Forward Chaining in Expert Systems: Application to Medical Diagnosis

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***Abstract*—The expert system presented in this study analyzes the data from the relay files and the reports provide a comprehensive overview of the digital relay operation. The first problem area is described. The research process is then described in detail: There are many cases of how CLIPS codes use different levels of knowledge, using forward-chained reasoning, logical reasoning, and backward-chained reasoning, respectively, to shape actions predict storage, identify unexpected storage, and identify symptoms. Finally, an example is provided to illustrate the capabilities of the expert system. People increasingly rely on physicians and nutritionists to determine whether health issues, especially vitamin deficiency treatment, are chronic or still low-grade diseases Can be consumed with expert systems and other technologies role to meet the community's priority needs for vitamin deficiency screening. One aspect of artificial intelligence that can learn to "adopt" an expert approach to thinking and reasoning when solving a problem is the expert system that makes decisions and draws various conclusions. The desktop application is used to implement the expert system for the diagnosis of vitamin deficiencies in humans. This application uses the forward chaining method. From provincial governors, regencies, and even governments to ministerial level. This study sought to develop a prototype decision support system for identifying patients with COVID-19, including controls, monitoring patients, and screening for viral infection. To obtain information from Covid-19 symptoms, the authors of this study proceed with a chain reaction**

***Index Terms*—Forward chaining, Back Sequence, Expert System, Inference Rules, Data-Driven Approach, Known Facts.**

I. Introduction

Today, technology is advancing so rapidly that it has penetrated many industries. We need to use these developments, like the use of computers in the health care sector, to keep pace with this trend. The health of each individual is the first priority because illness does not prevent people from living a full life. Many factors can affect a person's health, from external to internal factors. Unfavorable living conditions are an external influence .We can see an Expert system in the figure given below(Fig-1). It is made up of a user

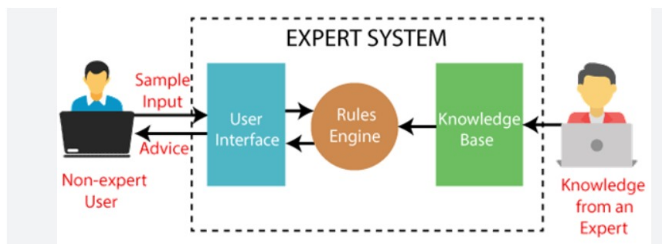

Fig. 1. Expert System

interface that gathers input from a non-expert user, a rules engine that applies preset rules and algorithms, a knowledge base that contains expert knowledge, and knowledge from an expert. The non-expert user is then given recommendations or decisions by the system once it has processed the input using the rules engine and knowledge base. The expertise of actual human professionals was used to build the system. The rule-based approach provides diagnostic insights that aid in early detection, enhancing healthcare professionals' efficiency and addressing challenges like limited access to healthcare during the pandemic [1]. Technologies have been applied during the COVID-19 pandemic to analyze symptom data, making a systematic approach for diagnosing symptoms and enhancing healthcare providers' efficiency and accuracy [2]. The system systematically evaluates symptoms against a knowledge base for early diagnosis, strengthening the accuracy through periodic updates from experts, and making healthcare accessible and efficient with scarce medical resources [3]. The system diagnoses by symptoms, giving diagnostic suggestions along with confidence levels. It uses the certainty factor to quantify the probability of some diagnosis, improving the accuracy and reliability of early ARI detection in clinical environments [4]. It helps doctors and patients detect gastric disorders systematically through inference of potential diagnoses from symptoms, making access to relevant medical advice more accessible, therefore decreasing the burden placed on healthcare facilities [5]. User-inputted symptoms can help to diagnose diseases and recommend proper medications by using forward chaining. This system has interactive multimedia features for user involvement, which could help to bring early intervention and treatment planning for CNS diseases. The application allows users to enter symptoms and analyze them against a rule-based knowledge base, making preliminary medical advice more accessible in resource-poor healthcare settings. [6]–[10]. It uses a hybrid approach in judging symptoms from users. This approach improves the reliability of the system in making medical decisions regarding rheumatic conditions. The study evaluates multiple methods for symptom data processing and diagnostic outcome generation towards identifying the best blood-related diagnostic tools. Thus, the hybrid approach improves diagnostic accuracy and reliability for conditions in the digestive tract of children and prenatal care in pregnant women, while drawing attention to the potential technology in specialized settings. [11]–[15]. The research offers a non-invasive approach to diabetes diagnosis with deep learning from tongue images, enhances heart disease prediction models based on sophisticated machine learning approaches, examines the effect of COVID-19 on liver cancer prediction and diagnosis, and employs deep learning methods to predict colon cancer based on histological images [16]–[19]

