UTILIZING FUZZY EXPERT SYSTEM TO AID IN DIAGNOSING HEART DISEASES AT SABRATA HOSPITAL, LIBYA

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ABSTRACT

Heart disease remains a leading global health challenge, particularly in resource-limited regions like Sabrata, where timely and accurate diagnosis is often hindered by limited access to skilled cardiologists and advanced diagnostic equipment. This study presents the development and evaluation of a fuzzy expert system tailored to aid healthcare providers at Sabrata Hospital in diagnosing heart conditions effectively. By leveraging fuzzy logic, the system addresses the inherent uncertainties in medical data, such as vague symptom descriptions and incomplete records, to deliver accurate diagnostic predictions.

The system integrates inputs like patient symptoms, medical history, and diagnostic test results, converting them into fuzzy values for analysis. Through fuzzification, inference, and defuzzification processes, the system generates crisp outputs to support clinical decision-making. Tools like Python, HTML, CSS, ECG, echocardiography, and angiography are utilized to implement and validate the system.

Evaluation of the fuzzy expert system demonstrated enhanced diagnostic precision and sensitivity compared to conventional methods, reducing errors and expediting decision-making in complex cases. The findings underscore the potential of fuzzy expert systems in improving healthcare outcomes in underserved areas by offering cost-effective, reliable diagnostic solutions. Future research is recommended to incorporate machine-learning techniques to further refine and expand the system's capabilities.

Keywords: - *Fuzzy Expert System, Heart Disease, Fuzzification, Defuzzification, and Medical Data Uncertainty*

1. Introduction

Heart disease is still a health issue globally. Poses serious challenges, for healthcare systems in areas with limited resources. Early detection and precise diagnosis are crucial, for lowering mortality rates and enhancing patient outcomes. However, the standard diagnostic techniques often require knowledge and specific data that may not always be easily accessible. Interpreting symptoms and medical history while considering test results can lead to challenges, in making precise diagnoses at hospitals like Sabra Hospital due, to the nature of healthcare data analysis.

Facing these obstacles has led to increased interest, in combining intelligence (AI) and expert systems for diagnosis purposes. Expert systems mimic human decision-making skills. Offer support to healthcare providers by examining intricate data and suggesting diagnostic solutions. Fuzzy logic stands out in diagnosis due, to its capability to handle uncertainties and imprecise information often encountered when assessing symptoms.

The goal of this study is to create an expert system for diagnosing heart conditions at Sabrata Hospital using fuzzy logic techniques. The diagnosis process enables the system to manage uncertain patient symptoms and medical information effectively This tool will offer healthcare providers a dependable resource to enhance diagnostic precision reduce errors, in diagnosis facilitate decision making in challenging cases and ultimately boost the quality of healthcare services provided within the hospital's medical departments.

The study does not just look at the side of building a system. Also highlights how it can be used practically in real healthcare settings. The aim of this investigation is to show that employing an expert system could be beneficial, in diagnosing heart diseases and offering a cost effective option to assist healthcare workers in places with limited resources such, as Sabrata Hospital.

2. Research Problem:

Heart conditions continue to be a factor, in mortality rates with timely detection playing a key role in successful interventions and averting serious consequences. The Sabrata Hospital system faces challenges due to a shortage of heart doctors and modern diagnostic equipment. Traditional diagnostic approaches demand knowledge and are often time intensive resulting in delays, in detecting heart ailments. Understanding symptoms and medical information can be challenging due, to uncertainties and vagueness, in some cases that are complex or unclear; this often hinders accurate conclusions from being drawn.

Healthcare professionals require a tool that can effectively analyze data and offer precise diagnostic predictions promptly to meet urgent needs, in the medical field. Developers face the challenge of designing a system of navigating the uncertainties in medical information like vague symptom descriptions or incomplete medical records. Conventional binary logic systems may encounter difficulties in offering diagnoses under these circumstances. Therefore, necessitate a more adaptable strategy, for making medical decisions.

