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The Certainty Factor Method in An Expert System for Tuberculosis Disease Diagnosis

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Abstract−Tuberculosis is an infection caused by acid-fast bacilli (AFB) and is an infectious disease that can attack anyone through the air. This disease is hazardous and chronic, with a high prevalence among individuals aged 15-35 years. The diagnosis of tuberculosis traditionally takes a long time because it involves an interview process by medical experts and testing sputum samples in the laboratory to determine whether the patient is positive or negative for this disease. This process is not only time-consuming but also requires significant resources. To overcome this problem and speed up the diagnosis process, a technology-based approach is needed, namely the Expert System with the certainty factor method. This method can handle uncertainty in medical diagnosis by providing a certainty value for each observed symptom. This article discusses in depth the application of the certainty factor method in an expert system to diagnose Tuberculosis. By using this method, the system can provide faster and more accurate diagnosis results in diagnosing tuberculosis with a confidence level of 94.6% and reduce the workload of medical personnel. The application of the certainty factor method allows the integration of various symptoms and relevant medical data to produce more precise and reliable diagnostic conclusions.

Keywords: Tubercolosis; Expert System; Certainty Factor; Disease; Diagnosis

1. INTRODUCTION

Tuberculosis (TB) is an infectious disease caused by the bacteria Mycobacterium tuberculosis, which generally attacks the lungs, although it can also attack other organs such as the kidneys, bones, and brain. This disease is still a significant public health problem both globally and nationally [1]. According to the Global Tuberculosis Report 2023 released by the World Health Organization (WHO), Indonesia ranks second in the number of TB cases globally, after India. Every year, it is estimated that there are more than 800,000 new cases of TB in Indonesia, with a mortality rate that is still quite high, mainly due to delays in detection and treatment [2]. The conventional TB diagnosis process involves several medical procedures such as sputum examination (microscopic or culture), radiology (chest X-ray), and tuberculin test [3]. Although this method is considered accurate, its application in the field often faces several obstacles, including limited professional medical personnel, high diagnostic costs, minimal laboratory facilities, and the geographical distribution of people living in remote areas. In addition, TB symptoms often resemble those of other respiratory diseases such as bronchitis or pneumonia, which can lead to misdiagnosis if only relying on subjective initial examinations [4].

Along with the development of information technology and artificial intelligence (AI), expert systems have become one of the promising solutions in helping the process of diagnosing diseases quickly, efficiently, and cost-effectively [5]. Expert systems are designed to imitate the way a medical expert thinks in analyzing information, drawing conclusions, and providing advice based on the knowledge base that has been entered into the system [6]. One method that is often used in expert systems is the Certainty Factor (CF) method, which allows the system to handle data that is uncertain or ambiguous [7]. CF provides a weight of confidence in a conclusion based on the belief and disbelief values originating from experts so that the system not only conveys a diagnosis but also shows the level of certainty of the diagnosis [8].

Various previous studies have developed expert systems based on the Certainty Factor for TB diagnosis, including research by Malo et all (2023) [9] who designed a TB expert system based on the main symptoms such as coughing up phlegm, chest pain, and fever. The system does not accommodate secondary symptoms or cases with overlapping symptoms. Research by Prameswati et all (2024) [10] used CF for TB diagnosis but used a simple linear combination of CF values without considering conflicts between symptoms. Several other studies used interfaces that were technical or not user-friendly, and their validity had not been tested using real case data from patients or medical personnel.

This study is here to overcome these limitations with a more comprehensive and applicable approach, namely developing a Certainty Factor-based TB diagnosis expert system with a knowledge base structure that includes main symptoms, secondary symptoms, risk factors, and patient medical history, so that the diagnosis can be closer to clinical reality [11]. Using a dynamic CF combination method, which considers conflicts between symptoms and adjustments to belief values based on complex real conditions, not just ordinary linear addition [12]. Building a user-friendly system interface that can be accessed offline, to reach users in areas with limited internet and technology. Involving medical experts (pulmonologists) in the system verification and validation process, and testing the accuracy of the system using real patient case scenarios as test data [13].

