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Implementation of Forward Chaining and Certainty Factor Methods in Determining the Eligibility Status of Covid-19 Vaccination

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Abstract

Screening for the COVID-19 vaccination is an important and mandatory step to ensure the eligibility status of each candidate for vaccination. The main obstacle experienced was the ineffective screening process (a long process) that resulted in the accumulation of patients. Sometimes it takes one to two hours from registration to receiving the vaccination paper. This situation certainly causes discomfort for both participants and vaccinators. Therefore, an expert system is needed to overcome these obstacles. The expert system plays a role in simplifying the service flow and shortening service time. This article discusses the application of the Forward Chaining method to formulate screening parameters to be used to determine vaccination eligibility accurately. Based on interviews with experts (expert doctors who handle vaccination), 12 rules were obtained from formulating 20 historical parameters, which served as a knowledge base for the Covid-19 vaccination screening expert system. The test was carried out by comparing the results of expert screening diagnoses with an expert system using 15 samples of test data. The test results using the Certainty Factor method show that the confidence level is 84% to 99%.

Keywords: *Covid-19 Vaccination; Screening; Expert system; Forward Chaining*

Introduction

2019 is a historic year for the world. The China Health Authority has warned WHO of several cases of pneumonia or unknown cause in Wuhan City in Hubei Province. This disease was later known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) or Covid-19 [1]. The clinical symptoms of Covid-19 vary widely. Common symptoms include fever, cough, sore throat, headache, weakness, muscle aches, and shortness of breath. Because of these pretty common symptoms, Covid-19 can be difficult to distinguish from other respiratory infections. However, in some patients, Covid-19 can lead to pneumonia, respiratory failure, and death by the end of the first week of illness due to a cytokine storm [2].

Since the emergence of Covid-19, every country and affiliated institution has tried to find solutions for prevention and cure, one of the prevention efforts is vaccination. Various countries have researched vaccines since 2020 after the SARS-CoV-2 virus strain was discovered [3]. Vaccine carrier agents can vary according to the type of vaccine. However, after the vaccine is in the body, our body will recognize the foreign protein and make T lymphocytes and B lymphocytes remember and is able to fight the Covid-19 virus in future infections [4]. Each vaccine has a different way of working, which has other effects. To date, several vaccine brands have been accepted by the FDA (Food and drug administration), namely Pfizer-BioNTech COVID-19 Vaccine, Moderna, and Janssen COVID-19 Vaccine [5]. Recent research on the efficacy ranking of Covid-19 vaccines shows that the Pfizer-BioNTech can reach up to 95% of efficacy, Moderna with 94%, Gamaleya 91%, J&J 67%, and AstraZeneca-Oxford with 67% [6]. Large-scale clinical trials to investigate the impact of vaccination on clinical symptoms of confirmed patients are still ongoing [7]. However, data from the AZ Heroes study show that the covid vaccine effectively prevents SARS-CoV-2 infection, and when the condition occurs, the rate of infection and disease impact is significantly reduced [8].

According to the Covid-19 Task Force website, as of July, the Covid-19 vaccination target in Indonesia has only reached 24.49%. This encouraged the Indonesian government to intensify the program of one million vaccines a day to achieve herd immunity [9]. To achieve the target of one million doses of vaccine in a day, the vaccination team of each Puskesmas (public health center) must work hard because the target for vaccine services in a day can reach 150 people. At the Lembang Health Center itself, the vaccine service model underwent several changes. Currently, the last model used is four tables using screening paper.

The obstacle experienced so far is the accumulation of patients because the speed of each officer at each table is different. The target patients must wait a long time from registration to receive the vaccination paper. Waiting time is ranging from one to two hours. The number of targets served is also quite large so that officers, especially doctors, feel very tired when screening questions. Suppose the table service model can be simplified, and the screening question task can be filled directly by the target, the vaccination service can be more effective and shorter and the number of vaccination targets can be increased. This can be realized by implementing an expert system. The expert system screens and provides diagnostic results like an expert because the expert system can make decisions comparable to an expert [10].

This article discusses the application of the Forward Chaining and Certainty Factor methods to determine vaccination eligibility as the basis for building an expert system for Covid-19 vaccination screening, including formulating a knowledge base, screening rules, and algorithm testing. The formulation of the knowledge base refers to the results of the socialization from the Indonesian Technical Advisory Group on Immunization based on the Decree of the Director-General of Disease Prevention and Control Number HK.02.02/4/423/2021 [11] concerning Technical Guidelines for the Implementation of Vaccination in The Framework for Combating the Corona Virus Disease 2019 (Covid-19) Pandemic.