This study tackles the issue by suggesting the creation of an expert system for diagnosing heart disease at Sabra Hospital. It is an effective way compared to the usual procedure which is particularly effective for dealing with unclear or uncertain information and can help imitate human thinking in intricate scenarios The primary objective is to connect the expertise available in medicine with the requirement, for precise and timely diagnoses Through incorporating fuzzy logic into the expert system this investigation endeavors to enhance the diagnosis process and lift up healthcare services at Sabrata Hospital

3. Research Objectives:

The main goal of this study is to create a fuzzy expert system to support healthcare providers, at Sabrata Hospital in identifying heart conditions effectively using fuzzy logic techniques to manage data uncertainties and inaccuracies commonly seen in patient information records.

3.1. Creating an expert system to diagnose heart disease

The initial goal is to create and put into action an expert system that relies on symptoms, medical background information and results of diagnostic tests to aid healthcare practitioners in identifying heart conditions. This task will require gathering knowledge from professionals and developing sets and guidelines to simulate the diagnostic procedure.

3.2. Assessing the precision and efficiency of the expert system

After its creation phase was completed, the system underwent testing, with data to evaluate its precision in comparison to conventional diagnostic techniques in terms of accuracy and sensitivity levels as well, as specificity measures. The primary goal of this assessment was to gauge the systems capability in accurately detecting instances of heart disease and distinguishing them from non-heart disease cases.

3.3. In order to enhance decision making, in healthcare and lessen errors in diagnosis

The ultimate goal is to incorporate the expert system into the healthcare environment, at Sabra Hospital and evaluate its influence, on decision-making processes. The aim is for the system to minimize inaccuracies by delivering prompt forecasts, which would improve patient results and aid the medical personnel.

4. Research Questions

A fuzzy expert system, for diagnosing heart disease is being developed at Sabrata Hospital to tackle issues concerning the effectiveness and usability of such a system in healthcare settings." In order to steer this investigation, in the direction “specific questions have been crafted to delve into the core features of the systems operations," influence," and effectiveness.

How precise is the fuzzy expert system when it comes to detecting heart disease in comparison, to techniques?

This question seeks to assess how well the system can diagnose accurately and determine its dependability in comparison, to the methods employed by healthcare professionals.

How well does the fuzzy expert system manage imprecise information?

When dealing with patient symptoms and test outcomes on hand the inquiry delves into how the system can handle incomplete or ambiguous data and still deliver valuable diagnostic conclusions.

What effects does the fuzzy expert system have on decision-making and reducing errors, in the healthcare environment at Sabra Hospital?

These questions explore how the systems used in healthcare settings at hospitals and its impact, on decision-making processes and the reduction of mistakes.

5. Literature Review

Fuzzy expert systems have become widely recognized in the sector for disease diagnosis as they excel in managing uncertain and imprecise data—an area that has sparked growing interest recently due, to their application in improving the accuracy and timeliness of diagnosing conditions, like heart disease that contribute significantly to global mortality rates.

"Utilizing Fuzzy Logic, for Medical Diagnosis"

Introduced by Zade in 1965, logic presents a structure that tackles ambiguous or inexact information effectively. A valuable tool, in medical diagnosis given the often uncertain or incomplete nature of patient information available. Unlike logic that relies on definite "yes/no" fuzzy logic accommodates varying degrees of truthfulness and is adept, at deciphering symptoms that lack straightforward categorization. Based on the findings of Torlak and colleagues, in 2017 fuzzy expert systems have proven effective in healthcare scenarios, such, as identifying illnesses like diabetes, cancer and heart issues. These systems use rules and fuzzy sets to replicate how medical experts make decisions aid healthcare providers in making choices.

"Fuzzy Expert Systems, for Diagnosing Heart Disease"

Numerous studies have highlighted the effectiveness of expert systems, in diagnosing heart disease. For instance, El Sappagh et al. (2020) created an expert system that utilized patient information like age blood pressure and cholesterol levels to predict heart disease. Their system demonstrated accuracy. Surpassed conventional diagnostic approaches, in managing intricate medical data. Likewise Anand et al. (2011) demonstrated that fuzzy logic based systems could accurately assess the risk of heart disease based on symptoms and lifestyle choices. These tools assist in addressing the obstacles presented by unclear information by offering a method, for making diagnoses.

