Journal of Computer Networks, Architecture and High Performance Computing
Volume 6, Number 2, April 2024
https://doi.org/10.47709/cnahpc.v6i2.3834

Submitted : May 7, 2024
Accepted : May 16, 2024
Published : May 20, 2024

Implementation of Naïve Bayes Method Diagnosing Diseases Nile Tilapia

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ABSTRACT

The Nile tilapia, also known as Oreochromis niloticus, was a freshwater fish species first produced in East Africa in 1969. It became a popular aquaculture fish in freshwater ponds across Indonesia. Besides its delicious taste, the Nile tilapia is rich in nutrients essential for human health. However, cultivating Nile tilapia was challenging due to frequent bacterial diseases. These diseases often led to mass fish deaths, causing financial losses, especially for new fish farmers. The rapid spread of diseases emphasized the need for prompt intervention to prevent further losses. Farmers needed adequate knowledge about Nile tilapia diseases, but often struggled to absorb information provided by the government. Hence, the presence of experts or veterinarians was crucial in assisting farmers to address these issues. Farmers of Nile tilapia sought assistance from experts or veterinarians, but this was not easy. It involved substantial costs and time, while quick intervention was necessary to mitigate losses. The solution proposed was the development of an expert system for diagnosing and treating Nile tilapia diseases. Thus, an expert system was built to assist fish farmers in identifying fish diseases and their treatments by implementing the naïve Bayes method. The expert system transferred human knowledge to computers, enabling them to solve problems like experts, thereby making expert knowledge accessible to non-experts. Naïve Bayes was implemented to determine the highest probability based on input symptoms. This research used five test data samples to apply the naïve Bayes method to diagnose Nile tilapia diseases, resulting in an accuracy rate of 80%. Therefore, the implementation of naïve Bayes in diagnosing Nile tilapia diseases is considered reasonably effective.

Keywords: Aquaculture; Expert System; Naïve Bayes; Nile Tilapia; Nile Tilapia Farmers

INTRODUCTION

Fish has been one of the readily available food sources in Indonesia and serves as a primary animal protein source after meat, milk, and eggs (Wibowo & Untari, 2023). Freshwater fish, including Nile tilapia or Oreochromis niloticus, has gained popularity in Indonesia due to its delicious taste and high nutritional content (Untari et al., 2022). Nile tilapia is rich in protein and has relatively low calorie content. Despite its high omega-6 fatty acid content, it has low levels of omega-3 fatty acids (Yuga et al., 2023). Fish consumption in Indonesia has been increasing, necessitating the supply of fish from various commodities and production areas (Nugraha et al., 2023). Therefore, freshwater fish farming becomes crucial in meeting the animal protein needs of society and the market.

In Nile tilapia farming, challenges are inevitable. One of them is bacterial diseases that can cause massive fish deaths and financial losses, especially for new farmers (Anggi et al., 2023). Swift handling is key to preventing the rapid spread of such diseases. Therefore, farmers need to have sufficient knowledge about Nile tilapia diseases (Azhar et al., 2020). However, government outreach efforts often fall short in effectively delivering information to farmers. Hence, the presence of an expert or veterinarian is highly required to provide necessary assistance (Sinubu et al., 2022).

Nile tilapia farmers require the help of an expert or veterinarian, but this isn't an easy task (I. T. Sianturi et al., 2021). Bringing them in entails significant costs and time, while swift handling is necessary to minimize losses (Arsatria et al., 2020). To address this issue, the proposed solution is to develop an expert system that can diagnose Nile tilapia diseases and provide treatment solutions.

An expert system is the implementation of human knowledge into computers, enabling them to solve problems as experts do. Its main goal is to transfer expertise from experts to computers and then transfer it to non-experts. Expert systems can provide accurate conclusions, even faster than experts in some cases (Alam et al., 2022). Naïve Bayes method is used to predict probabilities. The main characteristic of the Naïve Bayes Classifier is its strong assumption of independence among conditions or events. This method is considered quite effective in determining outcome probabilities (Suherman, 2021).

The aim of the research was to address the issue of Nile tilapia diseases which resulted in losses for fish farmers,

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especially those who were new to aquaculture. This was achieved by enhancing farmers' knowledge through a web-based expert system utilizing the Naïve Bayes method, enabling them to swiftly diagnose Nile tilapia diseases and implement appropriate measures. The objective was to minimize losses in Nile tilapia farming and optimize the utilization of technology in agriculture, thereby assisting farmers in enhancing productivity and reducing risk of losses.

