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Optimizing K-Nearest Neighbors with Particle Swarm Optimization for Improved Classification Accuracy

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ABSTRACT

This study aims to improve the performance of the K-Nearest Neighbors (KNN) algorithm in classifying public reviews of Batik Madura through optimizing the K value using the Particle Swarm Optimization (PSO) algorithm. Public reviews collected from the Google Maps platform are used as a dataset, with positive, negative, and neutral sentiment categories. Optimization of the K value is carried out to overcome the constraints of KNN performance, which is highly dependent on the K parameter, with PSO providing a more efficient approach than the grid search method. However, PSO also presents challenges such as sensitivity to parameter tuning and potential computational overhead. This study has succeeded in developing a web-based system using the Python Streamlit framework, which makes it easy for users to access sentiment analysis results. Testing shows that optimizing the K value with PSO increases the accuracy of KNN to 88.5% with an optimal K value of 19. However, this accuracy is not compared to other optimization techniques, leaving its relative advantage unverified. The results are expected to help Batik Madura entrepreneurs in evaluating public perception and guiding strategic innovations. Research outputs include a prototype, intellectual property registration, and journal publication, although the role of deep learning models is only briefly noted without further development.

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1. INTRODUCTION

Public reviews of a business are essential to evaluate the quality of the product or service being developed. Consumer input provides an objective view of how the product is received in the market, and whether it meets customer expectations and needs. In addition, public reviews can reveal product shortcomings or advantages that entrepreneurs may not be aware of. In other words, public reviews play a role as an important component in strategic decision-making regarding continued business development [1]-[4]. In Madura, there are more than 1,745 businesses engaged in Batik, an industry that not only reflects local traditions, but is also the main source of livelihood for craftsmen. Many of these craftsmen also act as Batik entrepreneurs. However, maintaining the continuity of Batik businesses amidst tight market competition is not easy. Batik entrepreneurs in Madura are faced with the challenge of continuing to innovate and adapt to environmental dynamics and changes in consumer preferences [5]-[8].

One effective method to evaluate public reviews is to classify the review data. This classification technique allows entrepreneurs to understand the general patterns in public reviews, whether they are positive, negative, or neutral. One of the algorithms often used for classification is K-Nearest Neighbor (KNN) [9]-[17].

This algorithm is simple yet effective, but its performance is highly dependent on the selection of important parameters such as the K value. The K value in KNN determines the number of nearest neighbors taken into account in the classification, and this value directly affects the level of classification accuracy. Finding the optimal K value is a challenge in itself, because a K value that is too small or too large can result in inaccurate classification [18]-[31]. The process of finding the right K value is often done using the gridsearch technique, but this method takes quite a long time [32]-[45]. To overcome these obstacles, the use of optimization algorithms is a reliable solution. One of the optimization algorithms known to be effective is Particle Swarm Optimization (PSO), which is inspired by the behavior of flocks of birds and fish [46]-[62]. This algorithm works by optimizing parameters based on interactions between particles in the search space.

By applying PSO to optimize KNN, it is expected that the classification accuracy can be significantly increased. Therefore, this study aims to build a community review classification system using the KNN algorithm optimized by PSO, with the ultimate goal of obtaining higher accuracy and better classification results.

2. METHODS

2.1. Data Collection and Testing Techniques

The data to be used is a dataset of public reviews on comments or evaluations in the Batik Madura business google map. The total data to be taken in the review is 1000 review data. Review data comes from posts in the form of comments or evaluations by the public on the Batik business from 2016 - 2022. The language used in the data mining process is Indonesian. The dataset is mined using the data mining method. The dataset is categorized into 3 classes, namely Positive, Negative and Neutral. Fig. 1 is one of the images in the discussion process with one of the batik entrepreneurs in Bangkalan Madura.

Fig. 1. Data retrieval

PSO is used as an optimization to obtain the best KKN performance by dividing the data into 3 parts, namely training data, testing and particle parameters on the PSO to be tested. The iteration used in determining the best K has been determined at 25 iterations as explained in Table 1.

