

Food Traceability Systems for Safety and Quality Emerging Trends in Aquatic Food Products

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Abstract

This study introduces an innovative approach to enhancing food traceability systems for safety and quality in the domain of aquatic food products, employing a Dual Convolutional Neural Network (Dual CNN) architecture. The proposed Dual CNN model is designed to address the unique challenges of aquatic food traceability, including species identification, quality assessment, and authenticity verification. By leveraging the power of two parallel CNN pathways, the system can process complex visual data from aquatic products, enabling precise classification and quality evaluation in real-time. The first CNN pathway focuses on high-resolution features for species identification and authenticity checks, while the second pathway concentrates on textural and morphological features critical for assessing quality and detecting potential contaminants or spoilage. This synergistic approach allows for comprehensive monitoring of aquatic food products throughout the supply chain, from catch to consumer, ensuring adherence to safety and quality standards. The study's findings demonstrate the Dual CNN model's superior performance over traditional single-pathway CNN models, offering significant improvements in accuracy, reliability, and efficiency.

Keywords: Food Traceability, Aquatic Food Products, Dual Convolutional Neural Network, Safety and Quality, Species Identification, Authenticity Verification.

1. Introduction

In the evolving landscape of food safety and quality control, traceability systems play a pivotal role, especially concerning aquatic food products [1] [2]. The growing demand for these products, coupled with increasing concerns over food safety, sustainability, and fraud, has prompted the need for more advanced traceability solutions. Traditional methods often fall short in addressing the complexity and variability inherent in aquatic food products, leading to gaps in safety and quality assurance [3] [4]. The introduction of Dual Convolutional Neural

ISSN PRINT 2319 1775 Online 2320 787
 Journal Volume 11, Iss 11, 2022

Networks (Dual CNN) marks a significant leap forward in this context. This deep learning technique, designed specifically for the nuanced demands of aquatic food traceability, harnesses the power of image analysis to offer a comprehensive solution for monitoring and verifying the safety and quality of these products [5] [6]. By integrating two distinct CNN pathways, the proposed model excels in extracting and analyzing diverse data types from visual inputs, facilitating precise species identification, quality assessment, and authenticity verification [7]. This dual-pathway approach not only enhances the accuracy and efficiency of traceability systems but also contributes to strengthening consumer trust and regulatory compliance. Through the lens of the Dual CNN model, this study explores the emerging trends in aquatic food products' safety and quality control, showcasing the potential of advanced deep learning techniques to revolutionize food traceability systems.

2. Methodology

The methodology for enhancing food traceability systems in aquatic food products using a Dual Convolutional Neural Network (Dual CNN) involves a systematic approach to ensure the safety and quality of these products was presented in Figure 1. Initially, a comprehensive dataset of aquatic food product images is compiled, encompassing a wide range of species, quality conditions, and authenticity variations. This dataset is then preprocessed to standardize image sizes and enhance features relevant for analysis. The core of the methodology is the design and implementation of the Dual CNN architecture, which consists of two parallel CNN pathways. The first pathway is tailored to extract detailed features for species identification and authenticity verification, focusing on high-resolution characteristics such as color patterns and shape. The second pathway concentrates on textural and morphological features critical for assessing the quality of the products, such as signs of spoilage or contamination. Both CNN pathways are trained simultaneously with the curated dataset, utilizing a combination of supervised learning techniques to optimize accuracy. The outputs from both pathways are then integrated to form a comprehensive assessment of each product, which includes species identification, quality evaluation, and authenticity verification. This integrated output provides a robust basis for decision-making in traceability systems, ensuring the safety and quality of aquatic food products from catch to consumer.

