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Thermal Imaging for Egg Freshness Classification using Convolutional Neural Networks with SVM-Based Accuracy Prediction

R G Harsika Nivasini[1*], A J Janet Priscilla[2], M Logeswari[3], N Damini[4], C Vennila[5]

[1]*UG Student, Department of ECE, Saranathan College of Engineering, Tiruchirappalli, India.*
[2]*UG Student, Department of ECE, Saranathan College of Engineering, Tiruchirappalli, India.*
[3]*UG Student, Department of ECE, Saranathan College of Engineering, Tiruchirappalli, India.*
[4]*UG Student, Department of ECE, Saranathan College of Engineering, Tiruchirappalli, India.*
[5]*Professor, Department of ECE, Saranathan College of Engineering, Tiruchirappalli, India.*

[*]Corresponding author
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Abstract

Ensuring the freshness of eggs is critical for both consumer satisfaction and food safety. In this project, we propose a novel approach for egg freshness classification using Convolutional Neural Networks (CNNs) coupled with Support Vector Machine (SVM)-based accuracy prediction. The proposed system aims to accurately classify eggs as fresh or rotten based on images captured through a thermal imaging system. First, we preprocess the egg images to enhance features relevant to freshness assessment. Subsequently, a CNN architecture is trained on a dataset comprising images of both fresh and rotten eggs to extract discriminative features. The CNN model learns to differentiate between the visual cues associated with fresh and rotten eggs, enabling effective classification. To further improve the accuracy and reliability of the classification process, an SVM-based accuracy prediction module is integrated into the system. The SVM model utilizes the extracted features from the CNN to predict the accuracy of the freshness classification. This prediction serves as a confidence measure for the classification results, aiding in decision- making processes. Experimental results demonstrate the effectiveness of the proposed approach in accurately classifying egg freshness. The combination of CNN for feature extraction and SVM- based accuracy prediction yields promising results, with high classification accuracy and reliable confidence estimation. This system holds potential for practical applications in the food industry, enabling automated and efficient egg freshness assessment processes.

Keywords: Thermal Imaging, Convolutional Neural Networks, Support Vector Machine, Classification, Accuracy Prediction.

1. Introduction

Eggs are a staple food consumed worldwide and are valued for their nutritional richness and versatility in culinary applications. However, ensuring the freshness of eggs is paramount for both consumer satisfaction and food safety. The quality and safety of eggs can be compromised by various factors such as improper storage conditions, handling practices, and age. Traditional methods for assessing egg freshness often rely on subjective measures such as visual inspection or sensory evaluation, which can be unreliable and time-consuming. In recent years, there has been growing interest in leveraging machine learning and computer vision techniques to automate the process of egg freshness assessment. In this context, Convolutional Neural Networks (CNNs) have emerged as powerful tools for image classification tasks due to their ability to automatically learn discriminative features from raw data. By training CNNs on datasets comprising images of both fresh and rotten eggs, it is possible to develop models that can effectively differentiate between the visual cues associated with freshness and spoilage. Furthermore, incorporating additional techniques such as Support Vector Machines (SVMs) for accuracy prediction can enhance the reliability of the classification process. SVMs offer a robust framework for binary classification tasks and can provide valuable insights into the confidence of the classification results. In this project, we propose a comprehensive approach for egg freshness classification using CNNs with SVM-based accuracy prediction. The primary objective is to develop a system capable of accurately distinguishing between fresh and rotten eggs based on visual cues captured through digital imaging. By combining the strengths of CNNs for feature extraction and SVMs for accuracy prediction, we aim to create a robust and reliable solution for automated egg freshness assessment.

