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Implementing the Certainty Factor Method in a Dental Disease Expert System

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A B S T R A C T

Health, including dental and oral health, is a fundamental human necessity often overlooked by many. Dental and oral diseases can affect anyone unexpectedly, underscoring the critical need for timely professional advice from dentists based on symptoms presented by patients. Various factors contribute to the reluctance in seeking dental consultations, including inadequate awareness of oral health importance, financial constraints, and discomfort from lengthy wait times. This research proposes an Expert System utilizing the Certainty Factor method to diagnose dental diseases efficiently. The Certainty Factor method quantifies the certainty or uncertainty of facts within expert systems. Through computational analysis of multiple symptoms, the system accurately diagnosed a patient with Tooth Faktur disease with a high certainty level of 98.8%. Such an expert system promises to significantly aid dental professionals in diagnosing diseases promptly, facilitating appropriate treatment interventions.

1. Introduction

Health is one of the basic human needs alongside food, housing and education, because only in a healthy condition can humans live, grow and work better. Many people pay little attention to health, especially dental and oral health because dental and oral diseases can attack anyone and at any time. Therefore, the need for fast and accurate information from a dentist is needed according to the symptoms of the disease experienced by the patient [1].

Expert knowledge which is realized in the form of an application, the level of solution can be the same as that of the experts, so that users can interact with the expert system computer without having to meet the expert, such as someone who suffers from a certain disease can use an appropriate expert system or match the symptoms of the disease to get a solution and suggestions from expert systems [2], [3] . An expert system is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require an expert to solve them [4], [5]. An expert system is a computer system that is intended to imitate all aspects (emulate) of an expert's decision making abilities. Expert systems make maximum use of special knowledge like an expert to solve problems [6].

The aim of an expert system is to transfer expertise from an expert into a computer and then transfer it to other people who are not experts. This process involves four processes, namely additional knowledge (from experts or other sources), knowledge inference, knowledge representation (on a computer), transfer of knowledge to users, inference. Inference is a procedure (program) that has the ability to carry out reasoning. Inference is displayed on a component called an inference engine which includes procedures regarding problem solving [7].

Certainty factor is a method for proving whether a fact is certain or uncertain in the form of a metric which is usually used in expert systems. This method is very suitable for expert systems that diagnose something that is uncertain [8], [9]. Certainty Factor is part of certainty theory, which was first put forward by EH Shorliffe and BG Buchanan in the creation of MYCIN (an early expert system application designed to identify infections in the blood) noting that experts often analyze existing information with expressions such as, for example : possible, most likely, and almost certain [10].

The Certainty Factor (CF) method is a process used to quantify an expert's confidence level regarding a particular situation or circumstance. It establishes a measure of competence in relation to reality or a given scenario, encompassing notions of belief and disbelief

within the certainty factor framework [11]. This certainty factor method can only process 2 weights in one calculation For weights that are more than 2 in number, there is no problem in carrying out calculations if the weights calculated are random, meaning there are no rules for combining the weights, because for any combination the result will remain the same [12].

The Analysis Design Develop Implement Evaluate (ADDIE) model is a systematic learning design model, this model is developed or structured programmatically with systematic sequences of activities in an effort to solve learning problems related to learning resources that suit the needs and characteristics of the system [13]. The ADDIE model is a model that is considered more rational and more complete compared to other models. Therefore, this model can be used for various forms of product development such as models, learning strategies, learning methods, media and teaching materials. ADDIE is also a model for designing systems using a systems approach in dividing the learning planning process into several steps in a logical sequence, then the outputs from each step as input for the next step [14].

Research on expert systems in various fields has been widely carried out. The following are several references used as references in this research. Ratniasih conducted research on an Expert System for Diagnosing Meningitis Using the Naïve Bayes Method. Meningitis is a deadly disease for sufferers. This disease is caused by bacteria, viruses or fungi. Lack of information about the symptoms of meningitis and the lack of information about this disease are the main causes of the high death rate among the community. So we need a system that can provide information about meningitis. Therefore, it is necessary to have an expert system to help the public obtain information about the symptoms of meningitis and solutions [15].

Another study developed an expert system to diagnose diseases caused by smoking. The high costs and long wait times for consultations with lung specialists at hospitals, coupled with the severe nature of smoking-related illnesses that endanger one's life, necessitate the adoption of human knowledge into computers. This allows computers to provide solutions akin to those offered by doctors. The expert system created utilizes the Forward Chaining method [16].

