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Expert System for Diagnosis of Hypertension Disease Using Naive Bayes Method

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abstract

Hypertension is a disorder of the blood vessels that causes the supply of oxygen and nutrients carried by the blood to be blocked to the body's tissues that need it. Hypertension is often referred to as a silent killer, because it is a deadly disease without symptoms as a warning to its victims. Hypertension sufferers range from 40 years of age and above to lifelong. In general, hypertension is caused by hereditary factors, unhealthy lifestyles, excessive salt consumption, alcoholic beverages and stress. Expert systems can be a solution to solve problems because this system works like an expert and is designed using the naive bayes method by looking at the rules and rule bases that exist in hypertension. Through this application, users can consult with the system like consulting an expert to diagnose the symptoms that occur in users and find solutions to the problems faced.

abstrak

Hipertensi merupakan suatu gangguan pada pembuluh darah yang menyebabkan suplai oksigen dan nutrisi yang dibawa oleh darah menjadi terhambat menuju jaringan tubuh yang membutuhkan. Hipertensi sering disebut sebagai silent killer, karena merupakan penyakit yang mematikan tanpa adanya gejala sebagai peringatan bagi para penderitanya. Penderita hipertensi berkisar antara usia 40 tahun ke atas hingga seumur hidup. Secara umum hipertensi disebabkan oleh faktor keturunan, pola hidup yang tidak sehat, konsumsi garam berlebih, minuman beralkohol dan stress. Sistem pakar dapat menjadi solusi untuk menyelesaikan permasalahan karena sistem ini bekerja layaknya seorang pakar dan dirancang menggunakan metode naive bayes dengan melihat aturan dan basis aturan yang ada pada hipertensi. Melalui aplikasi ini pengguna dapat berkonsultasi dengan sistem layaknya berkonsultasi dengan pakar untuk mendiagnosis gejala yang terjadi pada pengguna dan mencari solusi atas permasalahan yang dihadapi.

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ACM Computing Classification System (CCS)

EBSCOhost

Communication and Mass Media Complete (CMMC)

1. Introduction

High blood pressure, also called hypertension, is a medical condition in which the pressure of the blood against the walls of the arteries is high enough that it can eventually cause health problems, such as heart disease. This is because the heart has to work harder than usual to circulate blood through the blood vessels throughout the body. Blood pressure is usually measured with a tool called a sphygmomanometer, which consists of a pump, a pressure gauge, and a rubber cuff. This tool measures blood pressure in units called millimeters of mercury (mm Hg). Diagnosing high blood pressure is not easy because of the limited equipment and only a few experts can treat this disease. Hypertension is a disorder of the blood vessels that causes the supply of oxygen and nutrients carried by the blood to be blocked to the body's tissues that need it. A history of hypertension that coincides with an unhealthy lifestyle, such as consuming tobacco, high-fat consumption, lack of fiber, excessive salt consumption, lack of exercise, alcoholism, obesity, high blood fat, and stress, will increase the risk of complications such as myocardial infarction, stroke, and kidney failure (Sustrani, 2004).

In Indonesia, hypertension is the third leading cause of death after stroke and tuberculosis, accounting for 6.7% of the population's deaths at all ages. The prevalence of hypertension in Indonesia is on the rise. The prevalence in urban areas is 39.9% (37.0% - 45.8%), while in rural areas it is 44.1% (36.2% - 51.7%) (Dalimartha *et al.*, 2008). According to the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure VII/ JNC 2003, hypertension is defined as a condition where systolic blood pressure ≥ 140 mmHg and diastolic pressure ≥ 90 mmHg (Riskesdas, 2013). In diagnosing diseases in the medical field, tools such as artificial intelligence applications are needed. Therefore, an expert system was created to diagnose hypertension. With this expert system, it becomes easier for people to diagnose hypertension, as it is a deadly disease that does not exhibit symptoms initially as a warning to its victims. This study aims to develop a model of an expert system application that uses the Naive Bayes method to diagnose hypertension symptoms that can be used by the