Table 1. Test Scenario

No	Split Data	Number of Particles	Number of Iterations
1	80:20	10	25
2	80:20	15	
3	80:20	20	
4	70:30	10	
5	70:30	15	
6	70:30	20	

2.2. System Design

Fig. 2 is the architecture of the model that will be built in KNN modeling. Here is the explanation, Modeling begins with input data which is review data from Google Maps that has been labeled. Data preprocessing includes several stages to prepare the textual data for analysis, namely Cleaning (removing irrelevant characters and symbols), Case Folding (standardizing all text to lowercase), Tokenizing (splitting sentences into individual words), Filtering (eliminating stopwords and irrelevant terms), and Stemming (reducing words to their root form). The next process is to weight the words that have gone through the data preprocessing process using TF-IDF. Then, the PSO process to optimize the K value in KNN by measuring the accuracy of KNN as the PSO evaluation value. Then, after the best K value has been obtained from PSO, the classification process is carried out using KNN. After the process is complete, the evaluation is carried out using K-Fold by considering the results of accuracy, Precision, F1-score and Recall.

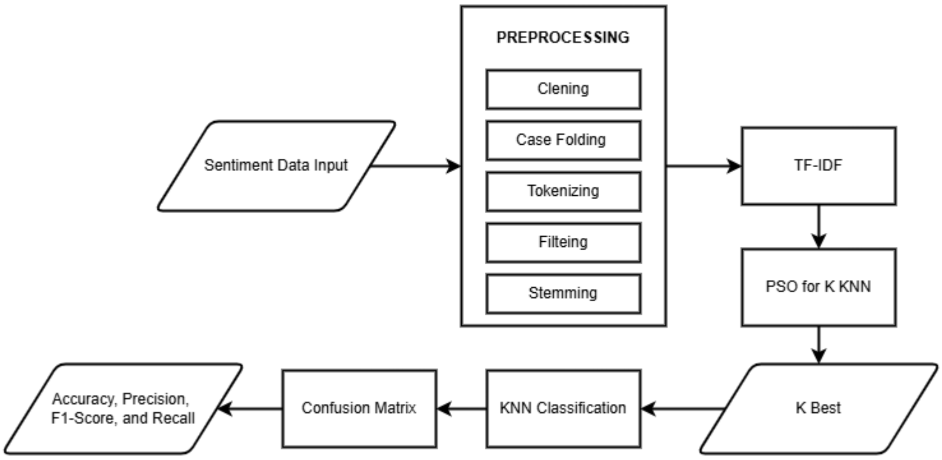

Fig. 2. System Design

2.3. Test Scenario

Fig. 3 is the architecture of PSO in finding the best K value that is useful for KNN in performing its classification. Here are the detailed explanations, The results of TF-IDF will be processed through PSO for K on KNN. Then, the value will be repeated 25 times as an iteration of the PSO search for the K value on KNN. The first stage in PSO is to determine the Particle value. After the particle value is determined, the best evaluation is based on the accuracy value of the KNN itself. The next stage will go through PSO processes such as getting the Individual best and Global best. This best value represents the K value on KNN. This will be repeated 25 times. After the iteration is achieved, the best K will be obtained so that the classification process using KNN with the best K is worthy of carrying out the classification process.

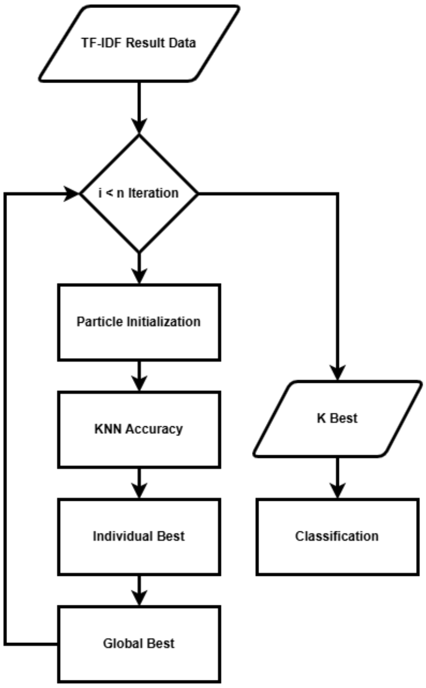

Fig. 3. PSO Scenario

2.4. Design System Design

The display system will be made into 2 layouts where the left side is the Menu Bar and the right side is the content using the Python framework, namely Streamlit. On the initial menu of this system, a welcome greeting will be provided to welcome users in using this system, as shown in Fig. 4.