Kadek Dwi Pradnyani Novi et al, conducted research on the diagnosis of lung disease in passive smokers using the Certainty Factor. Chronic Obstructive Pulmonary Disease (COPsD) is defined as a disease or lung disorder that causes ventilation abnormalities in the form of respiratory tract obstruction that is progressive and not completely reversible. With the Expert System, it only predicts (does not judge) with mathematical calculations based on the symptoms suffered using the Certainty Factor method. This system can be used to help the public find out what lung disease they may be suffering from based on the symptoms experienced by the user [17].

From the research described above, this research was carried out using expert system technology. There are many factors that cause people to rarely have examinations and consultations with a dentist, including a lack of attention or awareness of dental and oral health, high costs for consultations, long queues which cause patients to feel uncomfortable waiting. In an effort to obtain high calculation accuracy so that the final results obtained are optimal, the Certainty Factor method is used using symptom weights selected by the user.

2. Research methodology

The research framework is the concept or stages that will be carried out in the research. So that the steps taken by the author in this design do not deviate from the main discussion and are easier to understand, the sequence of research steps will be made systematically so that it can be used as a clear and easy guide for solving existing problems. The research framework that the author carried out in the research can be depicted in Figure 1.

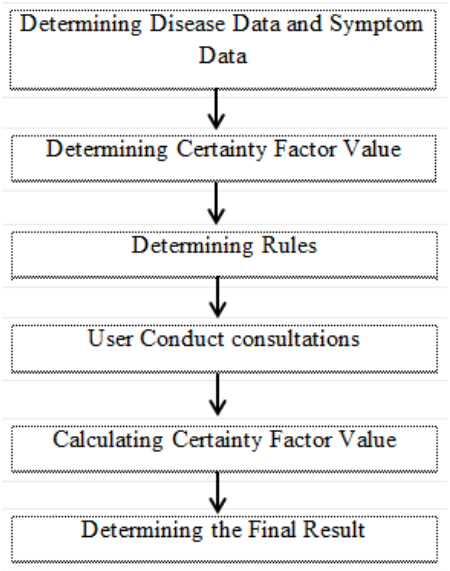

Figure 1. Research Framework

Certainty Factor, part of certainty theory introduced by E. H. Shortliffe and B. G. Buchanan in the development of MYCIN, a pioneering expert system designed to identify bloodstream infections, addresses how experts express their confidence in analyzed information using terms like "possibly," "likely," and "almost certain" [10].

The calculation steps in the certainty factor method to build an expert system for diagnosing malnutrition for toddlers are as follows:

2.1. Determining dental disease data.

This likely involves gathering data related to symptoms and indicators of dental diseases in toddlers.

2.2. Determining symptom data.

Gathering data on symptoms that could indicate malnutrition in toddlers, such as Teeth sway, fever, bad breath, etc.

2.3. Determining combined data

Combining symptom data (from step 2) with dental disease data (from step 1). This is crucial as it forms the basis for the rules used in the CF method.

2.4. Determination of the CF value.

Each rule or condition (which may relate symptoms to malnutrition or dental diseases) is assigned a Certainty Factor (CF) value. This CF value represents the degree of certainty or confidence in the relationship between the symptom and the disease.

2.5. Selection of symptom data by the user.

The user selects symptoms that are observed in the toddler.

2.6. Calculation of CF values from user symptoms.

For each symptom selected by the user, the CF values from the rules (derived in step 4) that involve that symptom are considered.

2.7. Results of diagnosis of dental disease.

The process of calculating the level of confidence begins by decomposing a rule that contains several symptoms into a number of rules that only involve one symptom. After that, each new rule will be assessed using a specific formula to calculate the Certainty Factor (CF) value [17].

$$\mathrm{CF(H,E)} = \mathrm{CF_{(user)}} * \mathrm{CF_{rule}} \quad (1)$$

Among the conditions that occur, there are several conditions that have the same result (in different rules), we need to collect or combine the Certainty Factor (CF) values from each existing condition to get the overall CF value using the following equation:

If both CFs > 0, then the formula is:

$$\mathrm{CF[H,E]} = \mathrm{CF_{[old]}} + \mathrm{CF_{[new]}}\,(1 - \mathrm{CF_{[old]}}) \quad (2)$$

If both CF < 0, then the formula is:

$$\mathrm{CF[H,E]} = \mathrm{CF_{[old]}} + \mathrm{CF_{[new]}}\,(1 + \mathrm{CF_{[old]}}) \quad (3)$$

If both CF < 0, then the formula is:

$$\mathrm{CF[H,E]} = \mathrm{CF_{[old]}} + \mathrm{CF_{[new]}} / (1 - \min \mathrm{CF_{[old]}} | \mathrm{CF_{[old]}}) \quad (4)$$

The results of the diagnosis are presented as percentages of possible diseases (malnutrition or dental disease). Each disease's percentage is determined by calculating the CF value based on the symptoms selected by the user. The disease with the highest percentage (or highest CF value) among all evaluated diseases is selected as the diagnosis. This is based on the principle that higher CF values indicate a higher degree of certainty or likelihood of the disease being present.

