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IMPLEMENTATION OF GAUSSIAN NAÏVE BAYES ALGORITHM FOR CLASSIFICATION OF BUMDESMA FINANCIAL HEALTH LEVELS

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ABSTRACT

Joint Village Owned Enterprise (BUMDesma) is a business entity established by two or more villages to strengthen local economic cooperation. In Batu Bara Regency, BUMDesma Cipta Karya Srikandi in Talawi District and Datuk Tanah Datar District has shown significant development with assets reaching Rp3.6 billion and more than 143 active member groups. However, BUMDesma's financial management still faces obstacles such as unsystematic recording and non-objective evaluation of financial reports. This research aims to implement the Gaussian Naïve Bayes algorithm to classify the financial health level of BUMDesma based on financial ratios from SPP loan development reports during the 2022-2024 period. This algorithm was chosen due to its ability to handle numerical data and produce efficient classification models. The research results show that from 60 sample data, 50 data were obtained in the healthy class with a prior probability of 83.33%, mean value (% return) of 94.72, and standard deviation of 2.87, while 10 data in the unhealthy class had a prior probability of 16.67%, mean value (% return) of 85, and standard deviation of 3.46. These classification results can serve as a reference for BUMDesma managers in decision-making related to fund management.

INTRODUCTION

Based on Law No. 6 of 2014 concerning Villages, village community empowerment is defined as an effort to enhance community independence and welfare by improving knowledge, attitudes, skills, behavior, abilities, and awareness, as well as by utilizing available resources through the formulation of policies, programs, activities, and facilitation aligned with the core issues and priority needs of village communities. One form of such empowerment is the establishment of the Inter Village Owned Enterprise (BUMDesma), a business entity formed by two or more villages to jointly manage their economic potential (Putri & Niswah, 2021).

In Batu Bara Regency, particularly in Talawi District and Datuk Tanah Datar District, BUMDesma Cipta Karya Srikandi has been established as an institutional platform for coordinating and managing community-based economic activities. This BUMDesma administers the Women's Savings and Loans Program (SPP) as a mechanism for strengthening community business capital. To date, BUMDesma Cipta Karya Srikandi has demonstrated notable growth, with assets amounting to Rp3.6 billion and more than 143 active member groups (Nadila, Ramadhan, Umaierah, & Afriyeni, 2024). However, its financial management still encounters several challenges, including unsystematic financial recording and reporting, susceptibility to data manipulation, and limitations in providing timely and accurate information for managerial decision-making (Aswiputri, 2022).

An objective assessment of the financial health of BUMDesma is essential to ensure the sustainability of its operations. Financial health can be measured through a range of financial ratios, including liquidity, profitability, and solvency ratios.

To improve the quality of BUMDesma's financial management, a system capable of processing financial ratio data effectively and producing objective classifications of financial health levels is required.

One applicable approach is the implementation of the Gaussian Naïve Bayes algorithm, a data mining method used for classifying numerical datasets. Gaussian Naïve Bayes is a probabilistic classification algorithm that calculates probabilities based on the frequency and combination of values within a given dataset. Recognized as one of the top ten data mining algorithms, it has exhibited strong performance across numerous real-world applications (Nugroho & Religia, 2021). A key advantage of the Naïve Bayes algorithm in classification tasks is its relatively low requirement for training data in parameter estimation, and its Gaussian variant performs better than other Naïve Bayes implementations when applied to numerical datasets that follow a normal distribution, including financial data.

This study aims to implement the Gaussian Naïve Bayes algorithm to classify the financial health level of BUMDesma Cipta Karya Srikandi based on financial ratios derived from the SPP loan development financial reports. The resulting classification is expected to serve as a reference for BUMDesma administrators in decision-making related to business management and strategic planning.

RESEARCH METHODS

This study employs a quantitative method with an experimental approach to implement the Gaussian Naïve Bayes algorithm for classifying the financial health levels of BUMDesma. The research stages begin with a literature study to gather information and references related to BUMDesma financial management and the Gaussian Naïve Bayes algorithm. Subsequently, relevant financial data from BUMDesma is collected, specifically the financial reports on SPP loan development required for the classification process.