Method

This research used a descriptive qualitative approach. Data collection techniques were observation and interviews. I was observing the implementation of Covid-19 vaccination activities in the working area of the Lembang Health Center, Majene, West Sulawesi, to find out the length of time for services and activities followed by programs. Meanwhile, direct interviews were conducted with the person in charge of the vaccination program and five doctors implementing the program (experts) as resource persons to formulate the basis for the Covid-19 vaccination screening. The data obtained were then analyzed by formulating the forward chaining algorithm and tested using the Certainty Factor method.

A. Research Framework

The research framework shows a series of problem-solving approaches used step by step approach, as shown in Figure 1.
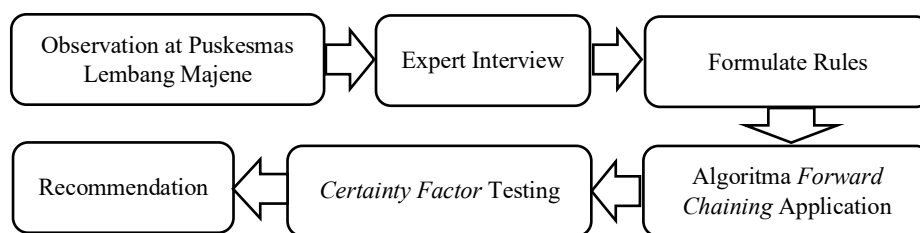

Figure 1. Research framework

B. Forward Chaining Method

The forward Chaining method is a method of searching/drawing conclusions based on existing data or facts leading to conclusions. The search starts from the existing facts and then moves forward through the premises to conclude [12]. This method is also called bottom-up reasoning because this method considers the evidence at the lower level, the facts, towards conclusions at the top level based on the facts [13].

C. Certainty Factor Method

In determining the certainty of facts according to experts, the Certainty Factor (CF) method is often used in expert system testing. This is because CF has an advantage in diagnosing uncertain values; the obtained CF value which has a value close to 1 indicates the most significant confidence value [14].

Result and Discussion

A. Knowledge Base on Expert System

The knowledge base was obtained through an interview process with an expert. In this case, a doctor was responsible for implementing vaccinations. Interviews were conducted clearly and in detail to obtain valid data in making expert systems [15].

Table 1. Knowledge Base Description

Skrining / Riwayat		Kategori		
Kode	Keterangan	S01	S02	S03
R001	Tidak memiliki riwayat alergi berat seperti: sesak nafas, bengkak, urtikaria seluruh badan	✓	✓	
R002	Tidak memiliki penyakit kronik seperti: paru-paru, asma, jantung, gangguan ginjal, penyakit liver/hati	✓	✓	
R003	Tidak memiliki penyakit tuberculosis (TB) atau memiliki riwayat penyakit tuberkulosis (TB) tetapi sudah minum obat diatas 2 minggu	✓	✓	
R004	Tidak memiliki riwayat penyakit kanker/keganasan atau sedang menerima perawatan kanker/keganasan	✓	✓	
R005	Tidak sedang mendapat pengobatan untuk gangguan pembekuan darah, defisiensi imun, menerima produk darah atau transfusi darah	✓	✓	
R006	Tidak sedang mengidap penyakit imun sistemik	✓	✓	
R007	Tidak memiliki penyakit Diabetes Melitus (DM) atau bagi yang memiliki riwayat penyakit Diabetes Melitus (DM) atau kencing manis, sudah minum obat secara teratur (terkontrol)	✓	✓	
R008	Tidak memiliki penyakit epilepsy atau bagi pasien yang memiliki riwayat penyakit epilepsi sudah terkontrol penyakit epilepsinya	✓	✓	
R009	Tidak memiliki penyakit HIV/AIDS atau bagi yang memiliki riwayat penyakit HIV/AIDS sudah minum obat secara teratur	✓	✓	
R010	Tidak sedang mendapatkan vaksin lain selain vaksin Covid-19	✓	✓	
R011	Tidak mengalami kesulitan naik 10 anak tangga		✓	
R012	Tidak sering merasa kelelahan		✓	
R013	Tidak memiliki riwayat penyakit seperti : hipertensi (tekanan darah tinggi), diabetes mellitus (kencing manis), kanker atau keganasan, stroke, penyakit paru obstruktif kronik (PPOK), serangan jantung, gagal jantung, ginjal, nyeri dada, asma, nyeri sendi		✓	
R014	Tidak kesulitan berjalan 100 – 200 meter		✓	
R015	Tidak mengalami penurunan berat badan bermakna dalam 1 tahun terakhir		✓	
R016	Suhu pasien dibawah 37^0C	✓	✓	✓
R017	Tekanan darah dibawah 180/110	✓	✓	✓
R018	Tidak ada kontak yang sedang melakukan pemeriksaan atau dalam perawatan Covid-19 dalam 14 hari terakhir	✓	✓	✓
R019	Pernah terkonfirmasi Covid-19 diatas 3 bulan	✓	✓	✓
R020	Tidak memiliki alergi berat atau mengalami gejala sesak nafas, bengkak, urtikaria seluruh badan setelah vaksinasi Covid-19 pertama			✓