public. In general, this study intends to provide solutions in the form of consultations, diagnoses, and predictions. As in the medical field, consultations, diagnoses, and predictions are highly reliable because they can anticipate and precisely determine the type of disease suffered, quickly and accurately (Bustami, 2014). Naive Bayes is a simple probability classifier based on Bayes' theorem. This method is used so that users can interact with the expert system in an efficient way, making it easier for them to use the system that is being created. Expert systems are generally systems designed to emulate human knowledge, enabling computers to solve problems in a manner similar to experts. In other words, expert systems are designed and implemented using specific programming languages to solve problems like experts would. Expert systems can be a solution to addressing issues, as these systems operate like an expert and are designed using the Naive Bayes method, which is based on the rules and rule bases inherent in hypertension (Kusrini, 2006). Through this application, users can consult with the system as if consulting an expert, to diagnose the symptoms they experience and find solutions to the problems they face. This expert system is designed by providing questions that require a 'yes' or 'no' answer, or with several answer choices that are recommendations based on the symptoms that occur. For this reason, in this study, a system will be developed titled "Expert System for Diagnosing Hypertension Disease Using the Naive Bayes Method at Aloe Saboe Hospital, Gorontalo City."

2. Research Methodology

Expert System

Expert systems are computer-based applications designed to solve problems in a manner similar to human experts. The expert in this context refers to a person who possesses specialized knowledge and skills to solve problems that cannot be addressed by laypeople. For instance, a doctor is considered an expert who can diagnose and treat diseases. An expert system acts as an intelligent consultant or advisor in a particular domain of expertise, utilizing a knowledge base that has been accumulated from various experts (Kusrini, 2006).

Expert systems consist of several components: the user interface, the expert system database, the knowledge acquisition facility, and the inference mechanism. The advantages of expert systems include:

- 1) Enabling non-experts to perform tasks typically requiring expert-level knowledge;
- 2) Automating repetitive processes;
- 3) Storing and preserving expert knowledge and expertise;
- 4) Operating effectively in hazardous environments;
- 5) Offering reliability;
- 6) Functioning with incomplete information and uncertainty;
- 7) Reducing time spent in decision-making.

Naive Bayes

Naive Bayes is a straightforward probability classifier based on Bayes' theorem. The primary advantage of this classifier is that it requires only a small amount of training data to estimate the necessary parameters (means and variances of the variables) for classification. Since Naive Bayes assumes that the variables are independent, it only requires the determination of the variances for each class, not the entire covariance matrix. In this process, Naive Bayes assumes that the presence or absence of a feature in one class is not related to the presence or absence of other features in the same class (Bustami, 2014).

$$P(B|A) = \frac{P(A|B) P(B)}{P(A)}$$

Where :

$P(B|A)$ = Probability of B if the type of disease is known

$AP(B|A)$ = Probability of evidence A if hypothesis B is known

$P(B)$ = Probability of hypothesis B regardless of any evidence

$P(A)$ = Probability of evidence of disease A

Using Bayes' theorem, equation (1) can be written as follows:

$$V_{MAP} = \underset{v_j \in V}{\operatorname{argmax}} \frac{P(a_1 a_2 \dots a_n | v_j) P(v_j)}{P(a_1 a_2 \dots a_n)}$$