The Advantages of Fuzzy Expert Systems

Despite the benefits, they offer fuzzy expert systems encounter hurdles in settings. Pasi and Yager (2016) noted that a key drawback is the struggle to gather expert insights, for crafting fuzzy rules. Healthcare practitioners frequently hold views complicating the establishment of a rule framework, for diagnosing conditions. According to Prasetyo, et al. study in 2021 fuzzy expert systems offer advantages that surpass these difficulties in regions with medical knowledge like rural or underserved areas. These systems enhance precision. Expedite the diagnosis process proving their significance in healthcare environments, with limited resources.

Fuzzy expert systems, within the setting of Sabrata Hospital

The health system, at Sabrata Hospital encounters challenges common to institutions linked with healthcare services in terms of resources and expertise availability. Introducing an expert system for diagnosing heart diseases could greatly improve the abilities of healthcare providers in such settings. Through incorporating logic, the system becomes capable of managing the uncertainties, in patient information leading to more precise and prompt diagnoses. The method coincides with the conclusions of Chouhan and Singh (2017) who suggest that fuzzy expert systems offer advantages in contexts where there is a scarcity of medical knowledge available.

In the evolving realm of expert systems development and application, in healthcare settings, it is essential for future studies to concentrate on enhancing these systems adaptability to varied medical scenarios and settings. Kaur and Wasan (2015) emphasize the significance of updating the rule sets applied in expert systems to align with the most recent advancements and practices in medicine. Furthermore; incorporating machine-learning algorithms, with logic has the potential to bolster the systems learning capacity from data inputs and refine its diagnostic precision progressively.

The literature suggests that fuzzy expert systems provide benefits, in diagnosis for heart disease by handling the uncertainty and imprecision present in medical data effectively. Implementing these systems within healthcare settings like Sabrata Hospital can enhance accuracy and decision-making processes significantly. However, the effectiveness of these systems relies on the quality of knowledge used in their development and the continuous updating of rule sets to align with advancements, in research.

6. Related Studies

In recent years, there has been a lot of research, on using expert systems in medical diagnosis with a focus, on heart disease specifically. The studies discussed in this section delve into how fuzzy expert systems are developed and applied in diagnosing heart disease and related conditions. They examine methods used and the outcomes of these studies to see how they contribute to the field of medicine.

"Utilizing Fuzzy Logic, in Expert Systems, for Diagnosing Heart Diseases"

Chouhan and Singh (2017) studied one of the instances where fuzzy logic was applied in diagnosing heart disease. They created an expert system that utilized patient information, like age and cholesterol levels along with chest pain details to estimate the chances of heart disease occurrence accurately. Their system showed promising results, in enhancing precision compared to approaches based on simple binary logic. The research concluded that fuzzy expert systems have the potential to minimize mistakes by handling the uncertainty in medical information.

In a vein, to Anand and colleagues work in 2011, which delved into using logic to categorize patients according to their heart disease risk levels, the team created a fuzzy expert system integrating various risk factors such as blood pressure levels and lifestyle choices alongside cholesterol levels with promising outcomes. Their findings demonstrated the system's ability to offer assessments in cases of incomplete or uncertain patient information thus highlighting the significance of fuzzy logic, in medical diagnosis.

Comparative Research, on Fuzzy Expert Systems, versus Conventional Approaches

Studies have also been done to compare how expert systems work compared to regular diagnostic approaches for heart disease detection according to El Sappagh et al. research in 2020. They tested the accuracy of their expert system against methods like decision trees and logistic regression in diagnosing heart disease. Their system combined fuzzy logic with medical information such, as age, blood pressure and family history leading to better accuracy and sensitivity. The research did not highlight the effectiveness of expert systems, in handling uncertain information but also underscored their potential for practical use, in medical settings.