Main objectives of using Forward Chaining in Expert Systems: Application to Medical Diagnosis are discussed below

- Real-Time Diagnosis :- Through the use of rules against known facts to facilitate early detection of disease and quick assessment
- Knowledge Representation :- Used to hold medical facts, symptoms, and treatment protocols, thereby providing a systematic, logical mechanism for data-driven decision-making within healthcare.
- Improving Accessibility :- It facilitates increased accessibility to healthcare in rural areas, cutting down on reliance on human experts for primary diagnosis.
- Consistency and Accuracy:- Expert systems, such as forward chaining, provide consistent and accurate decision-making, minimizing errors and enhancing medical diagnoses reliability,
- Scalability and Adaptability :- Medical knowledge is continually changing, and forward chaining expert systems can be updated with new rules and guidelines, making them current and effective in the evolving healthcare environment.

II. LITERATURE SURVEY

It is specifically used in medical diagnosis, especially COVID-19, but scalability, accuracy, and accessibility capabilities are limited. Affordability and proper diagnosis depend on using advanced technologies such as Android-based systems. [1]. Extensively, the impact on healthcare during a COVID-19 pandemic is more impactful on resource-deficit regions that require rapid diagnosis. Advances in DSS have improved real-time diagnosis; however, disadvantages include internet connectivity and complexity. Regional adaptations will be needed, such as cultural, technological, and infrastructural factors, to ensure effective use. [2].

The COVID-19 pandemic has posed a challenge to early and accurate diagnosis in resource-constrained environments of public health systems. Expert systems in health automatically perform the process of decision-making processes for medical diagnoses by offering benefits such as consistency, speed, and the ability to function without continuous expert oversight. For structured diagnostic problems like COVID-19, using the rule-based forward chaining method is appropriate. Ripple Down Rules (RDR) is an incremental knowledge acquisition technique that enhances expert systems without major redevelopment. Most of the previous works had dealt with expert systems to diagnose or respond to COVID-19 but were seen with both dependencies on specific sets of data and scalability issues. A combination of forward chaining and RDR may lead to more adaptive, accurate, and regionally relevant systems. [3].

It is on the determination of early detection in diagnosing acute respiratory infections (ARI), a leading global health concern, as discussed by Fitri et al. (2023). This paper highlights the issues encountered in diagnosing ARI due to overlapping symptoms with other respiratory diseases and why it is indispensable to have an early detection to lower morbidity and enhance treatment outcomes. Two of the most important applications that have come as aids to support medical diagnoses are artificial intelligence and expert systems. These allow benefits like automation, consistency in diagnosis, and scalability to less well-equipped environments. It is a rule-based inference technique followed in expert systems with such structured and symptom-driven diagnoses that can offer benefits like simplicity, real-time inferences, and an adherence to medical logic. Expert systems introduce certainty factors, which are the quantification of the level of confidence in a diagnosis given by available evidence. The requirement of integrated system that contains the ideas of forward chaining and certainty factors have quite well been represented in the paper to achieve the strong, accurate, and explainable diagnosis for very early detection of ARI. [4].

Expert systems are useful in automating medical diagnoses, providing consistent, scalable, and accessible support. Forward chaining is a rule-based approach to reasoning that maps symptoms to diseases and can be used in healthcare situations involving structured conditions. Systems currently in existence suffer from limitations in accessibility, low accuracy, and an inability to explain results. One reason forward chaining might be justified as a basis for developing system tailored for specific populations relates to the fact that gastric diseases have a colossal burden of health and are somewhat complicated to diagnose. That characteristic can also promote access, accuracy, and usability in populations with a minimum capacity to access advanced medical facilities. [5].

