

CLASSIFICATION OF SALT QUALITY BASED ON COLOR AND SHAPE FEATURES USING THE K-NEAREST NEIGHBOR (KNN) METHOD (CASE STUDY: PINGGIR PAPAS VILLAGE)

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Abstract

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*Digital Image Processing,
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Shape Features.*

The quality of salt crystals is one of the factors that determines the market value and quality of salt. The quality assessment process, which is still carried out manually, tends to be subjective because it relies on visual observation. This study aims to develop an image-processing-based salt crystal quality classification system using the K-Nearest Neighbor (KNN) method to support a faster, more objective, and consistent identification process. The research dataset consists of 600 salt crystal images divided into three categories: high, medium, and low quality, obtained from salt farmers in Pinggir Papas Village, Sumenep Regency. The research stages include preprocessing, segmentation, RGB and HSV color feature extraction, shape feature extraction, and classification using the KNN method. The system was implemented as a Streamlit-based application. The test results showed that the best model was obtained at $K = 3$, achieving an accuracy of 98.333% during the parameter selection process. Testing on 60 test images resulted in an accuracy of 86.67%, precision of 87.24%, recall of 86.67%, and an F1-score of 86.81%. These results indicate that the combination of color features, shape features, and the KNN method can classify salt crystal quality effectively and can therefore be used as an alternative supporting tool for the automated classification of salt quality.

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INTRODUCTION

Indonesia is an archipelagic country with a long coastline so it has abundant marine resource potential, one of which is salt commodities. Salt is a strategic commodity that plays an important role in supporting the national economy and becoming a source of livelihood for coastal communities. One of the salt production centers in Sumenep

Regency is Pinggir Papas Village, Kalianget District, which has a salting land area of around 826.77 ha with a production of 92,512 tons per year (Widiyanto et al., 2023), (Hasan, 2023). Most of the people in the village work as salt farmers, so the quality of production is an important factor that affects the selling value and competitiveness of the product.

The determination of salt quality at the farmer level is still carried out manually based on visual observation of the color and shape of salt crystals. This method relies heavily on the experience of the assessor so that it is subjective and has the potential to cause differences in assessment results between farmers and traders. This condition can affect the process of determining the quality and selling price of salt, especially because the distribution of production products still involves collecting traders as a marketing institution.

The development of digital image processing technology provides an opportunity to automatically classify salt quality. Through the *stages of preprocessing*, segmentation, and feature extraction, the visual characteristics of objects can be represented in the form of numerical data which is then used as the basis for the classification process. In this study, the features used include RGB and HSV color features as well as shape features consisting of area, perimeter, circularity, and aspect ratio. The combination of these features is expected to be able to represent the characteristics of salt crystals based on differences in color and shape so that the quality identification process can be carried out more objectively.

Method *K-Nearest Neighbor* (KNN) was chosen because it has a simple concept, is easy to implement, and is able to classify data based on proximity to distance using calculations *Euclidean Distance* (Warna et al., 2024), (Fansyuri & Yunita, 2023). By utilizing color and shape features, the KNN method is expected to be able to accurately distinguish the quality of salt crystals into high, medium, and low categories.

Based on these problems, this study aims to develop a salt crystal quality classification system based on digital image processing using the *K-Nearest Neighbor* (KNN) method. The system developed is expected to be able to help the process of determining salt quality more quickly, objectively, and consistently so that it can support the efficiency of the sorting process and become an alternative in salt quality assessment in Pinggir Papas Village.

LITERATURE REVIEW

Literature review is a theoretical foundation that is used as a basis for conducting research. This section contains some relevant previous research as well as supporting theories regarding digital image processing, color feature extraction, shape feature extraction, and the *K-Nearest Neighbor* (KNN) method. These theories are used as a reference in the development of a salt crystal quality classification system so that it can support the achievement of research objectives.