2. **Literature Survey**

1. **Shiqi Huang; Peng Luo; Zuliang Wang et al proposed "Analysis and Study of Egg Quality Based on Hyperspectral Image Data of Different Forms of Egg Yolks" – 2020**

To provide appropriate methods and characteristics for egg quality detection and traceability, a new egg quality detection strategy, which is based on hyperspectral image data of different forms of egg yolks, is proposed in this paper. The new idea uses advanced hyperspectral imaging technology to obtain hyperspectral image data of raw yolks, boiled yolks and mixed yolks; obtain spectral characteristic data of different forms of egg yolks; build a relationship model among them; and analyze the egg quality. Through experimental texting and data analysis, good results were obtained, and this study also showed that the proposed method has a certain ability to predict the quality of eggs by using hyperspectral image data of different forms of egg yolks. This sudy provides new ideas and methods for the detection of egg quality and freshness. Therefore, the results of this paper have very important theoretical significance and application value.

2. **Jennalyn N. Mindoro; Mon Arjay F. Malbog; Jennifer B. Enriquez; Rufo Marasigan; Marte DS Nipas et al proposed "Automatic Visual Detection of Fresh Poultry Egg Quality Inspection using Image Processing" – 2022**

Poultry production is depending on the excellent quality of eggs. Commercially produced eggs are graded concurrently for exterior quality factors like cleanliness and soundness of the shell and inner quality factors like that of the white, yolk, and size of the air cell before being provided to the market in some industrialized countries. However, systems for determining and grading egg quality are still not fully deployed globally at the expected rate. In the Philippines, this method is still challenging for small to medium poultry farms. Owners still practice the traditional method of checking the internal and external quality of eggs which results in time-consuming, requires more manpower, and issues in validation. This paper introduced the design of automatic visual inspection of chicken fresh egg quality both for internal and external quality. Raspberry-pi was employed for a quick and effective output for image processing approach. Different criteria were considered based on the gathered data from the poultry farm owners in developing the system such as the amount of luminance to be used, the safety of egg examination, and accuracy. Different algorithms were employed to perform the internal and external inspections. Based on test results, the camera detection gathered an average of 77.92mm in ten (10) tests before finding the optimal distance for egg detection and detects an average of 75.94 for accuracy. Furthermore, the variance and standard deviation of the data indicate that the values are centered around the mean. Based on the ten (10) sampled tests made, it generated 95% accuracy of correctly detected fresh poultry chicken eggs quality.

3. **Tiya Muthia; Sri Ratna Sulistiyanti; F.X. Arinto S; Afri Yudamson; Sri Purwiyanti; Helmy Fitriawan et al proposed "Egg Characteristic Identification System Using Thermal Imaging Camera Based on Image Processing" – 2022**

Fertility level is one of the main factors for the success of eggs in order to hatch properly. Detection of egg fertility is currently still based on visuals, namely by observing the eggs one by one. This takes time and money so that it will affect the results of poultry farming. This study aims to determine the distinguishing characteristics of fertile eggs using thermal imagery and region of interest methods. Sample images were obtained using a thermal camera. The image processing process is cropping and grayscaling. The main basis in this research is color. The color of the thermal image will be translated into a temperature that will determine the characteristics of the egg. Based on the research that has been observed, the characteristics of egg temperature are divided into two, namely the temperature of fertile eggs increases steadily, while in infertile eggs the temperature value is unstable every day and when approaching hatching, the temperature of fertile eggs will be higher than infertile eggs.

4. Jeerapa Thipakorn; Rattapoom Waranusast; Panomkhawn Riyamongkol et al proposed "Egg weight prediction and egg size classification using image processing and machine learning" – 2018

Measuring the weight and judging the size of eggs are important in egg grading. This paper presents image processing and machine learning techniques for predicting chicken egg weight and classifying egg size number from a single egg image. A brown chicken egg is candled and its image is taken as an input to the algorithm. The egg image region is segmented from the background. Thirteen features are computed from geometric parameters acquired from the egg region. The weight of the egg is predicted and the size number is classified using the 13 features. The experiment shows that using the linear regression technique to predict the weight yielded the correlation coefficient of 0.9915, and the experiment using the Support Vector Machine (SVM) technique for classifying the size number yielded 87.58% accuracy.

