Knowledge Based Expert System for Diagnosis of COVID-19

Betelhem Zewdu Wubineh[1], Ayodeji Olalekan Salau[2,4], Sepiribo Lucky Braide[3]

[1]Faculty of Information and Communication Technology, Wroclaw University of Science and Technology, Wroclaw, Poland

[2]Department of Electrical/Electronics and Computer Engineering, Afe Babalola University, Nigeria

[3]Department of Electrical and Electronics Engineering, Rivers State University, Port Harcourt, Nigeria.

[4]Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, India

Email: ayodejisalau98@gmail.com

DOI: 10.47750/pnr.2023.14.03.165

Abstract

The recent pandemic caused by the Coronavirus Disease (COVID-19) first surfaced in Wuhan, China in December 2019. This paper presents an expert system for the diagnosis of COVID-19 based on its symptoms to aid people in taking precautionary measures. When experts are not available, an expert system that can effectively diagnose the disease is crucial. It takes the place of one or more experts in decision-making and problem-solving. An expert system for diagnosis of COVID-19 is a system developed to recognize early COVID-19 symptoms that individuals may experience by allowing users to directly check the disease with results that can serve as a foundation for additional testing. This study's primary goal is to identify useful COVID-19 detection patterns or knowledge by examining the historical data we have obtained from the Kaggle dataset. The patterns are presented as rules, which are given to the expert system after consultation with a domain expert. A total of 1,048,575 pieces of data were used for model training and testing. To detect COVID-19 disease, we employ a PART rule-based algorithm, which performed 92.47% accurately in a 10-fold cross-validation test. We can therefore draw the conclusion that the algorithm produces a promising result and that the expert system aids in the diagnosis of the disease. The system offers a suggestion in line with the identified symptom.

Keywords: COVID-19; expert system; inference engine; knowledge base; user interface.

1. Introduction

A new virus started to spread all over the world in early 2020 due to its extraordinary speed of transmission. The World Health Organization gave the disease the official name COVID-19 [1]. It orginated from Wuhan, China, in December 2019. SARS-CoV-2 (severe acute respiratory syndrome coronavirus illness) is the official name of the virus, which originates from bats and has been linked to millions of infections and hundreds of thousands of fatalities worldwide [2]. SARS-CoV-2 infection causes COVID-19 disease, also known as coronavirus disease 2019 [3]. Coronavirus type COVID-19 has never before been observed in humans. Although COVID-19 can cause serious illness in some people, especially the elderly and those with serious underlying medical conditions like diabetes, heart disease, or lung disease, the symptoms of the coronavirus are similar to those of the common cold [4].

Individuals are affected by the COVID-19 virus differently. The majority of infected individuals only suffer from mild to moderate illness and recover without the need for hospitalization. However, it is expected that if someone has serious symptoms, they should seek immediate medical help. In general healthy people who only have minor symptoms should take care of themselves at home. The Covid-19 symptom should appear in a person after 5–6 days, though it sporadically may take as long as 14. People with COVID-19 have reported a wide range of symptoms, from minor aches and pains to serious illness. The symptoms, which can appear 2–14 days after exposure to the virus include fever, coughing, shortness of breath or difficulty breathing, chills, muscle pain, headache, sore throat, and new loss of taste or smell [4]. The symptoms of the coronavirus are strangely similar to those of the common cold, despite the fact that it can cause serious illness in some people, including the elderly and those with serious medical conditions (i.e. heart disease, lung illness, and diabetes). Currently, COVID-19 has no known treatment or recommended cure [1]. The virus COVID-19 cannot be treated with antibiotics. Numerous potential medications are currently undergoing testing by researchers. Treatments, however, only target the virus's escalating symptom. Testing the efficacy of novel treatments can be useful at times. Blood plasma transfusions, antiviral or retroviral medications, breathing assistance, including mechanical ventilation, steroids to reduce lung edema, and breathing assistance are some of the treatments used for these illnesses.

An expert system, a subset of artificial intelligence, involves incorporating human knowledge into a computer in order to solve problems that frequently require the application of human skills [5]. To assist users in making difficult decisions, it is also possible to mimic the cognitive processes of experts [6]. Expert systems are dependable, interactive, computer-based decision-making tools that use data and heuristics to solve difficult decision-making problems [7]. To mimic human ability, expert systems are developed with a focus on a specific area of knowledge. The expert system sought a satisfactory solution and also attempted to justify each step it took and any recommendations or conclusions it reached. It is also created on a particular field of knowledge in order to approximate human competence. It produces an answer that makes an effort to describe each step it took and provides justifications for any recommendations or conclusions [8]. An expert is someone who, in the field in which they are proficient, possesses knowledge or a special talent that others do not possess or are not capable of. Books, articles, and subject-matter experts can all be used to learn about expert systems. The user input is entered into the expert system, which then provides recommendations or advice.

An expert system is made up of two main parts: an inference engine and a knowledge base. A knowledge base is a structured collection of information about the system's domain. An inference engine, on the other hand, provides a response or a conclusion by analyzing and interpreting the data in the knowledge base. The conclusion is the expert system's answer to the user's query. Expert system tasks typically include classification, diagnosis, monitoring, scheduling, and planning [5]. To gather facts or draw patterns from data for a knowledge base, it is necessary to observe and interview human experts. Then, this understanding is commonly presented as if-then rules (production rules). If a certain condition is true, the inference can be used to draw a conclusion. A probability factor is frequently added to the conclusion and final suggestion of each production rule because the outcome is not always certain.

The objective of this work is to develop a knowledge based expert system to diagnose COVID-19 based on the symptoms entered by the user and to extract novel patterns to detect COVID-19 disease. The model created in this study helps medical professionals identify COVID-19 accurately and advises users for life safety even when the professionals are not present.