Category Vaccine Screening Question

    S01: Covid-19 Vaccine Screening Phase 1

    S02: Covid-19 Vaccine Screening Phase 1 For People Over 60 Years Old

    S03: Covid-19 Vaccine Screening Phase 2

B. Rules of expert knowledge

Expert knowledge was used as a system knowledge base at this stage. The knowledge base played a vital role in an expert system, containing data or information, facts, theories, knowledge, and rules [16], in this case, the vaccine screening process and the results of doctor diagnoses as experts in the COVID-19 vaccination screening process.

Table 2. Rules Skrining

PERTANYAAN SKRINING VAKSIN COVID-19 TAHAP 1 UNTUK USIA < 60 TAHUN				
Rule 1	IF	R001 AND R002 AND R003 AND R004 AND R005 AND R006 AND R007 AND R008 AND R009 AND R010 AND R016 AND R017 AND R018 AND R019	THEN	V01
PERTANYAAN SKRINING VAKSIN COVID-19 TAHAP 1 UNTUK USIA => 60 TAHUN				
Rule 2	IF	R001 AND R002 AND R003 AND R004 AND R005 AND R006 AND R007 AND R008 AND R009 AND R010 AND R011 AND R012 AND R013AND R016 AND R017 AND R018 AND R019	THEN	V01

Rule 3	IF	R001 AND R002 AND R003 AND R004 AND R005 AND R006 AND R007 AND R008 AND R009 AND R010 AND R011 AND R012 AND R014 AND R016 AND R017 AND R018 AND R019	THEN	V01
Rule 4	IF	R001 AND R002 AND R003 AND R004 AND R005 AND R006 AND R007 AND R008 AND R009 AND R010 AND R011 AND R012 AND R015 AND R016 AND R017 AND R018 AND R019	THEN	V01
Rule 5	IF	R001 AND R002 AND R003 AND R004 AND R005 AND R006 AND R007 AND R008 AND R009 AND R010 AND R011 AND R013 AND R014 AND R016 AND R017 AND R018 AND R019	THEN	V01
Rule 6	IF	R001 AND R002 AND R003 AND R004 AND R005 AND R006 AND R007 AND R008 AND R009 AND R010 AND R011 AND R013 AND R015 AND R016 AND R017 AND R018 AND R019	THEN	V01
Rule 7	IF	R001 AND R002 AND R003 AND R004 AND R005 AND R006 AND R007 AND R008 AND R009 AND R010 AND R011 AND R014 AND R015 AND R016 AND R017 AND R018 AND R019	THEN	V01
Rule 8	IF	R001 AND R002 AND R003 AND R004 AND R005 AND R006 AND R007 AND R008 AND R009 AND R010 AND R012 AND R013 AND R014 AND R016 AND R017 AND R018 AND R019	THEN	V01
Rule 9	IF	R001 AND R002 AND R003 AND R004 AND R005 AND R006 AND R007 AND R008 AND R009 AND R010 AND R012 AND R013 AND R015 AND R016 AND R017 AND R018 AND R019	THEN	V01
Rule 10	IF	R001 AND R002 AND R003 AND R004 AND R005 AND R006 AND R007 AND R008 AND R009 AND R010 AND R012 AND R014 AND R015 AND R016 AND R017 AND R018 AND R019	THEN	V01
Rule 11	IF	R001 AND R002 AND R003 AND R004 AND R005 AND R006 AND R007 AND R008 AND R009 AND R010 AND R013 AND R014 AND R015 AND R016 AND R017 AND R018 AND R019	THEN	V01
PERTANYAAN SKRINING UNTUK VAKSIN COVID-19 TAHAP 2				
Rule 12	IF	R016 AND R017 AND R018 AND R019 AND R020	THEN	V02

