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Application of Decision Tree Algorithm for Classification of Dental Diseases Based on Medical Records

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ABSTRACT

This study aims to apply the Decision Tree algorithm in diagnosing dental diseases based on patient medical record data at the Medika Saintika Clinic. The data used includes variables such as toothbrushing habits, age, gender, dental health history, symptoms of dental pain, and dental conditions. The analysis process begins with data collection and preprocessing to ensure the quality of the data used. The results of entropy and gain calculations are used to determine the most relevant attributes in building the decision tree. The developed model shows a high accuracy rate of 92% and an error of 8%, which demonstrates the effectiveness of the Decision Tree algorithm in diagnosing dental diseases. The tooth brushing habit factor proved to be the most influential, followed by symptoms of tooth pain and other factors. Although the accuracy of the model is quite good, this study suggests the need for further optimisation by adding variables and improving data processing methods.

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1. INTRODUCTION

Dental disease, especially caries, is a very significant health problem in Indonesia. According to the Ministry of Health of the Republic of Indonesia, the prevalence of caries in children aged 5-6 years reached 93.2%, and in children aged 12 years, the prevalence reached 88.8% [1]. This oral health problem not only affects the patient's quality of life, but also the general health condition of the body, because caries left untreated can develop into a more serious infection [2]. This condition requires more serious attention given its great impact on society and the country's health system.

In addition, dental disease, especially dental caries, can affect various aspects of a patient's life. Poorly treated caries can interfere with chewing and speaking functions and affect the patient's aesthetic appearance which in turn can reduce their self-confidence [3]. This decrease in quality of life can be felt more by children and adolescents who often experience social and emotional disturbances due to untreated dental disease [4]. It is therefore important to have a system that can detect dental disease early to avoid more serious complications.

The process of detection and diagnosis of dental disease currently relies heavily on manual methods and physical examination by medical personnel. However, these methods are often limited in terms of accuracy and efficiency. Manual management of medical record data is prone to errors that can potentially cause delays in diagnosis [5]. According to research conducted by Purba et al, well-structured medical record data management is essential to improve efficiency in disease diagnosis [6]. Therefore, technology is needed that can assist doctors in diagnosing dental diseases more quickly and accurately.

Technologies based on artificial intelligence (AI) and machine learning offer innovative solutions in the medical field including dentistry. By utilising machine learning the system can analyse data automatically to provide a more precise diagnosis. One of the widely used machine learning algorithms in the healthcare field is Decision Tree, which has the ability to classify data based on relevant attributes and provide clear decisions based on existing information [7], [8]. Research shows that Decision Tree can improve diagnosis accuracy, especially in diagnosing dental diseases including caries and periodontal disease [9].

This Decision Tree method relies on the division of data based on the most important attributes for diagnosis such as dental conditions, symptoms experienced by patients, as well as risk factors associated with dental health [10]. This algorithm has the advantage of transparency as it provides decisions that are easily understood by medical personnel, thus facilitating clinical decision-making [11]. Several previous studies have also shown that Decision Tree can provide highly accurate results in diagnosing various medical diseases including dental diseases [12], [13].

The use of Decision Tree can reduce reliance on intuition or doctor's experience which is often a subjective factor in diagnosis. With a machine learning-based system, diagnosis decisions can be based on more objective and measurable data [14]. For example, in a study conducted by Kumar and Sharma, the use of the Decision Tree algorithm in diagnosing heart disease showed promising results in terms of accuracy and efficiency [15].

AI-based systems can also automate many aspects of medical diagnosis including the analysis of patient medical records, which can speed up the diagnosis process and reduce human error [16]. This is of course very beneficial in dental practice, where early detection of dental diseases is essential to prevent more severe damage [17]. In addition, the application of machine learning in dentistry can help improve patient experience by providing more appropriate treatment recommendations based on historical patient data [18].

Recent research has shown that the Decision Tree algorithm can be applied successfully to diagnose dental diseases, especially those related to caries and dental infections [19]. In a study conducted by Lee et al, the Decision Tree successfully provided accurate predictions of periodontal disease and other diseases frequently encountered in dental practice [20]. This shows the great potential of AI technology in improving the diagnosis and overall management of dental diseases.