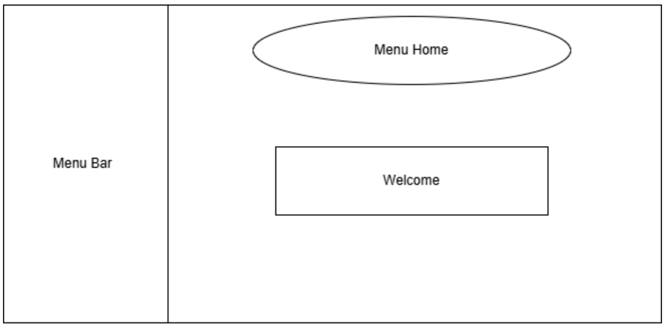

Fig. 4. Home menu

In the dataset and model menu as shown in Fig. 5, the contents of this menu are to display the dataset trained and used in this system. The model result data will also be displayed in the contents of this menu. The Classification Menu is the main feature of this model which is useful for predicting the classification results used by the model for input that will be carried out by the user to provide information regarding public perception/review of the Madura Batik business as shown in Fig. 6.

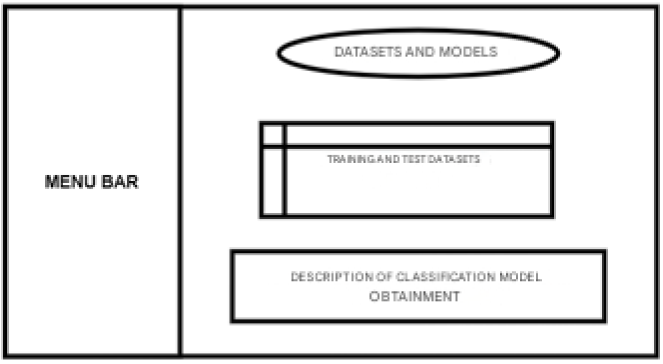

Fig. 5. Dataset and model menu

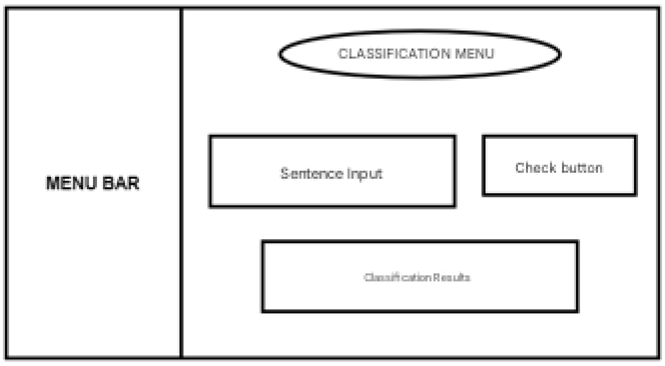

Fig. 6. Classification Menu

3. RESULTS AND DISCUSSION

The Batik dataset used in this study consists of 1000 data points, with three sentiment classes: Positive, Neutral, and Negative. The class distribution is relatively balanced, with each class represented in a proportionate manner: Positive (2), Neutral (1), and Negative (0). As a result, class imbalance does not significantly affect the classification process, ensuring that the model performs consistently across all sentiment categories.

The dataset contains four features: Name, Text, Year, and Label, with the analysis focusing on the Text and Label features only. Given the balanced distribution of sentiment categories, no specific techniques for handling class imbalance, such as resampling or class weight adjustments, were necessary for this study.