2. RELATED WORKS

The development of disease diagnosis systems has been the focus of numerous research studies. COVID-19 knowledge-based system for diagnosis in Iraq using internet of things (IoT) environment was proposed by Bashar et al. [4]. Using mobile applications linked to the IoT system, they attempted to predict COVID-19. Samy and Fatima [9] worked on a COVID-19 diagnosis expert system. For COVID-19 diagnosis, they used the CLIPS and Delphi XE10.2 languages. COVID-19 too many hypothesis too little evidence was a concept presented by Temesgen et al. [10]. They made an effort to evaluate a number of COVID-19 hypotheses using clinical facts that were already known, including epidemiology, clinical treatment, and regulatory measures. An expert system for early diagnosis of COVID-19 was presented by Sharana et al. [11]. They worked on a study to reduce the virus through early COVID-19 diagnosis. An model expert system for diagnosis of covid-19 using naive bayes classifier was another project in which Silahudin [12] worked. In order to diagnose COVID 19, the author used Naive Bayes as a classifier. Elmehdi et al. [13] used chest X-ray imaging and CT scans to identify COVID-19. By comparing CT scans and X-ray images, different convolutional neural networks (CNN) were employed in the study to identify COVID-19 infection. Indumathi et al. [14] study was on the prediction of COVID-19 outbreak with current substantiation by using machine learning approcaches. They attempted to predict the Covid-19 affected areas in India's Virudhunagar district using machine learning. Salau [15] used cutting-edge machine learning techniques to work on coronavirus disease detection. The author attempted to identify COVID-19 using discrete wavelet transform to extract features and support vector machine to classify the features.

Asharef [16] worked on the COVID-19 future forecasting using supervised machine learning models. The number of newly infected cases and recoveries over the course of 10 days was predicted by the author. Varan et al. [17] research on COVID-19 detection using deep learning-with full CT scans. Using the CT scans, they attempted to investigate the detection of COVID-19 with the help of deep learning algorithms. Using chest CT scans, Wajid et al. [18] developed an expert system to identify COVID-19 and estimate its severity. They tried to work predicition of covid severity by using CT scan. Stephen et al. [19] researched on the usefulness of chest ct imaging in patients with suspected or diagnosed COVID-19. They made an effort to investigate the effectiveness of patient chest CT images for COVID-19 diagnosis as well as for prognosis assessment, therapeutic guidance, and acute pulmonary problems identification.

Khadijeh et al. [20] compared machine learning algorithms for COVID-19 mortality prediction. They made an effort to use a machine learning algorithm to predict the mortality rate of COVID 19. In his research on performance change with training data, Kuniki [21] presented a case study demonstrating the use of convolutional neural networks for the binary classification of COVID-19 chest X-rays. They attempted to work a case study on how altering the number of training data could affect classification performance. Aleka et al. [22] worked on detection and classification of COVID-19 disease from X-ray images using CNN and HOG. Using a CNN and HOG approach, they attempted to detect and classify the COVID-19 illness. However, there is still a disconnect between the outcomes of various techniques and the actions that can be taken in response to them. Therefore, this paper presents a study on the development of a knowledge based expert system to diagnose COVID-19 using the information learnt from analyzing historical data, subject matter by experts, and reports from global health organizations. Additionally, the goal of this study is to advise the patient on how to take care of themselves and make corrections in the absence of experts.

3. METHODOLOGY

The sole source of the data used for this study is from kaggle online dataset the year from 2020-2021. From the data, we were able to extract 1,048,575 records and 10 attributes. The data does not contain any missed values, so no preprocessing is required. However, since the test date of the data is not required to identify COVID-19, it must first be eliminated. Table 1 contains a list of the attributes that were used in the study.

Table 1. Final selected attributes.

Number	Attribute Name	Description
1	Cough	The possible outcomes are yes, no, or unknown.
2	Fever	The possible outcomes are yes, no, or unknown.
3	Sore throat	The possible outcomes are yes, no, or unknown.
4	Shortness of breath	The possible outcomes are yes, no, or unknown.
5	Headache	The possible outcomes are yes, no, or unknown.
6	Age 60 and above	Age of the patient
7	Gender	Gender of the patient
8	Test indication	Test results from the tester that indicate foreign-sourced values, contact with the patient not specified.
9	COVID-19	Whether the patient's outcome is favorable or unfavorable

For this experimental research, Weka analysis tool, PART rule based algorithm and 10-fold cross validation test option are used in this experimental study to extract patterns. Following a discussion with domain experts, we obtain the information from patterns that were extracted from historical data and provided to the knowledge based expert system. The patterns are then represented in a rule format to create facts. Finally, knowledge should be represented in a knowledge base so that it can be easily translated into programming languages. The SWI-PROLOG tool with the PROLOG programming language is used to build the knowledge base. The data proportionality of the study is shown in Figure 1.

