GRADING QUALITY OF TUNA LOIN USING COMPUTER VISION AND DEEP LEARNING

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Abstrak - Kualitas tuna loin sangat penting untuk penerimaan pasar internasional, namun metode penilaian tradisional bergantung pada penilaian subjektif manusia yang sering kali menghasilkan evaluasi yang tidak konsisten. Studi ini memperkenalkan sistem penilaian cerdas yang menggunakan Computer Vision dan model DeepLearning untuk mengevaluasi kualitas tuna loin berdasarkan atribut visual seperti warna dan tekstur. Dengan memanfaatkan EfficientNetV2-M, model ini dilatih pada dataset yang telah disempurnakan dengan metode praproses seperti Self Adaptive Illumination Correction (SAIC) dan Contrast Limited Adaptive Histogram Equalization (CLAHE), mencapai akurasi 96% yang mengesankan. Model ini diterapkan pada Google Cloud Platform untuk inferensi yang skalabel dan cepat serta terintegrasi ke dalam aplikasi seluler berbasis Flutter. Aplikasi ini menyediakan umpan balik penilaian waktu nyata dan menggabungkan Firebase untuk autentikasi pengguna dan penyimpanan data profil. Solusi ini merupakan langkah maju dalam mengotomatiskan penilaian kualitas pangan, menawarkan mekanisme penilaian yang skalabel, objektif, dan akurat yang sesuai untuk penggunaan industri yang luas.

Kata kunci: tuna loin, internasional, metode, manusia, tidak konsisten, Computer Vision, DeepLearning, EfficientNetV2-M, dataset, Self Adaptive Illumination Correction (SAIC), Contrast Limited Adaptive Histogram Equalization (CLAHE), Google Cloud Platform, Firebase, aplikasi, otomatis, industry.

Abstract - Tuna loin quality is critical to international market acceptance, yet traditional grading methods rely on subjective human judgment that often leads to inconsistent evaluations. This study introduces an intelligent grading system that uses computer vision and deep learning models to evaluate tuna loin quality based on visual attributes such as color and texture. Utilizing EfficientNetV2-M, the model is trained on a dataset that has been enhanced with preprocessing methods such as Self Adaptive Illumination Correction (SAIC) and Contrast Limited Adaptive Histogram Equalization (CLAHE), achieving an impressive 96% accuracy. This model is deployed on Google Cloud Platform for scalable and fast inference and is integrated into a Flutter-based mobile application. The application provides real-time grading feedback and incorporates Firebase for user authentication and profile data storage. This solution represents a step forward in automating food quality assessment, offering scalable, objective, and accurate grading mechanisms suitable for widespread industrial use.

Keywords: tuna loin, international, method, human, inconsistent, Computer Vision, DeepLearning, EfficientNetV2-M, dataset, Self Adaptive Illumination Correction (SAIC), Contrast Limited Adaptive Histogram Equalization (CLAHE), Google Cloud Platform, Firebase, application, automating, industrial.

I. INTRODUCTION

This research utilizes a Convolutional Neural Network (CNN) architecture known as EfficientNetV2-M for image classification. The model was selected due to its proven performance in preserving detail in high-resolution imagery and its suitability for cloud deployment[1]. Tuna loin images were collected using smartphones with 48MP cameras under different lighting conditions. Preprocessing techniques, namely Self Adaptive Illumination Corrtion (SAIC) and Contrast Limited Adaptive Histogram Equalization (CLAHE)[2][3], were applied to enhance contrast and normalize brightness across images. Data augmentation (rotation, flipping, shearing, and zooming) was applied to expand and balance the dataset[4].

After training, the model was converted to ONNX format and deployed on Google Cloud Run, enabling scalable and efficient real-time inference. The front-end mobile application was built using Flutter and follows a structured UI/UX workflow developed in Figma. Firebase Authentication and Firestore Database were implemented for user login dan user registration, and profile management. This approach allows for a seamless, secure, and responsive mobile experience, even in areas with limited infrastructure[5][6][7].