3. Results and Discussion

3.1. Certainty Factor Method

a. Determine Dental Disease Data.

The initial stage in applying the Certainty Factor method involves determining dental disease data, which is presented in Table 1.

Table 1. Disease Data

No	Disease code	Disease Name
1	P01	Periodontal Abscess
2	P02	Periapical Abscess
3	P03	Dental Abrasion
4	P04	Bruxims
5	P05	Gingivitis (Gum Inflammation)
6	P06	Caries (cavities)
7	P07	Tooth Fracture
8	P08	Periodontitis

The Table 1 provides comprehensive information on various dental diseases categorized by specific codes and names. In this study, eight types of dental conditions are identified, each assigned a unique code from P01 to P08. This structured classification facilitates systematic analysis and diagnosis within the context of the Certainty Factor methodology, supporting accurate decision-making processes in dental healthcare.

b. Determining Symptom Data

The process of determining symptom data for diagnosing dental diseases involves identifying symptoms experienced by patients to accurately diagnose their conditions, as outlined in Table 2.

Table 2. Symptom Data

No	Symptom Code	Symptom Name
1	G01	Difficult to chew.
2	G02	Swelling or inflammation of the gums.
3	G03	Teeth sway.
4	G04	The jaw becomes swollen.
5	G05	Swollen lymph nodes around the jaw or neck.
6	G06	Fever.
7	G07	Bad breath.
8	G08	Pain or soreness around the gums.
9	G09	Teeth feel sore and sensitive.
10	G10	The shape of the teeth appears eroded
11	G11	Insomnia or feeling restless
12	G12	Headache
13	G13	Cavity
14	G14	Gums bleed easily
15	G15	The shape of the gums is slightly rounded
16	G16	The presence of plaque on the teeth

No	Symptom Code	Symptom Name
17	G17	Teeth seem to be eroded
18	G18	Pain that can appear and disappear suddenly
19	G19	Tooth pain when chewing/biting
20	G20	Tooth pain when chewing/biting

The Table 2 lists 20 symptoms coded from G01 to G20, which patients may present. After establishing disease and symptom data, the subsequent step is assigning weights to each symptom, detailed in Table 3 below. This table provides weight rules where each symptom (identified by its code) is assigned values for Medical Background (MB), Medical Diagnosis (MD), and Expert Certainty Factor. These weights facilitate a systematic evaluation of symptoms within the Certainty Factor framework, enhancing the precision of diagnostic decisions in dental healthcare.

Table 3. Weight Rule Data

No	Disease Name	Symptom Code	MB	MD	Expert Certainty Factor
1	Periodontal Abscess	G001	0.8	0.4	0.4
2		G002	0.8	0.4	0.4
3		G003	0.6	0.4	0.2
4	Periapical Abscess	G001	0.8	0.4	0.4
5		G004	1	0.4	0.6
6		G005	0.8	0.4	0.4
7		G006	1	0.6	0.4
8	Dental Abrasion	G007	1	0.4	0.6
9		G008	0.8	0.4	0.4
10	Bruxims	G009	0.6	0.4	0.2
11		G010	1	0.4	0.6
12	Gingivitis (Gum Inflammation)	G005	0.8	0	0.8
13		G014	0.6	0.4	0.2
14		G015	1	0.4	0.6
15	Caries (cavities)	G003	1	0.4	0.6
16		G007	0.6	0.4	0.2
17		G009	0.6	0.4	0.2
18		G010	0.6	0.4	0.2
19		G013	0.8	0	0.8
20		G016	0.8	0.4	0.4
21	Tooth Fracture	G019	1	0.4	0.5
22		G009	0.8	0	0.8
23		G010	0.8	0.4	0.4
24		G015	1	0.4	0.6
25		G017	0.8	0.4	0.4
26		G018	1	0.4	0.6
27		G019	0.8	0.4	0.4
28	Periodontitis	G002	0.8	0	0.8
29		G003	0.6	0.4	0.2
30		G007	1	0.4	0.6
31		G014	1	0.4	0.6
32		G016	0.8	0.4	0.4
33		G019	0.8	0	0.8
34		G020	0.8	0.4	0.4

In Table 4, users of the expert system have the ability to assign Certainty Factor (CF) values to various conditions based on the information they have gathered. This table facilitates decision-making and recommendation processes by quantifying the level of certainty or confidence in different hypotheses or statements. Below is a detailed description of the Table 4.