By all the research mentioned above we will get to know that expert systems have been developed for medical diagnosis, especially during the COVID-19 era, providing highly accurate and scalable ways to monitor symptoms and diagnosis. However, such existing solutions possess constraints on scalability, accuracy, and accessibility.. Ripple Down Rules (RDR) could give power to the expert systems without requiring much redevelopment. The expert systems also help in the early detection of ARI and gastric diseases, so that populations without proper access to good medical facilities can easily view, obtain, and use them. [1]–[5] A Support Vector Machine (SVM) is a ml model used as classifier optimized using Bayesian optimization and deep learning were utilized in the research to enhance the accuracy of prediction in histopathology image analysis. The technique is useful for the early diagnosis of cancer and understanding how chronic disease management is influenced by global health emergencies. enhanced classification performance, tuning of the hyperparameter model enhances its effectiveness in cardiovascular disorder diagnosis. The research provides a potential alternative to traditional blood-based diabetes diagnosis and validates the use of AI in the clinical environment for early detection and preventive treatment. [16]–[19]

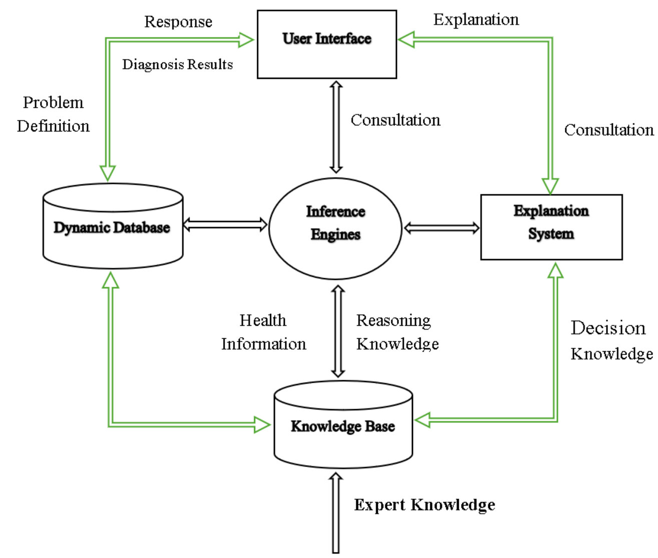

Fig. 2. Proposed framework

III. METHODOLOGY

The proposed research is to design and evaluate the forward chaining-based expert system for COVID-19 medical diagnostic purposes, focusing on identifying suspected cases from symptoms and patient history. Unlike traditional methods such as PCR or antigen tests, the system will be able to improve accuracy, data integration, explanation, adaptability, and accessibility. The WHO has developed a forward-chaining-based expert system for COVID-19 diagnosis that focuses on initial symptom-based triaging. It uses medical guidelines, clinical research papers, and expert consultations to formulate symptom-based rules, risk factor rules, and severity indicators. The forward chaining inference mechanism systematically collects user-input information and appropriately applies it to forward chaining mechanisms in order to trigger relevant rules. The system is developed using expert system tools and technologies with associated user interfaces for entry and visualizations. After development, the system is tested and validated against metrics including accuracy, precision, and recall on clinical datasets or simulated patient cases. The system is deployed as a web-based or mobile application with reliable maintenance of its updates and performance. Ethical and legal considerations are also considered so that the system advises on its role as a diagnostic aid.

A. System Architecture

The proposed framework design or the block outline of diagnosis of COVID 19 by using forward chaining in the Expert system is displayed in Fig. 2. The interface is a provider between the human and the expert, taking in inputs, such as the patient's symptoms and medical history. The Dynamic Database stores data, real-time and specific to each patient, and feeds this information to the Inference Engine to reason correctly. The Inference Engine uses forward chaining of facts and rules to find diagnoses, which it provides to the Explanation System and Knowledge Base to make decisions. The Knowledge Base involves expert knowledge in the form of rules and facts for medical diagnostics using "IF-THEN" decision rules. The Explanation System also adds the feature of transparency in reasoning, following a logical flow of decisions to establish greater confidence in usability. It ensures accuracy in diagnostics, transparency in reasoning, and scalability for updates to medical knowledge.