A. Previous Research

Research on object classification based on digital image processing has been widely carried out using various feature extraction methods and classification algorithms. One of the studies conducted by Cindy Suryanti and M. Ghofar Rohman classified the quality of apples using the *K-Nearest Neighbor* (KNN) with a combination of color features, GLCM textures, and shape features. The results of the study showed that the system obtained the best accuracy of 88.37%, so the combination of several features was able to improve classification performance

(Suryanti & Rohman, 2024).

Other research by Reswan *et al.* apply the KNN method to classify the ripeness level of pineapples based on RGB color features. The results showed that the best accuracy of 73% was obtained at $K = 5$ and $K = 9$, thus proving that color features play an important role in the object classification process (Reswan *et al.*, 2024).

In addition, Aminatus Syarifah *et al.* applied the KNN method using HSV color features and GLCM textures to classify the level of ripeness of guava. The study produced an accuracy of 93%, thus showing that the combination of color features and the KNN method is able to produce good classification performance (Aminatus Syarifah *et al.*, 2022).

Based on some of these previous studies, the KNN method has been proven to be able to provide good classification results on various objects based on digital images. However, the application of the KNN method to classify the quality of salt crystals using a combination of RGB, HSV, and shape features is still limited. Therefore, this study developed a salt crystal quality classification system using a combination of these features so that the identification process can be carried out more objectively and consistently.

B. Digital Image Processing

Digital image processing is the process of manipulating images using computers to improve image quality so that it is easier to interpret by humans and computer systems. This process aims to generate visual information that can be used in various applications, such as object identification and classification (Feriska Amalia & Rahma Dewi, 2024). The stages of image processing generally include *preprocessing*, segmentation, feature extraction, and classification. In addition, the use of HSV color space is considered more stable to changes in lighting than RGB because it is able to separate color information from light intensity (Rizka Rizka *et al.*, 2025).

In this study, digital image processing is used to process salt crystal images through the stages of *preprocessing*, segmentation, and extraction of color and shape features. The results of the processing are used as input data in the classification process using the *K-Nearest Neighbor* (KNN) method so that the system is able to distinguish the quality of salt crystals more objectively.

C. Color Features

Color feature extraction is the process of obtaining a numerical representation of the color characteristics of objects in digital images. This study uses RGB and HSV color spaces as the basis for feature extraction. The RGB model consists of *Red*, *Green*, and *Blue*, while HSV consists of *Hue*, *Saturation*, and *Value* which is able to separate the color components from the brightness level so that they are more resistant to lighting variations (Paliling *et al.*, 2025). The average value on each color channel is used as a representation of the object's color characteristics.

In this study, RGB and HSV color features were extracted from salt crystal images to obtain information about the color characteristics of each object. The value of the obtained feature is then used as one of the parameters in the process of classifying salt crystal quality using the KNN method.

D. Shape Features

Shape feature extraction is the process of taking the morphological characteristics of the segmented object so that it can distinguish an object based on its geometric structure. Form features play a role in representing the physical characteristics of objects through numerical parameters, such as area, perimeter, circularity, and aspect ratio, which can be used as differentiators between objects (Maharani & Ramadhanu, 2025).

In this study, shape features were obtained from the results of segmentation of salt crystal images. The parameters of area, perimeter, circularity, and aspect ratio are used to represent the size and shape of salt crystals. The combination of these features is expected to be able to improve the system's ability to distinguish the quality of salt crystals based on their morphological characteristics.

E. K-Nearest Neighbor (KNN)

K-Nearest Neighbor (KNN) is a classification algorithm based on *supervised learning* which determines the class of a data based on its proximity to the training data using calculations *Euclidean Distance*. The results of the classification are influenced by the quality of the features used and the K value chosen. The value of K indicates the number of closest neighbors used as the basis for decision-making. Too small a K-value can cause the model to be sensitive to *Noise*, while too large a value can reduce the model's ability to distinguish between classes (Muchtar & Muchtar, 2024).

