool that operates using domain-specific knowledge and logical rules derived from the experience of human specialists (Armstrong, 2002). Expert systems, a major branch of AI developed in the mid-1960s, are generally defined as intelligent computer programs that apply knowledge and inference techniques to address problems that typically require substantial human expertise. These systems are capable of solving complex tasks by leveraging specialized knowledge and reasoning procedures. Although expert systems vary in structure depending on the underlying technologies, they all trace their foundation to early systems such as MYCIN (Wu, 2008).

In basic terms, an expert system typically consists of three core components (Negnevitsky, 2017):

a. **Knowledge Base**: This contains the specialized information and expertise related to the specific domain.

b. **Inference Engine**: This component processes and applies the stored knowledge to draw conclusions or make decisions.

c. **User Interface:** This allows non-experts to interact with the system and access the embedded expert knowledge.

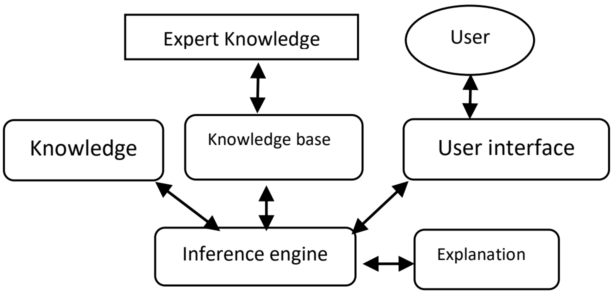


Figure 1: Architecture of simple expert system.

The structure of a basic expert system is shown in figure 1. The knowledge base contains all essential information, including data, rules, cases, and the relationships that the system relies on. It may also integrate the expertise of several human specialists. Within the knowledge base, rules function as conditional statements that connect specific conditions to corresponding actions or conclusions. Another method of representing knowledge is through frames, which associate an object or concept with various attributes, facts, or values.

A frame-based representation works particularly well with object-oriented programming principles. Expert systems that rely on frames for organizing and storing knowledge are therefore known as frame-based expert systems. The inference engine is responsible for searching through the knowledge base to identify relevant information and relationships, enabling it to deliver conclusions, predictions, or recommendations similar to those of a human expert. To do this effectively, the inference engine must correctly identify and combine the appropriate facts, interpretations, and rules.

The explanation facility helps users understand the reasoning process behind the system's conclusions. Meanwhile, the knowledge acquisition facility provides an efficient way to capture, structure, and store all elements of the knowledge base. In many cases, specialized user-interface tools are employed for building, modifying, and interacting with expert systems. The main purpose of the user interface is to make the expert system easy to use for developers, end-users, and administrators.

2.1.3 Coronary Heart Disease

Coronary heart disease is a life-threatening condition that often develops without visible external symptoms. Early prediction of CHD, or identifying the likelihood of its occurrence, can significantly improve prevention efforts and support timely heart-related care. Numerous AI-based studies have explored heart disease detection and prediction using various machine learning techniques and rule-based approaches (Amosa et al., 2017).

For instance, heart disease has been classified and predicted using Support Vector Machines (SVM) and Artificial Neural Networks (ANN) based on 13 attributes obtained from the UCI dataset. The results indicate that the SVM model provides higher accuracy compared to the ANN model (Amosa et al., 2017). Another study developed an Expert System for the Diagnosis and Management of Kidney Diseases, offering a general-purpose tool capable of identifying multiple renal disorders while delivering rapid and accurate diagnostic support.

Similarly, an expert system was created for diagnosing and managing coronary heart disease. This system is easy to use and accessible to individuals regardless of their location. It offers support for patients below five years of age and serves as a preliminary assistance tool for individuals requiring urgent help when a medical specialist is not immediately available (Thomas and Princy, 2016)

Rule-Based System and their Applications

One of the most widely used types of expert systems today is the rule-based system, also known as a production rule system. In this approach, a rule is a conditional statement that connects a specific condition to a corresponding action or outcome. Expert systems that utilize rules to represent and organize knowledge are referred to as Rule-Based Systems. The primary distinction among expert systems lies in the methods used to capture and store knowledge within the knowledge base.

A rule-based expert system is composed of IF–THEN rules, a set of facts, and an interpreter that manages the application of these rules to the given facts. Each IF–THEN rule typically follows the format: "IF X is A THEN Y is B," where the "IF" portion, X is A, is called the antecedent or premise, and the "THEN" portion, Y is B, is called the consequent or conclusion.