A number of other studies have also shown that the use of machine learning in medical record data management can speed up the diagnosis process, reduce treatment costs, and improve diagnosis accuracy [21], [22]. This technology also allows the creation of expert systems that can assist doctors in determining the right diagnosis based on more structured patient medical record data [23]. In this context, the Decision Tree algorithm is a good choice because of its ability to provide clear and data-based decisions.

Based on this, the application of Decision Tree in the diagnosis of dental disease at the Medika Saintika Clinic is expected to increase efficiency and accuracy in providing diagnosis to patients. With the application of AI-based systems, patient medical record data can be processed more quickly and accurately, thereby improving the quality of medical services provided [24], [25]. This is in line with the findings of Purba et al. who stated that sophisticated information technology-based systems can reduce medical errors and improve the quality of care [26].

Overall, the application of machine learning and AI in dentistry, especially through the use of the Decision Tree algorithm, has great potential to improve the diagnosis process of dental diseases, reduce medical errors, and improve patient experience [27]. Therefore, this study aims to implement Decision Tree in the dental disease diagnosis system at Medika Saintika Clinic, with the hope that it can make a significant contribution to improving the quality of dental health services in Indonesia.

2. METHOD

The research methodology aims to assist the author in completing the research so that the research becomes directed and achieves the desired goals. This methodology is carried out in a structured manner and serves as a guide for researchers in carrying out research, so that the results obtained stay on track and the expected goals can be achieved properly in accordance with predetermined goals. This research methodology includes a research framework that starts from identifying problems to making results and discussions. The framework in this study can be described in the following figure.

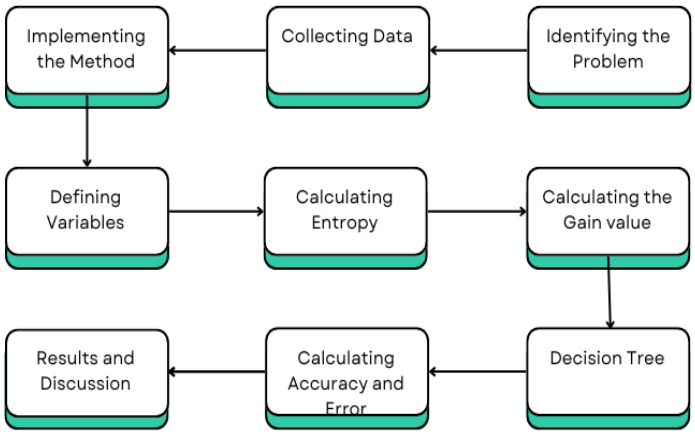

Figure 1: Research Framework

1. **Identifying the Problem**
   The problem identification stage is the first step in research that aims to identify various issues that exist in the object of research and determine the boundaries of the problems to be studied. At this stage, researchers will understand the challenges faced by the Medika Saintika Clinic related to the diagnosis of dental diseases, such as the accuracy of diagnosis and the potential inaccuracy of diagnosis based on medical record data. Problem formulation is done appropriately to determine the focus of research on the use of the Decision Tree algorithm in diagnosing dental diseases.
2. **Collecting Data**
   The data collection process is an important step in this research. The data needed to diagnose dental diseases are taken from the patient's medical records recorded at the Medika Saintika Clinic. The data collected includes various patient medical information such as symptoms experienced, examination results, history of dental disease, age, gender, and other factors related to the patient's dental condition. The quality of the data obtained greatly determines the accuracy of the model to be built.
3. **Implementing the Method**
   At this stage, researchers will use the Decision Tree algorithm to diagnose dental diseases based on patient medical record data. The Decision Tree algorithm is a predictive model used to make decisions or classifications based on rules generated from data. This algorithm will be applied to model the diagnosis of dental disease by considering the variables in the patient's medical record data.
4. **Defining Variables**
   Defining variables is an important step in selecting the data elements to be used in a dental disease diagnosis model. The variables selected reflect patient characteristics or features that are relevant to the diagnosis of dental conditions. Some of the variables used in this study include:
   1. Toothbrushing Habits
   2. Age
   3. Gender
   4. Dental Health History
   5. Symtoms of Tooth Pain
   6. (Sore or Not)
5. **Calculating Entropy**
   Calculating entropy is an important step in the Decision Tree algorithm, which serves to assess the level of uncertainty or irregularity in the dataset. Entropy is used to select attributes that are most effective in separating data into different categories. In this study, entropy is used to determine the attributes that have the most influence on the diagnosis of dental disease.
   The entropy formula used is:

$$\text{Entropy}(S) = \sum_{i=1}^{n} - \text{pi} * \log_2 \text{pi}$$

   Description:
   S : set of cases

N : number of partitions of S
Pi : proportion of Si to S

6. **Calculating the Gain Value**
   Gain value is used to measure the decrease in uncertainty after separating data based on certain attributes. A higher gain indicates that the attribute is more informative in separating data and determining the correct diagnosis.
   The formula to calculate Gain is:

$$\text{Gain}(S, A) = \text{Entropy}(S, A) - \sum_{1=1}^{n} \frac{|S_i|}{|S|} * \text{Entropy}(S_i) \quad (2)$$

   Description:
   S : set of cases
   A : attribute
   N : number of partitions of attribute A
   |Si| : number of cases in the i-th partition
   |S| : number of cases in S
7. **Decision Tree**
   A decision tree is a predictive model used to make decisions or perform classifications based on rules generated from data. In this context, a decision tree will be used to diagnose dental diseases based on the patient's symptoms and medical history. Each branch in the decision tree represents the separation of data based on certain attributes that will guide in the determination of dental disease diagnosis.
8. **Calculating Accuracy and Error**
   At this stage, accuracy and error will be calculated to evaluate how good the algorithm is in diagnosing dental diseases based on medical record data. A higher accuracy value indicates that the model can predict the diagnosis correctly, while a lower error value indicates that the model is more accurate.
   The formula for calculating Accuracy and Error is as follows:
   Accuracy = (Number correctly classified)/(Number of testing samples tested)
   Error = (Number of incorrectly classified)/(Number of testing samples tested)
9. **Producing Results and Discussion**
   Results and discussion aims to present the findings of this research. Through data analysis with the Decision Tree algorithm, the results will explain the extent to which this algorithm can be applied to accurately diagnose dental diseases. The discussion will include the interpretation of the analysed data, as well as its impact on the diagnosis practice at Medika Saintika Clinic. Significant findings and recommendations for improved diagnosis based on patient medical record data will be further discussed in this section.

3. RESULTS AND DISCUSSION

In In this study, the Decision Tree algorithm was applied to diagnose dental diseases based on patient medical record data at the Medika Saintika Clinic. The data used includes variables such as toothbrushing habits, age, gender, dental health history, symptoms of dental pain, and dental conditions (healthy or sick).

3.1. Data Processing and Preprocessing

The data used in this study includes 100 patient entries with various attributes. Prior to the application of the Decision Tree algorithm, a preprocessing stage was performed to ensure data quality. Missing, duplicate, and inconsistent data were carefully checked and handled. Most of the data had no missing values, which ensured accuracy in the model to be built.

3.2. Entropy and Gain Analysis

In the processing stage of the Decision Tree algorithm, entropy is calculated for each attribute to determine how much uncertainty there is in the data. Based on the entropy formula, each attribute is calculated to determine its contribution in separating data into more structured categories. The results of the calculation get the Entropy and Gain values at this stage called Node 1.

Table 1. Note 1

Node 1	Description	Number of cases	Sick	Healthy	Entropy	Gain
Total		100	25	75	0,811278	
Toothbrushing Habit	Yes	56	0	56	0	0,377198
	No	44	25	19	0,986545	
Age	Old	49	13	36	0,834648	0,000866
	Young	51	12	39	0,787127	
Gender	Male	11	3	8	0,845351	-0,04415
	Female	89	25	64	0,856673	
Dental Health History	Yes	56	11	45	0,714727	0,013978
	No	44	14	30	0,902393	
Symptoms of Dental Pain	Yes	42	17	25	0,973668	0,066637
	No	58	8	50	0,578795	

At Node 1, the calculation results show that Toothbrushing Habits have a significant influence on dental conditions, with a higher gain value than other attributes. However, to get more accurate results, this process needs to be repeated for each node in the decision tree, by recalculating the entropy and gain based on the partitioned data. Each step of searching for entropy and gain will continue to be carried out at each branching of the tree until an optimal classification for all dental conditions is obtained.