In this study, the KNN method was used to classify the quality of salt crystals into three categories, namely high, medium, and low quality based on a combination of RGB, HSV, and shape features. To obtain the best performance, several variations of the K value were tested, then the value that produced the highest accuracy was selected as a classification model in the developed system.

RESEARCH METHODS

The research method is a stage carried out to develop a salt crystal quality classification system based on digital image processing using the K-Nearest Neighbor (KNN) method. This research began with the collection of salt crystal imagery datasets, then continued with the process of preprocessing, segmentation, extraction of color and shape features, classification using the KNN method, and evaluation of system performance. The series of stages is systematically arranged to produce a model that is able to classify the quality of salt crystals objectively, quickly, and consistently.

A. Research Flow

The research flow describes the stages carried out systematically in the development of a salt crystal quality classification system based on digital image processing using the *K-Nearest Neighbor* (KNN) method. Each stage is interconnected to produce an accurate and objective classification process. The research flow carried out in the development of the salt crystal quality classification system is shown in Figure 1.



Image 1. Diagram Alur

in Figure 1. The research began with the process of collecting salt crystal image datasets obtained from salt farmers in Pinggir Papas Village, Sumenep Regency. Furthermore, the image goes through *the preprocessing* stage to improve the image quality and prepare data before the segmentation process is carried out. The segmentation stage aims to separate the salt crystal object from the background so that the object can be analyzed more accurately. The segmented objects are then extracted using RGB and HSV color features and shape features that include *area*, *perimeter*, *circularity*, and *aspect ratio*. All the features obtained are used as input in the classification process using the *K-Nearest Neighbor* (KNN) method. The final stage is the evaluation of system performance using a *confusion matrix*, *accuracy*, *precision*, *recall*, and *F1-score* to measure the success rate of the system in classifying the quality of salt crystals.

B. System Diagram Blocks

The system diagram block describes the workflow of the salt crystal quality classification system developed in this study. The diagram shows the stages of the process starting from image input, image processing, feature extraction, to classification using the K-Nearest Neighbor (KNN) method. The block diagram of the system used in this study is shown in Figure 2.

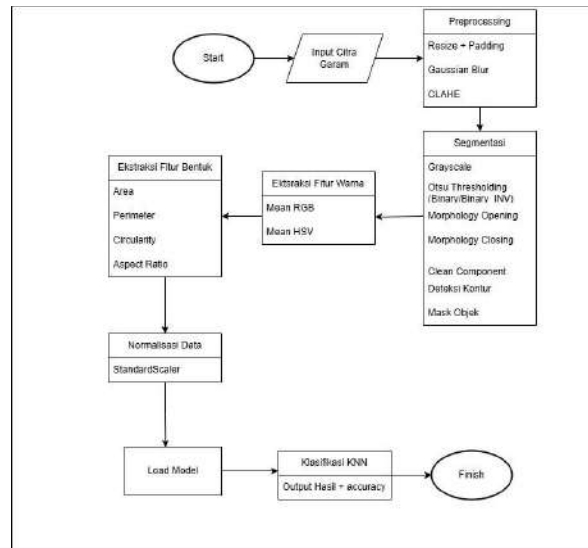


Image 2. System Diagram Blocks

Based on Figure 2, the process begins with entering salt crystal images as input data, then *preprocessing* is carried out in the form of *resize* with *padding*, *Gaussian Blur*, and *CLAHE* to improve image quality. Next, the image is segmented using *grayscale*, *Otsu Thresholding*, morphological operations, contour detection, and *mask formation* to separate the salt object from the background. The segmented objects were then extracted using RGB and HSV color features as well as shape features in the form of *area*, *perimeter*, *circularity*, and *aspect ratio*. These features are normalized using *the StandardScaler* and used as input to the K-Nearest Neighbor (KNN) method to determine the quality category of salt crystals. The results of the classification are then evaluated using *accuracy* to determine the performance of the system.