Table 4. Certainty Factor Condition Value

No	Condition	CF value
1	Definitely Yes	1
2	Almost Certainly Yes	0.8
3	Most likely Yes	0.6
4	Maybe yes	0.4
5	Don't know	0

Table 4 outlines a systematic approach for assigning Certainty Factor (CF) values to different conditions within an expert system, aiding in decision-making processes. Each entry is sequentially numbered for clarity, detailing specific statements or hypotheses under evaluation and their corresponding levels of certainty. CF values range from 0 (indicating no certainty) to 1 (denoting complete certainty), allowing users to apply these values accordingly: CF = 1 for "Definitely Yes" when there is unequivocal evidence, CF = 0.8 for "Almost Certainly Yes" when evidence strongly supports a likely truth with minor uncertainty, CF = 0.6 for "Most likely Yes" indicating moderate certainty, CF = 0.4 for "Maybe yes" suggesting some evidence with significant uncertainty, and CF = 0 for "Don't know" when evidence is insufficient for a conclusive judgment. This structured framework enables the expert system to provide informed recommendations aligned with the available evidence, enhancing decision-making reliability across various applications.

Table 5 provides the Certainty Factor (CF) values associated with different answers or conditions related to diagnosing dental disease. Each answer has an assigned weight that reflects the degree of certainty it provides toward diagnosing the disease. Here's how you can interpret and use this table.

Table 5. Certainty Value Factors in Patients

Code	Answer	Weight
G009	Definitely Yes	1
G010	Maybe yes	0.4
G015	Maybe yes	0.4
G017	Most likely Yes	0.6
G018	Almost certainly Yes	0.8

The Table 5 provides a structured breakdown of information crucial for diagnosing dental disease. Each entry is identified by a unique code, detailing various responses or conditions observed during diagnosis. The associated Certainty Factor (CF) weight assigned to each answer ranges from 0 to 1, indicating the degree of certainty it contributes to the diagnosis. For instance, if a patient exhibits symptoms aligned with G009 (Definitely Yes), the CF value assigned is 1, indicating absolute certainty of the disease presence. Responses like G010 and G015 (Maybe yes) offer a CF value of 0.4 each, suggesting moderate certainty. G017 (Most likely Yes) provides a CF value of 0.6, indicating a higher likelihood compared to the 'Maybe' responses, while G018 (Almost certainly Yes) holds the highest CF value of 0.8, signaling strong certainty in diagnosing the dental disease. These CF values help

clinicians objectively assess and combine diagnostic information to make informed decisions regarding the patient's condition.

The final step is to combine the CF values and each rule, combine CF1 to CF5 with the following equation :

$CF_{COMBINE}(CF_1, CF_2) = CF_1 + CF_2 * (1 - CF_1)$

$= 0.8 + 0.4 * (1 - 0.8)$

$= 0.8 + 0.4 * 0.2$

$= 0.8 + 0.08$

$= 0.88\ C_{Fold1}$

$CF_{COMBINE}(C_{Fold1}, CF_3) = 0.88 + 0.6 * (1 - 0.88)$

$= 0.88 + 0.6 * 0.12$

$= 0.88 + 0.072$

$= 0.952\ C_{Fold2}$

$CF_{COMBINE}(C_{Fold2}, CF_4) = 0.952 + 0.4 * (1 - 0.952)$

$= 0.952 + 0.4 * 0.048$

$= 0.952 + 0.019$

$= 0.971\ C_{Fold3}$

$CF_{COMBINE}(C_{Fold3}, CF_5) = 0.971 + 0.6 * (1 - 0.971)$

$= 0.971 + 0.6 * 0.029$

$= 0.971 + 0.017$

$= 0.988\ C_{Fold4}$

$Percentage = CF_{COMBINE} * 100\%$

$= 0.988 * 100\ \%$

$= 98.8\ \%$

Based on the results of the CF value combination above, the diagnosis for the user is Tooth Invoice disease with a certainty level of around 98.8%. The CF value is used to express the level of confidence of the system in making decisions or diagnoses. The higher the CF value, the greater the confidence that the diagnosis or decision produced by the system is correct.

4. Conclusion

Through computational analysis of multiple symptoms, the system accurately diagnosed a patient with Tooth Faktur disease with a high certainty level of 98.8%. Such an expert system promises to significantly aid dental professionals in diagnosing diseases promptly, facilitating appropriate treatment interventions. The clinic and patient expert system is more selective in conducting consultations and diagnosing dental disease online on the Assalam Dental Clinic website and applying the Certainty Factor method using the Addie Model in the expert system is expected to provide precise and accurate results of analyzing dental disease in patients.

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