LITERATURE REVIEW

The analysis of the Bayes Theorem Method in Diagnosing Miscarriages in Pregnant Women Based on Food Types by (F. A. Sianturi, 2019) showed that the process of diagnosing miscarriages in pregnant women could take into account the effects of the food consumed. The Bayes Theorem method was applied to diagnose food types and provide diagnosis results along with the risk levels of each food effect quickly. This study also included the design of an expert system application using Microsoft Visual Studio.

The Expert System for Diagnosing Human Dental Diseases Using the Naïve Bayes Method by Henry Prasetyo Utomo, Iskandar Fitri, and Winarsih, proved that the Naïve Bayes method could be used in diagnosing human dental diseases. This application could assist the public in prevention or initial aid before consulting a dentist. The application was accurate using 68 training data from experts and an accuracy test showing that 28 out of 30 test data were suitable, with an accuracy rate of 93% (Utomo et al., 2020).

Previous research on expert systems for diagnosing tilapia diseases has served as a reference for researchers to further study. (Anwar et al., 2022) investigated the Naïve Bayes method in "Expert System for Diagnosing Tilapia Diseases Based on Bayes Method". This study used a web-based platform with data on 8 diseases and 30 symptoms, achieving a diagnostic accuracy of 95.24%. Another study by (Saripurna & Syahputra, 2020) on "Designing an Expert System for Diagnosing Bacterial Diseases in Catfish at the Department of Fisheries and Marine Affairs, Serdang Begadai Using the Dempster Shafer Method" showed that the Dempster Shafer method could be applied in diagnosing catfish diseases, with a probability of White Spot Disease reaching 99.4%.

The difference between this study and previous studies using the Naïve Bayes method lies in the location, data, object, and method. This study used more disease data and focused on tilapia, while previous studies focused on catfish. Additionally, this study was web-based, whereas previous studies were desktop-based.

1. METHOD

Research Methodology

In research methodology, there is a sequence of framework that must be followed. This framework sequence provides an overview of the steps to be taken to ensure the research proceeds smoothly (Batubara & Nasution, 2023). The stages of the research framework in this study were as follows.

Planning

The initial stage of this research involved a series of planning steps. Firstly, the researcher determined the topic of the issue to be addressed in the final project, namely implementing the Naïve Bayes method in diagnosing diseases in Nile tilapia. Secondly, Pasar 1, located in the Medan Tuntungan District, was selected as the research object. Subsequently, problem formulation was conducted to identify the issues to be examined and to establish the problem's boundaries. The outcome of this stage was the formulation of the problem statement for the final project. Additionally, based on observations of the research object, the researcher defined the research title that corresponds to the examined issue. Finally, goal determination was performed to clarify the objectives of this research.

Data Collection Techniques

This research was conducted systematically using quantitative methods and secondary data. Secondary data were obtained from the laboratory database on diseases and symptoms of tilapia at the Medan City Fish Seed Center. The data collection process resulted in 11 diseases and 24 symptoms presented in tables. The initial stage of the research involved literature review to find relevant studies and obtain theoretical sources. Additionally, interviews were conducted with the head of the laboratory at the Medan City Fish Seed Center to obtain direct information about the symptoms of tilapia diseases. Observations were also made by visiting tilapia farms in Pasar 1, Medan Tuntungan Sub-District, to record relevant information.

Analysis

In this stage of requirement analysis, activities were conducted to identify the needs and specifications of the system to be developed. The aim was to clearly understand how the system should align with the predetermined problem

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constraints. The outcome of this analysis was a document that would serve as a reference for subsequent stages. The system requirement analysis was divided into two parts, namely functional and non-functional requirements. Functional requirements depicted the processes to be performed by the system, including features such as login capability, input of disease symptoms, and display of diagnosis results. Meanwhile, non-functional requirement analysis, which was not directly related to system features, encompassed hardware and software analysis. In this case, the software utilized was a web-based application designed using PHP programming language and MySQL database.