C. Research Dataset

The research dataset is in the form of salt crystal images obtained from salt farmers in Pinggir Papas Village, Kalianget District, Sumenep Regency. The image was taken using a digital camera with a *top view* position and a black background. The dataset consists of 600 images, namely 200 high-quality, 200 medium-quality, and 200 low-quality images, with consistent lighting and shooting distances.



Image 3. Sample Salt Granules

The dataset was divided into training data and test data using *Stratified Sampling* with an 80:20 ratio, so that 480 training data images and 120 test data images were obtained. This distribution is carried out to maintain the proportion of each salt quality category so that the KNN training and testing process is more representative. The

distribution of the dataset is shown in Table 1.

Table 1. Research Dataset

<i>Salt Quality</i>	<i>Training Data</i>	<i>Test Data</i>	<i>Total</i>
<i>Height</i>	160	40	200
<i>Medium</i>	160	40	200
<i>Low</i>	160	40	200
<i>Total</i>	480	120	5000

The test data were used to evaluate the ability of the Support Vector Machine (SVM) model to classify rice varieties that had never been processed before. The test results were then analyzed using evaluation parameters in the form of accuracy, precision, recall, and F1-score to determine the performance of the resulting model.

D. Preprocessing and Segmentation

The *preprocessing* and segmentation stages are carried out to improve the image quality and separate the salt crystal objects from the background. *Preprocessing* includes *resize* with *padding* to standardize size, *Gaussian Blur* to reduce *noise*, and CLAHE to improve image contrast. Furthermore, segmentation is carried out through *grayscale*, *Otsu Thresholding (Binary Inverse)*, morphological operations (*opening* and *closing*), *clean components*, and contour detection to obtain salt crystal objects. The results of the two stages are used as the basis for the extraction of color and shape features so that the classification process using the *K-Nearest Neighbor* (KNN) method can be carried out more optimally.

E. Feature Extraction

Feature extraction is carried out to obtain important information from the segmented images as input for the classification process. The features used consist of color and shape features. Color features are obtained from RGB and HSV models by calculating the mean values on each channel, namely Mean Red, Mean Green, Mean Blue, Mean Hue, Mean Saturation, and Mean Value. The shape features include *area*, *perimeter*, *circularity*, and *aspect ratio* to represent the morphological characteristics of salt crystals. All color and shape features are then combined into one feature vector as input to the *K-Nearest Neighbor* (KNN) method.

Table 2. Feature Extraction

<i>Feature Groups</i>	<i>Parameter Fitur</i>
<i>RGB Color</i>	Mean Red, Mean Green, Mean Blue
<i>HSV Color</i>	Mean Hue, Mean Saturation, Mean Value
<i>Shape</i>	Area, Perimeter, Circularity, Aspect Ratio

Based on Table 2, the features used consist of color features in the form of RGB and HSV average values and shape features in the form of *area*, *perimeter*, *circularity*, and *aspect ratio*. All of these features are used as inputs to the *K-Nearest Neighbor* (KNN) method to classify the quality of salt crystals into high, medium, and low categories.

F. K-Nearest Neighbor (KNN) Classification

The *K-Nearest Neighbor* (KNN) method is used to classify the quality of salt crystals based on the proximity of the test data and the training data using *Euclidean Distance*. Before classification, features are normalized using *StandardScaler*. The test was carried out with a variation of K values = 3, 5, 7, 9, and 11, then the K value with the highest accuracy was selected as the best model. The results of the classification were determined based on *majority voting* and evaluated using a *confusion matrix* with *accuracy*, *precision*, *recall*, and *F1-score* parameters.

RESULTS AND DISCUSSION

The results and discussions included system implementation, preprocessing and segmentation, feature extraction, K-value testing, and evaluation of KNN performance using *confusion matrix*, *accuracy*, *precision*, *recall*, and *F1-score*.

A. System Implementation

The system is implemented in a *Streamlit-based* application using Python that automatically integrates *preprocessing*, *segmentation*, *feature extraction*, *StandardScaler* normalization, and KNN classification.



