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Valuation Of Svm Kernel Performance In Organic And Non-Organic Waste Classification

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A B S T R A C T

In an era of increasing concern for environmental sustainability, waste management remains an important global issue. Efficient waste classification, in particular distinguishing between organic and recyclable materials, is essential for reducing environmental impact. Traditional manual classification methods are often error-prone and inefficient. This research evaluates the performance of SVM models with RBF and Polynomial kernels for waste classification, using SqueezeNet for feature extraction. Datasets from Kaggle were preprocessed and augmented to improve model training. The experimental results show that the SVM model with RBF kernel outperforms the Polynomial kernel in classifying organic and recyclable waste, with an accuracy of 97.9% compared to 97.3% for the Polynomial kernel. This finding underscores the importance of kernel selection and parameter tuning in optimising SVM models for non-linear classification tasks. This research contributes to the development of more efficient and accurate waste classification technologies, promoting better waste management practices. Further research is recommended to explore advanced feature extraction methods and expand the scope of classification to cover a wider range of waste categories.

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INTRODUCTION

In an increasingly environmentally conscious modern era, waste management is a major concern for the global community (Romano & Molinos-Senante, 2020), (Hemidat et al., 2022). One important aspect of waste management is the efficient classification of waste, which allows for the segregation between organic and recyclable waste (Altikat et al., 2022), (Chhabra et al., 2024). Proper classification is crucial in ensuring that waste is properly processed and recycled, reducing its negative impact on the environment (Toğaçar et al., 2020), (Wang et al., 2021).

Traditional approaches to waste classification often involve manual processes that are prone to errors and inefficient in terms of time and cost (Zhang et al., 2021), (Huang et al., 2021). In addition, with the increasing complexity of modern waste composition, more sophisticated solutions are required to address these challenges (Puspaningrum et al., 2020), (Azis et al., 2020).

Therefore, research using advanced technologies such as Machine Learning algorithms is becoming increasingly important (Marchesi et al., 2023), (Sunardi et al., 2023). One algorithm that stands out in this context is the Support Vector Machine (SVM) (Khadijah et al., 2021), (Behera et al., 2020). SVM has demonstrated its effectiveness in the classification of data with complex feature spaces, and its potential to be applied in the clustering of organic and recyclable waste is an interesting subject of research (Xu et al., 2023), (Zayd et al., 2022).

Although there have been previous attempts using SVM for organic and recyclable waste classification, there is still room for improvement in terms of accuracy and efficiency, especially when faced with complex and diverse environments (Dubey et al., 2020), (Sami et al., 2020), (Hanbal et al., 2020). Thus, the main focus of this article is to compare the performance of SVM kernels in distinguishing between organic and recyclable waste.

The purpose of this article is to evaluate the performance of SVM kernels in classifying organic and recyclable waste. Through experimental testing, we present results that show how well the kernel Support Vector Machine (SVM) can classify these waste, as well as provide an overview of its potential in improving efficiency in waste classification. Although our focus is limited to evaluating the performance of the kernel, the results of this study are expected to provide useful insights for the development of more advanced and efficient waste management technologies.

LITERATURE REVIEW

A study explores the issue of waste classification using deep learning techniques. The goal of the research was to identify individual waste objects in images and categorize them into recycling types such as metal, paper, and plastic. The approaches examined include the use of SVM with HOG features, simple CNN, and CNN with residual blocks. Evaluation results indicate that the simple CNN model, both with and without residual blocks, demonstrates promising performance in addressing the waste classification issue. This research shows potential effectiveness in solving the litter classification problem due to the deep learning techniques employed (Meng & Chu, 2020).

Another study examines waste classification using the SVM method. The goal is to classify recyclable waste based on Local Binary Pattern (LBP) features extracted from waste images. LBP is a method used to describe texture in images by comparing the intensity of neighbouring pixels to the central pixel. This research aims to optimise the performance of waste classification by utilising LBP and SVM features. The results show that the combination of LBP features with SVM provides good accuracy in classifying recyclable waste. From a theoretical perspective, the use of SVM and LBP features has proven effective in various image processing applications. These findings can be an important contribution to the development of better and more efficient litter detection and classification technologies (Leonardo et al., 2020).