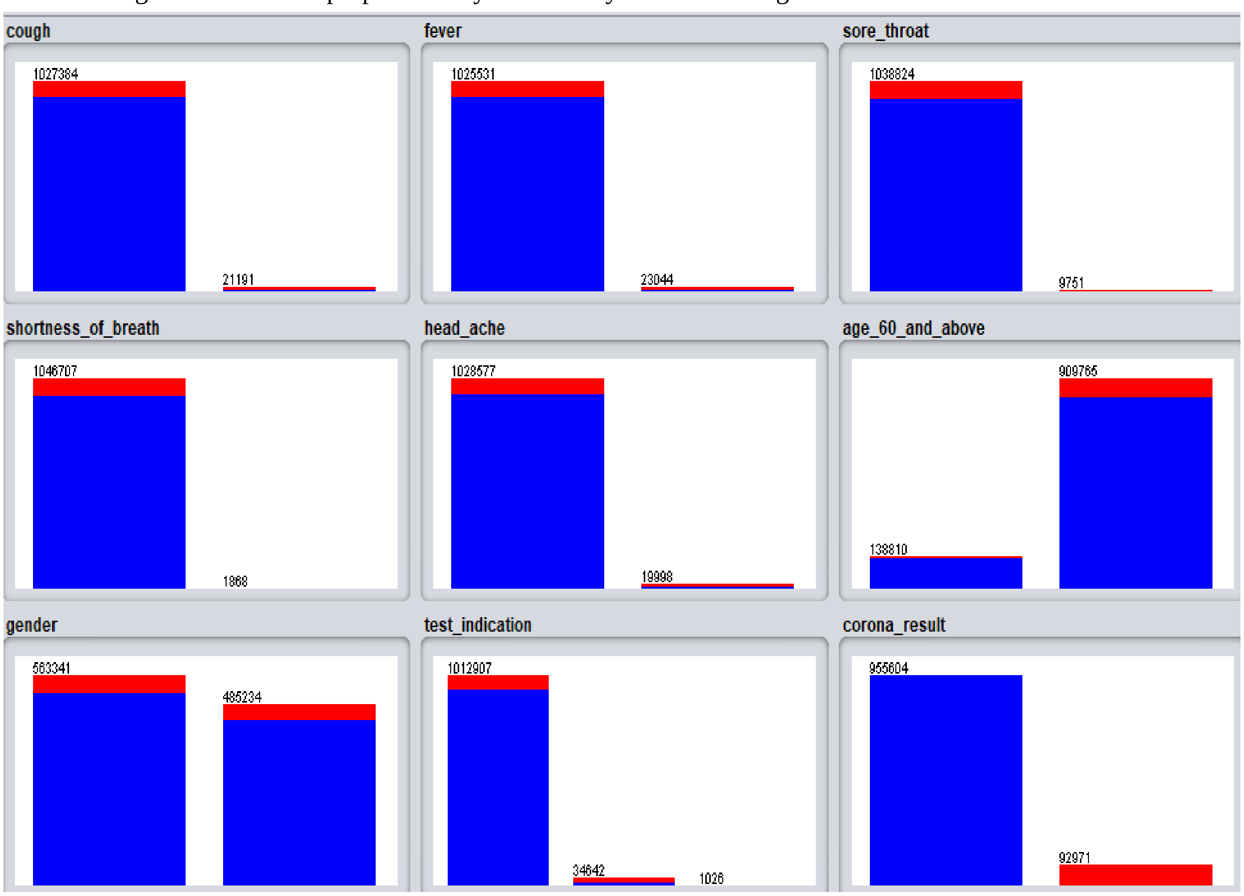


Figure 1. Proportionality of the dataset.

The architecture of expert system is depicted in the following Figure 2.

Knowledge Base: The knowledge base contains the data needed for understanding, creating, and resolving problems [23].

Inference Engine: The inference engine is the mind of the expert system. Based on user the responses and firing rules, it is used to carry out the task of matching antecedents.

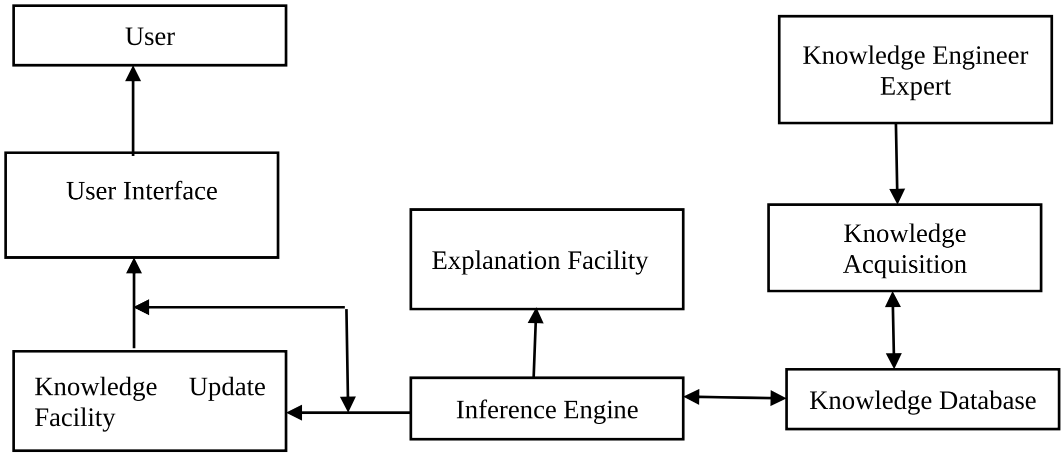


Figure 2. The Architecture of expert system.

Knowledge Acquisition: The consolidation, transfer, and translation of problem-solving abilities from experts and/or documented knowledge sources to a computer program constitutes knowledge acquisition, which is used to grow or build the knowledge base. Additionally, it entails gathering, recovering, and organizing knowledge that has been gathered and organized in cooperation with authorities on the specific subject [24-26].

Knowledge Representation: The representation of knowledge as rules is known as knowledge representation. The conclusions are reached if certain conditions are met.

Explanation Facility: It is a part that exemplifies how the system functions.

User interface: It acts as a channel or intermediary for the user and the system, or just as a means of communication for the user.

Knowledge Engineer: is involved in the creation of the knowledge base's organization, inference engine, and user interface [27].

4. Results and Discussion

The information obtained from the study comes from the rule that was drawn from the earlier data.

The following Table 2 shows the confusion matrix of the outcome.