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3.1. Implementation of Design and Research Results

The system was successfully implemented in WEB form with results as shown in Fig. 7. The initial display is the Home menu display consisting of the Bangkalan map location and the application data greeting for users who will use this application. The display on this application is shown in Fig. 7.

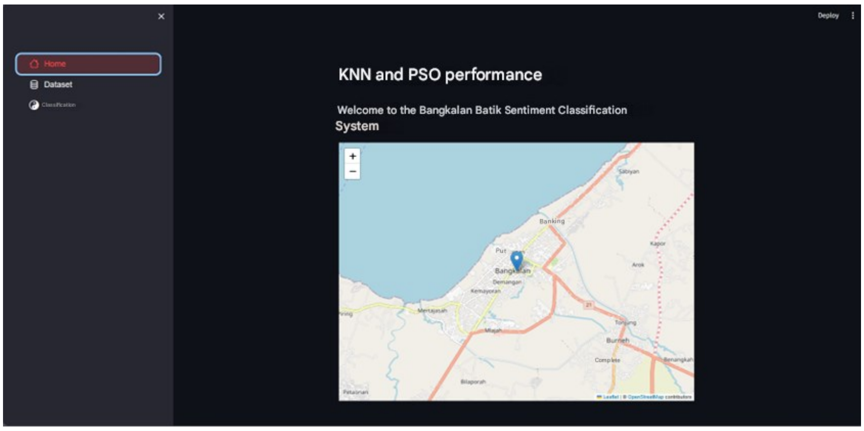

Fig. 7. Home page view

In the dataset and model menu, the purpose is to introduce users that the dataset used to perform the training process is the dataset shown in the application. In addition, to provide clarity to users as a model used to perform the classification process. The accuracy of the model is also shown that the accuracy obtained is 88.5%. The results of this menu are shown in Fig. 8.

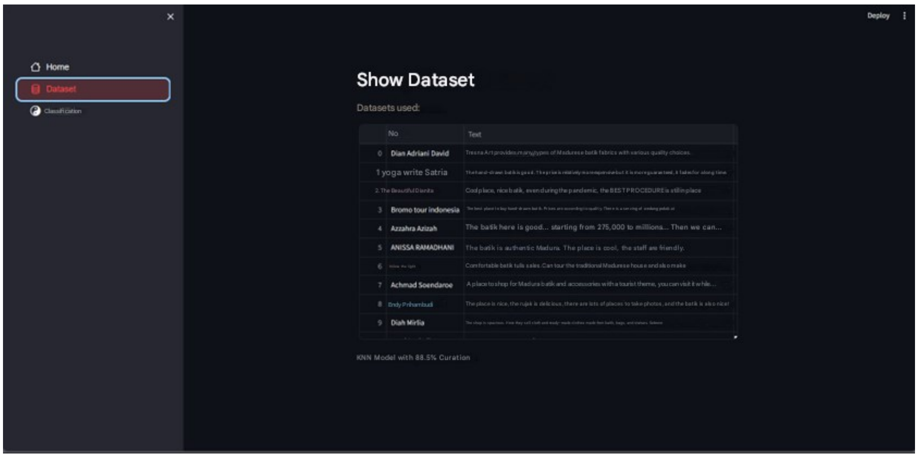

Fig. 8. Dataset and Model Page View

The classification menu is the main menu for processing and knowing the sentiment results carried out by the reviewers of Bangkalan batik. This process involves the best model on the test results and then shows the probability that is closer to the positive, negative or neutral class. The results of this menu are shown in Figure 9.

3.2. Test Results

3.2.1. First Test Results

In the first test, the test conducted was to divide the dataset into 80:20 with PSO optimization for K values of 1 - 10. These results indicate that the best K value obtained is K = 9 with an accuracy frequency of 84% as shown in Figure 10. The optimization time required to perform this task is 15.7973 seconds and the model training time is 0.0137 seconds. The results of the Confusion matrix are shown in Fig, 11.