Data Mining

Data Mining is the process of analyzing data from different perspectives and summarizing it into important information that can be used to increase profits, reduce expenses, or both (Turban, Aronson, & Liang, 2004). Technically, data mining can be referred to as the process of discovering correlations or patterns from hundreds or thousands of fields in a large relational database (Connolly & Begg, 2020). According to Turban, Aronson, and Liang (2005), data mining is a process that uses statistical data, mathematics, artificial intelligence, and machine learning to extract and identify useful information and related knowledge from various large databases (ANDARU, 2018). Meanwhile, according to Connolly and Begg (2020), data mining is a process of extracting or mining previously unknown data, but which can be understood and useful from large databases so that it is used to make very important business decisions (Yanti, Alimah, & Ritonga, 2018).

Functions of Data Mining

In general, the functions of data mining are (Sulasmoro, 2022):

1. Classification, which is the process of finding a model or function that describes and distinguishes data classes or concepts.
2. Clustering, which functions to find groupings of attributes into segments based on similarity (Mukmin, 2017).
3. Association, which functions to find relationships between attributes or item sets based on items that appear and existing association rules (Prasetio & Pratiwi, 2015).
4. Regression, which aims to find predictions from existing patterns (Ananda , Rahmawati, & Rachmawati, 2021).
5. Forecasting, which functions to predict future time based on trends that have occurred in previous times (Devita, Rachman, & Sari, 2018).
6. Sequence Analysis, which functions to find sequence patterns from a series of events (Rezekika, 2020).

7. Deviation Analysis, which functions to find rare events that are very different from normal conditions (abnormal events) (Saleh, 2015).

Database

According to Andaru (2018), a database is a collection of information stored systematically in a computer so that it can be controlled by a computer program to retrieve information from the database (Ermanto & Humaeroh, 2020). The term "database" comes from computer science. According to Yanti, Alimah, and Ritonga (2018), a database is an arrangement or collection of data records stored in a computer (Harahap, Lubis, & Ramadhan, 2018). The relationships between entries in a database can be used as a source of information for users. Until now, many database records are still displayed in text form as information to users. This is one of the vulnerabilities that cryptographic analysis has in accessing, manipulating, or leaking and distributing database records (Manalu, Simanjuntak, & Hutabarat, 2017).

Localhost

Localhost is the standard name given as the loopback network interface address. Localhost is used to direct a web browser to an http server downloaded on a local computer.

The function of localhost is to serve as a local server in order to access or process databases using PhpMyAdmin using programming languages such as HTML, CSS, JavaScript, and PHP. On localhost, you can create your own virtual domain with the default address 127.0.0.1 as the default localhost.

Algorithm

An algorithm is a very meaningful part and is inseparable from programming. Even if the syntax and semantics are correct, problems solved with programming methods will not succeed with the wrong algorithm (Kelly & Johnson, 2021). Basically, the main use of algorithms is to solve problems. The functions of algorithms are as follows (Sulasmoro, 2022).

1. Can simplify large and complex programs.
2. To facilitate programming in a particular problem.
3. Helps classify problems logically and systematically.

Gaussian Naïve Bayes Algorithm

One algorithm used in data mining techniques for classification is the Naïve Bayes algorithm. Naïve Bayes is one of the popular classification methods and is among the top ten algorithms in data mining (Jahromi & Taheri, 2018). Naïve Bayes is a simple probabilistic classifier that calculates a set of probabilities by summing the frequency and combinations of values from the given dataset (Ananda , Rahmawati, & Rachmawati, 2021); (Devita, Rachman, & Sari, 2018); (Rezekika, 2020); (Saleh, 2015). Empirically, the Naïve Bayes algorithm shows good performance in various real-world applications.