In comparison to studies like that of Kaur and Wasan in 2015 which examined AI systems such as fuzzy expert systems and further investigated their difficulties and constraints; it was highlighted that although fuzzy systems are adept at handling uncertainties on their own merit; incorporating machine learning algorithms could enhance their capabilities by allowing them to adapt and grow with new information over time. This recommendation sets a path for upcoming studies that aim to merge fuzzy logic with machine learning to develop stronger diagnostic tools, for various applications.

Expanding the Uses of Fuzzy Expert Systems, in Wider Medical Diagnosis

In addition, to heart disease diagnosis applications and fuzzy expert systems have been used to identify medical ailments as well. Pasi and Yager (2016) created an expert system for identifying diabetes that encountered difficulties, in interpreting ambiguous patient symptoms. Their system successfully classified patients into risk categories by utilizing sets that represent a range of symptoms. While their primary emphasis was diabetes diagnosis; the techniques used in creating sets and logical rules can also be applied to diagnosing heart disease.

In addition, to that study by Prasety and colleagues in 2021 broadened the application of expert systems to diagnosing cancer cases effectively highlighting how fuzzy logic can handle uncertainties well especially highlighting the superior performance of fuzzy expert systems compared to traditional diagnostic methods particularly in settings, with scarce medical knowledge.

Challenges and Constraints Encountered in Creating Fuzzy Expert Systems

While fuzzy expert systems have achieved some victories in their applications, they encounter difficulties, in rule formulation and knowledge gathering. As mentioned by Torlak and colleagues in 2017 the effectiveness of an expert system is greatly influenced by the caliber of expertise utilized to develop the rules. This issue is further complicated by the reality that diverse medical professionals may hold viewpoints resultant in inconsistencies within the rule frameworks. According to Pasi and Yager (2016) progress, in AI methods has simplified the creation and refinement of expert systems through improved knowledge acquisition techniques.

In general, the studies that were looked over show proof supporting the usefulness of expert systems, in diagnosing heart disease and other medical uses. They emphasize how these systems could enhance precision significantly in situations where uncertainty plays a crucial role. Besides, they give us a glimpse, into research paths like combining fuzzy logic with machine learning to boost system efficiency and effectiveness.

7. Methodology

7.1. Participants

Researchers conducted a study, at Sabrata Hospital that aimed to create and assess an expert system for diagnosing heart disease successfully, identifying healthcare professionals and patients involved in the hospitals procedures were essential, for the study's selection of 20 participants who provided valuable insights.

Healthcare professionals, including 10 participants;

Four skilled heart specialists were involved in the research to offer their expertise in creating the rules and assisting with the decision making process of the system. Their insights played a role, in outlining the symptoms, medical history factors and diagnostic standards, for heart conditions.

Three family doctors participated by confirming the systems suitability, for use in settings testing it with actual patient scenarios and offering insights on its practicality and impact, in basic healthcare settings.

Two medical technicians were responsible, for running machinery and verifying that the system integrated laboratory test findings and medical imaging data while assessing the systems performance.

An IT expert assisted in setting up and rolling out the system in collaboration, with the research team to smoothly integrate it into the hospitals healthcare system.

Patients (10 participants):

The research included 10 individuals who were undergoing evaluation, for heart disease or had recently received a heart condition diagnosis. These individuals shared their real life information such, as medical background details and symptoms to assess the precision and dependability of the expert system. The participants varied in age range and gender. Had risk factors associated with heart disease to ensure that the system was thoroughly tested across various scenarios.

Both healthcare professionals and patients were involved in assessing the expert system, at Sabatara Hospital to enhance heart disease diagnosis in a clinical context effectively.

7.2. Data Collection

The study, on the "Advanced Heart Disease Diagnosis System at Sabrata Hospital" involved collecting information, from patients and clinical data for diagnosing heart conditions effectively using an expert system approach that incorporates both precise data and fuzzy logic rules to determine the probability and seriousness of heart disease cases. The data gathered were utilized to confirm the systems capability to address life scenarios by comparing input, with a database and generating practical diagnostic outcomes.