Table 2 confusion matrix of the result using PART algorithm

Actual	**Predicted**		**Total**
	a (Negative)	b (Positive)	
A	933941	21663	955, 604
B	57249	35722	92,971
Total	991,190	57,385	1,048,575

Table 2 shows that out of a total of 1,048,575 records, 969,663 are correctly classified while 78,912 are incorrectly classified. As a result, out of 955,604 negative records, 933,941 are classified as such correctly, while 21,663 are misclassified as such. Out of a total of 92,971 positive records, 57,249 positive records are incorrectly categorized as negative, while 35,722 positive records are correctly categorized as positive. Sample rules are:

1. If you have shortness of breath = Yes AND sore_throat = Yes AND cough = Yes AND fever = Yes AND head_ache = Yes: then the result is Positive
2. If headache = No AND fever = No AND cough = No AND test_indication = Other AND sore_throat = No AND shortness_of_breath = No : then the result is Negative
3. If shortness_of_breath = Yes AND sore_throat = Yes AND cough = Yes AND fever = No: then the result is Positive

This work makes a contribution by sifting through a sizable dataset for novel patterns and developing the rules in collaboration with subject matter experts for insertion into a knowledge based system. In addition, the system gives the user advice on what to do next whether the diagnosis is positive or negative. As a result, this method is used to suggest life safety measures when specialists or doctors are not available.Figures 3-6 show the proposed knowledge-based expert system. Figure 3 shows the welcome page in its entirety. To enter the system, users type "go."

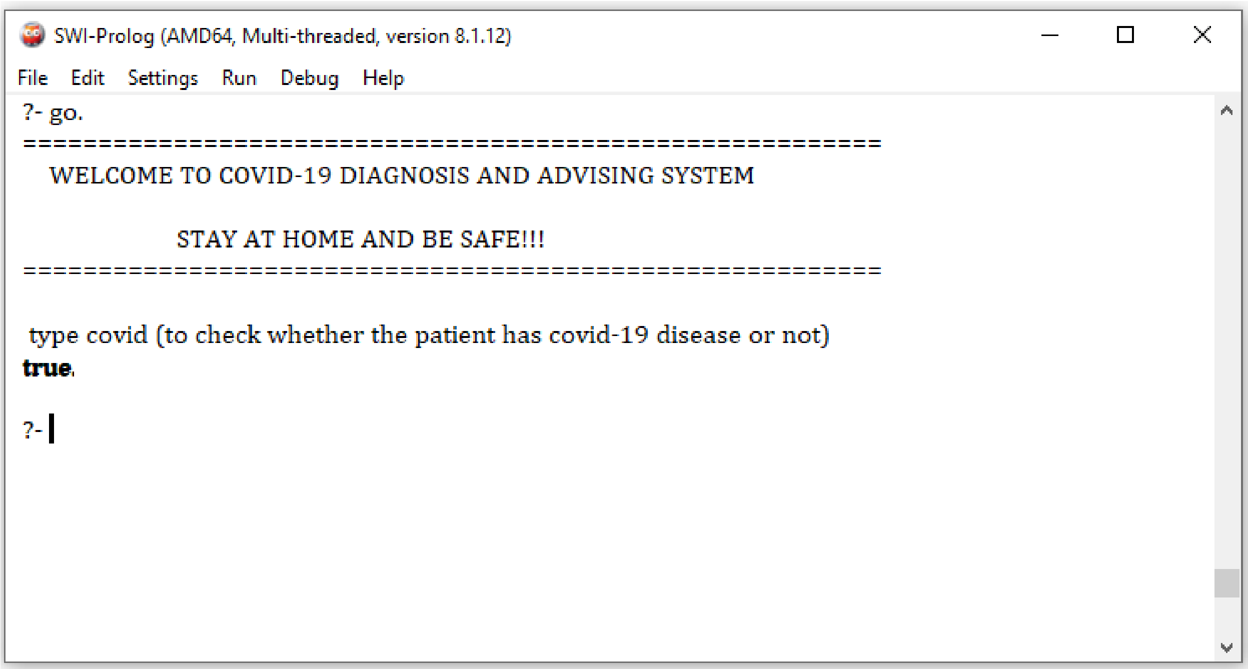


Figure 3. Welcome interface page of the system.

If the user wants to determine whether or not they have COVID-19 based on the "covid" symptom type. The user is presented with a question by the system, and they can choose to answer it with "y" or "n" (yes/no). The list of questions is shown in Figure 4. Afterwards, the inference engine checks the user input against the knowledge base that has been stored.

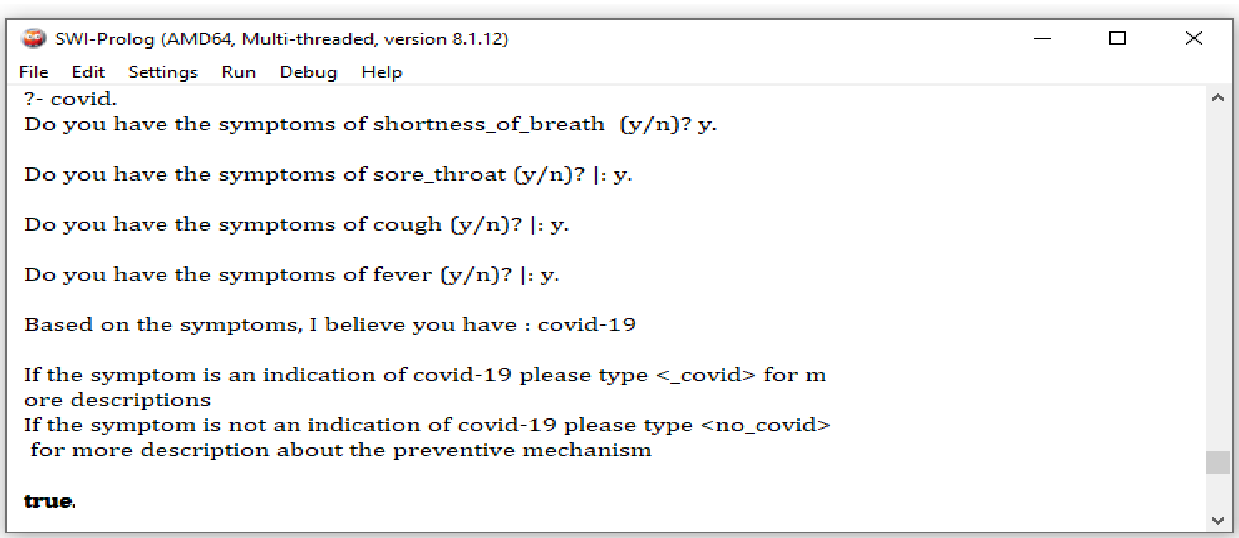


Figure 4. Screenshot of questions displayed for the user.