The advantage of using the Naïve Bayes algorithm in the classification process is that it only requires a small amount of training data to determine parameter estimates (Devita, Rachman, & Sari, 2018); (Ermanto & Humaeroh, 2020); (Harahap, Lubis, & Ramadhan, 2018); (Manalu, Simanjuntak, & Hutabarat, 2017); (Saleh, 2015). Bayesian classification also has classification capabilities similar to decision trees and neural networks (Ermanto & Humaeroh, 2020); (Mukmin, 2017); (Prasetio & Pratiwi, 2015).

The Naïve Bayes classifier using Gaussian performs slightly better than other Naïve Bayes implementations (Multinomial, Bernoulli, and complement probability distribution assumptions) on Gaussian-like datasets (Kelly & Johnson, 2021). According to (Shah, Patel, & Kumar, 2020), the performance of the Gaussian Naïve Bayes Classifier is better than the multinomial Naïve Bayes Classifier. The Gaussian Naïve Bayes algorithm is used because financial data is numerical and follows a normal distribution.

The research data was obtained from the financial reports on SPP loan development of BUMDesma Cipta Karya Srikandi in 2022, 2023, and 2024, totaling 60 data points. Each data point has four indicators: loan allocation (the amount of funds given or allocated by BUMDesma to a village), repayment realization (the amount of money that has been returned by the loan-receiving village), loan balance (the remaining loan that has not been returned), and repayment percentage (the percentage of repayment from the total loan allocation), as well as the BUMDesma financial health level label as the target class.

The system analysis and design stage includes analysis of system requirements and the design of a classification system that encompasses system architecture design, database design, and user interface (UI) design. The system is designed using PHP 8.2.12 programming language and Bootstrap 5.3.3 framework. The database is designed using MySQL with the assistance of PhpMyAdmin as the database interface. System implementation is carried out according to the results of the analysis and design that has been done, including the implementation of the Gaussian Naïve Bayes algorithm.

The Gaussian Naïve Bayes algorithm is implemented through several stages. First, calculating the prior probability of classes by dividing the number of data in each class by the total data. Second, calculating the mean (average) value of each parameter in the same class. Third, calculating the standard deviation of each class to determine the spread or variation of data against the average. Fourth, calculating the Gaussian probability of each class on test data using the Gaussian (normal) distribution function. Fifth, calculating the posterior probability of each class (likelihood combined) on test data by multiplying all attribute probabilities in a class. Sixth, calculating the posterior probability by considering prior and likelihood. Seventh, normalizing the probability so that the probability values of all classes have a total of 1. Finally, determining the prediction result by selecting the class with the highest posterior probability value.

Application testing is conducted to measure the classification accuracy level and ensure the system runs according to the research objectives. Testing is carried out using the black box testing method to test system functionality and validate the classification results of the Gaussian Naïve Bayes algorithm. The research results are then documented in the form of a thesis report as the final form of the research.

RESULTS AND DISCUSSION

Application Implementation

Administrator Login Interface

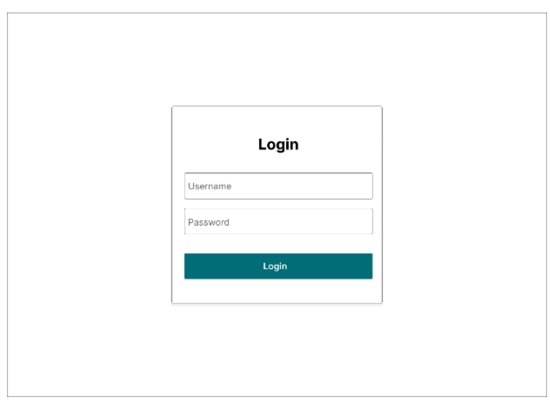

Figure 1. Administrator Login Interface

Figure 1 illustrates the administrator login page, which serves as the system’s entry point. The interface is designed with two primary input fields: a username field and a password field. Users must enter valid credentials to proceed. The layout is simple and intuitive, supporting ease of access for system administrators. Once correct credentials are submitted, the system authenticates the user and redirects them to the main dashboard.