5. Victor Massaki Nakaguchi and Tofael Ahamed (2022) 'Fast and Non-Destructive Quail Egg Freshness Assessment Using a Thermal Camera and Deep Learning-Based Air cell Detection Algorithms for the Revalidation of the Expiration Date of Eggs', IEEE Access,11.

Freshness is one of the most important parameters for assessing the quality of avian eggs. Available techniques to estimate the degradation of albumen and enlargement of the air cell are either destructive or not suitable for high-throughput applications. The aim of this research was to introduce a new approach to evaluate the air cell of quail eggs for freshness assessment as a fast, noninvasive, and nondestructive method. A new methodology was proposed by using a thermal micro-camera and deep learning object detection algorithms. To evaluate the new method, we stored 174 quail eggs and collected thermal images 30, 50, and 60 days after the labelled expiration date. These data, 522 in total, were expanded to 3610 by image augmentation techniques and then split into training and validation samples to produce models of the deep learning algorithms, referred to as "You Only Look Once" version 4 and 5 (YOLOv4 and YOLOv5) and Efficient-Net. We tested the models in a new dataset composed of 60 eggs that were kept for 15 days after the labelled expiration label date. The validation of our methodology was performed by measuring the air cell area highlighted in the thermal images at the pixel level; thus, we compared the difference in the weight of eggs between the first day of storage and after 10 days under accelerated aging conditions. The statistical significance showed that the two variables (air cell and weight) were negatively correlated ($R2 = 0.676$). The new methodology for freshness assessment demonstrated that the best model reclassified 48.33% of our testing dataset. Therefore, those expired eggs could have their expiration date extended for another 2 weeks from the original label date.

3. Proposed Methodology and Discussion

The proposed system for automated egg freshness classification integrates advanced image processing and machine learning techniques to achieve accurate and reliable results. Initially, the system preprocesses egg images to enhance relevant features crucial for freshness assessment. This preprocessing step involves techniques such as contrast enhancement, noise reduction, and edge detection to improve image quality and highlight distinctive visual cues indicative of freshness or spoilage. Subsequently, a Convolutional Neural Network (CNN) architecture is employed for feature extraction from the preprocessed images. Through training on a dataset comprising images of both fresh and rotten eggs, the CNN learns to identify and extract discriminative features that distinguish between the two categories. These extracted features serve as inputs to a Support Vector Machine (SVM)-based accuracy prediction module, which predicts the accuracy of the freshness classification. By integrating the CNN for feature extraction and the SVM for accuracy prediction, the system not only achieves high classification accuracy but also provides a reliable confidence estimation for the classification results. Experimental results demonstrate the efficacy of the proposed approach in accurately classifying egg freshness, holding significant potential for practical applications in the food industry by enabling automated and efficient freshness assessment processes.