Other research examines the waste management problem by employing a machine learning system to determine the type of waste based on digital image data. The goal is to address the waste management problem using the most precise classification model. The types of waste investigated in this research are restricted to only two categories: organic and inorganic. Data was collected and revised from the Kaggle dataset, then brought into the system using Python. The data was trained and used to classify litter based on the source images. The litter images will be categorized using a SVM model with feature extraction through convolution layers. The results showed that the system effectively classified waste using the SVM model combined with CNN with an accuracy of 96.16% and an error rate of 7.25% in all categories. This research has the potential to enhance efficiency in waste management through the application of appropriate and accurate machine learning technology. (Fahmi & Yudhana, 2023).

Other studies examined the problem of litter classification using the Gray Level Co-occurrence Matrix (GLCM) and SVM methods. The goal is to classify litter based on texture features extracted from litter images. GLCM is a method used to describe the spatial relationship between pixel intensities in an image. In this research, the stages involve the image training process by converting RGB colour images into grayscale images. After going through the dataset training process, testing is conducted with litter images sourced from Kaggle. The evaluation findings indicated that the system achieved an accuracy rate of 83% after going through the second testing stage. From a theoretical perspective, the use of GLCM and SVM methods has proven effective in various image processing applications. This research makes an important contribution to the development of better and more efficient litter classification technology (Alamsyah et al., 2023).

The other research examines the problem of litter classification using the SVM method. The goal is to classify litter based on texture features extracted from litter images. GLCM is a method used to describe the spatial relationship between pixel intensities in an image. This research aims to optimise the performance of litter classification by utilising Gray Level Co-Occurrence Matrix (GLCM) and Color Moments features. The proposed method was assessed using the TrashNet dataset. Several key parameters were fine-tuned for this study, including the angular orientation of GLCM, the C parameter for soft margin in SVM, and the γ parameter for RBF. Data sharing was conducted through 10-Fold

Cross Validation. The findings revealed that the optimal combination involved GLCM features with a 45° angular orientation and Colour Moments, resulting in an average accuracy of 78.87% with a C parameter of 32 and a γ parameter of 4. The highest test accuracy was achieved in the 3rd fold, reaching 85.43%, which was then applied as a new testing scenario for 30 additional waste images. The assessment using the best model yielded an accuracy of 70%. This research has the potential to improve efficiency in waste management thanks to the application of appropriate and accurate machine learning technology (Nisa et al., 2022).

METHODS

In this study, a series of steps have been taken to achieve the goal of organic waste classification and recycling. The steps are depicted in Figure 1.

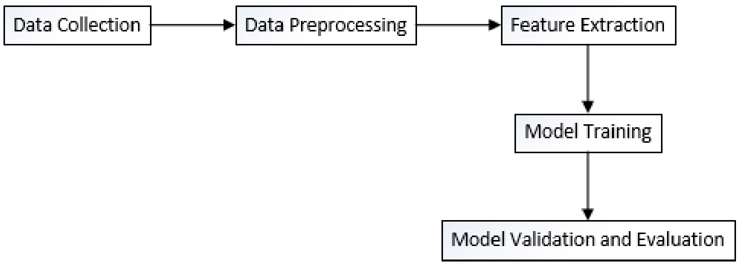

Figure 1. Research Stages

Data Collection

Data collection is done using datasets available from trusted sources, namely from Kaggle. This dataset has been used previously in research to investigate waste classification (Pandey et al., 2023). The dataset includes images of diverse organic and recyclable waste, which have been provided with appropriate labels to facilitate the training and testing process of the waste classification model, with the link: https:// www.kaggle.com/code/ nitinchoudhary012 /waste-classification-tensorflow/ input. By utilising previously validated datasets in the context of waste classification, it is hoped that this research can make a significant contribution to the development of better and more efficient waste classification solutions.