A step in developing a forward chaining expert system in COVID-19 diagnosis involves a number of steps. Problem Definition and Scope: This aims at developing an expert system which helps in diagnosing COVID-19 by symptoms, exposure history, and risk factors. Hence, knowledge sources are medical guidelines, clinical research papers, and expert consultations. Knowledge representation translates into rules of if then, as exemplified by "If the patient suffers with fever, cough, fatigue, shortness of breath, and recent contact with an individual who tested positive to COVID-19.

The creation of a rule base focuses on symptom-based, risk factor rules, and severity indicators. Then comes the forward chaining mechanism for inferences, by gathering user inputs, and applying forward chaining for the firing of appropriate rules, and output. System development tools and technologies are used, then user interfaces are implemented for data inputting and visualization of outputs. The performance of the system is tested and validated using clinical datasets or simulated patient cases, and it is deployed as a web-based or mobile application for wider reach. Maintenance is through the updating of the rule base and monitoring the performance. Ethical and legal considerations include data protection laws that should be complied with, mitigation of bias, and a clear explanation of the role of the system as a diagnostic assistant. Now we will see how our model works in the analysis of

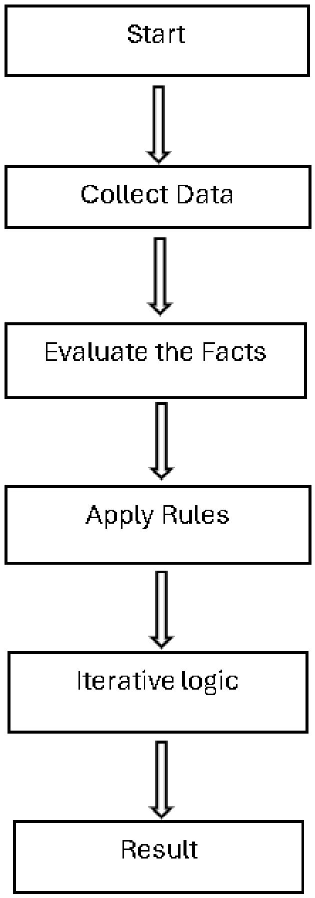

Fig. 3. Steps involved

COVID-19 using forward chaining. Take a look at fig: 3, In this fig we can see steps involved in the analysis of COVID-19 disease. Now we are going to discuss how it works in each step in a detailed manner,

1) START:
This is where the diagnosis process begins. The process is activated by a user, either a paA user would start by inputting data into the system, such as symptoms or seeking instructions for a suspected case of COVID-19. tient or a health care provider, interacting with the expert system.
2) COLLECT DATA:
Information is collected in the system pertaining to the problem. This may comprise of symptoms, history, or even tests. Symptoms (for example, including:. Blunted taste and/or smell. Dyspnoeic). Test results-for example, positive or negative antigen test. Medical history, including comorbidity such as diabetes, and asthma. Patient demographics (age, vaccination status, recent travel, exposure to known COVID-19 cases). The device can also gather such real-time data as oxygen saturation, pulse, and temperature from related devices.
3) EVALUATE THE FACTS:
The expert system analyzes the data collected to identify and verify facts. Facts are individual pieces of information that the system will utilize in applying its rules.
The system monitors for critical signs, including oxygen saturation ¡95Groups its symptoms into:
   - Low-grade manifestation: Recurrent fever, cough, headache.
   - Moderate: Decreased breath strength, and giddiness.
   - Severe symptoms: Chest pain, confusion, cyanosis are very common.