7.3. Patient Data Collection

In the phase of data collection process; pertinent patient information was obtained by posing a set of organized inquiries, to the patients themselves The questions revolved around symptoms and medical markers that were subsequently converted into concise input data points These data inputs encompassed things, like;

- **Chest Pain**: Patients were requested to assess their chest discomfort using a 1 to 4 scale where 1 denoted "typical angina" 2 denoted "atypical angina" 3 denoted " non-anginal pain" and 4 denoted "asymptomatic." This clear information offered details, on the nature and intensity of the patient's chest pain.
- **Blood Pressure**: The individuals' blood pressure was noted as a number, which can indicate the risk of heart disease if it is too high or too low.
- **Cholesterol Levels**: The system logged the cholesterol levels of every patient, as it is a risk factor for heart disease progression; high cholesterol can contribute to the formation of atherosclerosis that often precedes heart issues.
- **Blood Sugar**: The recorded blood sugar level was noted to assess the patients' blood sugar levels since diabetes plays a role, in the development of diseases.

- **ECG Results**: The ECG findings indicated that an electrocardiogram was conducted to identify irregularities, in the hearts functions such as heartbeats and potential heart conditions like blockages, in the arteries and thickening of the left ventricle muscle wall thickness were entered into the system as a clear data point.
- **Maximum Heart Rate**: The patients' maximum heart rate, over a 24-hour period was measured to evaluate their health and heart performance.
- **Sports Activity**: During the assessment of patients' physical readiness, for sports activities s they were inquired about their suitability for activities and their responses were categorized into values. 0 Representing a recommendation against sports activity and 1 indicating that engagement, in sports is deemed appropriate.
- **Peak Old**: The patients recorded level of depression or emotional stress was noted as a factor as emotional stress has connections, to heart disease.
- **Thallium Levels**: Thallium levels were. Noted in the context of stress tests to assess heart blood flow health with three outcomes. 3 (Within normal range) 6 (moderate) or 7 (elevated) indicating the presence and seriousness of any anomalies detected during the evaluation process.
- **Gender**: In the study data collection process, for heart disease analysis gender was categorized as either male (coded as 1 in the dataset) or female (coded as 2) due to its impact, on the occurrence and manifestation of heart conditions.
- **Age**: The medical professional also took note of the patients' age since age plays a role, in determining the risk of heart disease.

7.4. Input Processing and Rule Application

After extracting data, points from the information the fuzzy expert systems inference engine analyzed the input, against a database of established rules derived from expert knowledge in cardiology. Using logic rules the systems engine evaluated the data to decide whether to trigger a rule, for diagnosis.

When a patient shows signs, like cholesterol levels and unusual ECG results along with increased blood pressure readings, the system uses logic to evaluate the likelihood of heart disease risk factor involved. If the information aligns with the rules saved in its database; the system triggers a rule to give a diagnosis of whether or not heart disease's present and its severity level. In cases where there are no matches with any existing rules, in the systems knowledge base; it will not be able to provide a diagnosis based on that input.