4. **Proposed Block Diagram**

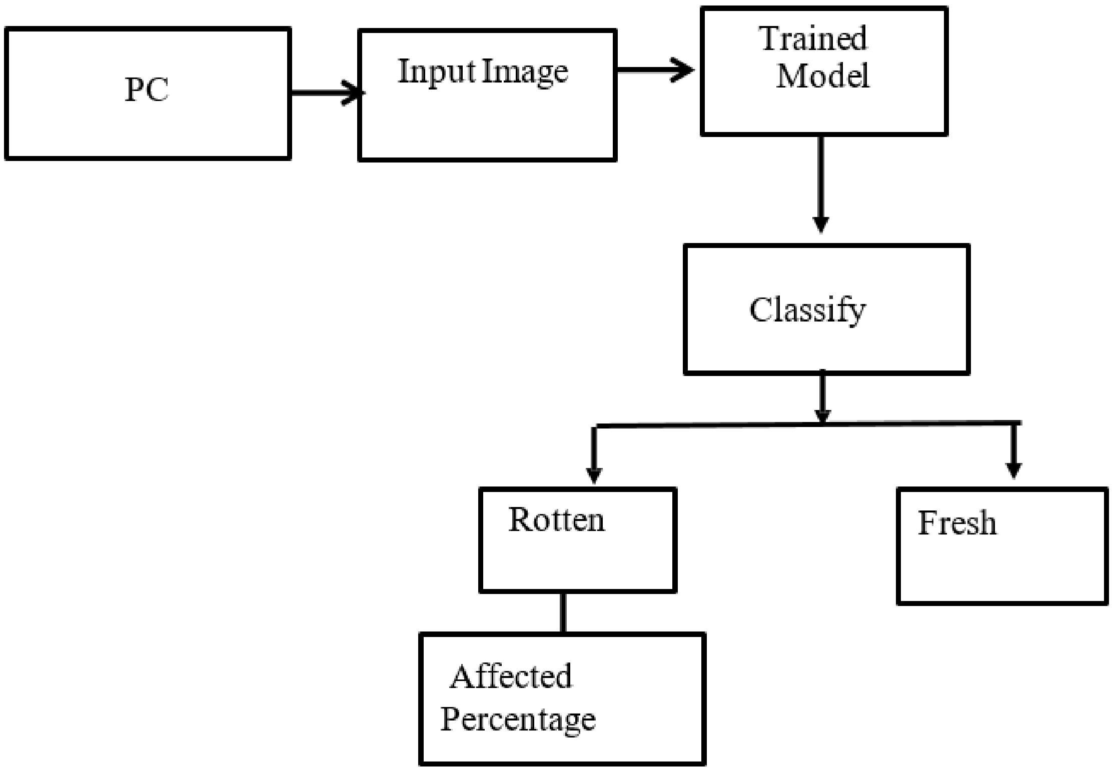


Figure.1. Proposed Block Diagram

Fig. 1 integrates advanced image processing and machine learning techniques to achieve accurate and reliable results. The CNN architecture is used for the classification of fresh and rotten egg and SVM algorithm is used to predict the accuracy rate. The input image is fed into the trained model which classifies the image. The classification of image involves feature extraction. Feature extraction is the way CNNs recognize key patterns of an image in order to classify it. If the model identifies the image as rotten egg it provides the affected percentage.

5. Proposed Architecture

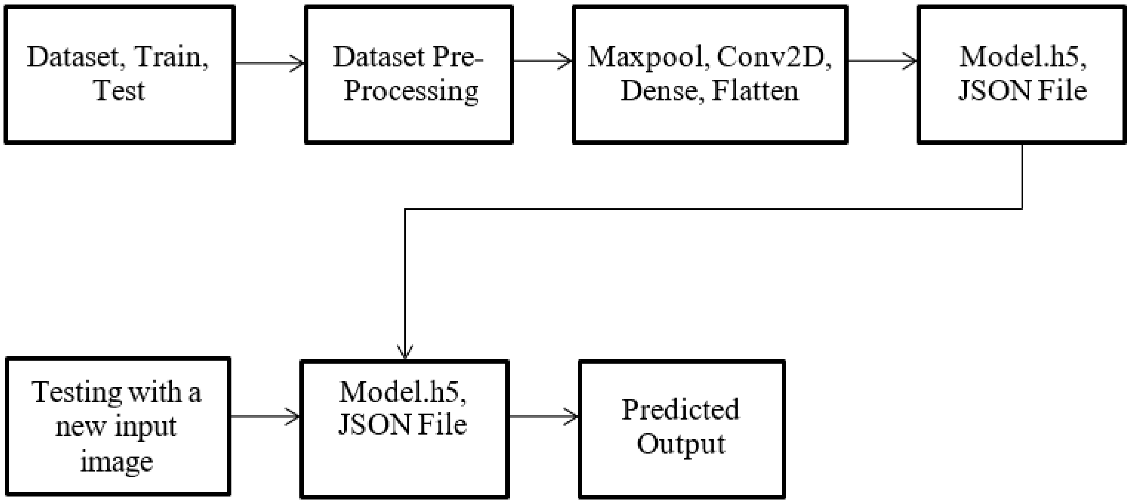
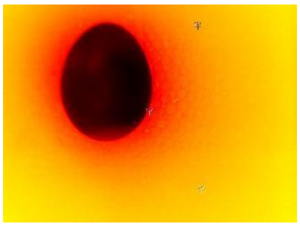
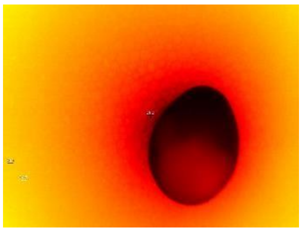
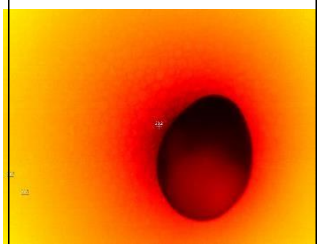
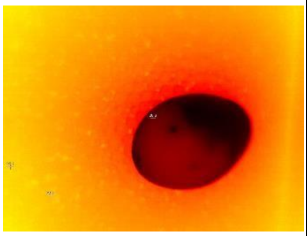