With this approach, the expert system developed is not only a diagnostic tool, but can also function as a public education tool and support for early medical decision-making. This research is expected to provide real contributions in the field of digital health (e-health), especially in order to support the TB elimination program initiated by the Indonesian government for 2030.

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2. RESEARCH METHODOLOGY

2.1 Research Stages

This study uses an experimental software engineering approach to develop an expert system for diagnosing tuberculosis based on the Certainty Factor (CF) method. The study was conducted through several systematic stages. The process in this study is arranged through a framework first. The description of the framework in this research method is as follows:

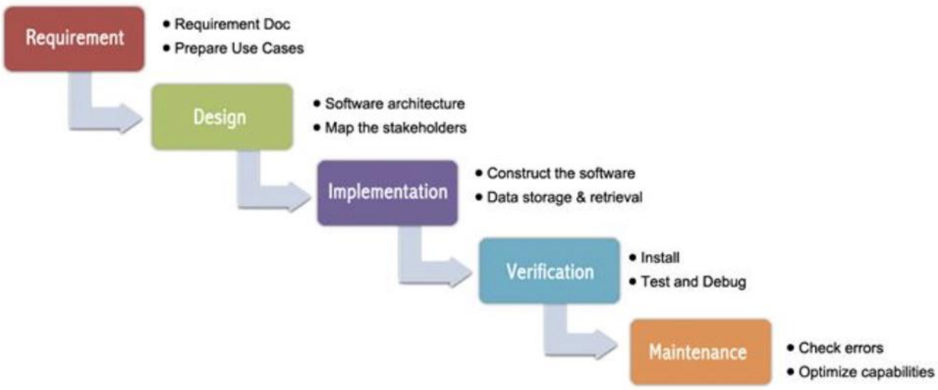

Figure 1. Research Stages

The research flow process follows the Waterfall model with the SDLC (Systems Development Life Cycle) approach. In this method, each stage has a clear purpose, ensuring that the data is analyzed thoroughly and the system developed is able to provide accurate solutions in diagnosing Tuberculosis, as shown in Figure 1 [14].

a. Requirement
The first stage is Requirement, where a comprehensive identification and analysis of system needs is carried out. At this stage, researchers or developers collect information from medical experts regarding the types of tuberculosis, the symptoms that appear, and the level of certainty of the relationship between symptoms and the disease. This information is then poured into a system requirements document and a use case scenario that describes user interaction with the system [15]. The main objective of this stage is to ensure that the system will be developed based on the real needs of users (doctors, patients, or health workers).

b. Design
At the design stage, technical system design is carried out. The design includes software architecture, database structure, and diagnostic process flow. One of the main focuses is to design a representation of expert knowledge in the form of rules (rule-based system), where each rule consists of a combination of certain symptoms associated with a certain type of tuberculosis disease, complete with a certainty factor (CF) value weight. In addition, at this stage, stakeholders who will interact with the system are also mapped, so that the system interface and functionality can be adjusted to the needs of each user [16].

c. Implementation
The implementation stage is the process of coding or building a system based on the design that has been prepared. The expert system is developed by implementing an inference engine based on the certainty factor method, where the calculation of the CF value is carried out using formula (1). This method is used to combine the confidence values of various symptoms selected by the user to determine the possible type of tuberculosis disease [17]. In addition, a database system is also built to store data on symptoms, diseases, expert rules, and diagnosis results. The user interface components are designed to be easy to use by both lay users and medical personnel.

d. Verification
After the implementation is complete, the system enters the verification stage, namely, system testing. At this stage, the debugging process, functionality testing, and validation of diagnosis results are carried out. The system is tested with various combinations of symptom inputs to ensure that the inference process using the certainty factor method produces a diagnosis that is made by an expert decision. In addition, installation testing is carried out on various platforms to ensure that the system can be run properly in different environments [18]. This testing also includes usability testing to assess the extent to which the system is easy to use and understand by users.

e. Maintenance
The last stage is maintenance, which is the maintenance of the system after it is used by users. At this stage, monitoring of system performance, fixing bugs or errors found during use, and improving features to optimize system capabilities are carried out. For example, if there are new symptoms or new types of TB that are not yet covered in the system, the rules and CF values in the knowledge base must be updated. Maintenance also includes ongoing development, such as integration with electronic medical record systems or mobile health applications [19].