II. THEORY REVIEW

This study centers around a mobile-based solution designed to classify the quality of tuna loin. The application serves as a tool that enables users to assess the grade of tuna based on image input, returning results with high reliability. The grading process is powered by a deep learning model hosted in the cloud, offering rapid and consistent predictions without relying on manual inspection. The mobile app is developed using Flutter and Dart, enabling a responsive and cross-platform interface experience[8][9].

To manage users and ensure secure data flow, the system leverages Firebase services. Firebase provides robust user authentication as well as real-time database capabilities that simplify backend operations. On the inference side, the grading engine runs in a containerized format on Google Cloud Run, enabling the system to perform image-based analysis without requiring intensive processing on the user's device[7].

Through this integration, the application offers a fast, accessible, and low-resource method for grading tuna quality. The goal is to support standardization in seafood classification, improve efficiency in the field, and reduce subjectivity in quality assessment. The combination of mobile technology and cloud computation allows even non-technical users to benefit from AI-driven decision support directly from their smartphones.

A. Flutter Framework

Figure II-1 Flutter Logo

Flutter is an open-source UI toolkit developed by Google that allows for building natively compiled applications for mobile, web, and desktop from a single codebase using the Dart programming language [11]. Flutter is widely used due to its ability to deliver high-performance applications with beautiful and consistent UI designs across platforms.Some key advantages of Flutter include:

- Cross-Platform Development: Developers can create Android and iOS apps from the same codebase, significantly reducing development time and effort.
- Hot Reload: Changes made to the source code can be immediately reflected in the emulator or physical device, enabling fast UI iteration and debugging.
- Widget-Based Architecture: UI elements in Flutter are built using a composable widget system, which supports reusable, scalable, and customizable interface components.
- High Performance: Flutter compiles to native ARM code and renders directly using Skia, providing 60fps performance and fluid animations even on low-end devices.

In this research, Flutter serves as the foundation for the mobile-based Tuna Grading application. It supports camera integration for image capture, UI components for grading display, and real-time connectivity to backend services.

B. Dart Language

Figure II-2 Dart Logo

Dart is a client-optimized programming language developed by Google and used in Flutter. It is known for its expressive syntax, fast compilation, and strong support for asynchronous programming using `Future`, `Stream`, and `async/await` constructs [9]. Dart's Just-In-Time (JIT) compilation enables quick iteration during development, while Ahead-Of-Time (AOT) compilation ensures optimized release builds

C. Figma

Figure II-3 Figma Logo

The application's interface was designed using Figma, a web-based design and prototyping tool widely adopted for collaborative user interface development. Figma enables designers and developers to co-edit UI components, apply consistent styling, and visualize the flow between screens through interactive mockups [5].

In this project, flowcharts for login, grading, profile, and dashboard pages were first built in Figma. These flowcharts guided the application structure, helping the team ensure a logical navigation experience and consistency in visual

design. The layout used oceanic color schemes , aligning with the theme of PT. Aruna as a partner.

D. Firebase

Figure II-4 Firebase Logo

Google Firebase is a Backend-as-a-Service (BaaS) platform that supports fast integration of authentication and cloud storage in mobile apps [6]. Firebase Authentication was used in this app to manage user sign-up, login, and session persistence using email and password.

User profile data is stored using Cloud Firestore, Firebase's NoSQL real-time cloud database. Each user has a unique identifier (UID), and the application can fetch and update their associated records (such as full name and email). Firebase rules ensure data access is protected, preventing unauthorized access and ensuring compliance with data privacy policies.

III. RESEARCH METHODS

A. Application Review

This mobile-based application was designed to bring together deep learning, mobile UI, and cloud computing to automate tuna loin quality grading. It features a structured and user-friendly interface built with Flutter and Dart, offering responsive navigation and seamless interaction. Each function—such as login, grading, history, and profile—is represented visually in a flowchart that describes user pathways and logic rules. These flowcharts served as the foundation of the application's architecture.