Dashboard Menu Interface

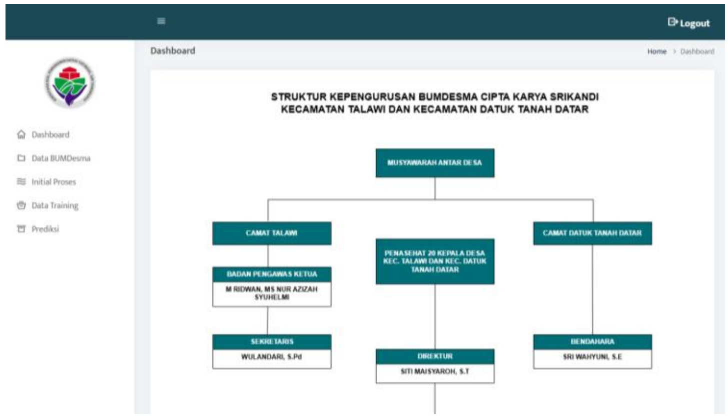

Figure 2. Dashboard Menu Interface

Figure 2 presents the Dashboard interface, which acts as the central hub after login. The dashboard displays essential information related to BUMDesma Cipta Karya Srikandi, including organizational structure, operational summaries, and a brief profile describing its service areas: Talawi Subdistrict and Datuk Tanah Datar Subdistrict. The dashboard is designed to help users quickly navigate to other system features.

BUMDesma Data Menu Interface

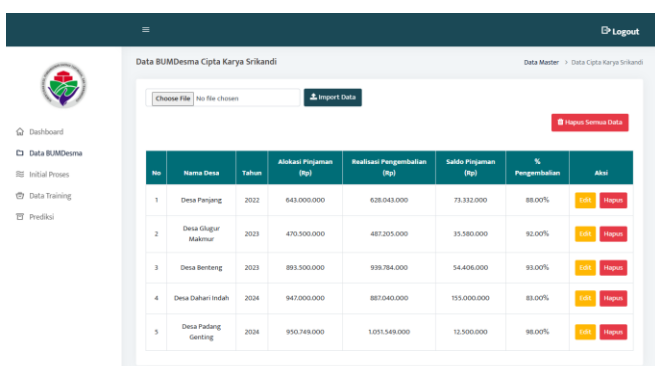

Figure 3. BUMDesma Data Menu Interface

Figure 3 shows the BUMDesma Data menu. This interface allows users to upload datasets in Excel format (.xls or .xlsx) using the Choose File option. After selecting the file and clicking Import File, the dataset is processed and displayed in table format.

The figure visually demonstrates how imported data appears in structured rows and columns, enabling efficient data monitoring. It also highlights the presence of Edit, Delete, and Delete All Data buttons, which support data management tasks.

Initial Process Menu Interface

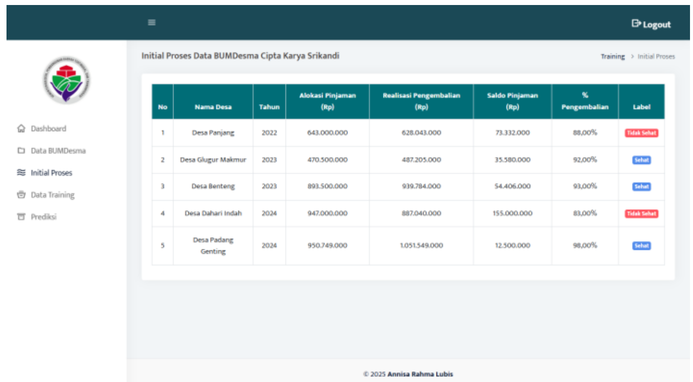

Figure 4. Initial Process Menu Interface

Figure 4 displays the Initial Process menu. In this figure, the dataset previously imported is shown with automatically assigned class labels: Healthy or Unhealthy. This step is crucial, as it prepares the data before the training process begins. The interface visually confirms that the system successfully reads, labels, and organizes the dataset for subsequent model development.