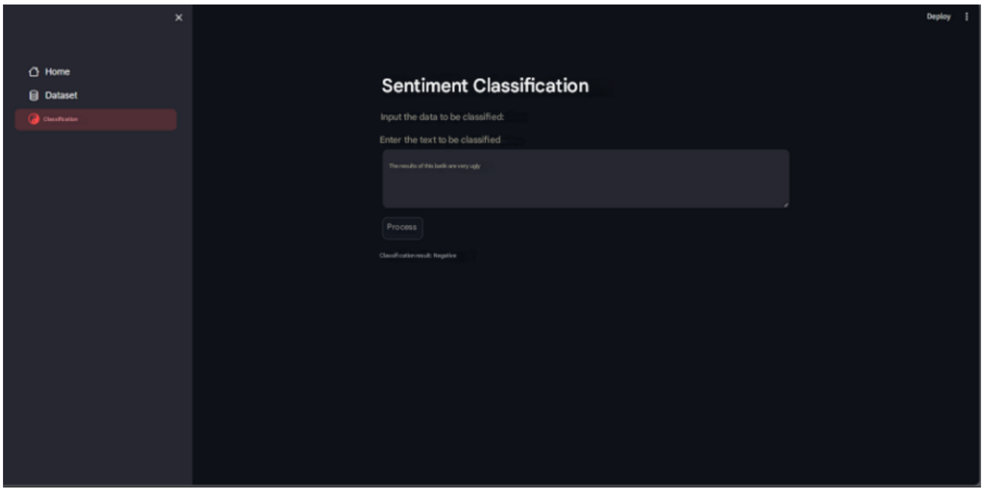

Fig. 9. Classification Menu

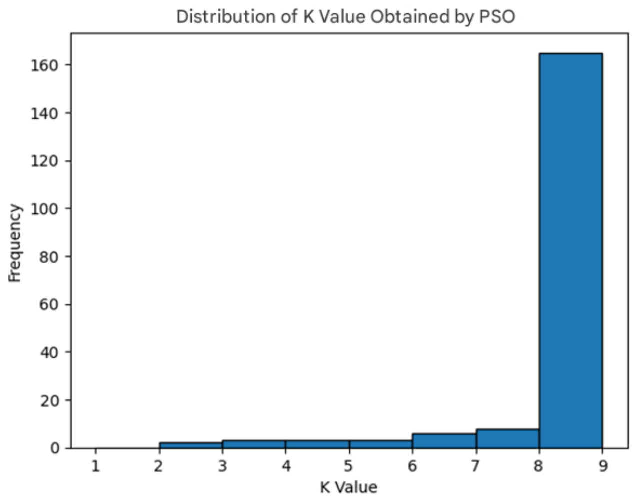

Fig. 10. Frequency Results of First Test K Value

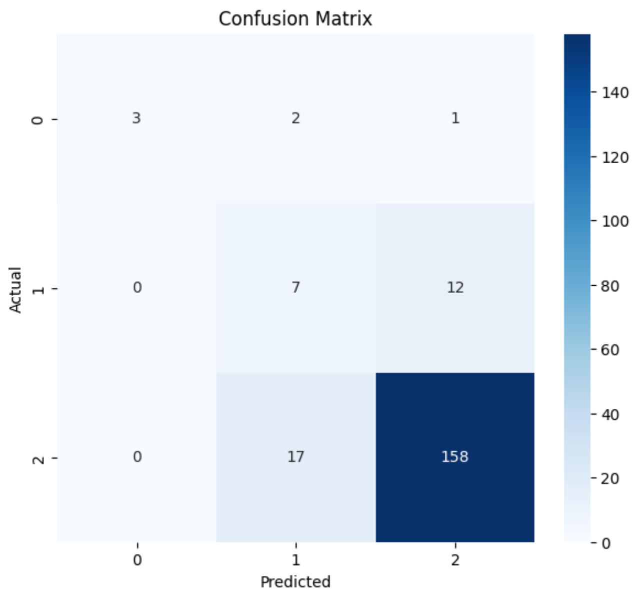

Fig. 11. Confusion matrix results First Test

3.2.2. Second Test Results

In the second test, the test conducted was to divide the dataset into 80:20 with PSO optimization for K values of 1 - 15. These results indicate that the best K value obtained is K = 11 with an accuracy frequency of 86% as shown in Fig. 12. The optimization time required to perform this task is 11.3382 seconds and the model training time is 0.0272 seconds. The results of the Confusion matrix are shown in Fig. 13.