Data Preprocessing

To prepare the dataset for use in model training, each image in the dataset underwent a careful preprocessing process. These preprocessing steps include size normalisation, resolution resizing and contrast adjustment to ensure consistency and quality of the data provided to the model. Size normalisation ensures that all images have uniform dimensions, while resolution resizing helps in optimising the image quality for better analysis. In addition, contrast adjustment is performed to clarify the differences between image details, ensuring optimal visual representation quality. In addition to the basic preprocessing, the dataset is also expanded through data augmentation techniques such as rotation, horizontal inversion, and shifting. The objective is to enhance the variety and appeal of the dataset, allowing the algorithm to learn from a wider variety in the dataset, thus improving the model's ability to better recognise and classify waste. With the combination of careful data preprocessing and appropriate data augmentation techniques, it is expected that the prepared dataset can provide a solid foundation for training a litter classification model with Support Vector Machine (SVM) using SqueezeNet feature extraction.

Figure 2. Organic Waste Data Processing

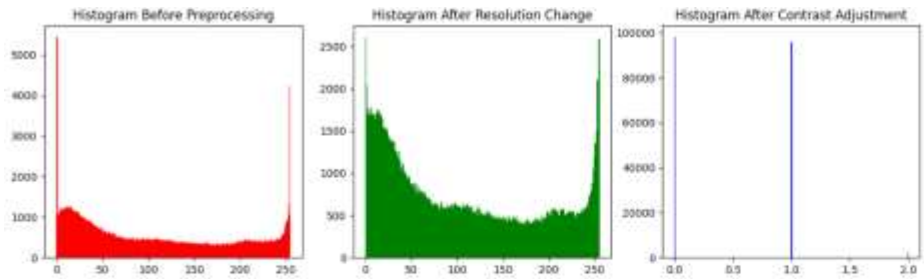

Figure 3. Histogram of Organic Waste Data Processing

Figure 4. Recycling Waste Data Processing

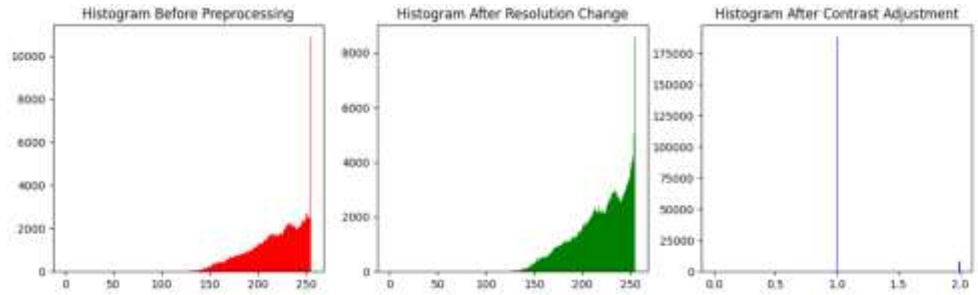

Figure 5. Histogram of Recycling Waste Data Processing

Feature Extraction

For feature extraction, we use a convolutional neural network architecture known as SqueezeNet. SqueezeNet was chosen due to its advantages as a lightweight and computationally efficient architecture, which allows for efficient use even on devices with limited resources (zhi Wentao, Gao Lan, 2020), (Yulita et al., 2023). The features generated by SqueezeNet will be a representation of the garbage images in our dataset. This representation will then be used as input for the SVM classification algorithm. By using SqueezeNet for feature extraction, we can optimise the feature extraction process by considering the balance between performance and computational efficiency. This will allow us to utilise SqueezeNet's advantage in generating relevant and meaningful features from litter images, which in turn will improve the performance and accuracy of the litter classification model using the SVM algorithm.

Model Training

The next step is to train the SVM model to perform classification between organic and recycled waste. The training process is done using the features that have been extracted from the waste images in the pre-processed dataset. However, before starting the training, it is important to test and tune the parameters for the RBF (Radial Basis Function) kernel and Polynomial kernel in order to optimise the performance of the model. This hyperparameter tuning process involves experimenting with various parameter values to find the combination that gives the best performance on separate test data. Once the optimum parameters are found, the SVM model will be trained using the extracted features. Through this training process, the SVM model is adjusted to properly separate the organic and recyclable waste classes. The goal is to produce an optimal decision boundary so that the model can classify waste accurately based on the extracted features. As such, the SVM training process plays an important role in improving the model's ability to recognise and distinguish between different types of waste.