In the Naive Bayes classification process, the goal is to calculate the highest probability (VFOLDER) associated with a particular disease type. The probability of a disease type, denoted as $P(v_j)$, represents the likelihood of that specific disease. Additionally, the probability of a set of attributes, $P(a_1, a_2, \dots, a_n | v_j)$, refers to the likelihood of observing these attributes given the disease type, v_j . Since the value of $P(a_1, a_2, \dots, a_n)$ remains constant for all v_j , the equation can be simplified to $V_{MAP} = \underset{v_j \in V}{\operatorname{argmax}} P(v_j | a_1, a_2, a_3, \dots, a_n | v_j) * P(v_j)$. This equation helps to identify the disease with the highest probability, given the observed symptoms. As the number of symptoms increases, the computation of the product $P(a_1, a_2, \dots, a_n | v_j) * P(v_j)$ becomes increasingly complex, as it involves considering all combinations of symptoms across the different disease categories. To calculate $P(a_i | v_j)$ for the Naive Bayes classifier, the formula is used where nc represents the number of records in the training data for a particular disease (v_j) and a specific attribute (a_i), while p is the prior probability of the disease type. The calculation also involves m , which is the number of symptoms or parameters, and n , which is the total number of records in the dataset for each class.

$$P(a_i | v_j) = \frac{n_c + mp}{n + m}$$

Where :

nc = number of records in the learning data where $v = v_j$ and $a = aip = 1 / \text{number of types of class / disease}$

m = number of parameters / symptoms

n = number of records in the learning data, $v = v_j$ / each class

Hypertension

Hypertension is a condition that affects the blood vessels, leading to a disruption in the delivery of oxygen and nutrients carried by the blood to the tissues that require them. This disorder poses a significant health risk, as individuals may suddenly be diagnosed with high blood pressure without prior symptoms or warning. The condition can remain unnoticed for a long time, which contributes to its classification as a "silent killer." The absence of visible signs in its early stages often makes it difficult for individuals to recognize its presence until significant damage has occurred.

Table 1. Classification of blood pressure measurements

Blood Pressure Classification	Systolic Blood Pressure (mmHg)	Diastolic Blood Pressure (mmHg)
Normal	< 120	< 80
Prehypertension	120-139	80-89
Hypertension	≥ 140	90
Hypertension Stage 1	140-159	90-99
Hypertension Stage 2	≥ 160	≥ 100

The classification of blood pressure measurements for adults (aged ≥ 18 years) is based on the average of two or more blood pressure readings taken at different clinical visits. Blood pressure is categorized into four groups. Normal blood pressure is defined as a systolic blood pressure (SBP) of less than 120 mmHg and a diastolic blood pressure (DBP) of less than 80 mmHg. Pre-hypertension, while not classified as a disease, identifies individuals at risk of developing hypertension in the future. Hypertension is further divided into two stages, with patients in this category typically requiring medication for management. A hypertensive crisis represents an extreme form of high blood pressure, typically greater than 180/120 mmHg, and is a clinical emergency due to the potential for target organ damage. This condition demands immediate intervention to lower blood pressure and prevent further harm to organs. If untreated, hypertension is associated with both unmodifiable and modifiable risk factors. Unmodifiable risk factors include age, gender, and heredity (genetics), while modifiable risk factors include obesity, smoking, physical inactivity, excessive salt intake, dyslipidemia, excessive alcohol consumption, and psychosocial stress.

3. Results and Discussion

Results

Type of Disease and Symptoms

The various types of diseases associated with hypertension and their corresponding symptoms are outlined in Table 2. These include different forms of hypertension-related conditions, each with distinct characteristics and manifestations. The symptoms related to hypertension can vary widely, depending on the type and severity of the disease, but they often include signs such as high blood pressure, fatigue, headaches, and other physical symptoms that may indicate underlying cardiovascular issues. By analyzing the symptoms in relation to the disease type, healthcare providers can make more accurate diagnoses and recommend appropriate treatments.