If the user response is "yes" to all of the questions, then it is likely the person has COVID-19 disease. If the users response is "no," the system has to move on to the second rule, which is not contagious. Figure 5 provides an overview of general information about COVID-19. When a user types "covid," the system displays general information about COVID-19 to check if COVID-19 is the cause of the symptoms. The system then shows the menu, such as those in Figure 5 that are about COVID, symptoms, preventive measures, and further diagnosis. The user then enters "1" to obtain general COVID-19 information.

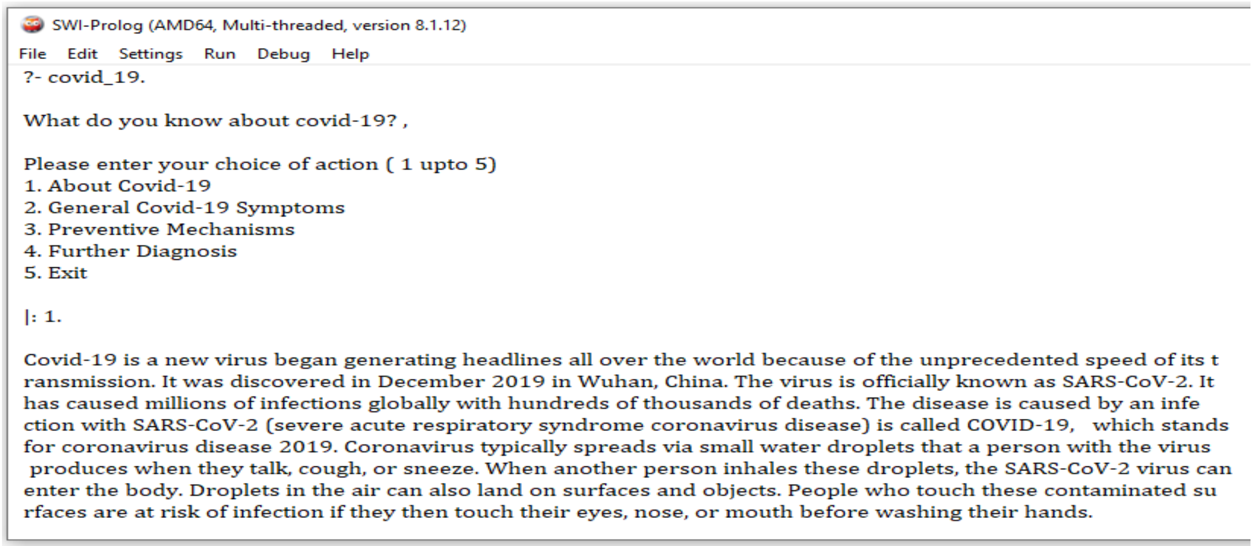


Figure 5. Screenshot of COVID-19's general information.

Users can access more information about the COVID-19 by entering the menu number. The COVID-19 prevention mechanism is shown in Figure 6.