Model Validation and Evaluation

After completing the training of the SVM model using the features extracted from the waste images, the next step is to validate and evaluate the performance of the model. The evaluation is done by utilising the testing data that has been previously separated from the training data. The model performance will be evaluated using various metrics, including accuracy, precision, recall, F1-score, and AUC (Area Under Curve). These metrics are used to measure the effectiveness and reliability of the model in performing the classification between organic and recyclable waste.

Accuracy measures how well the model classifies the data overall. Precision measures the proportion of positives correctly classified out of all results classified as positive. Recall measures the proportion of positives correctly classified out of all data that are actually positive. F1-score provides a blend of precision and recall, thus providing a more complete picture of the model's performance especially when there is class imbalance. AUC, on the other hand, provides a measure of model performance that is independent of the classification threshold, describing the model's ability to distinguish between positive and negative classes.

By evaluating using these metrics, it is possible to understand how well the model performs the classification task and gain the necessary insights for future model improvements. This evaluation is an important step in validating the reliability and quality of the SVM model that has been developed to effectively classify organic and recyclable waste.

RESULTS

Table 1. Performance Evaluation of SVM Models with RBF and Polynomial Kernels

Dataset	Model	Label	Evaluation				
			AUC	Accuracy	Precision	Recall	F1-score
Garbage Classification	SVM (RBF)	Organic	0.997	0.979	0.988	0.970	0.978
		Recycling	0.997	0.979	0.970	0.988	0.979
Garbage Classification	SVM (Polynomial)	Organic	0.996	0.973	0.973	0.972	0.973
		Recycling	0.996	0.973	0.972	0.973	0.973

From the evaluation results, it can be observed that the SVM model with RBF kernel performs slightly better than the SVM model with polynomial kernel. For organic data, the SVM model with RBF kernel achieved an AUC of 0.997, accuracy of 0.979, precision of 0.988, recall of 0.970, and F1-score of 0.978. On recycling data, this model also achieved an AUC of 0.997, accuracy of 0.979, precision of 0.970, recall of 0.988, and F1-score of 0.979. Meanwhile, the SVM model with a polynomial kernel (poly) showed slightly lower performance with an AUC of 0.996, accuracy of 0.973, precision of 0.973, recall of 0.972, and F1-score of 0.973 for both data categories (organic and recycling).

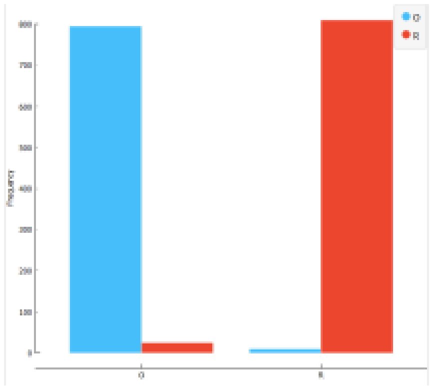

Figure 6. Data Distribution on RBF Kernel

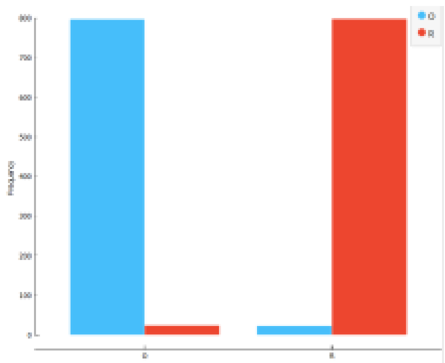

Figure 7. Data Distribution on Polynomial Kernel

Using the SVM model, the ability to produce high accuracy is possible with proper tuning of the kernel used. In this case, in Figure 6 the organic data with RBF kernel, 96.95% is well classified, while 3.05% is not well classified and reads as recycling. In the recycled data, 98.78% is well classified, while 1.22% is not well classified and reads as organic. Conversely, in Figure 7, organic data with polynomial kernel, 97.20% is well classified and 2.80% is read as recycling, while in recycling data, 97.32% is well classified and 2.68% is read as organic.