Table 2. Types Disease

Code	Name Disease
P01	Chronic Hypertension
P02	Superimposed Pre-Eclampsia
P03	Gestational Hypertension
P04	Mild Pre-Eclampsia
P05	Severe Pre-Eclampsia
P06	Eclampsia
P07	Hypotension

Table 3. Symptom Disease Hypertension

Code	Symptom
G01	Blood pressure > 120/80 mmHg
G02	Blood pressure < 120/80 mmHg
G03	Normal blood pressure or equal to 120/80 mmHg
G04	Gestational age < 20 weeks
G05	Gestational age > 20 weeks
G06	Proteinuria/urine dipstick test
G07	Platelets < 100,000 mm ³

G08	Trismus/Mouth opening disorder
G09	Fatigue
G10	Faint
G11	Depression
G12	Stres
G13	Seizures
G14	Proteinuria Result 2.0 g/day or > 2+ dispstick
G15	Proteinuria results > 300 mg/day or > 1+ dyspstick
G16	Oliguria/urinary disorders
G17	Urine volume/day < 400 ml/hour
G18	Muscle spasm/Muscle tension
G19	Headache
G20	Blood pressure increases > 160/110 mmHg
G21	Fetal growth retardation
G22	Elevated levels of ALT or AST enzymes
G23	LDH/Lactate Dehydrogenase increased
G24	Fever
G25	Stiff neck
G26	Disorientation
G27	Visual impairment
G28	Vomit
G29	Difficulty concentrating
G30	The seizures that occur are generalized
G31	Severe headache
G32	History of hypertension before pregnancy
G33	Multipara
G34	History of hypertension runs in the family
G35	Proteinuria is persistent
G36	Heartburn
G37	Thrombocytopenia
G38	History of epilepsy
G39	Loss of consciousness
G40	Stiff face
G41	Stiff neck
G42	Stiff neck
G43	Stiff abdominal wall

In this section, we demonstrate how to perform a manual calculation using the Naive Bayes classification method. The example applies to a patient who exhibits symptoms numbered 1, 9, 31, and 40. These symptoms include blood pressure exceeding 120/80 mmHg, fatigue, severe headache,

and a stiff face. To calculate the probability, we first identify the disease category, which in this case is Severe Pre-Eclampsia (hypertensive disease 5), with a total of 7 records.

$$p = \frac{1}{7} = 0.14285714$$

We then examine each symptom: for symptom 1 (blood pressure > 120/80 mmHg), the count (nc) is 1, indicating the symptom is present in the dataset; for symptom 9 (fatigue), nc is 0, indicating it is not present; for symptom 31 (severe headache), nc is 1, and for symptom 40 (stiff face), nc is 0. The values of nc for each symptom are then used in the Naive Bayes calculation to determine the likelihood of the disease being Severe Pre-Eclampsia.

Calculating the value of $P(a_i | v_j)$ and calculating the value of $P(v_j)$.

$$P(1|PB) = \frac{1 + 43 \times 0.14285714}{1 + 43} = 0.14285714$$

$$P(9|PB) = \frac{0 + 43 \times 0.14285714}{1 + 43} = 0.13961039$$

$$P(31|PB) = \frac{1 + 43 \times 0.14285714}{1 + 43} = 0.14285714$$

$$P(40|PB) = \frac{0 + 43 \times 0.14285714}{1 + 43} = 0.13961039$$

$$P(PB) = 1/7 = 0.14285714$$

Calculate $P(a_i | v_j) \times P(v_j)$ for each v

$$\begin{aligned} P(PB) &= 1/7 = 0.14285714 \\ &= P(PB) \times [P(1|PB) \times P(9|PB) \times P(31|PB) \times P(40|PB)] \\ &= 0.14285714 \times [0.14285714 \times 0.13961039 \times 0.14285714 \times 0.13961039] = 5.68252473e-5 \end{aligned}$$

In the case study taken in this study is Severe Pre-Eclampsia disease. Initially looking at the symptoms experienced by patients with Severe Pre-Eclampsia disease. After that the next step is to determine the nc value (number of records in the data) for the Pre-Eclampsia disease class. After we know the value, the next step is to calculate the $P(a_i | v_j)$ value and the $P(v_j)$ value for each symptom of Severe Pre-Eclampsia disease. After the results are obtained, then calculate the $P(a_i | v_j) \times P(v_j)$ value for each v according to equation 3 above. The results obtained for severe Pre-Eclampsia disease with its symptoms get a result of 5.68252473e-5. This should be

compared with other symptoms to find out other types of diseases suffered by the patient.