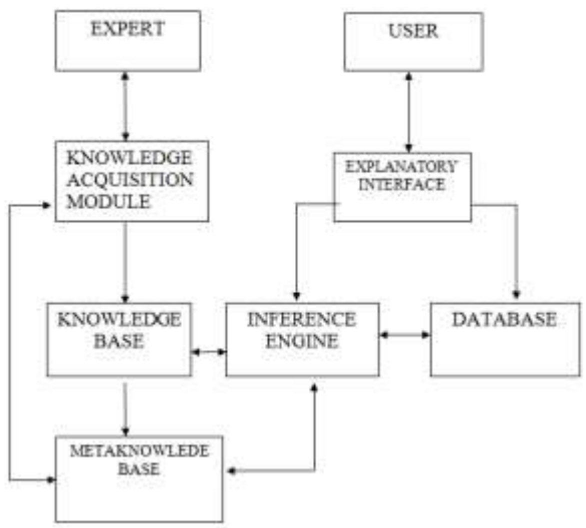


Figure 2: Structure of an expert system

Figure 2 illustrates the structure of a typical expert system and its key components. Expert systems usually operate on interactive computers, such as personal computers (PCs) or workstations. The Knowledge Acquisition Module allows the system to update the knowledge base (KB) or meta-knowledge base through interactions with human experts. The system also incorporates appropriate machine learning algorithms, such as Socratic learning or example-based learning, alongside an inference engine. Connected to the inference engine is the knowledge base, which stores inference rules and relevant factual information pertaining to a specific domain.

Expert System and Medical Field

Several expert systems have been developed for applications in the medical field. Some notable examples include:

MYCIN: Developed by Shortliffe at Stanford University, MYCIN was one of the earliest well-known medical expert systems (Buchanan & Shortliffe, 1984). It was designed to diagnose and recommend treatments for bacterial infections, particularly for doctors who were not specialists in antimicrobial therapy. The system uses a backward-chaining inference procedure to support decision-making in prescribing antibiotics for blood infections.

PERFEX: PERFEX is a medical expert system created to assist clinicians in evaluating perfusion studies (Ezquerra et al., 1992). Its knowledge base, central to the system, contains over 250 rules derived from the expertise of clinicians and researchers at Emory University Hospital.

INTERNIST-I: Developed at the University of Pittsburgh in 1974, INTERNIST-I is a rule-based expert system designed for diagnosing complex problems in general internal medicine (Kumar et al., 2009).

ONCOCIN: ONCOCIN is a rule-based medical expert system for oncology protocol management, developed at Stanford University (Wiederhold et al., 2001). It assists physicians in managing cancer patients undergoing chemotherapy by providing treatment recommendations.

Dxplain: Dxplain is a decision support system that generates a ranked list of possible diagnoses based on a set of clinical findings, including signs, symptoms, and laboratory data, which may explain the patient's clinical manifestations (Elhanan et al., 1996).

PUFF: PUFF is an expert system for interpreting pulmonary function tests in patients with lung disease. It is considered one of the first AI systems to be applied in routine clinical practice.

3.0 METHODOLOGY

After defining the software requirements, the next step involved gathering relevant information on the subject. This information was collected from various sources, including:

a) Observation

b) Research

c) Browsing method

The system modeling was performed using UML diagrams. jQuery was employed for general programming tasks within the application, while Hypertext Preprocessor (PHP) handled the server-side operations, including data retrieval and processing. MySQL was used as the database server to manage and store application data.

During the system analysis phase, the operation of the existing system was thoroughly examined. All relevant information about how the current system functions was gathered and analyzed. The strengths and weaknesses of the existing system were clearly identified, which helped in defining the system requirements and objectives.

3.2 System Model

In this study, UML diagrams were utilized to represent the system. The activity diagram illustrates the flow of activities within the system, as shown in figure 3, while the use case diagram depicts the system's structure by showing its classes, attributes, operations, and the relationships among objects, as presented in figure 4.

Figure 3: System activity diagram

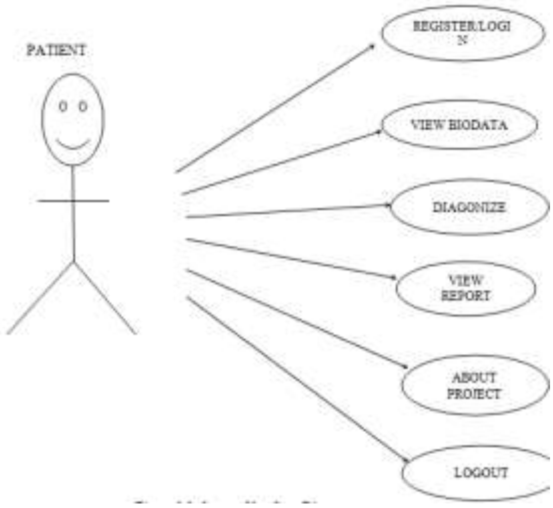
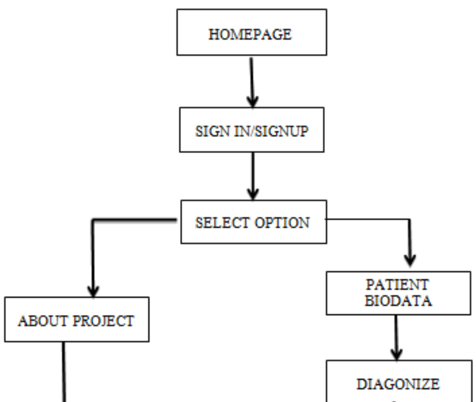


Figure 4: System Use Case Diagram

3.3 Flow Chart of the New System

Figure 5 illustrates the process by which a patient can be diagnosed. The system presents a series of questions related to coronary heart disease for the user to answer. The user selects a response from the available options (Yes/No) and clicks Submit. Based on the user's input, the system retrieves relevant information from the Fact Database and displays the diagnostic result as shown in figure 6.