The use of the RBF kernel resulted in better performance compared to the polynomial kernel. However, since the performance difference between these two kernels is very small, the Polynomial kernel may still be considered if other factors such as interpretability or training speed are taken into consideration. The selection of an appropriate kernel could be the key to improving the performance of SVM models in separating and classifying organic and recyclable waste. This highlights the importance of carefully exploring and tuning model parameters to achieve optimal performance, which in turn can support the development of more effective and accurate waste classification solutions in the context of waste management.

DISCUSSION

In this study, the evaluation results show that the SVM model with RBF kernel performs slightly better than the SVM model with polynomial kernel in classifying organic and recyclable waste. For organic data, the SVM model with RBF kernel achieved AUC of 0.997, accuracy of 0.979, precision of 0.988, recall of 0.970, and F1-score of 0.978. As for the recycling data, this model also showed high performance with an AUC of 0.997, accuracy of 0.979, precision of 0.970, recall of 0.988, and F1-score of 0.979.

In contrast, the SVM model with polynomial kernel showed lower performance with AUC of 0.996, accuracy of 0.973, precision of 0.973, recall of 0.972, and F1-score of 0.973 for both data categories (organic and recycled). Further analysis showed that on organic data with RBF kernel, 96.95% were well classified, while 3.05% were read as recycled. On recycled data, 98.78% were well classified, while 1.22% were read as organic. Conversely, in organic data with a polynomial kernel, 97.20% is well classified, while 2.80% is read as recycling. On recycled data, 97.32% were well classified, while 2.68% were read as organic.

This finding suggests that the use of the RBF kernel is suitable for this litter classification case as it is more effective in handling non-linear data, as may be the case in litter images with diverse characteristics. However, the performance difference between these two kernels is very small, so if other factors such as interpretability or training speed are taken into consideration, the Polynomial kernel may still be considered.

This discussion highlights the importance of proper kernel selection in building SVM models, as well as its implications in the development of more effective waste classification solutions in the context of waste management and the environment as a whole. In addition, these results provide valuable insights for future research in optimising waste classification models using SVM by considering various factors including the type of kernel used.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this study shows that in the context of organic and recyclable litter classification, the SVM model with RBF (Radial Basis Function) kernel is slightly superior in classification compared to the SVM model with polynomial kernel. This finding confirms the importance of proper kernel selection in building SVM models for non-linear classification cases such as waste. Based on the evaluation results that show a slightly higher AUC, accuracy, precision, recall, and F1-score for the RBF kernel, it can be concluded that the use of the RBF kernel is more suitable for handling the complexity and diversity in litter image data.

As a recommendation, the use of SVM model with RBF kernel can be widely adopted in waste management system to improve the accuracy and effectiveness in classifying organic and recyclable waste. In addition, this study also highlights the importance of tuning the model parameters, including the kernel, so further exploration of these parameters is recommended to significantly improve the model performance. Further research could involve the use of more advanced feature extraction techniques as well as the use of more complex models to improve litter classification performance. Thus, this research makes a valuable contribution to the development of more effective and efficient waste classification solutions in the context of waste management.

FURTHER STUDY

While this research has provided valuable insights into the use of SVM models with RBF and polynomial kernels in litter classification, there are some limitations that need to be recognised. Firstly, this study only utilises one type of convolutional neural network architecture (SqueezeNet) for feature extraction. Further studies could consider using other architectures or even more advanced feature extraction techniques to improve the feature representation of litter images. In addition, this study is also limited to the binary classification of organic and recyclable waste, whereas in practice, waste management may involve more complex classification with more categories. Therefore, future research can expand the scope of classification to cover a wider range of waste categories.

Suggestions for future research include further exploration of the factors that affect the performance of SVM models, including more careful parameter tuning, use of better regularisation techniques, and integration with more advanced image processing techniques. In addition, future research could take a more holistic approach by considering the environmental and social aspects associated with waste management, such as the environmental impact of appropriate classification choices. Thus, further research is expected to address these limitations and provide more comprehensive insights for the development of more effective waste classification solutions

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