Description Category Vaccine Screening Question

    V01: Covid-19 Vaccine Phase 1

    V02: Covid-19 Vaccine Phase 2
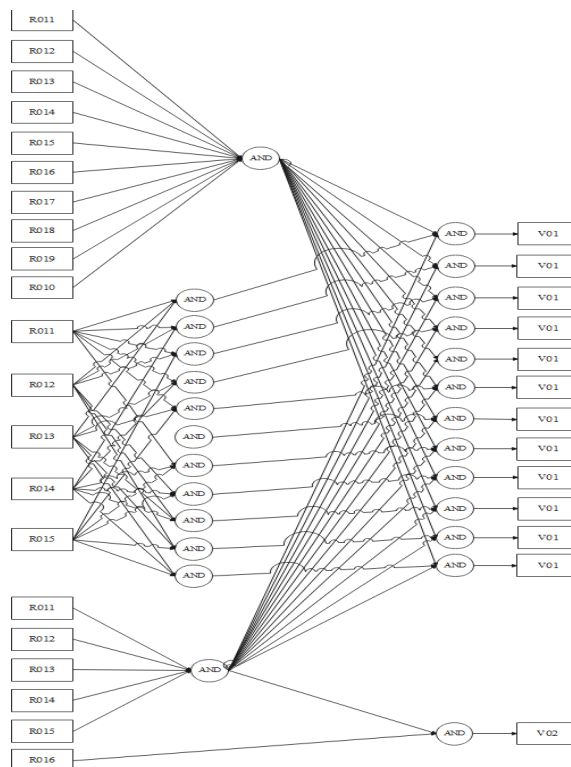
C. *Expert tree*

Figure 2. Expert Tree for Covid-19 Vaccination Screening

The expert tree was built according to the rules and system requirements to facilitate understanding of the expert system built [17]. The root tree of the Covid-19 vaccination screening expert system is shown in Figure 2.

D. Algorithm Testing Using Certainty Factor Method

This study, testing the Forward Chaining method using the Certainty Factor method to show a measure of certainty against the expert trust. The test is carried out with three different case examples, namely categories S01, S02, and S03, using the following equations 1, 2, and 3.

$$CF = CF_{(User)} * CF_{(Pakar)} \dots\dots\dots\dots \tag{1}$$

Next, we calculated the value of the CF combination using equation 2 below:

$$CF_{Combine} (CF_1, CF_2) = CF_{(1)} + CF_2 * (1 - CF_1) \dots\dots\dots\dots \tag{2}$$

$$Confidence\ percentage = CF_{(Combine)} * 100\% \tag{3}$$

To determine the value of Weight (Belief), it is determined based on the confidence value of the target to answer each question with points as shown in Table 3.

Table 3. Determining the Value of Weight

Kondisi	CF
Ya	0.9
Kemungkinan Ya	0.6
Kemungkinan Tidak	0.3
Tidak	0

a) Example Case I, category S01 (first vaccination): Target aged 32 years. The CF value obtained is 0.96 X 100% = 96%, indicating the system's trust value to the expert of 96%. Calculation details are shown in Table 4.

Table 4. CF_{Pakar} Expert Calculation Case I

CF	Riwayat	Skrining	Bobot (Belief)	Bobot (Pakar)	CF	$CF_{Combine}$
CF_1	R001	S01	0.9	1	0.90	0.99
CF_2	R002	S01	0.9	1	0.90	0.99
CF_3	R003	S01	0.9	1	0.90	0.99
CF_4	R004	S01	0.9	1	0.90	0.99
CF_5	R005	S01	0.9	1	0.90	0.96
CF_6	R006	S01	0.6	1	0.60	0.96
CF_{10}	R007	S01	0.9	1	0.90	0.99
CF_{16}	R008	S01	0.9	1	0.90	0.99
CF_{17}	R009	S01	0.9	1	0.90	0.96
CF_{18}	R010	S01	0.6	1	0.60	0.84
CF_{19}	R016	S01	0.6	1	0.60	0.96

b) Example Case II, category S02 (first vaccination, age over 60 years): The target is 63 years old. The CF value obtained is 0.96 X 100% = 96%, indicating the system's trust value to the expert is 96%. Details of the calculation results are as shown in Table 5.