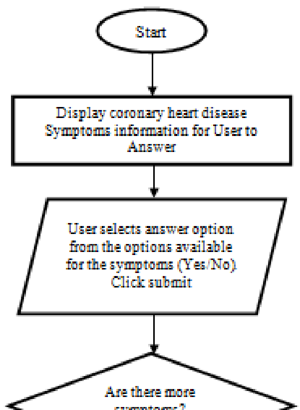


Figure 5: Flow chart of the Coronary Heart Disease Diagnosis System

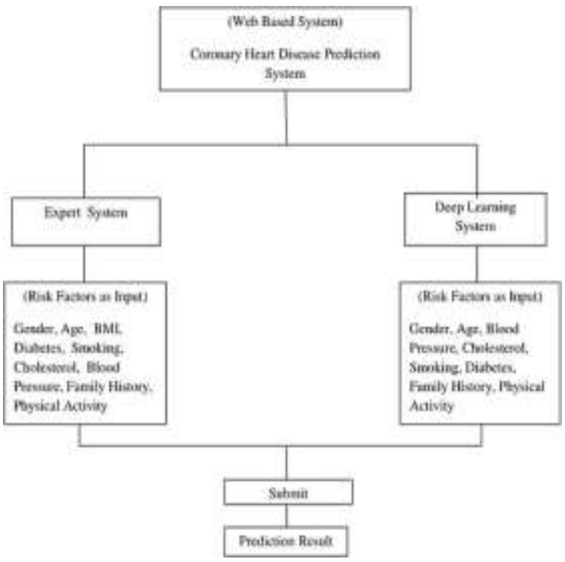


Figure 6: Block Diagram of the System

4.0 RESULT AND DISCUSSION

4.1 Introduction

A web-based system has been developed that incorporates two effective AI methods to predict an individual's likelihood of developing Coronary Heart Disease (CHD). The first method is a rule-based expert system, while the second employs a deep learning approach. Both systems take into account key factors such as gender, age, cholesterol, blood pressure, diabetes, smoking, family history, and physical activity for prediction.

The expert system additionally considers Body Mass Index (BMI), which reflects body weight and obesity. It generates predictions based on predefined rules, with a total of 18 rules created using CLIPS. In contrast, the deep learning system predicts outcomes by learning patterns from the training and testing of the provided datasets.

4.2 System Evaluation and Testing

During the preliminary evaluation of the expert system, several classical test cases were used, and the system's results were found to be consistent and accurate when compared with those of human experts by 4.4% resulted in an overall accuracy of 90%, indicating a notable improvement, particularly for a condition that affects a large segment of the population.

The Coronary Heart Disease Prediction System is a web-based application developed using CLIPS. It integrates two AI approaches: a rule-based expert system and a deep learning system to predict the likelihood of developing CHD. Users are required to log in or sign up to access the system, providing their personal details for assessment. Once authenticated, any user can utilize the system to check their CHD risk, as illustrated in Figures 7 and 8.

4.3 Report on Coronary Heart Disease Prediction System

Figure 7: New Patient Registration Page

Figure 8, shown below, illustrates how patients interact with the expert system's diagnostic engine for a series of questions related to Coronary Heart Disease (CHD). The system presents a sequence of questions and generates a conclusion based on the user's responses.

Fig 8: Coronary Heart Disease (CHD) Diagnoses

After the user answers the questions, the inference engine gathers sufficient information to determine whether the patient has Coronary Heart Disease (CHD) and to identify the specific type of CHD, as illustrated in Figure 9.

Figure 9: Diagnosis Report Page (Output)

5.0 CONCLUSION

The system, a web-based expert system for the diagnosis and management of Coronary Heart Disease (CHD), has been designed and implemented to assist patients, particularly those over 40 years of age, who require regular medical attention. The system reviews various causes of CHD, facilitates early diagnosis, and supports more effective treatment. Additionally, it provides temporary assistance to individuals who need immediate guidance when a medical expert is not readily available.

Furthermore, the system has been carefully designed to be user-friendly and accessible to anyone, regardless of their location. Users can interact with the website at any time and from anywhere to diagnose or manage various types of Coronary Heart Disease (CHD) based on their input. The results generated by the system have been validated with domain experts using relevant datasets. The knowledge is represented through IF-THEN rules and reasoning is performed using forward chaining. This expert system requires minimal training to use and features a simple, intuitive, and attractive interface.

6.0 RECOMMENDATIONS

This paper recommends that teaching hospitals, as well as public and private healthcare institutions, implement web-based expert systems to provide temporary support for individuals requiring immediate assistance when a human expert is unavailable due to time or location constraints.

For the system to operate effectively, users should possess basic computer literacy, and a reliable power backup such as an Uninterruptible Power Supply (UPS), solar power, or a standby generator should be available to ensure uninterrupted access during power outages

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