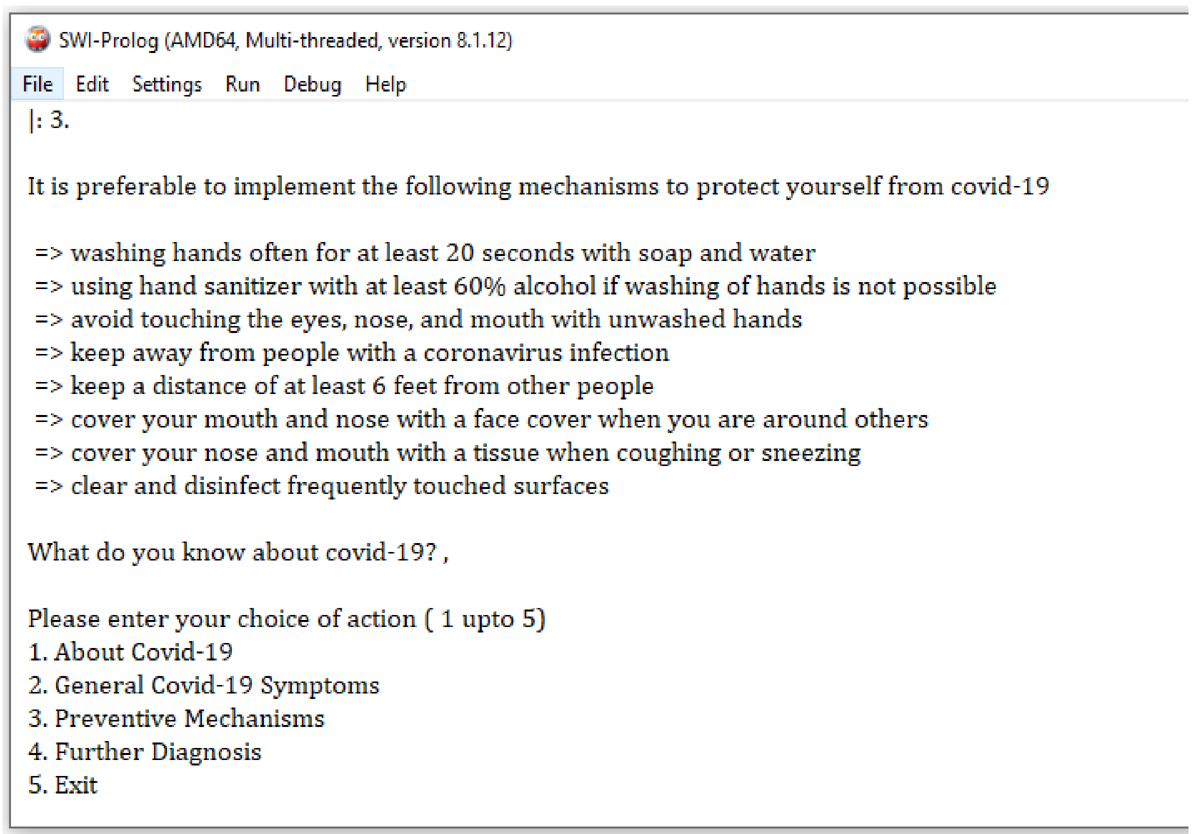
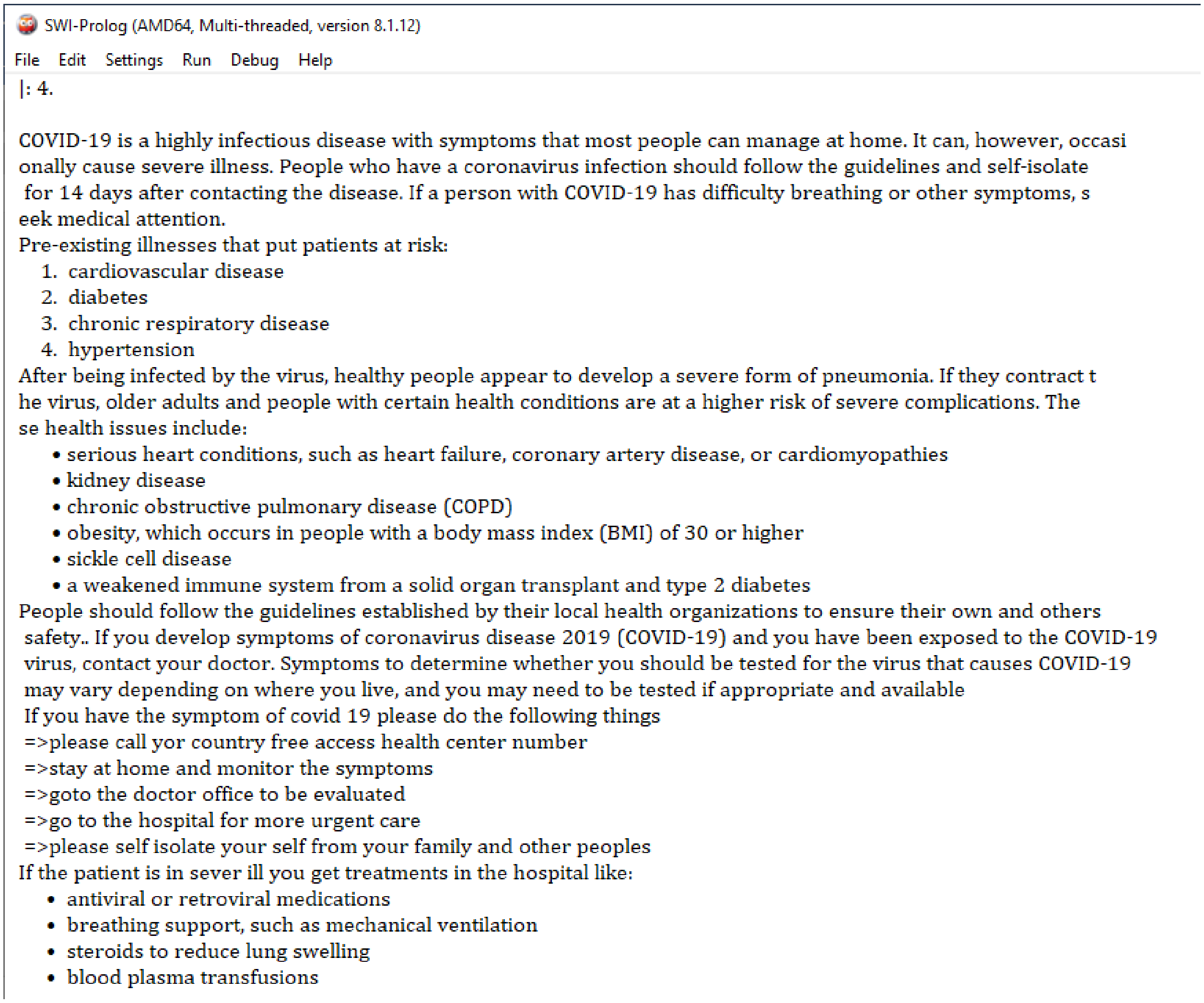


Figure 6. Screenshot of the COVID-19 prevention measures.

Figure 7 shows the COVID-19 diagnosis. It covers things like pre-existing conditions that put patients at higher risk, older adults and people with specific health conditions who are more likely to experience severe complications, guidelines that come after a symptom is noticed, and finally hospital treatment.