The backend of the system utilizes Firebase for both user authentication and cloud-based data storage. For AI computation, the model is deployed in Google Cloud Run**,** allowing the app to remain lightweight while offloading complex processing to the cloud. The mobile system design emphasizes performance on low-end devices and secure, real-time interaction across pages.

The system is divided into four main components:

1. *User Interface and Flow Navigation*
2. *Authentication System*
3. *Grading System (AI Inference)*
4. *User Data Management and History Storage*

Each component is supported by detailed flowcharts designed in Figma to ensure logical interaction flow and efficient user task completion.

B. System Design

Figure III-1 Flow system

Figure 3.1 illustrates begin by capturing or selecting an image through the mobile app. The image is then uploaded to the cloud, where it undergoes preprocessing (using SAIC and CLAHE) to enhance visual features. Next, the enhanced image is processed by the EfficientNetV2-M model hosted in the cloud. The model classifies the tuna grade and returns the result as a prediction response. This response is sent back and displayed in the mobile app interface.

The system's workflow is visualized through page-based flowcharts that include:

- *Login and Registration Flowchart**:***

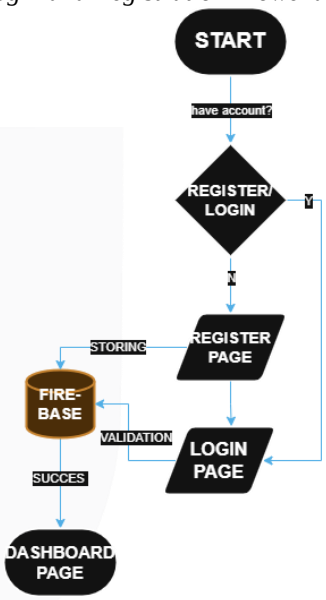

Figure III-2 Login and Registration Flow

Details the authentication process, covering input validation, email-password verification via Firebase, and redirection to the dashboard.

- *Dashboard Flowchart:*

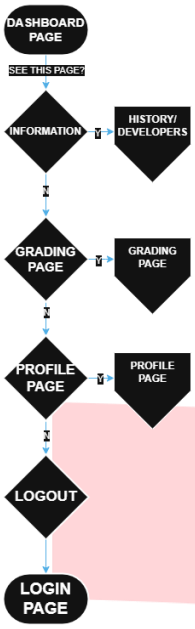

Figure III-3 Dashboard Flow

The users can do 4 possibilites such as Information Page to shows company history and developers of the application, Grading page usefor detecting the quality grade of tuna loin, Profile Page shows users details are fetched from Firestore, and Logout to go back to login page

- *Grading Flowchart:*

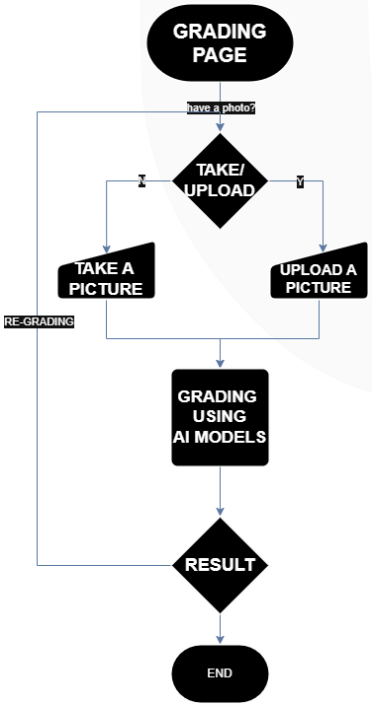

Figure III-4 Grading Flow

Outlines the process of selecting or capturing a photo, preprocessing it, uploading to the cloud, and receiving the result.