3.3. Decision Tree

The decision tree is built based on the results of entropy and gain calculations. This decision tree shows how classification decisions are made based on rules derived from the data. Each branch of the tree illustrates the separation of data based on different attribute values.

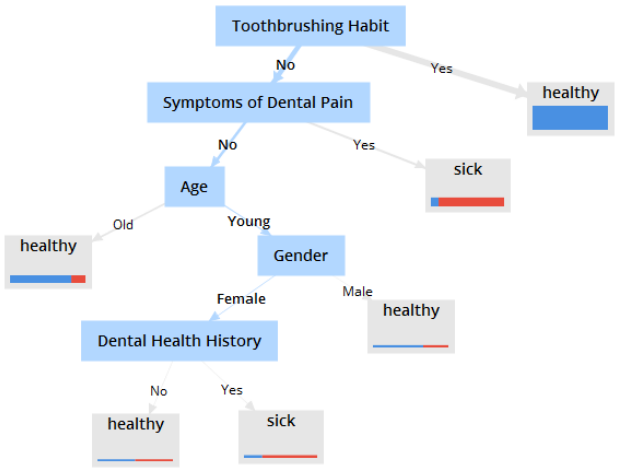

Figure 2. Decision Tree

The results of the decision tree show that tooth brushing habits are the most influential factor on the patient's dental condition. Patients who brush their teeth regularly tend to have healthy teeth, regardless of symptoms or other factors. In contrast, for patients who do not have good brushing habits, the symptom of tooth pain is an important factor in determining whether their teeth are healthy or sick. If the patient does not feel pain, age is a factor, and if they are older, their teeth tend to be more prone to problems. Gender and dental health history also have less influence on dental condition, but still play a role in predicting dental disease.

3.4. Accuracy and Error

After the decision tree was formed, the model was evaluated using test data. The accuracy value obtained is 92%, which indicates that the Decision Tree algorithm is quite effective in diagnosing dental diseases based on patient medical record data. In contrast, the error rate of 8% indicates that there is room for improvement, especially in terms of separating data with categories that are more difficult to predict.

This accuracy suggests that most patients can be correctly diagnosed using this model. However, the model also exhibits some misclassification, which may be due to data imbalance or errors in attributes that are not detected by the model.

3.5. Discussion

Based on the decision tree analysis, tooth brushing habits are proven to have a huge influence in determining the condition of a person's dental health. Patients who regularly brush their teeth have a higher tendency to have healthy and problem-free teeth. In contrast, for patients who do not regularly maintain dental hygiene through tooth brushing, symptoms such as pain in the teeth are the main factors that affect their dental health condition. Patients with complaints of dental pain are more likely to experience painful or damaged teeth, which can eventually lead to more severe dental problems if not treated properly. In addition, other factors such as age, gender, and dental history also play an important role in determining the diagnosis and condition of one's dental health. For example, older patients or women often show a greater tendency towards certain dental problems, such as tooth decay due to declining dental health with age or hormonal changes in women. A history of poor dental health can also make matters worse, especially in patients who have had previous dental treatment or have dental problems that have not been properly treated. All of these factors interact with each other, providing a more complete picture of how an individual's habits and conditions affect their overall dental health.

4. CONCLUSIONS

The Decision Tree algorithm proved effective in diagnosing dental diseases based on patient medical record data. The developed model shows a high accuracy of 92% with an error rate of 8%, although there is still potential for improvement. The application of this algorithm can have a positive impact in improving the accuracy of diagnosis at the Medika Saintika Clinic. Further research is needed to optimise model performance by adding more relevant variables and improving data processing methods. In the resulting decision tree analysis, the first root or branching factor is tooth brushing habits, which is proven to have the greatest influence on the patient's dental condition. After that, other factors such as dental pain symptoms, age, gender, and dental history followed as variables determining the patient's dental health condition. Thus, a deeper understanding of these factors can further improve the accuracy and effectiveness of the diagnosis performed by this model.

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