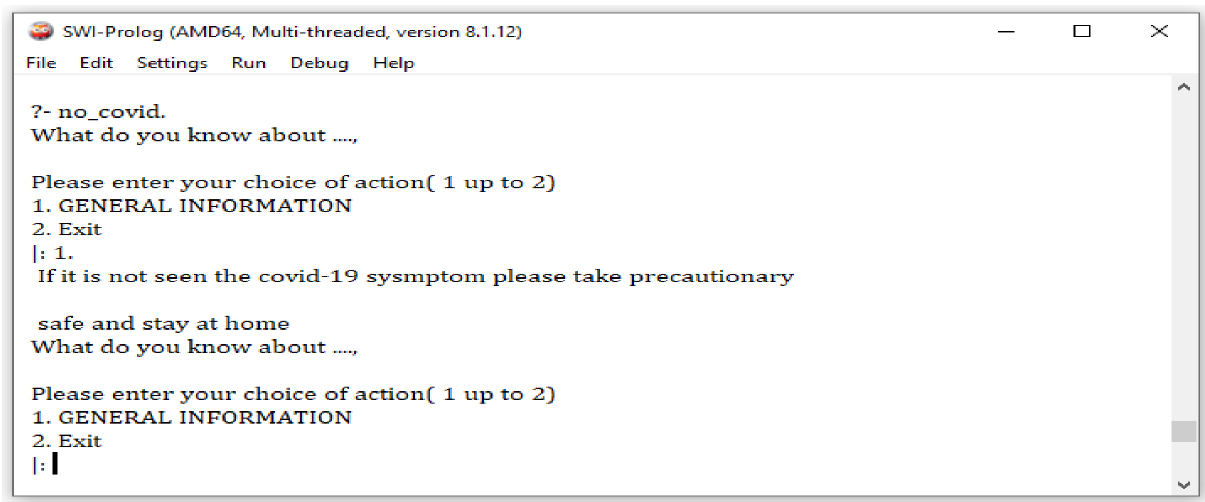


```
SWI-Prolog (AMD64, Multi-threaded, version 8.1.12)
File  Edit  Settings  Run  Debug  Help
|: 4.

COVID-19 is a highly infectious disease with symptoms that most people can manage at home. It can, however, occasi
onally cause severe illness. People who have a coronavirus infection should follow the guidelines and self-isolate
 for 14 days after contacting the disease. If a person with COVID-19 has difficulty breathing or other symptoms, s
eek medical attention.
Pre-existing illnesses that put patients at risk:
   1. cardiovascular disease
   2. diabetes
   3. chronic respiratory disease
   4. hypertension
After being infected by the virus, healthy people appear to develop a severe form of pneumonia. If they contract t
he virus, older adults and people with certain health conditions are at a higher risk of severe complications. The
se health issues include:
    • serious heart conditions, such as heart failure, coronary artery disease, or cardiomyopathies
    • kidney disease
    • chronic obstructive pulmonary disease (COPD)
    • obesity, which occurs in people with a body mass index (BMI) of 30 or higher
    • sickle cell disease
    • a weakened immune system from a solid organ transplant and type 2 diabetes
People should follow the guidelines established by their local health organizations to ensure their own and others
 safety.. If you develop symptoms of coronavirus disease 2019 (COVID-19) and you have been exposed to the COVID-19
 virus, contact your doctor. Symptoms to determine whether you should be tested for the virus that causes COVID-19
 may vary depending on where you live, and you may need to be tested if appropriate and available
 If you have the symptom of covid 19 please do the following things
 =>please call yor country free access health center number
 =>stay at home and monitor the symptoms
 =>goto the doctor office to be evaluated
 =>go to the hospital for more urgent care
 =>please self isolate your self from your family and other peoples
If the patient is in sever ill you get treatments in the hospital like:
   • antiviral or retroviral medications
   • breathing support, such as mechanical ventilation
   • steroids to reduce lung swelling
   • blood plasma transfusions
```

Figure 7. Further diagnostic steps for the diagnosis of COVID-19.

The non-infected people's procedures are shown in Figure 8.



```
SWI-Prolog (AMD64, Multi-threaded, version 8.1.12)
File  Edit  Settings  Run  Debug  Help

?- no_covid.
What do you know about ....,

Please enter your choice of action( 1 up to 2)
1. GENERAL INFORMATION
2. Exit
|: 1.
 If it is not seen the covid-19 sysmptom please take precautionary

 safe and stay at home
What do you know about ....,

Please enter your choice of action( 1 up to 2)
1. GENERAL INFORMATION
2. Exit
|:
```

Figure 8. Screenshoot of non-infected people procedures.

5. CONCLUSION

This paper presented the development of a knowledge based expert system for the diagnosis of COVID-19. To extract patterns from the dataset used, we employ a PART rule algorithm in 10 fold cross validation. The algorithm's accuracy rating is 92.47%, which is good. The expert system receives the patterns in the form of knowledge, which are represented as rules. Expert systems are made to do more than just fill in for human experts; they also make knowledge and skill more widely available, enhancing the productivity of non-experts.

The success of the expert system depends on its development, deployment, and proper management. The system can show general details about COVID-19, symptoms, protective measures, and the diagnosis for treatment options. The system has a user interface as it was built using SWI-PROLOG tool with PROLOG programming language and it shows the user's Y or N (Yes/No) response to the question. Upon receiving a Y or N response, the system deduces the outcome as either COVID-19 disease or not. Based on the symptom, the computer system formulates recommendations.