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2.2 Certainty Factor Method

In dealing with problems, we are often faced with situations where the answers given are not absolute or certain. This uncertainty can be related to the probability or chance of the outcome of a particular event [20]. This kind of situation is very common in disease diagnosis systems, where medical experts cannot always determine with certainty the relationship between symptoms and the causes of the disease. As a result, various possible diagnoses can occur. Therefore, expert systems must be able to operate in this situation of uncertainty. To show the measure of certainty of a fact or rule, here is the definition of the certainty factor notation used for calculations [21]:
Certainty Factor Notation:

$$CF[h,e] = MB[h,e] - MD[h,e] \quad (1)$$

CF[h, e] = Certainty Factor
MB[h, e] = Measure of Belief
MD[h, e] = Measure of Disbelief
E = Evidence
H = Hypothesis

Certainty Factor is a value that states the level of confidence (trust) in a fact or hypothesis based on the knowledge of an expert [22]. The CF value ranges from 1 (very confident that the fact/hypothesis is true), 0 (don't know/not sure), -1 (very confident that the fact/hypothesis is false) [23]. However, in practice, the CF value is usually stated in the range [0, 1] for positive (confidence) and [-1, 0] for negative (distrust) as shown in table 1. No indication of symptoms; conditions are very unlikely to support the presence of disease. Possibly; symptoms may be present, but are not strong enough to support a diagnosis. Most likely; symptoms are strong enough to support the presence of disease. Almost certainly; symptoms are very strong, strongly supporting a diagnosis of disease. If two rules produce CF for the same hypothesis, the combination is calculated by:
If both CFs are positive.

$$CF\ Combined = CF1 - CF2(1 - CF1) \quad (2)$$

If both CFs are negative Apabila kedua CF negatif

$$CF\ Combined = CF1 - CF2(1 + CF1) \quad (3)$$

If it has opposite sign, then

$$CF\ Combined = \frac{CF1+CF2}{(1-\min(|CF1|,|CF2|)} \quad (4)$$

Determine the final result of the CF value in percentage form.

$$CFpresentase = CFcombine * 100\% \quad (5)$$

Table 1. Certainty Factor Value Table [24]

Description	Weight Value
None	0 - 0.2
Possibly	0.3 – 0.4
Most Likely	0.5 – 0.6
Almost Certainly	0.7 – 0.8

3. RESULT AND DISCUSSION

3.1 Certainty Factor Method Analysis

Calculation with the certainty factor method in diagnosing Tuberculosis (TB) in a system designed based on the certainty factor algorithm involves analyzing the symptoms experienced by a person. This system uses the certainty factor algorithm to determine the level of certainty that a person has TB based on the symptoms that appear [25]. In this system, each symptom is given a certainty factor value that reflects how strongly the symptom supports or opposes the diagnosis of TB [26]. Data analysis is the process of processing data to change it into understandable and useful information in solving problems, especially those related to research. In other words, data analysis is a series of activities carried out to change research data into valuable information [27]. This information can later be used to make accurate conclusions. This process includes various techniques and methods used to extract, interpret, and present data so that the results can help in decision-making and problem-solving [28]. Data analysis not only helps in understanding the characteristics of the data but also allows researchers and professionals to gain deeper insight into the problems being studied and design more effective solutions [29]. The results of the research that has been carried out obtained data on tuberculosis disease shown in Table 2, and tuberculosis symptomps shown in Table 3. The data as follow:

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Table 2. List of Tuberculosis Diseases

Code	Disease	Description	Weight
D1	Pulmonary TB	Tuberculosis disease that attacks and infects the lungs.	0.3
D2	Skin TB	Tuberculosis disease that attacks the skin, usually like chronic scabs that do not heal.	0.5
D3	Glandular TB	Tuberculosis disease that attacks the lymph nodes, usually causing enlargement of the lymph nodes in the neck.	0.6
D4	Bone TB	Tuberculosis disease attacks the spine in the thoracic area (back of the chest).	0.5
D5	Brain TB	Tuberculosis usually attacks children by attacking the membranes of the brain or commonly known as meningitis.	0.4