Design

After completing the requirement analysis phase, the system design could proceed. System design could be formulated in the form of a system flowchart diagram to illustrate the sequence of processes in the system. The diagram for implementing the Naïve Bayes method in diagnosing diseases in Nile tilapia is as follows:

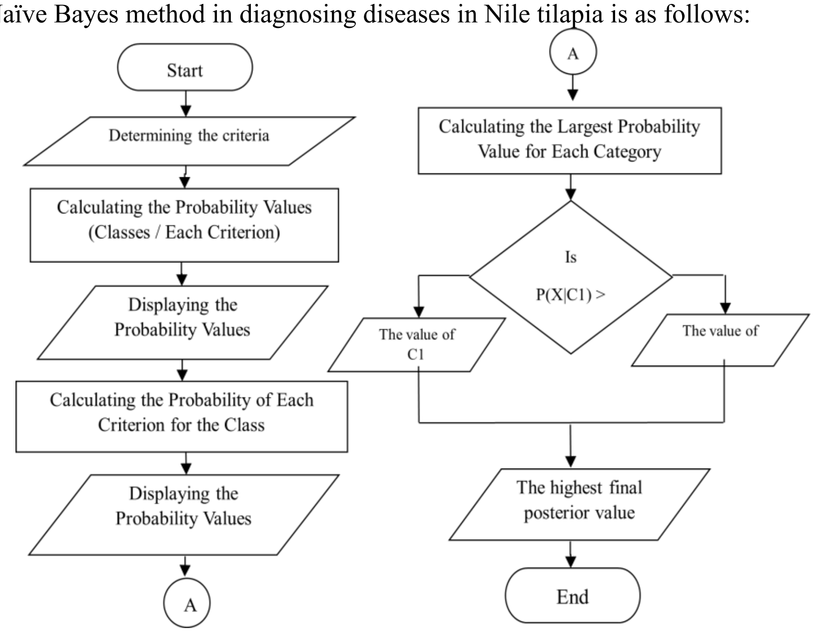

Fig. 1 Flowchart Naïve Bayes

The image depicts the flow of a Naïve Bayes method in diagnosing diseases in Nile tilapia. The initial step involved preparing data on the symptoms and diseases of Nile tilapia. Subsequently, the prior probabilities were computed, followed by the calculation of likelihood probabilities. Upon obtaining the results, the posterior probabilities were calculated, and the highest posterior value was chosen as the final outcome representing the type of disease in Nile tilapia.

The Naive Bayes method was utilized for predicting probabilities. It constituted a form of statistical classification known as the Naïve Bayesian Classifier. This method was grounded on the simplistic assumption that attribute values were conditionally independent of one another given the output value. Its advantage lay in requiring minimal training data and often proving more effective than anticipated in complex real-world situations. The Bayes' theorem was a method used to compute the uncertainty of data into definite data by comparing between the data of yes and no.

$$P(H|X) = \frac{P(X|H)P(H)}{P(X)} \quad (1)$$

Description:

X	: Data with an unknown class.
H	: The hypothesis that the data belongs to a specific class.
P(H\X)	: The probability of hypothesis *H* given condition *X* (posterior probability)
P(X\H)	: The probability of *X* given condition *H*
P (H)	: The probability of hypothesis *H* (prior probability)
P (X)	: The probability of *X*

Implementation

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In this study, the Naïve Bayes procedure was applied. The implementation of this system allowed tilapia fish farmers to easily identify diseases affecting Nile tilapia and their corresponding remedies. Implementation involved constructing a system based on previous literature studies and designs. The expert system application was developed by implementing interfaces and methods. The system output included diagnosis results along with their respective solutions.

Testing
The testing phase was necessary to ensure that the system could function according to its objectives. Testing was conducted by comparing the results obtained by experts with those by users. Additionally, black box testing was performed to demonstrate the software's functionality, assessing whether the input and output data operated as expected (Syahranitazli & Samsudin, 2023).

RESULT

Analysis
Analysis represents the system's outcomes from the research that will be implemented later. Analysis is a step or process to gain understanding by identifying and describing existing problems and determining the necessary requirements.
In this expert system for diagnosing diseases in tilapia fish, data collection and needs analysis were conducted, with the data obtained from the Laboratory of the Fish Seed Center in Medan City. Data collection was performed to obtain information related to the system's requirements, which would then be included in the sample data. The information or data obtained from the Laboratory of the Fish Seed Center in Medan City were in the form of .docx files. The total number of symptom data collected was 24, with 11 diseases included in the dataset. There were no empty data in the dataset used, thus data cleaning was unnecessary.

In the diagnostic process for tilapia fish diseases, the data obtained consisted of symptoms of tilapia fish obtained from the fish seed farm in the Tuntungan district of Medan. Subsequently, these data were analyzed using the naive Bayes method, aimed at deriving diagnostic outcomes for the respective fish diseases.