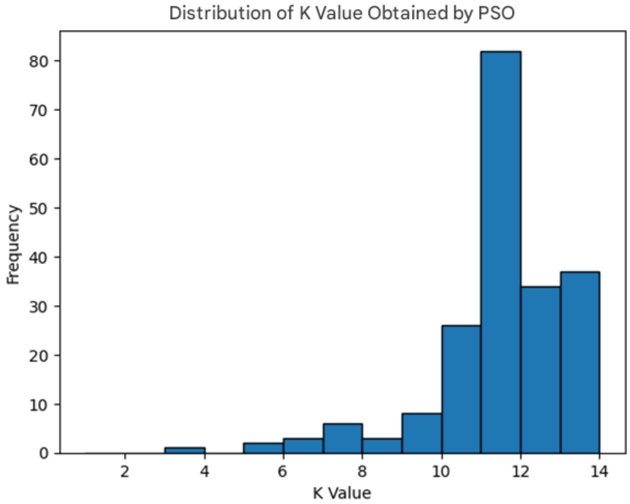

Fig. 12. Second Test K Value Frequency Results

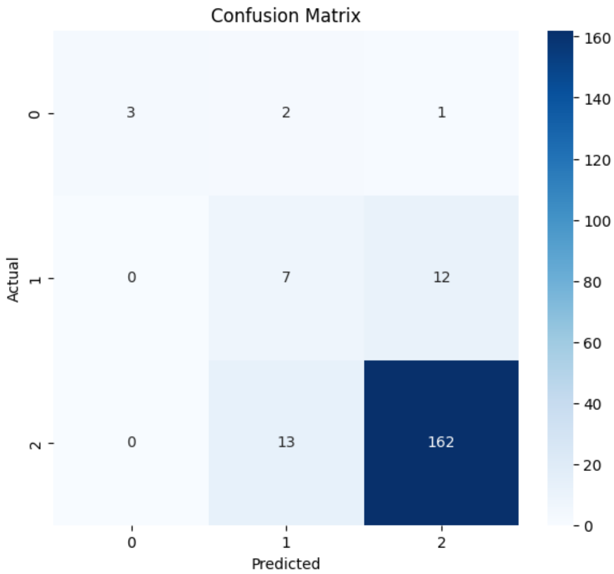

Fig. 13. Confusion matrix results of the second test

3.2.3. Third Test Results

In the third test, the test conducted was to divide the dataset into 70:30 with PSO optimization for K values of 1 - 20. These results indicate that the best K value obtained is K = 15 with an accuracy frequency of 88% as shown in Fig. 14. The optimization time required to perform this task is 14.7155 seconds and the model training time is 0.0101 seconds. The results of the Confusion matrix are shown in Fig. 15.

3.3. Test Evaluation Results

The results of all tests shown in Fig. 16, that the best accuracy is obtained in the third test with an accuracy of 88.5%. In this test, training is relatively fast with an optimization time of 15.0388 seconds and a model training time of 0.0177 seconds with an optimal K value produced for KNN of 19.