References

1. L. Z. ,. T. Jingdong Yang, "CrodenseNet: An efficient parallel cross DenseNet for COVID-19 infection detection," Biomedical Signal Processing and Control, 2022.
2. S. F. A. ,. H. Z. A. M. N. T. ,. S. S. Mujeeb Khan, "COVID-19: A Global Challenge with Old History, Epidemiology and Progress So Far," molecules, 2021.
3. H. A. ,. M. K. ,. T. T. ,. Seda Arslan Tuncer, "Scat-NET: COVID-19 diagnosis with a CNN model using scattergram images," Computers in Biology and Medicine, 2021.
4. Y. M. M. N. M. H. N. A. H. Bashar M. Nema, "COVID-19 Knowledge-based System for Diagnosis in Iraq Using IoT Environment," Indonesian Journal of Electrical Engineering and Computer Science, vol. 15, no. 3, 2020.
5. E. K. H. Yanal Mahmoud Mohammad Kilani, "Exploitation of expert system in identifying organizational ethics through controlling decision making process," Management Science Letters, p. 1417–1426, 2019.
6. W. P. M. K. a. R. R. Robbi Rahim, "Online Expert System for Diagnosis Psychological Disorders Using Case-Based Reasoning Method," in The 1st International Conference on Engineering and Applied Science, 2019.
7. S. Rani, "Expert System of AI," International Journal of Current Engineering and Technology, vol. 4, no. 5, 2014.
8. A. Keleş, " Expert Doctor Verdis: Integrated medical expert system," Turkish Electr. Eng. Comput. Sci., vol. 22, no. 4, p. 1032–1043, 2014.
9. S. S. A.-N. Fatima M. Salman, "Expert System for COVID-19 Diagnosis," International Journal of Academic Information Systems Research (IJAISR), vol. 4, no. 3, pp. 1-13, 2020.
10. T. B. K. J. Temesgen Sidamo, "COVID -19: Too Many Hypothesis Too Little Evidence," International Journal of Scientific & Engineering Research, vol. 11, no. 5, 2020.
11. F. M. M. S. Sharana Dharshikgan Suresh Dass, "Expert System for Early Diagnosis of COVID - 19," International Journal of Current Research and Review, vol. 12, no. 22, November 2020.
12. D. Silahudin, D. Henderi, A. Holidin, "Model Expert System for Diagnosis of Covid-19 Using Naïve Bayes Classifier," IOP Conference Series: Materials Science and Engineering, 1007, 012067. DOI: 10.1088/1757-899x/1007/1/012067
13. E. Benmalek, " E. Benmalek, J. Elmhamdi, A. Jilbab, "Comparing CT scan and chest X-ray imaging for COVID-19 diagnosis," Biomedical Engineering Advances, 1, 100003, 2021. DOI: 10.1016/j.bea.2021.100003
14. N. Indumathi, M. Shanmuga Eswari, A.O. Salau, R. Ramalakshmi, R. Revathy Prediction of COVID-19 Outbreak with Current Substantiation Using Machine Learning Algorithms. Intelligent Interactive Multimedia Systems for e-Healthcare Applications. Springer, Singapore, 2022. DOI: 10.1007/978-981-16-6542-4_10
15. A. O. Salau, "Detection of Corona Virus Disease Using a Novel Machine Learning Approach," 2021 International Conference on Decision Aid Sciences and Application (DASA), pp. 587-590. DOI: 10.1109/DASA53625.2021.9682267.
16. D. Asharef, "COVID-19 Future Forecasting Using Supervised Machine Learning Models," International Journal of Science and Research, vol. 11, no. 2, 2022.
17. N. G. ,. A. K. ,. D. K. S. Varan Singh Rohila, "Deep learning assisted COVID-19 detection using full CT-scans," Internet of Things, 2021.
18. S. A. A. ,. S. A. ,. G. u. I. ,. S. A. A. Wajid Arshad Abbasi, "COVIDC: An expert system to diagnose COVID-19 and predict its severity using chest CT scans: Application in radiology," Informatics in Medicine Unlocked, 2021.
19. D. P. A. S. A. T. B. M. M. O. Stephen Machnicki, "The Usefulness of Chest CT Imaging in Patients With Suspected or Diagnosed COVID-19," Education and Clinical Practice CHEST Reviews, 2021.
20. M. S. Z. M. H. K. Khadijeh Moulaei, "Comparing machine learning algorithms for predicting COVID-19 mortality," BMC Medical Informatics and Decision Making, 2022.
21. K. S. Kuniki Imagawa, "Performance change with the number of training data: A case study on the binary classification of COVID-19 chest X-ray by using convolutional neural networks," Computers in Biology and Medicine, 2022.
22. A.M. Ayalew, A.O. Salau, B.T. Abeje, B. Enyew, "Detection and Classification of COVID-19 Disease from X-ray Images Using Convolutional Neural Networks and Histogram of Oriented Gradients," Biomedical Signal Processing and Control, Vol. 74, 103530, pp. 1-11, 2022. DOI: 10.1016/j.bspc.2022.103530
23. K. P. Tripathi, "A Review on Knowledge-based Expert System: Concept and Architecture," IJCA Special Issue on Artificial Intelligence Techniques - Novel Approaches & Practical Applications, 2011.
24. T. M. C. R. Michael Galetakis, "Development of an Expert System for the Prediction of the Performance of Bucket-Wheel Excavators Used for the Selective Mining of Multiple-layered Lignite Deposits," Springer International Publishing Switzerland, 2015.
25. A. G. Yadessa, A. O. Salau, "Low Cost Sensor Based Hand Washing Solution for COVID-19 Prevention," 2021 International Conference on Innovation and Intelligence for Informatics, Computing, and Technologies (3ICT), pp. 93-97. DOI: 10.1109/3ICT53449.2021.9581821.
26. Salau, A.O., Jain, S. Sood, M. (2022). Computational Intelligence and Data Sciences: Paradigms in Biomedical Engineering. Book published by CRC Press, Taylor and Francis, pp. 1-272, eBook ISBN: 9781003224068. DOI: 10.1201/9781003224068. Available online: https://www.taylorfrancis.com/books/edit/10.1201/9781003224068/computationalintelligence-data-sciences-ayodeji-olalekan-salau-shruti-jain-meenakshi-sood
27. A. O. Salau, W.B. Demilie, A.T. Akindadelo, J. Nnenna, "Artificial Intelligence Technologies: Applications, Threats, and Future Opportunities," Proceedings of the Advances in Computational Intelligence, its Concepts & Applications (ACI 2022), pp. 265-273, 2022.