From the symptom data obtained above, the diseases of the fish can be determined based on the symptoms to be analyzed. For further clarity, please refer to the table below:

Tilapia Fish Disease Data
The following is the presentation of tilapia fish disease data consisting of 11 diseases and can be seen in the table below:

Table 1. Tilapia Fish Disease Data

Code	Disease Type
P01	Dropsy
P02	Vibriosis
P03	Columnaris
P04	Exophthalmia
P05	Bacterial kidney disease
P06	Tuberculosis
P07	Edwardsilosis
P08	Saprolegniasis/ Jamur Saprolegnia
P09	Octomus
P10	Aeromonas hydropylla
P11	Aeromonas salmonicida

Tilapia Fish Symptom Data
The following is the presentation of symptom data consisting of 24 symptoms. The symptom data used in diagnosing diseases in tilapia fish were obtained based on interviews with the Head of the Laboratory. The following are the symptom codes for each symptom as indicated in the table below:

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Table 2. Tilapia Fish Symptom Data

Code	Symptom Description	Importance	
		Yes	No
G001	Bloated abdomen	0.4	0
G002	Raised scales resembling pineapples	0.7	0
G003	Pale gills	0.6	0
G004	Boils often appear, releasing reddish-yellow fluid	0.5	0
G005	Bleeding on the abdominal wall	0.7	0
G006	Loss of appetite	0.4	0
G007	White spots on infected areas	0.5	0
G008	Loss of gills and fins	0.8	0
G009	Bulging and swollen eyes	0.6	0
G010	Changes in eye color (Pale)	0.8	0
G011	Dark skin changes to bluish	0.7	0
G012	Blood spots are often found at the base of the pectoral fins	0.6	0
G013	Small wounds on the skin	0.6	0
G014	Boils	0.5	0
G015	Eggs are covered with filamentous fungus-like threads	0.8	0
G016	Wounds and damage accompanied by secondary infection	0.6	0
G017	Fish often rub their bodies against hard objects	0.5	0
G018	White spots on the body surface	0.8	0
G019	Irritated skin	0.6	0
G020	Fish leap to the water surface	0.5	0
G021	Changes in fish color (Pale)	0.4	0
G022	Pus-filled wounds on the body surface	0.7	0
G023	Decayed or ulcerated wounds	0.5	0
G024	Excessive mucus	0.6	0

Tilapia Fish Disease Solutions
Below is the presentation of solution data consisting of 11 solutions to be applied to tilapia fish diseases. These solutions were obtained from the Laboratory of Fish Seed Center in Medan City. Here are the solution codes for each solution as listed in the table below:

Table 3. The solution data for tilapia fish diseases

Code	Solution
S01	- Soaking in potassium permanganate (PK) solution 10-20 ppm for 30-60 minutes or 3-5 ppm for 12-24 hours, nitrofuran solution 5-10 ppm for 12-24 hours, oxytetracycline 5 ppm for 24 hours, and Imequil 5 ppm for 24 hours. - Injection with oxytetracycline 20-40mg/kg fish weight, kanamycin 20-40 mg/kg fish weight, or streptomycin 20-60 mg/kg fish weight. - Feeding pellets mixed with oxytetracycline 50 mg/kg fish weight
S02	- Injecting oxytetracycline HCI 25-30 mg/kg fish weight repeated every three days, three times
S03	- Soaking in oxytetracycline 10 ppm for 24 hours or Baytril 8-10 cc/m³ water for 24 hours. - Soaking in Malachite green 1:50,000 for 10-30 seconds, CuSO4 500 ppm for 1-2 minutes
S04	- Injection of oxytetracycline 20-40 mg/kg fish weight or streptomycin 20-60 mg/kg fish weight
S05	- Using sulfonamides at a dose of 100-200 mg/kg fish weight/day given for four consecutive days
S06	- Maintaining water quality. - Administering kanamycin 0.02 mg/gram fish weight by injection into the abdomen.
S07	- Injection of oxytetracycline HCI at a concentration of 25-30 mg/kg fish. - Feeding with sulfamerazine at 100-200 mg/kg fish weight/day until the third day, or oxytetracycline HCI at a dose of 50 mg/kg fish weight/day given for 7 days
S08	- Soaking fish in Malachite green solution 1 mg/l for 1 hour, formalin solution 100-200 for 1-3 hours. - Soaking with sambiroto leaves or betel leaves
S09	- Increasing the temperature to 28-30 °C. - Using antiparasitic drugs such as formalin 25 ppm or affordable options like salt 1-2 ppt for 24 hours
S10	- Treatment with oxytetracycline (soaking). - Extracting tapak liman leaves and mixing them into feed (20 lb/kg feed)