Training Data Menu Interface

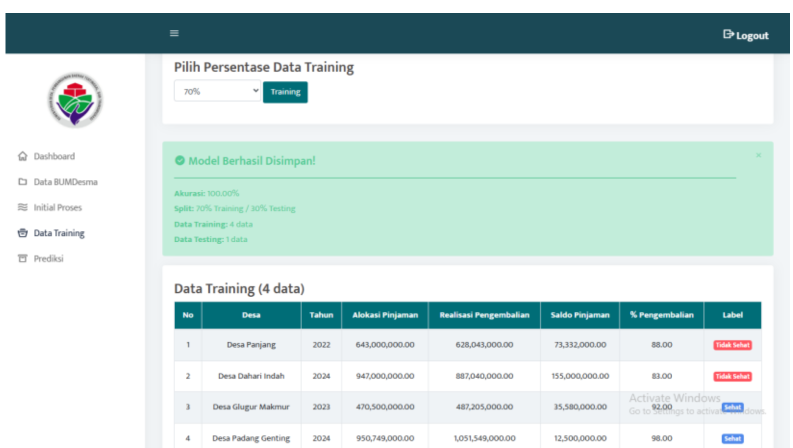

Figure 5. Training Data Menu Interface

Figure 5 illustrates the first view of the Training Data menu. This interface allows users to determine the percentage split between training and testing datasets. The figure shows a dropdown or selection area where the user chooses the data distribution ratio. It also presents the *Training* button, which initiates the machine learning process.

In the Data Training menu, users can perform the model training process for the Gaussian Naïve Bayes algorithm using the dataset that has been uploaded in the BUMDesma Data menu and has gone through the Initial Process menu. This menu also measures the accuracy level of the model in classifying the financial health of BUMDesma through the generated accuracy value. The steps are as follows:

1. The user determines the percentage split between training data and testing data.
2. The training data is used to build the model, while the testing data is used to measure the model's accuracy.
3. By clicking the Training button, after selecting the desired training data percentage, the system automatically divides the dataset according to the selected proportion.
4. The Gaussian Naïve Bayes model is then constructed based on the training data.
   This process involves calculating the mean and standard deviation of numerical attributes according to their respective class labels.
5. After the training process is completed, the system displays the results of the data split, including the number of training data, number of testing data, split percentage, the mean and standard deviation of each attribute, as well as the accuracy value obtained from the model's evaluation on the testing data.

The continuation of the Data Training menu interface can be seen in Figure 6.

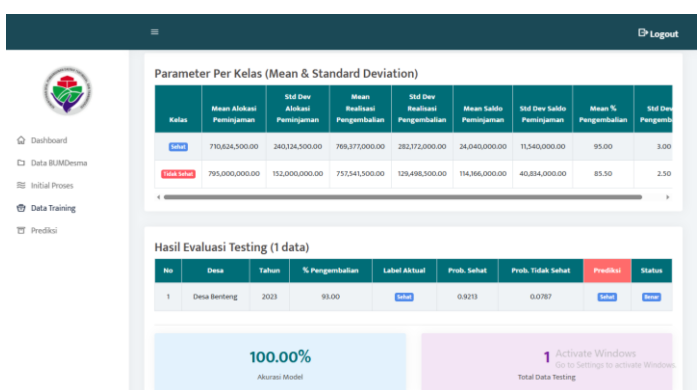

Figure 6. Continuation of Training Data Menu Interface

Prediction Menu Display

The Prediction menu serves as the final implementation stage of the Gaussian Naïve Bayes algorithm for new data entered by the user. This menu differs from the Data Training menu, as the system no longer uses data that has been divided into training and testing subsets. Instead, the system utilizes the entire dataset that has been processed in the Initial Process menu. The purpose of this approach is to ensure that the Gaussian parameters used (mean, standard deviation, and prior probability) are more stable and representative of the overall data population.

In this menu, the final prediction model is computed using the full dataset, resulting in classification outcomes for new data that are more consistent and closer to actual conditions. The interface for this process can be seen in Figure 7 and Figure 8.