K	acc_accuracy, %	test_accuracy, %
3	98.12%	98.12%
5	97.75%	96.63%
7	97.5%	96.63%
9	97.08%	95.63%
11	97.29%	95.63%

Image 4. Application Display of Salt Crystal Quality Classification

Based on Figure 4, the *Streamlit-based* application is able to integrate the classification process automatically, starting from uploading images to displaying model evaluation results, K-value comparisons, and color and shape features used in KNN classification.



	Actual High	Actual Medium	Actual Low
Predicted High	10	0	0
Predicted Medium	0	10	0
Predicted Low	0	0	10

Image 5. Salt Crystal Quality Classification Results

Based on Figure 5, the application displays the results of the classification of salt crystal quality in the form of high, medium, or low categories, along with K, *accuracy*, *precision*, and *confidence* values. The application also displays *confidence prediction* and evaluation of K values as supporting information.

B. Preprocessing and Segmentation Results

The *preprocessing* and *segmentation* stages aim to improve image quality and separate salt crystal objects from the background as the basis for feature extraction

for KNN classification. The results of these stages are shown in Figures 6 to 8.



Image 6. Original Image

Based on Figure 6, the original image shows salt crystals on a black background and *the top view* shooting position. A uniform background is used to simplify the segmentation process, while *preprocessing* is done to improve image quality and reduce *noise*.



Image 7. Preprocessing Results

Based on Figure 7, the image was resized using *resize* with *padding* to uniformize the size without changing the proportions of the object. The blank area is filled with black so that the image can be processed consistently at the next stage.

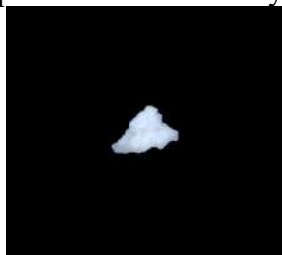


Image 8. Segmentation Results

Based on Figure 8, segmentation successfully separated the salt crystals from the background using *Otsu Thresholding*, morphological operations, *clean components*, and contour detection. The result is cleaner objects so that color features and shapes can be extracted more accurately.

C. Feature Extraction Results

Feature extraction was carried out on the segmented image to obtain color and shape characteristics as KNN input. The features used include RGB and HSV averages, as well as *area*, *perimeter*, *circularity*, and *aspect ratio*. The extraction results are shown in Table 3.

Table 3. Feature Extraction Results

<i>Features</i>	<i>Value</i>
<i>Mean R</i>	165.5932
<i>Mean G</i>	184.7437
<i>Mean B</i>	209.2767

<i>Mean H</i>	106.8157
<i>Mean S</i>	54.4501
<i>Mean V</i>	209.2768
<i>Area</i>	2166.9800
<i>Perimeter</i>	192.8572
<i>Circularity</i>	0.7318
<i>Aspect Ratio</i>	1.0135

Based on Table 3, the system produces ten features consisting of six color features and four shape features. All features are combined into one vector as input for the KNN classification.

D. K-Value Test Results

K value testing was carried out to determine the best KNN parameters with variations $K = 3, 5, 7, 9$, and 11 . The test results are shown in Table 4.

Table 4. K-Value Test Results

<i>K Value</i>	<i>Accuracy %</i>
$K = 3$	98,333%
$K = 5$	95,833%
$K = 7$	96,667%
$K = 9$	95,833%
$K = 11$	95,833%

Based on Table 4, the value of $K = 3$ resulted in the highest accuracy of 98.333% so it was chosen as the best parameter. The value of $K = 7$ reached 96.667%, while $K = 5, 9$, and 11 were 95.833% respectively. These results show that the selection of K values affects the performance of the KNN, with $K = 3$ providing the best results in the research dataset.

E. Salt Image Classification Results

The KNN classification was tested on 60 test data from three salt quality categories using a combination of RGB, HSV, and shape features. Due to space limitations, only a few samples of the classification results are presented as a representation of system performance.