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Code	Solution
S11	- Treatment with Sulfa meracine, oxytetracycline. - Extracting Miana leaves and soaking them (1 lb/liter water) and mixing them into feed (10 lb/kg feed)

The Implementation of the Naïve Bayes Method
The researcher employed the naive Bayes method to fulfill user requirements. This method was utilized to address data uncertainty through the aid of probabilistic theory, providing a fundamental approach to data analysis by considering the probabilistic relationship between symptoms. In this chapter, an experiment was conducted by collecting symptom data for diagnosing diseases in tilapia fish. This data was compared with symptoms causing diseases in tilapia fish, followed by calculations using the naive Bayes method. These calculations involved disease type data and symptom data. For detailed calculations of each disease value, please refer below:

One of the cases being handled:
Mr. Arif seeks consultation for diagnosing the tilapia fish being cultivated to identify the disease affecting them. The implementation process involves an inference engine that utilizes probabilities, employing the naïve Bayes method. Mr. Arif diagnoses by answering questions, and the variables used are as follows:

Table 3. Consultation (First Hypothesis)

No	Question	Answer
1	Is the fish's abdomen bloated?	No
2	Are the fish scales protruding like pineapples?	No
3	Are the fish gills pale?	No
4	Are there boils emitting reddish-yellow fluid?	Yes
5	Is there bleeding on the abdominal wall?	No
6	Is the fish losing its appetite?	No
7	Are there white spots on the infected area?	No
8	Are the fish's gills and fins missing?	No
9	Are the fish's eyes bulging and swollen?	No
10	Is there a change in eye color?	No
11	Is there a change in skin color to bluish-dark?	Yes
12	Are blood spots often found at the base of the pectoral fins?	Yes
13	Are there small wounds on the skin?	No
14	Are there boils?	No
15	Are the eggs covered with fungus resembling fine threads?	No
16	Are there wounds and damage on the fish accompanied by secondary infection?	No
17	Does the fish often rub its body against hard objects?	No
18	Are there white spots on the body surface?	No
19	Is the skin irritated?	No
20	Does the fish jump to the water surface?	No
21	Is there a change in color (pale) in the fish?	No
22	Are there pus-filled wounds on the body surface?	No
23	Are there decayed or ulcerated wounds?	No
24	Is there excessive mucus?	Yes

There are symptoms of the disease experienced by tilapia fish as reported from consultations with tilapia fish farmers in the following table:

Table 4. Selected Symptoms

Code	Symptom
G04	Boils appear, emitting reddish-yellow fluid
G11	Dark skin changes to bluish
G12	Blood spots are often found at the base of the pectoral fins
G24	Excessive mucus

Based on the selected symptoms in the table above, calculations for diagnosis can be conducted using several steps:

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Determining the probability values

Vibriosis [P02]

G04 = 0.5

Bacterial kidney disease [P05]

G11= 0,7

G12=0.6

Aeromonas salmonicida [P11]

G24=0.6

Processing Probability Values P(Hi)

$$\sum_{Gn}^{n}(P(E|H1) + (P(E|Hi))) \quad (1)$$

For the disease P02 Vibriosis

$$\sum_{Gn}^{n} = 0.5$$

For the disease P05 Bacterial kidney disease

$$\sum_{Gn}^{n} = (0.7) + (0.6) = 1.3$$

For the disease P11 Aeromonas salmonicida

$$\sum_{Gn}^{n} = 0.6$$

Determining the universe value

$$\sum_{Gn}^{n} = (P(H|P2) + (P(H|P5) + (P(H|P11) \quad (2)$$

$$\sum_{Gn}^{n} = (0.5) + (1.3) + (0.6) = 2.4$$

Determining the value P(Hi|E)

$$\text{P(Hi)}= \frac{P(Hi)}{\sum_{Gn}^{n}} \quad (3)$$

The value (Hi|E) for disease P02

$\text{P(Hi)}= \frac{0.5}{2.4} = 0.208$

for disease P05

$\text{P(Hi)}= \frac{1.3}{2.4} = 0.541$

for disease P11

$\text{P(Hi)}= \frac{0.6}{2.4} = 0.25$

Calculating the probability value of evidence E

P(H2)*P(E|H2) + P(H5)*P(E|H5) + P(H11)*P(E|H11) (4)