Table 5. Perhitungan CF_{Pakar} Case II

CF	Riwayat	Skrining	Bobot (Belief)	Bobot (Pakar)	Hasil CF	Hasil $CF_{Combine}$
CF_1	R001	S02	0.9	1	0.90	0.99
CF_2	R002	S02	0.9	1	0.90	0.99
CF_3	R003	S02	0.9	1	0.90	0.99
CF_4	R004	S02	0.9	1	0.90	0.99
CF_5	R005	S02	0.9	1	0.90	0.99
CF_6	R006	S02	0.9	1	0.60	0.99
CF_7	R007	S02	0.9	1	0.90	0.99
CF_8	R008	S02	0.9	1	0.9	0.99
CF_9	R009	S02	0.9	1	0.9	0.99
CF_{10}	R010	S02	0.9	1	0.90	0.99
CF_{11}	R011	S02	0.9	1	0.90	0.99

CF_{12}	R012	S02	0.6	1	0.60	0.99
CF_{13}	R013	S02	0	1	0	0.60
CF_{14}	R014	S02	0.9	1	0.90	0.99
CF_{15}	R015	S02	0.9	1	0.90	0.99
CF_{16}	R016	S02	0.9	1	0.90	0.99
CF_{17}	R017	S02	0.9	1	0.90	0.99
CF_{18}	R018	S02	0.9	1	0.90	0.96
CF_{19}	R019	S02	0.6	1	0.60	0.96

c) Example Case III, category S03 (second vaccination): The target is 25 years old. Obtained a CF value of 0.90 x 100% = 90%, indicating the system's trust value to the expert is 90%.

Table 6. Calculation of CF_{Pakar} Target 3

CF	History	Skrining	Weight (Belief)	Weight (Expert)	Result CF	Result $CF_{Combine}$
CF_{20}	R020	S03	0.9	1	0.90	0.90

Furthermore, to test the accuracy of expert system diagnosis using the Certainty Factor method, the comparison of expert diagnosis results used 15 test data, namely vaccination data at the Lembang Majene Health Center on July 14, 2021, as shown in Table 7.

Table 7. Results of Comparison of Diagnosis

No	Target	Age	Category	Expert System Diagnostic			Expert Diagnosis	Conclusion System Vs Expert
				Rule	CF	Status		
1	1	32	S01	Rule 1	0.84	Feasible	Feasible	Consistent
2	2	20	S01	Rule 1	0.96	Feasible	Feasible	Consistent
3	3	15	S01	Rule 1	0.99	Feasible	Feasible	Consistent
4	4	47	S01	Rule 1	0.99	Feasible	Feasible	Consistent
5	5	51	S01	Rule 1	0.99	Feasible	Feasible	Consistent
6	6	43	S01	Rule 1	0.84	Feasible	Feasible	Consistent
7	7	27	S01	Rule 1	0.99	Feasible	Feasible	Consistent
8	8	18	S03	Rule 12	0.96	Feasible	Feasible	Consistent
9	9	65	S03	Rule 12	0.84	Not Feasible	Not Feasible	Consistent
10	10	63	S02	Rule 2	0.96	Feasible	Feasible	Consistent
11	11	52	S01	Rule 1	0.96	Not Feasible	Not Feasible	Consistent
12	12	74	S03	Rule 12	0.99	Feasible	Feasible	Consistent
13	13	32	S03	Rule 12	0.99	Feasible	Feasible	Consistent
14	14	28	S03	Rule 12	0.99	Feasible	Feasible	Consistent
15	15	22	S03	Rule 12	0.99	Feasible	Feasible	Consistent

Conclusion

The utilization of expert systems for vaccination screening can simplify service flow and shorten the service time. Services can be more effective without the making the patients line up for the service. Based on the results of testing the expert system for the Forward Chaining method using the Certainty Factor method, the confidence in the Covid-19 vaccine screening expert system ranges from 84% to 99%. Testing the expert system compared to expert screening also got the appropriate results.

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