- *Profile Flowchart:*

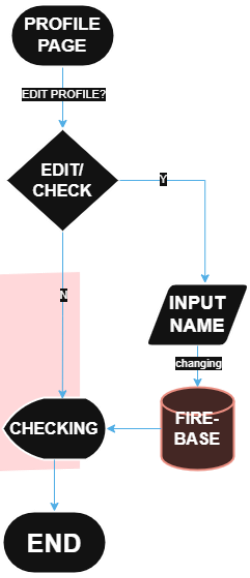

Figure III-5 Profile Flow

Shows how user details are fetched from Firestore and updated through the UI.

C. Application Development

The application interface was developed using Flutter and follows modern principles of mobile UI/UX. Screens were prototyped in Figma, focusing on clarity, ease of navigation, and aesthetic design.

- *Login & Register Pages*:

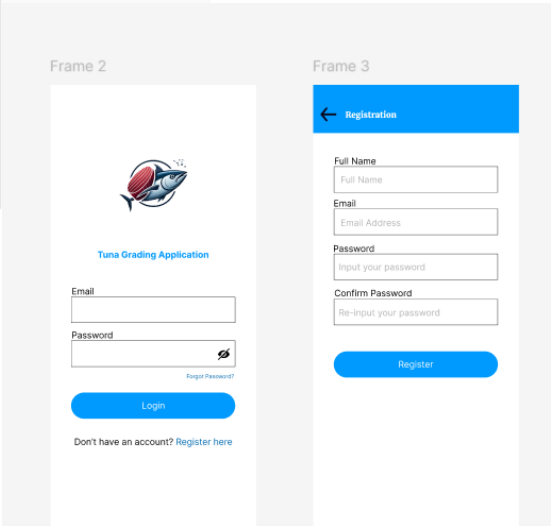

Figure III-6 Login & Registration pages

Allow users to securely create accounts or sign in, with validation and error handling implemented using FirebaseAuth.

- *Dashboard Page*:

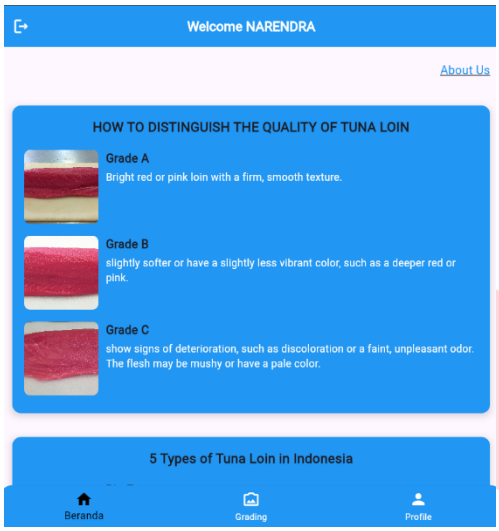

Figure III-7 Dashboard page

Serves as the home screen after login. It contains grading access, history in Aboutus, educational content about tuna grading, and information about 5 Types of Tuna loin in Indonesia.

- *Grading Page*:

Figure III-8 Grading page

Enables users to take or upload tuna images. Results are returned by the cloud-hosted AI model and displayed with interpretation.

- *Profile Page:*

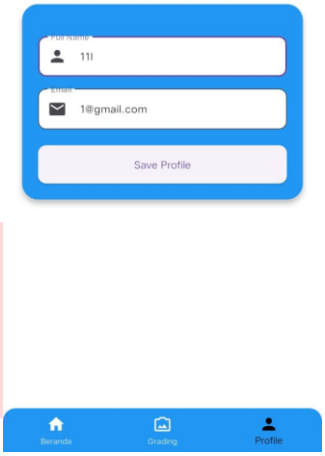

Figure III-9 Profile page

Displays the user's full name and email. Users can update their data which is synced in real-time with Firestore.

Each UI element follows responsive design rules, ensuring smooth performance across various Android devices.

D. Application Testing

The system underwent two types of evaluation:

- *System Usability Scale (SUS)* was used to measure user satisfaction. Respondents tested the app and completed the SUS form. Results were analyzed to determine perceived usability, efficiency, and design quality.
- *Black-Box Testing* was applied to all functions, including login, grading, data update, and history retrieval. Test cases verified expected behavior against user actions without inspecting the internal code.