   It manages facts to ensure consistency and cross-validation with the rules of the knowledge base.
4) APPLY RULES:
The system evaluates the facts on the basis of its rule-based knowledge base. Rules are ”if-then” statements. For example, Fever and cough are accompanied by a positive test result. Suspect COVID-19 if there are such symptoms. If oxygen saturation less than 95, then recommend hospitalization. If there are no severe symptoms but a loss of taste or smell, then encourage isolation and retest in 3 days. If patient has been vaccinated and symptoms are not serious, then recommend home care and observation.
It runs the facts against the rules to narrow the set of possible diagnoses or recommendations.
5) ITERATIVE LOGIC:
Forward chaining is an iterative process where new facts derived from previous steps are used to trigger additional rules.
Initial facts: The patient has a fever and tested positive. The rule applied: Fever and positive test suggest mild COVID-19. New information gathered: Monitor oxygen saturation. Oxygen saturation checked: if it is 90, another rule is activated to categorize as severe COVID-19. A new recommendation is generated: Immediate medical attention.
The system loops through until no more rules can be applied or until a conclusive result is reached.
6) RESULT:
The system wraps up with a diagnosis, a recommendation, or a decision.
Mild case: Recommend self-isolation, symptomatic treatment (e.g., paracetamol), hydration, and periodic monitoring. Moderate: Teleconsult with the doctor and oxygen saturation monitored frequently. Severe case: Urgent referral for hospitalization and advanced care (e.g., oxygen support or ventilation). COVID-19 unlikely: Recommend testing for other possible causes or a differential diagnosis.

RESULTS

From the fig: 4 we will come to that the query diagnosis function diagnoses the symptoms of a particular patient according to predefined rules by the system. The first rule matched the patient1 because of fever, cough, and fatigue. So there is probably a confirmed diagnosis. However, the second

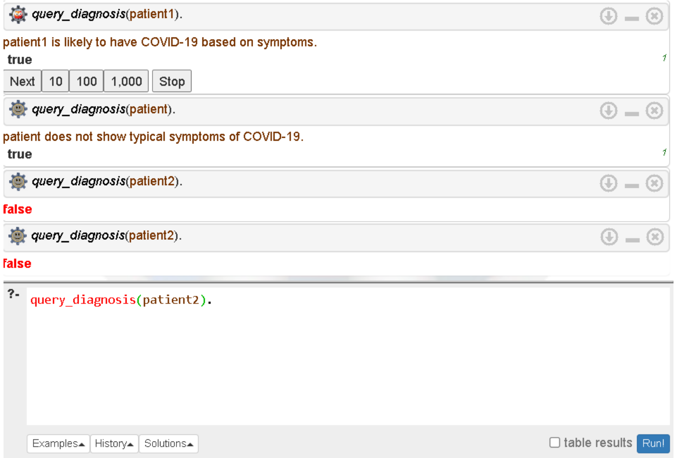

Fig. 4. COVID-19 Diagnosis

```
Model Accuracy: 100.00%

Please enter the following symptoms as 1 for Yes and 0 for No:
Do you have Fever? (1/0): 1
Do you have Cough? (1/0): 0
Do you feel Fatigued? (1/0): 1
Have you lost your sense of Smell or Taste? (1/0): 1
Do you have Breathing Difficulty? (1/0): 1

Prediction: You are COVID-19 Positive. Please consult a doctor.
```

Fig. 5. COVID-19 Prediction

rule did not match for patient2 since the patient did not exhibit typical symptoms. The query does not apply to patient2 since his symptoms do not agree with the rules. The implication is that the question needs either refinement or specificity. Recommendations include changes to Rule 4 concerning fever without other major symptoms, having a query specific to the patient identifier, and adding new rules - sore throat or headache being but one example to broaden the range of diagnosis.

In the fig: 5 we can see that our model predicts COVID-19 based on the symptoms provided. Here '1' refers to YES and '0' refers to NO. In this figure, we can see that a person is suffering from all the major symptoms which helps to predict COVID-19 disease. In this (fig: 5) patient has a fever, fatigue(tiredness), difficulty breathing, and loss of the sense of smell or taste, so these all are the major contributors leading to COVID-19 positivity, so it suggests a user to consult a Doctor for treatment

In the fig: 6 we can see that our model predicts COVID-19 based on the symptoms provided. In this figure, the patient does not have any major symptoms that will contribute to the prediction of COVID-19 disease and Cough is not a problem it is one of the common symptoms seen in an individual, so our model predicts COVID-19 as negative, so it tells Stay safe and healthy. Here we derived all these results from Kaggle [20]