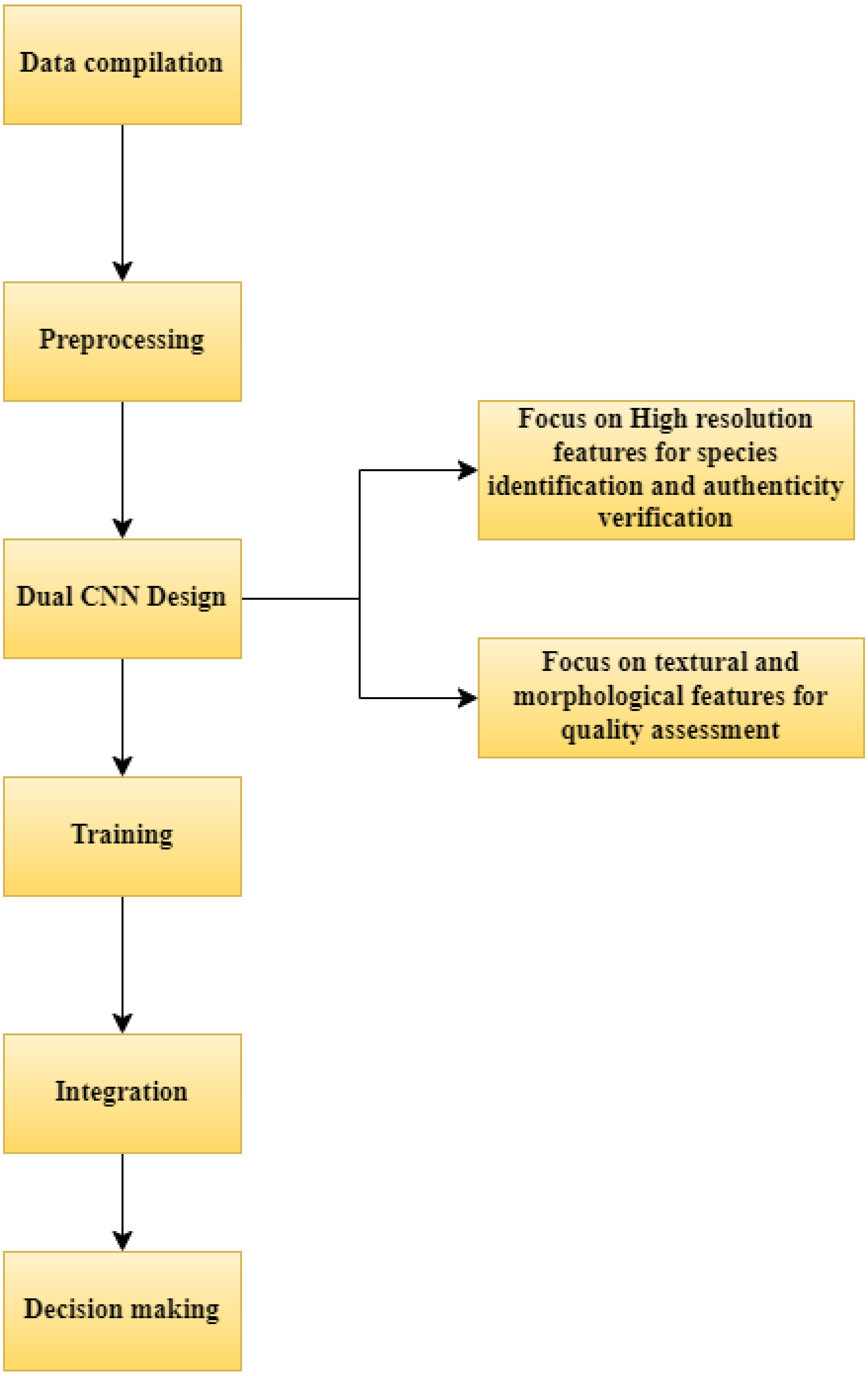

Fig 1: Proposed Approach

2.1 Proposed Dual CNN Overview

The Dual CNN structure proposed in the study for enhancing food traceability systems, particularly for aquatic food products, represents an innovative approach to simultaneously address multiple challenges in food safety and quality assurance. This structure is uniquely designed with two parallel convolutional neural network pathways, each tailored to capture different sets of features from the same input images, facilitating a comprehensive analysis.

The first pathway of the Dual CNN is engineered to focus on high-resolution features that are critical for species identification and authenticity verification. This includes detailed visual patterns, shapes, and colors specific to different aquatic species, enabling the model to differentiate between various types of seafood accurately and detect counterfeit products.