Table 3. Tuberculosis Symtomps List

Code	Description	Weight
S1	Continuous cough with phlegm for three weeks or more.	0.5
S2	Blood-tinged phlegm	0.7
S3	Shortness of breath and chest pain	0.4
S4	Weak body, decreased appetite, and weight loss	0.6
S5	Sweat at night, even without activity	0.2
S6	Fever chills (mild fever) for more than a month	0.6
S7	The appearance of lumps in the neck, armpits, and groin areas	0.6
S8	Repeated diarrhea that does not heal with regular diarrhea medication	0.2
S9	If there is a partial blockage of the bronchus (the channel leading to the lungs) due to pressure from enlarged lymph nodes, it will cause wheezing (weakened breathing sounds) accompanied by shortness of breath	0.4
S10	If there is fluid in the pleural cavity (the lining of the lungs), it can be accompanied by complaints of chest pain.	0.4
S11	If it affects the bones, symptoms such as bone infection will occur, which at some point can form a channel and flow into the skin above it. At this point pus will come out.	0.8
S12	In children, it can affect the brain (the layer covering the brain) and is called meningitis (inflammation of the brain membrane). The symptoms are high fever, decreased consciousness, and seizures.	0.8
S13	The presence of scrofuloderma or skin tuberculosis (like chronic scabs that do not heal).	0.8
S14	The presence of phlyctenular conjunctivitis (sometimes the eyes are red, then there are white spots).	0.2
S15	The presence of specific lymphadenopathy (enlarged lymph nodes in the neck).	0.8
S16	In tuberculosis, usually the enlarged glands will be in a row or more than one.	0.4

3.2 Expert System Rule

In the certainty factor (CF) method, a rule is a rule used to associate symptoms with a particular diagnosis based on the certainty factor value [30]. This rule helps in formulating diagnostic decisions using the CF values assigned to each symptom. In general, the rule is represented in the following form [5]:

IF E1 AND E2 ....AND En THEN H (CF Rule)
Or
IF E1 OR E2 ....OR En THEN H (CF Rule)
Where:
E1 ... En: Existing facts (evidence)
H: Hypothesis or conclusion generated
CF (Rule): Level of confidence in the occurrence of hypothesis H due to the facts E1 ... En
The following are the rules of the expert system in diagnosing tuberculosis:

Rule 1: *IF Continuous cough with phlegm for three weeks or more is True*
AND Blood-stained phlegm is True
AND Shortness of breath and chest pain are True
AND Weak body, decreased appetite, and weight loss are True
AND Sweating at night, even without activity, is True
AND Fever chills (mild fever) for more than a month is True
AND The appearance of lumps in the neck, armpits, and groin is True

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AND If there is partial obstruction of the bronchus (the channel leading to the lungs) due to pressure from enlarged lymph nodes will cause wheezing (weakened breathing sounds) accompanied by shortness of breath is True
AND If there is fluid in the pleural cavity (the lung covering), it can be accompanied by complaints of chest pain is True
THEN Pulmonary TB

Rule 2: *IF Fever chills (mild fever) for more than a month chest is True*
AND The presence of scrofula or skin TB (such as chronic scabs that do not heal) is True
THEN Skin TB

Rule 3: IF Continuous cough with phlegm for three weeks or more is True
AND Fever chills (mild fever) for more than a month is True
AND The appearance of lumps in the neck, armpits, and groin areas is True
AND If there is partial obstruction of the bronchus (the channel leading to the lungs) due to pressure from enlarged lymph nodes will cause wheezing (weakened breathing sounds) accompanied by shortness of breath is True
AND The presence of specific lymphadenopathy (enlarged lymph nodes in the neck) is True
AND In TB, usually the enlarged glands will be in a row or more than one is True
THEN TB Gland

Rule 4: *IF Fever chills (mild fever) for more than a month are True*
AND If it affects the bones, there will be symptoms like bone infection, which at some point can form a channel and flow into the skin above it, at this outlet pus will come out. Is True
THEN TB Bone