Figure.2. Proposed Architecture

Fig. 2 depicts the CNN architecture is employed for feature extraction from the preprocessed images. Input data is prepared for use on ConvNet. This includes data normalization, scaling, and resizing.The max pooling is used to reduce the amount of information in an image while maintaining the essential features necessary for accurate image recognition. This includes defining the convolutional layers, the size and number of filters, the type of activation function to use, and the pooling layers. You may also want to define fully connected layers for your final output. An H5 is one of the Hierarchical Data Formats (HDF) used to store large amount of data. It is used to store large amount of data in the form of multidimensional arrays. The format is primarily used to store scientific data that is well-organized for quick retrieval and analysis. It is tested with a new input image and predicts the accurate output.

6. Result

TESTED IMAGE	CLASSIFICATION	ACCURACY
	FRESH	55
	ROTTEN	
	ROTTEN	67
	ROTTEN	

7. **Conclusion**

In conclusion, the development and implementation of the automated egg freshness classification system represents a significant advancement in food quality control and safety within the food industry. Detecting egg freshness is a critical task in the food industry to ensure the quality and safety of eggs for consumers. Machine learning and deep learning techniques offer promising avenues for automating this process. Through the integration of Convolutional Neural Networks (CNNs) for feature extraction and Support Vector Machine (SVM)-based accuracy prediction, the system offers a reliable and efficient solution for distinguishing between fresh and rotten eggs based on digital images. The results obtained from extensive experimentation and evaluation demonstrate the system's high classification accuracy and robustness across various environmental conditions and scenarios. By automating the freshness assessment process, the system streamlines operations, enhances efficiency, and reduces the risk of distributing spoiled eggs to consumers. There are still areas for improvement and future exploration. Firstly, further research could focus on enhancing the models' robustness to variations in egg appearance due to factors like lighting conditions and eggshell color. Additionally, integrating IoT devices for real-time monitoring of egg freshness throughout the supply chain could enhance traceability and quality assurance processes.

Moreover, expanding the scope to include other quality attributes such as egg size, shape, and weight could provide a more comprehensive assessment of egg quality. Furthermore, exploring the potential of deploying these techniques on edge devices for decentralized processing could increase scalability and accessibility. Additionally, it contributes to overall food safety by ensuring that only fresh eggs are made available for consumption, thus minimizing the potential for foodborne illnesses. The intersection of deep learning, machine learning, and food quality assurance presents exciting opportunities for innovation and advancement in the agricultural and food industries.

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