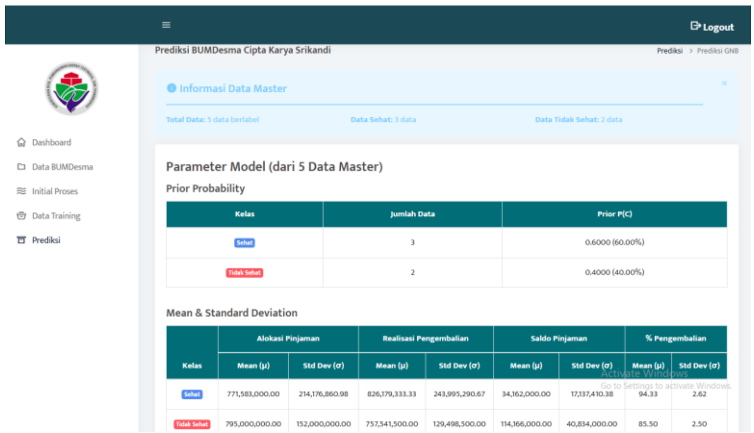

Figure 7. Prediction Menu Display

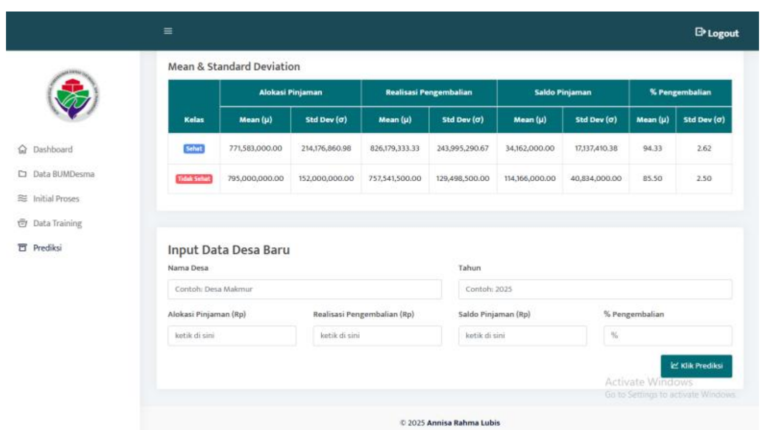

Figure 8. Extended Display of the Prediction Menu

Next, if the user performs a new data test, the extended display of the prediction results can be seen in Figures 9 and 10.