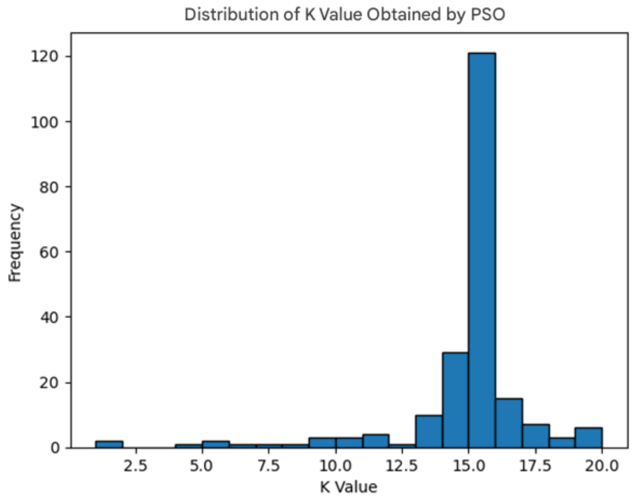

Fig. 14. Third Test Frequency K Value Results

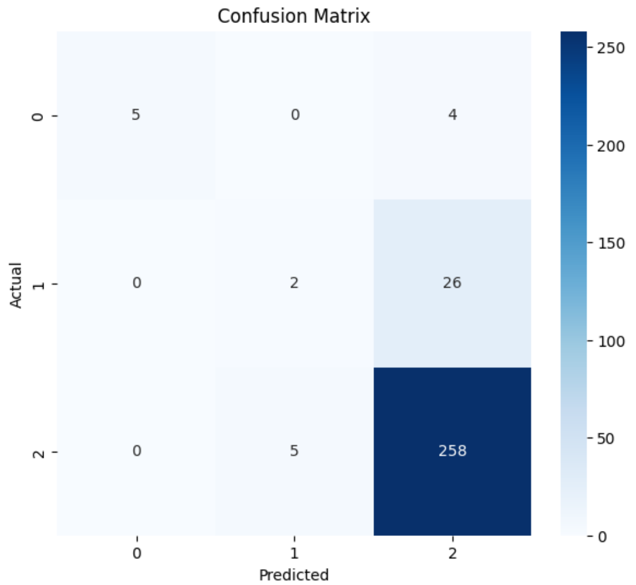

Fig. 15. Confusion matrix results of the third test

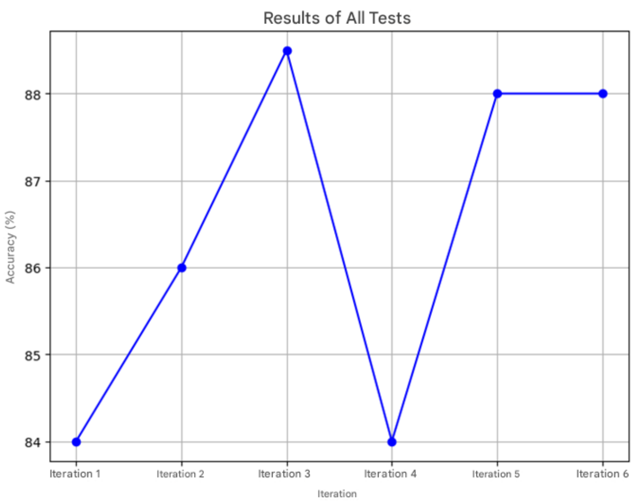

Fig. 16. Overall Test Accuracy Results

4. CONCLUSION

The results of the study showed that the use of the Particle Swarm Optimization (PSO) technique to optimize the K value in the K-Nearest Neighbor (KNN) algorithm gave very satisfactory results, with a fast optimization time of 15.0388 seconds, and an optimal K value of 19 based on the third test with an accuracy of 88.5%. This time is much better than the basic method, such as the grid search approach, which takes much longer to optimize the K parameter with a time required for 27.2312 seconds, with an accuracy obtained of 88.2% during testing with the same iteration. The application of PSO has proven effective in accelerating the process of finding the right K parameter, so there is no need to do all the iterations as applied by the Grid Search technique. The WEB-based application built using Python with the streamlit framework can run properly. The application can show results in the form of sentiment analysis if the user inputs a comment sentence from the commentator. This application is expected to help Batik Bangkalan entrepreneurs analyze consumer sentiment towards Batik products more easily and accurately. By leveraging this technology, entrepreneurs can gain deeper insights into market preferences and needs, so they can make more informed strategic decisions to improve product quality and drive relevant innovation based on consumer expectations.

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