In this fig: 7 our model predicts as a positive and sends a message to the patient as, Please consult a doctor. The main reason for our model to predict a disease as positive is, that all the major symptoms contribute to our prediction such as fever, breathing difficulty and so on.

```
Model Accuracy: 100.00%

Please enter the following symptoms as 1 for Yes and 0 for No:
Do you have Fever? (1/0): 0
Do you have Cough? (1/0): 1
Do you feel Fatigued? (1/0): 0
Have you lost your sense of Smell or Taste? (1/0): 0
Do you have Breathing Difficulty? (1/0): 0

Prediction: You are COVID-19 Negative. Stay safe and healthy.
```

Fig. 6. COVID-19 Prediction

```
Model Accuracy: 100.00%

Please enter the following symptoms as 1 for Yes and 0 for No:
Do you have Fever? (1/0): 1
Do you have Cough? (1/0): 0
Do you feel Fatigued? (1/0): 0
Have you lost your sense of Smell or Taste? (1/0): 1
Do you have Breathing Difficulty? (1/0): 1

Prediction: You are COVID-19 Positive. Please consult a doctor.
```

Fig. 7. COVID -19 Prediction

Fig8 explains the algorithm for the COVID-19 Prediction and by using this algorithm we will get an idea to implement and predict disease

IV. Conclusion and Future Enhancement

The research study "Design of Expert System Application for Diagnosis of Human Vitamin Deficiency" takes upon the concept of creating an application named Vitamin Deficiency Diagnosis application that will save time and money by detecting and storing information about vitamin deficiency. A model decision support system in COVID-19 diagnosis among inpatients, observation, and outpatient care patients utilizes the forward chain method. All the information about a person infected with the virus is provided, which would be useful for treatment and use as a reference point for patients. Models used in this study are those applying fuzzy logic, backward chaining, fixatives, and other development techniques to decision support systems.

The Python code represents a Decision Tree Classifier that predicts COVID-19 as positive or negative based on the

Algorithm for COVID-19 Prediction

***Step 1*: Initialize the Program:** Print the model accuracy and user instructions.

***Step 2*: Take User Input:** Ask the user to enter 1 (Yes) or 0 (No) for each symptom: Fever, Cough, Fatigue, Loss of Smell or Taste, Breathing Difficulty

***Step 3*: Apply Rule-Based Decision**

I. If the user has at least one from: **Fever, Cough, OR Fatigue**

II. AND at least one from: **Loss of Smell/Taste, OR Breathing Difficulty.**
Then **predict COVID-19 Positive**, Otherwise, **predict COVID-19 Negative.**

***Step 4*: Display the Prediction:** Print the final diagnosis message.

Fig. 8. Algorithm For COVID-19 Prediction

symptoms. It uses synthetic and small datasets with features of binary properties applied to common complaints such as fever, cough, fatigue, loss of smell/taste, and difficulty in breathing. For this case, the target variable, COVID as Positive, states if the person is positive or negative. Training is applied to the dataset, with high accuracy attained based on the test set for a Decision Tree Classifier. The program allows users to input in the form of symptoms in binary where positive predictions suggest medical consultation and negative predictions advise safety and health.

Some enhancements to increase the accuracy, reliability, and usability of a COVID-19 prediction model include, Extending the dataset to utilize a large, real-world dataset with diverse records of symptoms and statuses. Add new features, such as sore throat, headache, muscle aches, and runny nose symptoms. Balance the dataset by implementing techniques like oversampling or undersampling. Use advanced algorithms like Random Forests, Gradient Boosting, or Neural Networks to achieve better performance.Enhancing forward chaining in medical diagnosis with dynamic updates of rules, complex rules, context-aware rules, expansion of the knowledge base, new input data mechanism, optimization in reasoning mechanisms, integration with machine learning, scalability and deployment, personalization, ethical and legal aspects, feedback with continuous learning, and broader applications beyond COVID-19.

Among the conclusions obtained from this discussion include the importance of digital relays in security systems, the promise of opportunities for conservation engineers in developing intelligent applications using expert systems, the effectiveness of the integration of rear and front chain logic in expert management systems, the flexibility of new chains in the focused expert programming shells, and further, the potential of expert systems in conservation engineering.

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