Steps to Run the System

To begin using the expert system, users must follow a series of steps that guide them through the diagnostic process. The system is designed to be user-friendly, ensuring that individuals can easily navigate through each stage to input symptoms and receive accurate results. Below is an overview of the steps to run the system, starting with the display of the initial menu.



Figure 1. Menu view

Pilih Gejala Yang Dialami
Form Konsultasi :
☒ Tekanan darah > 120/80 mmHg ☒ Tekanan darah < 120/80 mmHg ☐ Tekanan darah normal atau sama dengan 120/80 mmHg ☐ Usia kehamilan < 20 minggu ☒ Usia kehamilan > 20 minggu ☐ Proteinuria/tes celup urine . ☐ Trismus/Gangguan pembukaan mulut ☐ Kelelahan ☐ Pingsan ☐ Depresi ☐ Kejang ☐ Hasil Proteinuria 2.0 g/hari atau > 2+ dispstick ☐ Hasil Proteinuria > 300 mg/hari atau > 1+ dispstick ☐ Volume air kemih/hari < dari 400 ml/jam ☐ Spasme otot/Ketegangan otot ☐ Trombosit < 100.000 mm3 ☐ Stres ☐ Oliguria/gangguan air kemih ☐ Sakit kepala ☐ Tekanan darah meningkat > 160/110 mmHg ☐ Pertumbuhan janin terhambat

Figure 2. Symptom Menu View

GEJALA YANG DIALAMI	HASIL DIAGNOSA
☒ Tekanan darah > 120/80 mmHg ☒ Tekanan darah < 120/80 mmHg ☒ Usia kehamilan > 20 minggu	Berdasarkan hasil diagnosa pada pasien, Nama : Alan Jenis Kelamin : Perempuan Umur : 27 Alamat : Rambutan berdasarkan gejala-gejala yang diinputkan maka dapat disimpulkan anda menderita penyakit : Hipertensi Kronis / Sebesar 50% Definisi Penyakit : Pada penderita Hipertensi kronis, terjadi peningkatan tekanan darah pada kehamilan > 24 minggu. Bila disertai dengan proteinuria maka disebut hipertensi kronis superimposed pre-eclampsia. Solusi Pengobatan : Checkup sebulan sekali tekanan darah, hindari minum beralkohol, hindari stress berat.

Figure 3. Diagnostic Result Display

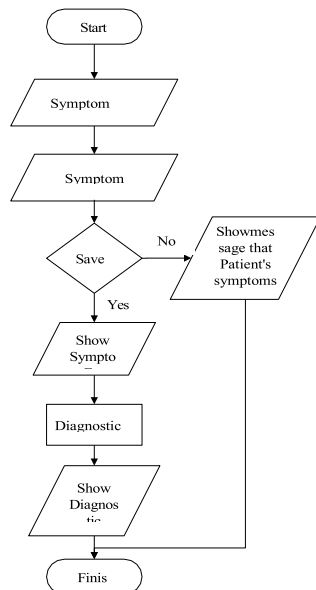


Figure 4. Flowchart

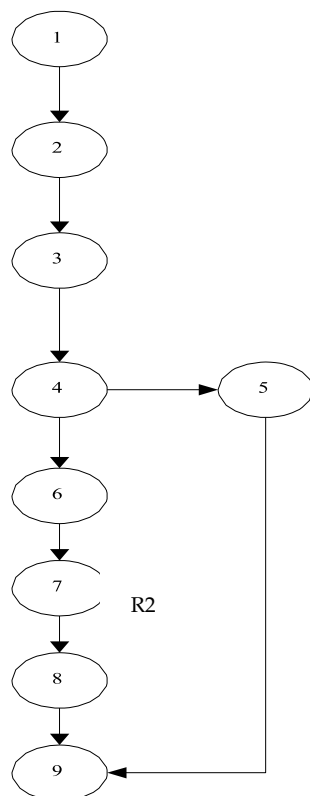


Figure 5. Flowgraph

Cyclomatic complexity $V(G)$ for flow graphs is calculated using the formula:

$$V(G) = E - N + 2$$

From the flowgraph above we get:

$$\text{Region (R)} = 2$$

$$\text{Node (N)} = 9$$

$$\text{Edge (E)} = 9$$

$$\text{Predicate Node (p)} = P + 1$$

$$V(G) = E - N + 2 = 9 - 9 + 2 = 2$$

$$V(G) = P + 1 = 1 + 1 = 2$$

$$\text{Cyclomatic Complexity (CC)} = R1, R2 = 2$$

Based on the flow sequence, a flow graph basis group is obtained as follows: $R1 = 1-2-3-4-6-7-8-9$

$$R2 = 1-2-3-4-5-9$$

Black Box Testing

In system testing, it will be ensured that an event or input will run the right process and produce output that matches the design. For black box testing, the diagnostic data form is taken as a measurement.

Table 4. Black box testing table

Input /Event	Results Which expected	Results Testing
Select Login Menu	Display the login menu by entering your username and password then click login.	Success
Select the patient data menu	Displays a form to be filled in by the patient in the form of Name, Gender, Date of Birth, Address and Telephone Number then click register	Success
Select Symptom List	Displays a list of symptoms suffered by the patient	Success
Select disease data and solutions	Displays disease data and solutions suffered by patients by filling in disease codes, types of examinations, definitions and so on. the solution is then saved	Success
Select Diagnosis	Displays diagnostic results that match the symptoms selected by the patient as well as solutions to the disease experienced.	Success
Select exit	Closing the application	Success

Discussion

To operate the expert system, users begin by navigating to the initial menu, which acts as the primary interface for interaction. This menu offers a straightforward path for users to start the diagnosis process by selecting the "Start Diagnosis" option. Upon selection, the system prompts users to input their symptoms, which are displayed as a series of questions related to common indicators of hypertension, such as high blood pressure, fatigue, headaches, and other relevant symptoms (Sustrani & Lanny, 2004; Dalimartha *et al.*, 2008). The system uses predefined rules and a knowledge base to compare the entered symptoms with medical data regarding hypertension. These rules are derived from established medical research and expert knowledge, as indicated by Kusrini (2006). As users provide their symptoms, the system processes the information through the Naive Bayes algorithm, which classifies the data based on probabilities, helping users identify potential hypertension-related conditions (Bustami, 2014). After the symptoms are entered, the system generates a diagnostic result, which is displayed on a dedicated results page.

This page outlines the likelihood of the user suffering from a particular hypertension condition, such as chronic hypertension or pre-eclampsia, and provides recommendations for next steps. According to Sustrani and Lanny (2004), this type of diagnostic support is crucial in identifying hypertension early, as the disease often remains asymptomatic, making it difficult to detect without intervention. Throughout the entire process, the expert system ensures that the user interface remains clear and intuitive, guiding users step by step in a way that minimizes confusion. By providing an easy-to-navigate platform for self-diagnosis, the system empowers users to take proactive steps in managing their health. This is particularly significant given that hypertension is a leading cause of mortality worldwide, as outlined by Riskesdas (2013). The system, therefore, provides not only immediate diagnostic feedback but also raises awareness about the importance of early hypertension detection and management.

4. Conclusion

From the results of the study above, several things were found that can be concluded that the expert system for hypertension using the naive bayes method can help the public in diagnosing hypertension. The calculation of this expert system is calculated based on the rule-based process. After testing several main processes using naive bayes, the system has generally worked well. Based on the tests that have been carried out, the author provides suggestions that in making the next system, it can be added with more interesting program features, in addition it is hoped that the next system can be developed with other calculation models, such as: Fuzzy, GAP, or others and of course develop into an android-based application so that the public will find it easier to access it.

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