7.5. Final Output

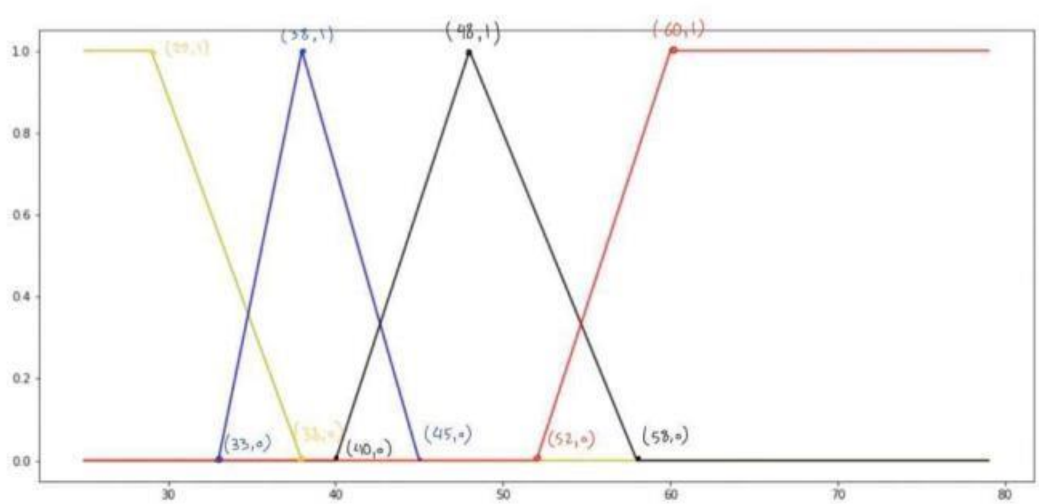
The systems result was a diagnosis that determined whether a patient had heart disease or not by analyzing the information provided by the patient through an inference engine and cross-referencing it with the expert systems database to assess the severity of the condition and recommend medical treatments accordingly.

The data gathered played a role in assessing the effectiveness of the expert system, at Sabra Hospital, for real world medical diagnosis by guarantee accuracy and potential.

8. Findings

First step: Fuzzification

To solve the problem with the help of fuzzy logic, we convert our values from crisp to fuzzy values (imprecise, relative). This is called Fuzzification. For this purpose, fuzzy sets are defined, and according to their membership



function, for each value I calculated the degree of belongingness to its fuzzy set.

For this purpose, the membership functions of the required sets are in the project description. For example, here is the membership function for

"Age" input:

Yellow indicates age young; **blue** indicates age mid; **black** indicates age old; **red** indicates age very old.

Second step: Inference

In order to solve the problem, it is necessary to check the fuzzy output values obtained from the existing rules (see rules.py). It is called inference. For example, consider the following rules:

"If (age is old) and (blood pressure is very high) then (result is sick (s4))"

It simply says that if a person is old and has very high blood pressure; his heart disease is type 4. Knowing the membership function for each parameter in a rule, we can calculate the fuzzy value of its output. Note that we need to apply MAX-MIN operations to find the membership value of each law output. That is min=AND and max=OR

If (low cholesterol) and (low blood pressure) then (health result)

This law says that if a person's cholesterol level is low and his blood pressure is low, he is healthy.

If (blood pressure is high) and (maximum heart rate is average) then (result is sick (s2)) this law states that if a person has high blood pressure and their maximum heart rate is average, their heart disease is type 2. Now suppose that according to the calculations made in the previous steps, the parameter values used in the above rules are as follows:

Age=0.6

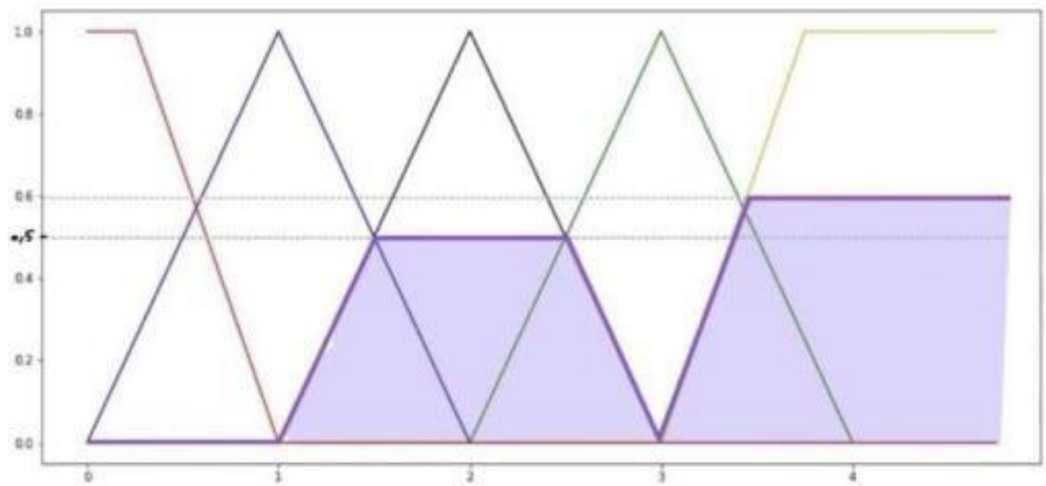
Blood pressure = 0.7 Cholesterol = 0

Maximum heart rate = 0.5

Now, if we put the numbers into the bases, we have: With the help of the above expressions, the following expressions are obtained: membership (sick (s4) = minimum (0.6, 0.7) = 0.6 membership (healthy) = minimum (0.6, 0) = 0 membership (sick (s2) = minimum (0.7, 0.5) = 0.5 High values are called the strength of each base. In this case, rules 1 and 3 are the only rules in effect. This step obtains the output, which is the different scores of the disease with different belonging values.

Third step: defuzzification

In this step, the defuzzification process translates the fuzzy inference results back into a crisp, absolute value to provide a clear output. The following tools and technologies were employed during this step:



HTML – Used for creating the user interface of the system.

CSS – Applied to style the interface and ensure a user-friendly design.

Python Language – Utilized to implement the logic for processing and defuzzifying the fuzzy values.

Electrocardiogram (ECG) – Incorporated to assess the heart's electrical activity as part of the diagnostic process.

Echocardiogram – Used to visualize heart structures and functions.

Angiography – Facilitated the evaluation of blood vessels, contributing to accurate diagnosis.

The most commonly used method for defuzzification in this system is the center of mass method, calculated as follows:

The output function is divided into distinct segments.

Integrals of each segment are computed to determine the centroid, representing the defuzzified result.

This approach ensures that the fuzzy logic-derived outputs are translated into actionable and precise diagnostic results.

Angiography and widely used method is the center of the mass method, which is calculated as below:

The result of fuzzy logic is interfering and it is necessary to divide the output

$$x^* = \frac{\sum_{i=1}^{n} \mu_{\bar{C}}(x_i) \,.\, x_i}{\sum_{i=1}^{n} \mu_{\bar{C}}(x_i)}$$

function into parts and calculate the integral from each part.

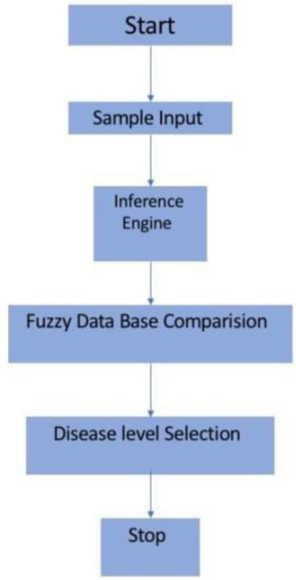


Figure 1: The system flow diagram.

9. Simulation and Results

Data have been collected from Sabratha Hospital, by performing tests on the patients' age, gender, blood sugar, heart rate, and ECG to calculate the value after the test process is completed. In the next step, diagnosis tests at the hospital were performed by the expert system, the crisp, fuzzy INTELLIGENT SYSTEMS 2024.

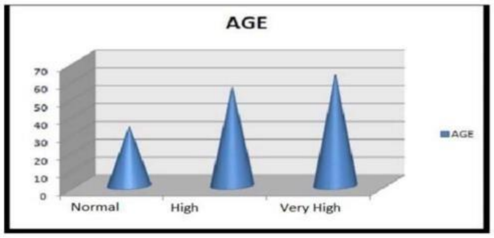


Figure 7. Levels of the patients' age.

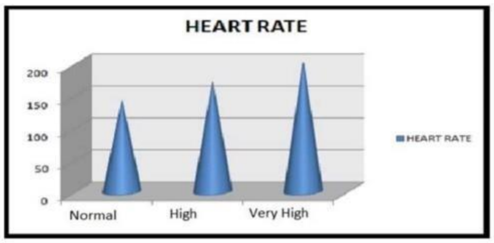


Figure 8. Patients' heart rate levels.