Testing confirmed that all workflows operate as expected under normal network conditions and on mid-range Android smartphones.

IV. RESULT AND ANALYSIS

A. Classification Performance

The deep learning model used in this study was EfficientNetV2-M, trained with images of tuna loin captured under various lighting conditions. The dataset consisted of three quality grades: A (bright red), B (pale red), and C (brownish red). To ensure reliable classification, preprocessing techniques such as Self-Adaptive Illumination Correction (SAIC) and Contrast Limited Adaptive Histogram Equalization (CLAHE) were applied prior to model input[3].

After training, the model achieved a maximum accuracy of 96% on the test set, confirming its effectiveness in distinguishing between tuna grades. Precision and recall metrics also showed high values across all classes, with Grade A exhibiting the most consistent results due to clearer visual features. The confusion matrix indicated minimal misclassification between Grades B and C, which were visually closer in tone and texture[1].

These findings align with prior research in food quality prediction, where models that combine deep learning with texture and color feature extraction tend to outperform traditional image classifiers .

B. Mobile System Performance

On the front-end, the application built with Flutter maintained stable performance across mid-range Android devices. Testing on devices with 3–4GB RAM confirmed that grading predictions were returned in under 3 seconds when connected via 4G or Wi-Fi. This quick turnaround was enabled by cloud offloading to Google Cloud Run, which handled ONNX-based model inference in containerized environments[7][13].

Real-time system testing showed consistent behavior during typical use cases: login, image capture, prediction request, and result display. The mobile interface successfully synchronized grading history and user data through Firebase Firestore with minimal latency.

C. User Experience Evaluation

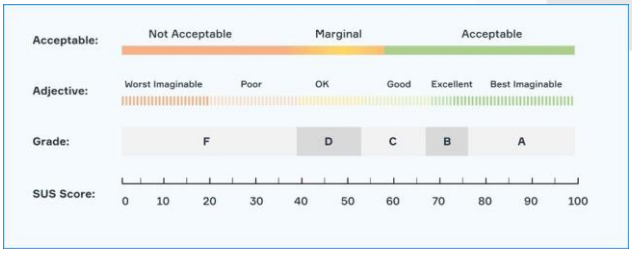

Figure IV-1 SUS Parameters

To measure usability, the app was evaluated using the System Usability Scale (SUS)**.** Respondents included students and testers with non-technical backgrounds. The average SUS score obtained was 70.25**,** which corresponds to a rating "Acceptable" and "Excellent" based on industry standards. Participants noted the intuitive navigation, clear button layout, and consistent flow between login, grading, and history views[15][16].

Additional open feedback revealed that users appreciated the simplicity of the interface and the visual feedback during the loading process. Based on the results, the app's UX design fulfilled its purpose of being accessible even to users unfamiliar with mobile AI tools.

D. Comparative Insights

Compared to other mobile-based AI applications in fisheries and agriculture, this solution shows strong performance both in accuracy and usability. Prior works have used web-based dashboards or offline models, but this system takes advantage of cloud deployment for lightweight real-time grading. Moreover, the use of Firebase Authentication and Firestore adds security and scalability that are often lacking in similar projects[3][6].

V. CONCLUSION

This research successfully demonstrates the potential of combining computer vision, deep learning, and cloud computing to automate the quality grading of tuna loins. The EfficientNetV2-M model, trained with robust preprocessing and augmentation techniques, proved capable of delivering highly accurate predictions. Its integration with a cloud-hosted backend and a Flutter-based mobile application creates an accessible and scalable platform for end-users in the fisheries industry.

Furthermore, the application’s intuitive design and Firebase-based authentication ensure secure and user-friendly interactions. The adoption of such automated systems stands to greatly improve consistency in product quality, reduce labor dependency, and enable data-driven decision-making across the supply chain. Future improvements may focus on expanding the dataset, integrating multi-angle image capture, and refining the grading criteria to include additional quality indicators such as fat content or freshness.

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