Rule 5: *IF Fever chills (mild fever) for more than a month are True*
AND In children, it can affect the brain (the layer covering the brain) and is called meningitis (inflammation of the meninges), the symptoms are high fever, decreased consciousness, and seizures is True
AND Repeated diarrhea that does not heal with regular diarrhea medication is True
THEN TB Brain

3.3 Case study

Analysis of tuberculosis disease diagnosis using the certainty factor method can be loaded as in the following case. A case of tuberculosis, where the symptoms of the disease and the answers are as follows:

a. Blood-stained phlegm = 0.7
b. Continuous cough with phlegm for three weeks or more = 0.5
c. Shortness of breath and chest pain = 0.4
d. Fever (mild fever) for more than a month = 0.6

To calculate the certainty factor (CF) value based on the symptoms given in the case of Tuberculosis, we will use the CF values that have been given in the previous symptom table. Here are the steps:

a. Blood-tinged phlegm: CFG02 = 0.7
b. Continuous cough with phlegm for three weeks or more: CFG01 = 0.5
c. Shortness of breath and chest pain: CFG03 = 0.4
d. Fever chills (mild fever) for more than a month: CFG06 = 0.6

To combine CF values from several symptoms, we use the following CF combination formula:

$$CFCombine = CF1 + CF2(1 - CF1)$$

Next is to calculate the combined CF in stages:

a. Combining CF from the first and second symptoms:
$CF12 = CFG02 + CFG01(1 - CFG02)$
$CF12 = 0.7 + 0.5(1 - 0.7)$
$CF12 = 0.7 + 0.5 * 0.3$
$CF12 = 0.7 + 0.15$
$CF12 = 0.85$
b. Combining the first combined CF with the third symptom:
$CF123 = CF12 + CFG03(1 - CF12)$
$CF123 = 0.85 + 0.4(1 - 0.85)$
$CF123 = 0.85 + 0.4 * 0.15$
$CF123 = 0.85 + 0.06$
$CF123 = 0.91$
c. Combining the second combined CF with the fourth symptom:
$CF1234 = CF123 + CFG06(1 - CF123)$
$CF1234 = 0.91 + 0.6(1 - 0.91)$
$CF1234 = 0.91 + 0.6 * 0.09$

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$CF1234 = 0.91 + 0.054$
$CF1234 = 0.964$

Based on this calculation, the combined certainty factor value of the given symptoms is 0.964. According to the certainty factor value table, the probability value of 0.964 is in the range of 0.9 – 1.0, which indicates “Certain”. So, based on the certainty factor method, with the given symptoms, the diagnosis of Tuberculosis can be said to be “Certain”.

4. CONCLUSION

The application of the certainty factor method in an expert system can provide a significant contribution to the process of diagnosing tuberculosis (TB). This method allows the system to handle uncertainty in medical decision making by measuring the level of confidence or certainty of each symptom inputted by the user. The expert system developed can process the entered symptom data and provide diagnostic results based on the calculation of certainty values that refer to the knowledge of medical experts. Thus, this system can provide an estimate of the level of possibility of someone suffering from tuberculosis more rationally and measurably. Based on the analysis using the certainty factor method on the symptoms experienced by the patient, namely phlegm mixed with blood (0.7), continuous cough with phlegm for three weeks or more (0.5), shortness of breath and chest pain (0.4), and fever for more than a month (0.6), the combined certainty factor value reached 0.964. This value is in the range of 0.9 - 1.0, which indicates the "Certain" category according to the Value Table. Therefore, the diagnosis of Tuberculosis in this patient can be confirmed with a very high level of confidence. The results of the system testing show that the level of diagnostic accuracy is quite high, provided that the knowledge base used is valid and obtained from competent sources. In addition, this system can be used as a tool by medical personnel and the general public to carry out early detection of TB, especially in areas with limited access to health services. Immediate treatment is highly recommended, accompanied by further examinations such as chest X-rays and sputum tests to confirm the diagnosis and determine the stage and type of TB. In addition, precautions must be taken to prevent transmission, including temporary isolation of patients and using masks. However, this system is not intended to replace the role of doctors, but rather as a support in the initial screening process. Future system development can be directed at expanding the types of diseases that can be diagnosed, increasing accuracy through updating the knowledge base, and integrating with digital medical record data to support a technology-based health service system.

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