(0.208*0.5)+(0.541*1.3)+(0.25*0.6)

= 0.104+0.703+0.15

= 0.957

Calculating the Bayes value

$$P\ (H|E) = \frac{P\ (E|H)*P(H)}{P(E)} \quad (5)$$

$P(H2|E) = \frac{0.208 * 0.5}{0.957} = 0.10$

$P(H5|E) = \frac{0.541 *1.3}{0.957} = 0.73$

$P(H11|E) = \frac{0.25 *0.6}{0.957} = 0.15$

Determining the Bayes value

P02 = 0.10*100% = 10%

P05 = 0.73*100% = 73%

P11 = 0.15*100% = 15%

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Table 5. Total Calculation

Disease	Total
Vibriosis	10%
Bacterial kidney disease	**73%**
Aeromonas salmonicida	15%

Based on the calculations in the table above, the highest total value obtained for each symptom calculated based on symptoms and diseases indicates that "Bacterial kidney disease" has a higher value than Vibriosis and Aeromonas hydropylla, namely 73%. Therefore, the fish is diagnosed with "Bacterial kidney disease".

Design

Rule Design

In the design of the knowledge base, production rules are used as a means to represent knowledge. The rules in this design are written in the form of IF (Premise) THEN (Conclusion). In the design of the knowledge base of this expert system, the premises are the observable symptoms, and the conclusion is the disease in tilapia fish, so the statement form is if (symptom) then (disease). The premise part of these rules can have multiple propositions, meaning it can have more than one symptom. These symptoms are connected with the logical operator AND. The statement form is: If (Symptom 1) And (Symptom 2) And (Symptom 3) Then (Type of Disease). This stage presents the knowledge needed by the system to draw conclusions from the established rules. The facts and rules are as follows.

Table 6
Rule

No	Rule
1	IF G01 AND G02 THEN P01 AND S01
2	IF G03, G04 AND G05 THEN P02 AND S02
3	IF G06, G07 AND G08 THEN P03 AND S03
4	IF G09 AND G010 THEN P04 AND S04
5	IF G11 AND G12 THEN P05 AND S05
6	IF G13 AND G14 THEN P06 AND S06
7	IF G15 AND G16 THEN P07 AND S07
8	IF G17 AND G18 THEN P08 AND S08
9	IF G19 AND G20 THEN P09 AND S09
10	IF G21 AND G22 THEN P10 AND S10
11	IF G23 AND G24 THEN P11 AND S11

System Flowchart Design

The flowchart diagram to be used for diagnosing diseases in tilapia fish is as follows:

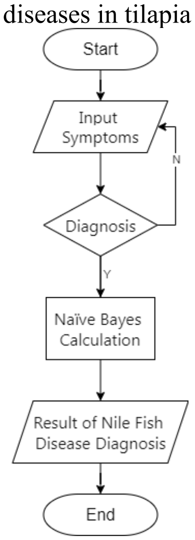

Fig. 2 System Flowchart

In the image above, the process starts with inputting symptom data. Then, the user can begin the diagnosis, and the system will display selectable symptoms based on the symptom questions that appear (yes or no). Once all questions

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have been answered, the system will process calculations using the naive Bayes method and output the diagnosis results in the form of a conclusion regarding the type of disease and the solution.

Implementation

Here is the calculation display of naive Bayes for the expert system diagnosing diseases in tilapia fish using the built system. If you want to know the diagnosis results of diseases in tilapia fish using the naive Bayes method, the steps below are the determination steps for diagnosis by inputting symptom data.

The image below shows the disease menu, which includes data on tilapia fish diseases along with their solutions, as well as the symptom display for tilapia fish diseases. In this menu, there are forms for adding, editing, and deleting.

Fig. 3 Disease Menu

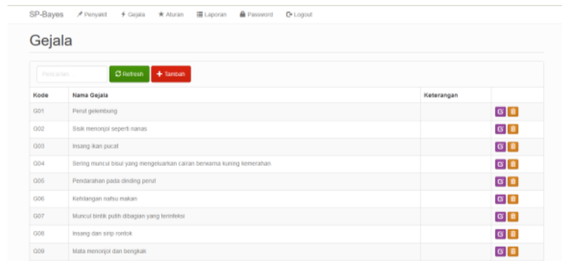

Fig. 4 Symptom Menu

The image below shows the rule menu, which contains rules for diagnosing diseases in tilapia fish along with their known weight values provided by an expert.