Table 5. Examples of Some Trial Data Classification Results

<i>Classes</i>	<i>Original Image</i>	<i>Prediction Results</i>	<i>Image Results</i>	<i>Remarks</i>
<i>Height</i>		Height		TRUE
<i>Medium</i>		Medium		TRUE
<i>Low</i>		Low		TRUE

Based on Table 5, the system successfully classified most of the test data samples according to the actual grades, i.e. high, medium, and low quality. These results show that the combination of RGB and HSV color features as well as shape features in the form of *area*, *perimeter*, *circularity*, and *aspect ratio* is able to represent the visual characteristics of salt crystals well. The *K-Nearest Neighbor* (KNN) method can recognize the difference in characteristics between categories based on the features that have been extracted. However, there are still some test data that have been misclassified due to the similarity in color and shape characteristics between categories. The recapitulation of test results from 60 test data is presented in Table 6.

Table 6. Salt Quality Classification Trial Data Results

<i>Salt Quality Class</i>	<i>Number of Images</i>	<i>Accuracy (%)</i>
<i>Height</i>	20	90%
<i>Medium</i>	20	85%
<i>Low</i>	20	85%
<i>Average</i>	60	86,67%

Based on Table 6, testing of 60 test data yielded an accuracy of 90% for high quality, and 85% for medium and low quality. Overall, the system obtained an accuracy of 86.67%. Misclassification is mainly caused by the similarity in color and shape characteristics between categories. More detailed results are presented through a *confusion matrix*.

Table 7. Confusion Matrix Citra Garam

Actual Labels	Height	Medium	Low	Total
Height	18	2	0	20
Medium	2	17	1	20
Low	0	3	17	20
Total	20	22	18	60

Based on Table 7, the *confusion matrix* shows that out of 20 high-quality test data, 18 images were correctly classified and 2 as moderate. At medium quality, 17 images were correct, 2 were predicted to be high, and 1 was low. Meanwhile, low quality produced 17 correct images and 3 predicted medium. Classification errors are mainly due to the similarity in color and shape characteristics between categories, especially in medium quality. The results of the evaluation of *accuracy*, *precision*, *recall*, and *F1-score* are presented in Table 8.

Table 8. Precision, Recall, F1-Score

<i>Salt Quality Class</i>	<i>Precision (%)</i>	<i>Recall (%)</i>	<i>F1-Score (%)</i>
<i>Height</i>	90,00	90,00	90,00
<i>Medium</i>	72,27	85,00	80,95
<i>Low</i>	94,44	85,00	89,47
<i>Average</i>	87,24	86,67	86,81

Based on Table 8, the system obtained an *accuracy* of 86.67%, with an average *accuracy* of 87.24%, *recall* of 86.67%, and an *F1-score* of 86.81%. High quality obtained *precision*, *recall*, and *F1-score* of 90%, while low quality had the highest *precision* of 94.44% and *F1-score* of 89.47%. Medium quality obtained a *precision* of 72.27%, *recall* 85%, and an *F1-score* of 80.95% due to the similarity of characteristics with other categories. Overall, the combination of color, shape, and KNN features provides good classification performance.

CONCLUSION

Based on the results of the study, a salt crystal quality classification system based on digital image processing using the *K-Nearest Neighbor* (KNN) method was

successfully developed using a combination of RGB, HSV, and shape features in the form of *area*, *perimeter*, *circularity*, and *aspect ratio*. The test results showed K=3 as the best parameter with an accuracy of 98.333%. Testing of 60 test data resulted in an accuracy of 86.67%, accuracy of 87.24%, recall of 86.67%, and an F1-score of 86.81%, so that the system is able to support automatic salt quality classification.

Further research suggests increasing the number and variety of datasets and texture features to improve accuracy. The performance of KNN can also be compared to SVM, Random Forest, or *Deep Learning*. The system can be developed into a mobile or web application that integrates cameras and provides recommendations for the quality and selling price of salt.

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