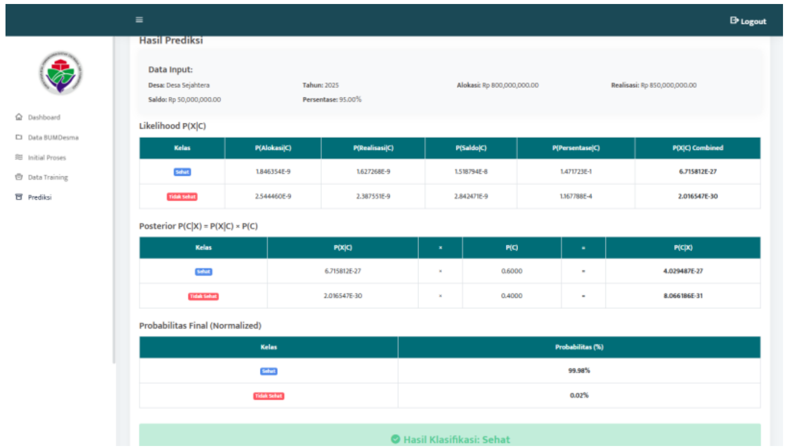

Figure 9. Prediction Result Display

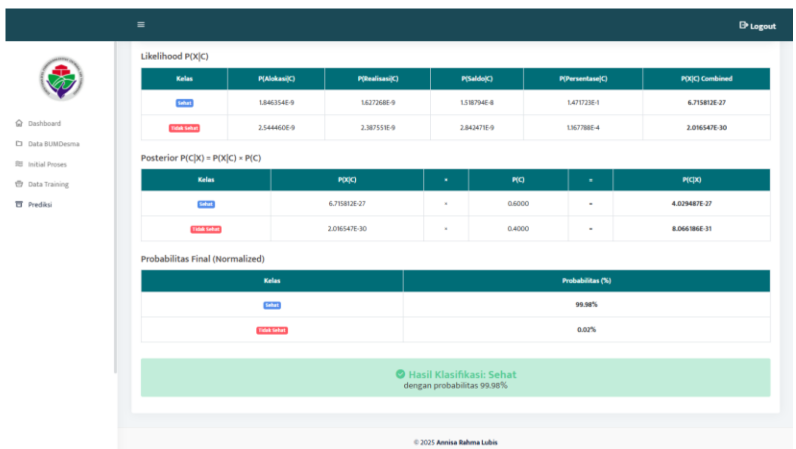

Figure 10. Extended Display of the Prediction Results

Blackbox Testing Results on the Application

Table 1 Blackbox Testing Results

No.	Testing Scenario	Test Case	Test Result	Expected Result	Conclusion
1	System displays the login page	Open the application through the browser	The login page appears with username and password fields	The system displays the login page	As expected (valid)
2	System allows login with correct credentials	Enter a registered username and password, then click the "Login" button	The system successfully enters the dashboard page	The system directs the user to the main page	As expected (valid)
3	System rejects login with incorrect credentials	Enter an unregistered username or password, then click "Login"	The system displays the message "Incorrect username or password" on the login page	The system does not allow login with incorrect data	As expected (invalid)

4	System can navigate to the Dashboard	After successful login, click the "Dashboard" menu	The Dashboard page appears showing brief information about BUMDesma	The system displays the application's main page	As expected (valid)
5	System can navigate to the BUMDesma Data page	Click the "Data BUMDesma" menu	The Dataset page appears containing BUMDesma data	The system displays data from the database table	As expected (valid)
6	System can add data via Excel import	Click the "Data BUMDesma" menu, choose "Choose File," select an Excel file, then click "Import Data"	Data from the Excel file successfully appears in the BUMDesma data table	The system displays BUMDesma data from the Excel file and saves it to the database	As expected (valid)
7	System rejects import of unsupported file formats	Click "Choose File" and select a non-Excel file (e.g., .txt or .jpg), then click "Import Data"	The system displays an error message: "Invalid file format"	The system should not import non-Excel files	As expected (invalid)
8	System can edit data in BUMDesma Data	Click "Edit" on one row, modify the values, then click "Save"	The data updates according to the new input	The system updates the data in the database	As expected (valid)
9	System can delete a row of data in BUMDesma Data	Click "Delete" on one row of data	The data is immediately removed from the table	The system deletes the data from the database	As expected (valid)
10	System can delete all data in BUMDesma Data	Click the "Delete All Data" button on the BUMDesma Data page	All data in the table is erased, leaving the table empty	The system deletes all BUMDesma data from the database	As expected (valid)
11	System can navigate to Initial Process page	Click the "Initial Proses" menu after uploading an Excel file	The Initial Process page appears, showing the uploaded BUMDesma data	The system displays the Initial Process page and the dataset with assigned class labels	As expected (valid)
12	System can navigate to Data Training after Initial Process	Click the "Data Training" menu in the navigation	The Data Training page opens and displays labeled BUMDesma data	The system displays data ready for training–testing splitting	As expected (valid)
13	System can process data percentage for training	Click the "Training" button	A table of training data appears along with Gaussian parameters (Mean and Standard Deviation) for each class, testing data results, and model accuracy	The system displays training data, Gaussian class parameters, and the testing evaluation table	As expected (valid)
14	System can navigate to the Prediction menu	Click the "Prediksi" menu in navigation	The Prediction page opens displaying Gaussian parameters (mean, standard deviation, and prior probability) from BUMDesma Data and a form for new data input	The system displays Gaussian parameters from the full BUMDesma dataset and the prediction input form	As expected (valid)
15	System can perform new data prediction and display full computation	Fill out the prediction form, then click the "Prediksi" button	The system displays the Likelihood Table, Posterior Table, Final Probability, and the prediction result	All tables and prediction results appear according to Gaussian Naïve Bayes computation	As expected (valid)
16	System rejects empty input on prediction form	Leave all prediction input fields empty, then click "Prediksi"	The system displays the message "Input cannot be empty"	The system should not process predictions with empty input	As expected (invalid)

17	System can log out	Click the "Logout" button	The system returns to the login page	User session ends	As expected (valid)

Analysis

This analysis is derived from the implementation results of the Gaussian Naïve Bayes algorithm for classifying the financial health levels of BUMDesma. The algorithm operates by calculating the mean, standard deviation, and prior probability for each class (Healthy or Unhealthy) based on the BUMDesma dataset that has been labeled accordingly.