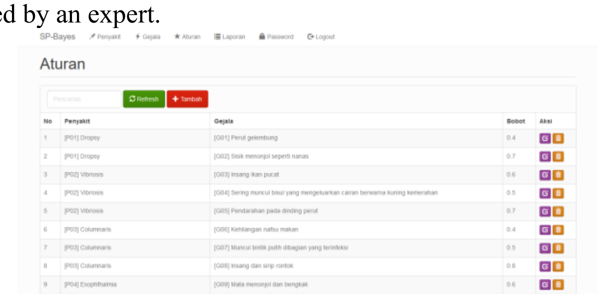

Fig. 5 Rule Menu

In the menu below, the report menu displays the results of reports from users/fish farmers who have conducted diagnoses. The admin can print the report results for users.

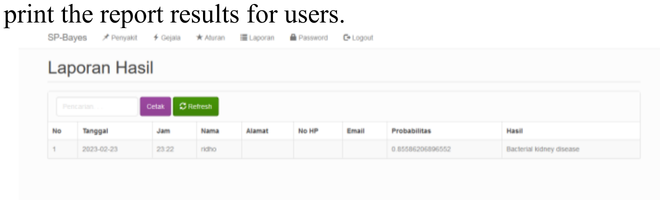

Fig. 6 Report Menu

Based on the image below, users can conduct diagnoses on the system by answering questions about symptom data. After answering these questions, users can see the disease suffered by the tilapia fish. Users can also view the Naive Bayes value and provide solutions for each type of disease affecting the tilapia fish. Thus, the history of questions from users who have conducted diagnoses can be seen.

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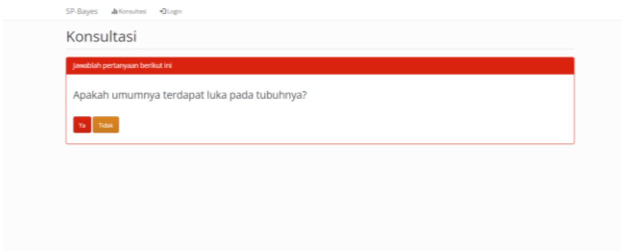

Fig. 7 Question Menu

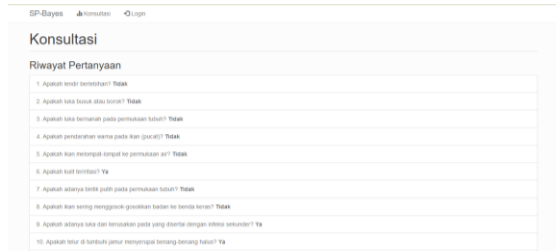

Fig. 8 Question History

Based on the image below, this page contains the diagnosis results using the naive Bayes method. There is a naive Bayes calculation process on that page which can be printed by the user.

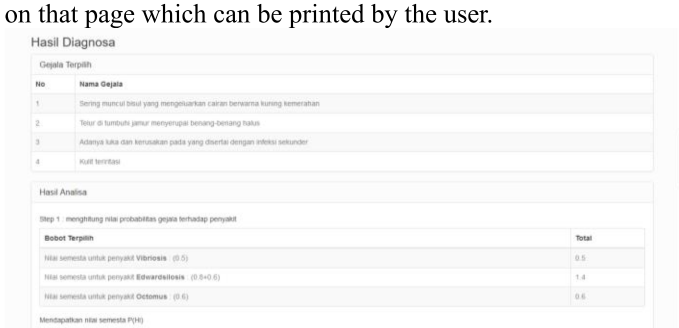

Fig. 9 Naive Bayes Calculation

Based on the image below, this is part of the diagnosis results detailing the type of disease and its solution.

Fig. 10 Diagnosis Results

Testing

System testing was conducted to evaluate the success of the expert system that had been developed. There were two testing methods employed, namely accuracy testing and blackbox testing. Accuracy testing involved comparing the system's diagnostic results with those of an expert. Blackbox testing assessed whether the system functioned properly.