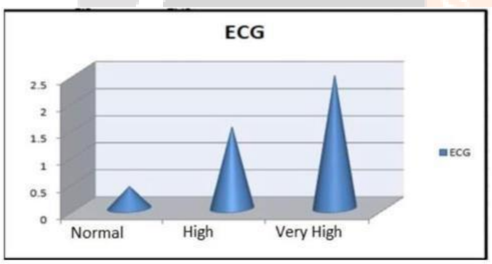


Figure 2. ECG levels.

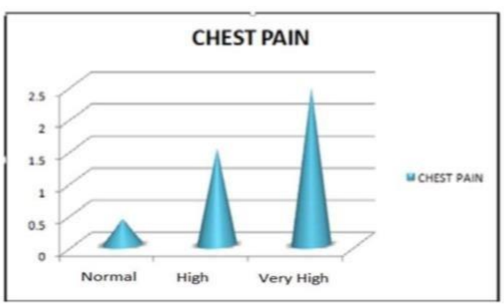


Figure 3. Chest pain levels.

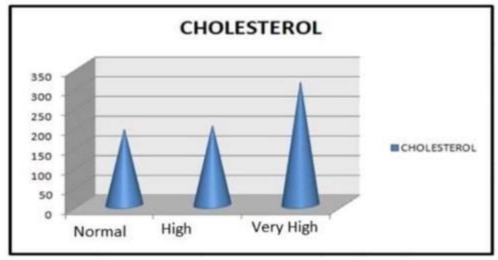


Figure 5. Cholesterol levels.

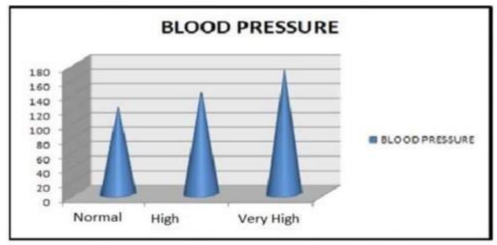


Figure 6. Blood pressure levels.

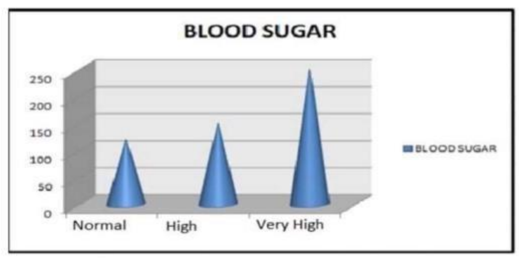


Figure 4. Blood sugar levels.

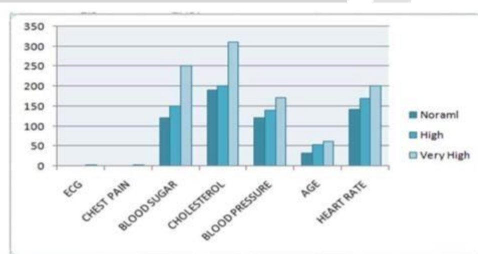


Figure 9. The levels of heart disease output.

Patient Selected for Diagnosis

A person was selected for testing, the symptoms were entered into the system, and the results were taken according to mysterious rules.

Figure 10: Expert system simulation in Html and css

Figure 11: output system is " sick 2, sick 3".

10. Conclusion

In the proposed research, all input is taken from the patients and then evaluated by the expert, who verified all the test results. The evaluation of the system is designed very effectively, and the system is more reliable and beneficial, reducing the rush at the hospital to avoid continuous patient monitoring. A fuzzy expert system is helpful and useful for all patients and doctors to diagnose heart disease patients. Fuzzy member functions and fuzzy rules have been made by fuzzy logic. After that, the results were implemented using the Python & CSS & HTML, which is specially used for the expert system for heart disease diagnosis and treatment, and all the results were put together.

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