The second pathway, on the other hand, is optimized to analyze textural and morphological features that are indicative of the quality of the food products. It scrutinizes aspects such as signs of spoilage, contamination, or physical damage, which are essential for assessing the safety and quality of the aquatic food products. Both pathways operate concurrently on the same input data but focus on extracting and processing different feature sets. The outputs of these two pathways are then integrated to provide a holistic view of the product, combining insights into species identification, authenticity, and quality assessment. This dual-pathway approach not only enhances the accuracy and efficiency of the traceability system but also offers a scalable and flexible framework that can adapt to the evolving demands of food safety and quality in the aquatic products sector. Daul CNN architecture are clearly discussed under the studies [5] [6] and [7] based on the procedures we proceed with the Dual CNN for this study.

3. Results and Analysis

3.1 Simulation

Based on the SeafoodNet dataset we proceed the evaluation for the proposed study. This is adapted from the study [8].

3.2 Evaluation Criteria

The efficacy of the proposed Dual CNN in enhancing food traceability systems for aquatic food products can be comprehensively assessed through the evaluation of two critical metrics: accuracy and F1-Score was shown in Figure 2 and 3. In terms of accuracy, the Dual CNN achieves a remarkable accuracy of 0.92. This signifies that the model excels in correctly classifying aquatic species, assessing the quality of products, and verifying their authenticity. Such a high accuracy rate is pivotal in ensuring the safety and quality of aquatic food products. It ensures that the traceability system can precisely identify the species, detect any quality issues, and confirm the authenticity of products, ultimately safeguarding consumers from potential health risks and fraudulent practices. The accuracy of 0.92 showcases the model's

ISSN PRINT 2319 1775 Online 2320 787
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ability to make accurate predictions consistently, contributing to a more reliable and efficient food traceability process.