Based on the Gaussian Naïve Bayes calculation using 60 datasets, the computed mean values are shown in Table 2.

Table 2 Mean Values for 60 Sample Data

Indicator	Healthy Class	Unhealthy Class
μ (Loan Allocation)	3,336,533,900	1,545,062,000
μ (Repayment Realization)	3,506,818,702	1,538,226,390
μ (Loan Balance)	171,447,580	165,934,300
μ (Return Percentage)	94.72	85

The resulting standard deviation values are shown in Table 3.

Table 3 Standard Deviation Values for 60 Sample Data

Indicator	Healthy Class	Unhealthy Class
σ (Loan Allocation)	2,940,526,675	1,322,855,479
σ (Repayment Realization)	3,127,655,951	1,438,630,936
σ (Loan Balance)	199,740,893	53,116,131
σ (Return Percentage)	2.87	3.46

Table 3 represents the computed mean values of the dataset, and the prior probability for each class is presented in Table 4.4.

Table 4 Prior Probability for 60 Sample Data

Class	Number of Data	Prior Probability
Healthy	50	0.8333 = 83.33%
Unhealthy	10	0.1667 = 16.67%

The results of the Gaussian probability computation for each class on the testing data are shown in Table 5.

Table 5 Gaussian Probability Results on Testing Data

Indicator	Healthy Class	Unhealthy Class
P(Loan Allocation)	9.352027×10^{-11}	2.57442×10^{-10}
P(Repayment Realization)	8.892041×10^{-11}	2.473233×10^{-10}
P(Loan Balance)	1.660217×10^{-9}	6.937387×10^{-10}
P(Return Percentage)	1.383052×10^{-1}	1.785497×10^{-3}

Furthermore, the likelihood combined results are shown in Table 6.

Table 6 Combined Likelihood Results on Testing Data

Class	Combined Likelihood
Healthy	1.909460×10^{-30}
Unhealthy	7.883778×10^{-32}

The posterior probability and normalized probability results are shown in Table 7.

Table 7 Posterior Probability and Normalized Probability

Class	Posterior Probability	Normalized Probability
Healthy	1.591217×10^{-30}	99.18%
Unhealthy	1.313963×10^{-32}	0.82%

CONCLUSION

Based on the results of the research and the implementation of the Gaussian Naïve Bayes algorithm for classifying the financial health level of the Inter-Village-Owned Enterprise (BUMDesma), it can be concluded that the financial health classification system was successfully designed and developed using the Gaussian Naïve Bayes algorithm. The system is capable of processing BUMDesma's financial data through statistical computation procedures and generating output in the form of financial health classification results.

Testing conducted on 60 sample data points indicates that 50 data points fall under the healthy class with a prior probability of 83.33%, a mean (repayment percentage) of 94.72, and a standard deviation of 2.87. Meanwhile, 10 data points fall under the unhealthy class with a prior probability of 16.67%, a mean (repayment percentage) of 85, and a standard deviation of 3.46. The classification results produced by the system can serve as a reference for the administrators of BUMDesma Cipta Karya Srikandi in making more precise decisions related to the management of BUMDesma funds in Talawi District and Datuk Tanah Datar District.

For future research, it is recommended to conduct comparative testing using other classification algorithms such as Decision Tree, Random Forest, or Support Vector

Machine (SVM) to evaluate prediction accuracy. Additionally, the system needs to be further developed so that it can be implemented on an online hosting platform, enabling access through the internet. Continued research is also necessary to develop a system that is superior in terms of accuracy, efficiency, and ease of use.

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