Accuracy Testing

Accuracy testing was performed by calculating performance based on the comparison of the system's results with those of the expert to obtain accuracy values. A total of 5 sample cases were tested. The comparison of the expert system's diagnostic results with those of the actual expert (human expert) is shown in the table below:

Table 7. Accuracy Testing

Farmer	Symptom	System	Expert	Result
1	G04,G11,G12,G24	Bacterial kidney disease	Bacterial kidney disease	Yes
2	G01,G02,G09,G14,G24	Vibriosis	Dropsy	No

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Journal of Computer Networks, Architecture and High Performance Computing
Volume 6, Number 2, April 2024
https://doi.org/10.47709/cnahpc.v6i2.3834

Submitted : May 7, 2024
Accepted : May 16, 2024
Published : May 20, 2024

3	G06,G09,G10	Exophthalmia	Exophthalmia	Yes
4	G04,G15,G16,G19	Edwardsilosis	Edwardsilosis	Yes
5	G09,G21,G22	Aeromonas hydropylla	Aeromonas hydropylla	Yes

Based on the comparison table above, accuracy testing was conducted with 5 sample data, resulting in the following accuracy values according to the calculations:

$$\text{Accuracy Value} = \frac{\text{The Number of Accurate}}{\text{The Total Number of Data}} \times 100\%$$

$$\text{Accuracy Value} = \frac{4}{5} \times 100\%$$

$$= 80\%$$

From the accuracy testing results, it can be concluded that the accuracy of the expert system based on the 5 test data is 80%, indicating that this expert system functions quite well in accordance with the expert diagnosis.

Blackbox Testing

In this research, black box testing was employed to observe the outputs of various inputs into the system. If the system's outputs conformed to the design for different data variations, then the system could be deemed satisfactory. This testing involved the participation of three respondents who were tilapia fish farmers. Below are the results of the black box testing for the diagnosis of tilapia fish diseases.

Table 8. Blackbox Testing

Menu	*Test Case*	System Response	Condition
Disease	Click Disease	Displaying a page to add, edit, and delete disease data as well as solutions in preventing tilapia fish diseases.	Valid
Symptoms	Click Symptoms	Displaying a page to add, edit, and delete symptom data.	Valid
Rule	Click Rules	Displaying the rule page along with the probability values of each symptom data.	Valid
Reports	Start by clicking on "Reports"	Displaying a page with fields for name, date, time, address, phone number, email, probability, and the result of the naive Bayes value.	Valid
Consultation	Start consultation	Displaying a page for symptom questions and the diagnosis results of tilapia fish diseases along with the naive Bayes value.	Valid

Based on the black box testing results that have been conducted, it can be concluded that:
The system operates well and as expected.
The interface design is easy to understand and quite appealing.
The system built is in accordance with the designed flowchart.

DISCUSSIONS

This research has developed an expert system utilizing the Naive Bayes method to diagnose diseases in tilapia fish. Testing was conducted using accuracy testing to measure the accuracy of diagnosis results and blackbox testing to identify whether the system ran as designed. It was essential to use a laptop with minimum specifications to prevent system failure during operation, including an Intel(R) Celeron(R) CPU N3050 @ 1.60Hz 1.60 GHz processor with 2.00 GB of RAM, and a 64-bit operating system with an x64-based processor. Additionally, continuous enhancement of database security was necessary to minimize potential damage. For future development, it was recommended to further explore the Naive Bayes method to achieve differentiation and development in line with technological advancements. Additional features that are more appealing and user-friendly, along with the inclusion of symptom data for tilapia diseases, could also be incorporated. Further research was also advised to enhance the system with both web-based and mobile-based application versions.

CONCLUSION

Based on the research findings, the naïve Bayes method has been proven to be applicable in diagnosing diseases in tilapia fish using 24 symptoms data. This enables tilapia farmers to comprehend the symptoms of diseases in tilapia fish along with their diagnosis and solutions. The research has yielded a web-based application for diagnosing diseases in tilapia fish, allowing tilapia farmers to conduct diagnoses without the need for direct consultation with an expert.

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Submitted : May 7, 2024
Accepted : May 16, 2024
Published : May 20, 2024

The research also involved testing using sample data, resulting in an accuracy rate of 80%. To enhance this research in the future, several developments are planned. One of them is to improve the appearance and features of the application to make it more appealing and user-friendly. Additionally, symptom data for tilapia fish diseases will be added. Despite the fact that this application design only utilized the naïve Bayes method, the author hopes that future research will further develop using other methods.

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