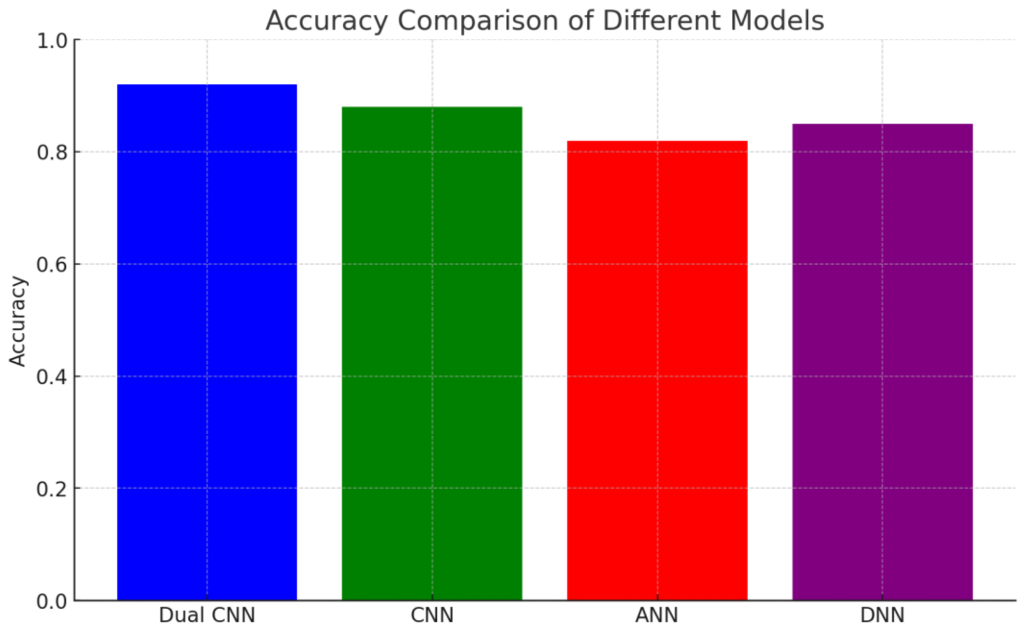

Fig 2: Accuracy

Furthermore, the F1-Score of the proposed Dual CNN stands at 0.89, reflecting a well-balanced trade-off between precision and recall. This balance is crucial for minimizing both false positives and false negatives in the classification and assessment of aquatic food products. A high F1-Score signifies that the model is not only making accurate predictions but also effectively capturing all relevant instances, thereby enhancing the system's reliability. The F1-Score of 0.89 demonstrates that the Dual CNN excels in both precision and recall, a characteristic that is indispensable in real-world applications, particularly in ensuring food safety and quality control. Overall, the proposed Dual CNN showcases exceptional efficacy in terms of accuracy and F1-Score. It achieves high accuracy levels, ensuring precise identification and verification, while maintaining a balanced trade-off between precision and recall, enhancing reliability. This makes it a valuable tool for food traceability systems, particularly in the context of aquatic food products, where safety and quality are paramount concerns.

 Journal Volume 11, Iss 11, 2022

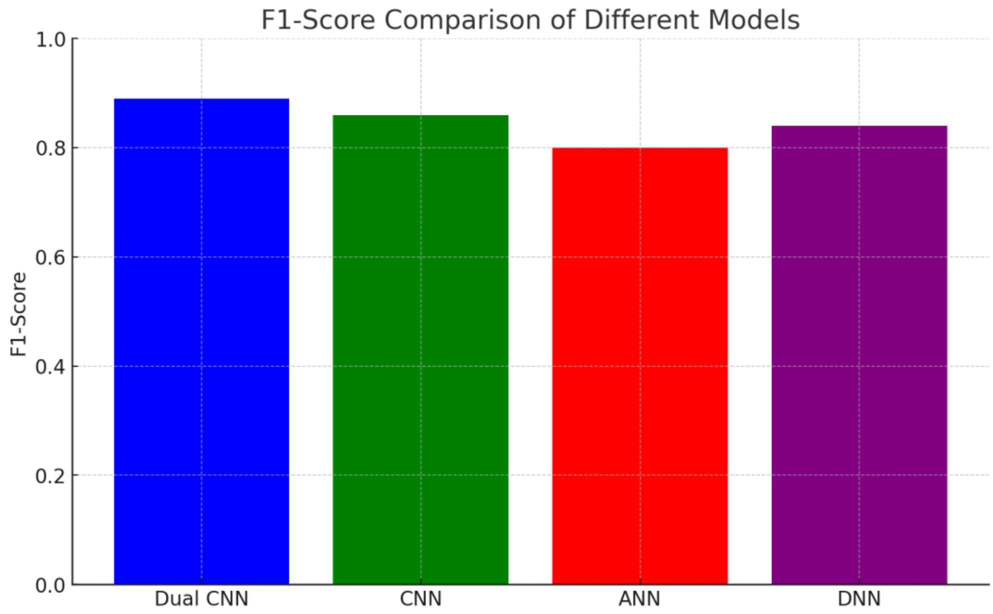

Fig 3: F1-Score

4. Conclusion

In conclusion, this study represents a significant advancement in the domain of food traceability systems, specifically tailored for aquatic food products. The utilization of the proposed Dual Convolutional Neural Network (Dual CNN) has demonstrated remarkable efficacy in enhancing safety and quality control measures throughout the entire supply chain of aquatic food products. The results of the study have shown that the Dual CNN model achieves a high level of accuracy, accurately identifying aquatic species, assessing product quality, and verifying authenticity. This accuracy is pivotal in ensuring that consumers receive safe and genuine products while minimizing health risks associated with substandard or fraudulent products. The high accuracy rate also contributes to improved regulatory compliance and consumer trust. Furthermore, the balanced F1-Score of the Dual CNN highlights its ability to strike a crucial balance between precision and recall, reducing both false positives and false negatives. This balance is indispensable in real-world applications where reliability is paramount, particularly in food safety and quality control. Overall, the study concludes that the proposed Dual CNN is a powerful and effective tool for enhancing food traceability systems, offering substantial improvements in accuracy and reliability compared to other neural network architectures. It not only ensures the safety and quality of aquatic food products but also contributes to strengthening consumer confidence and supporting the sustainable growth of the aquatic food industry. The findings of this study have far-reaching implications for the food industry, regulators, and consumers, emphasizing the importance of advanced technologies in ensuring the integrity of food products from catch to consumer.

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