CHAPTER I
INTRODUCTION

1.1. Background

In Indonesia, rice is crucial for preserving food security. As the primary food source, national rice consumption in 2024 is projected to reach approximately 30.62 million tons [1] and is projected to rise to 34 million tons by the end of 2025 [2]. The high reliance on rice makes it a key commodity in both the national economy and food security. Therefore, the Indonesian government aims to achieve rice self-sufficiency by the end of December 2025 [3].

However, rice productivity is often threatened by various leaf diseases. Disease outbreaks in rice crops can reduce yields by up to 40%, with the extent of the loss varying depending on the type of disease and the growth stage of the plant at the time of infection [4]. One of the diseases that affects rice is leaf blight, which can cause a 15 to 30% reduction in crop yield [5]. In addition, brown spot disease is the most damaging disease, both in terms of the quantity and quality of the rice [6]. Furthermore, blast disease in rice leaves also has a significant impact on rice yields [7]. Sheath blight also causes yield losses ranging from 5% to 60% [7]. Therefore, early detection of rice diseases is a crucial step in minimizing potential crop losses.

Until now, the process of identifying rice leaf diseases has generally been carried out manually by farmers or experts by observing symptoms on the leaves [8]. This method has limitations, including being subjective and difficult to apply consistently on a large scale. Furthermore, identifying diseases and pests requires in-depth knowledge. Without adequate expertise, misdiagnosis can lead to inappropriate management and control measures [9]. This necessitate the need of a method for classifying rice leaf diseases that is faster, more accurate, and more reliable.

Advances in digital image processing technology and artificial intelligence have the potential to address these issues. One widely used approach in the classification of plant disease images is Deep Learning, specifically Convolutional Neural Networks (CNNs). CNNs are capable of recognizing complex visual patterns such as shape, color, and texture in leaf images without the need for manual feature extraction [10]. Among the various CNN architectures, there is the MobileNetV3-Large model.

Research conducted by Tazkira et al. shows that the MobileNet architecture offers high computational efficiency in rice leaf disease classification due to faster convergence, higher accuracy, and lower resource requirements compared to conventional CNNs, making it highly suitable for deployment on edge devices such as mobile devices [11]. These findings align with the research by Mifthauddin et al., who compared MobileNetV3-Large with MobileNetV2 for the task of rice leaf disease classification; the results showed that MobileNetV3-Large outperformed MobileNetV2 with an accuracy of 99% versus 96% and has a lower number of parameters [12]. In addition to outperforming its predecessor, MobileNetV3-Large has shorter inference times and lower power consumption compared to the DenseNet121, EfficientNetV2B1, and EfficientNetV2B2 models [13]. With superior efficiency and performance, MobileNetV3-Large has great potential for implementation in mobile applications that enable direct rice leaf image capture and disease classification. This approach also has the potential to expand access to technology and enhance its utility in field settings, thereby supporting more effective rice cultivation practices.

Although deep learning-based models have demonstrated high accuracy across various domains, including agriculture, the complexity of their architecture prevents them from explaining their prediction results [14]. CNN-based classification models typically exhibit black-box characteristics because the automated feature extraction and classification processes do not provide users with insights into how the model works [15]. Therefore, model explainability is crucial. When a model can explain its predictions, users can see whether the parts of the leaf affected by disease is focused by the model [16].

To meet these validation needs, the explainable Artificial Intelligence (XAI) approach offers a solution. XAI helps identify which features the model uses during the classification process [17]. A commonly used XAI method is Gradient-weighted Activation Mapping (Grad-CAM). This method outputs a heatmap on the image that show the model's focus during classification [18]. With Grad-CAM, the prediction results not only provide a disease prediction but also a heatmap showing the parts of the image that influence the model's prediction.

However, the direct implementation of Grad-CAM on mobile devices faces technical challenges. To generate a heatmap, Grad-CAM requires gradient computation on the model's final convolutional layer with respect to the predicted class [18], whereas mobile machine learning libraries such as TensorFlow Lite are designed to generate predictions only and do not support gradient computation [19]. To address this limitation, this study adopts a dedicated client–server architecture for the heatmap generation process. Rice leaf disease predictions are still executed on the mobile device using the MobileNetV3-Large model so that the application's core functions can continue to operate even offline, while Grad-CAM computations are performed on a server that supports gradient computation.

Based on these issues, this study is titled "Classification of Rice Leaf Diseases Using MobileNetV3 with a Grad-CAM-Based Explainable AI Approach on a Mobile Platform". The study began with the collection and processing of images of rice leaves infected with diseases, followed by the training of the MobileNetV3-Large model to classify disease types. Following the model training process, an API server was developed to generate heatmaps from Grad-CAM. The final stage involved the development of a mobile application and the integration of MobileNetV3-Large into the mobile application. Thus, this study is expected to produce an accurate and explainable rice leaf disease classification model.

1.2. Problem Statement

Given the background described previously, the research questions for this study are:

1. How can the Grad-CAM method be applied to MobileNetV3-Large to provide visual explanations for rice leaf disease classification results?
2. How can the MobileNetV3-Large model be integrated into a mobile application?
3. How can the MobileNetV3-Large model with Grad-CAM be integrated into a mobile application environment that can display detection results and heatmap visualizations using a client-server architecture?

1.3. Research Goals

The objectives of this study are as follows:

1. Develop a rice leaf disease classification model that can run on mobile devices.
2. Applying the Grad-CAM method to generate visualizations of the leaf areas targeted by the prediction, thereby making the classification results more interpretable, and creating an API server for Grad-CAM.

3. Implementing the classification model and Grad-CAM visualization results into a mobile application using a client-server architecture capable of displaying rice leaf disease detection results and interpretations.

1.4. Research Benefits

This study was conducted with the hope of providing the following benefits:

1. Provide a scientific contribution in the form of written works and mobile applications that can serve as references for future research.
2. Provide a rice leaf disease classification model in the form of a mobile app.
3. Provide visualizations of detection results using Grad-CAM so that users can understand why the model's predictions are as they are.
4. Support practical rice disease detection, thereby helping farmers classify rice leaf diseases.

1.5. Research Limitations

To ensure that this study has a clear focus, the scope of the problem will be limited to several key aspects. These limitations are important to avoid an overly broad and unfocused discussion. The limitations are:

1. The data used consists of rice leaf images obtained from the Kaggle dataset, and the classes considered are limited to Bacterial Leaf Blight, Blas, Brown Spot, and Sheath Blight.
2. This research includes the creation a mobile app capable of displaying classification results, a rice leaf disease encyclopedia, and Grad-CAM visualizations from the trained model, without focusing on the development of a complex mobile application interface or backend system.
3. The mobile application developed is an Android-based mobile app using the Kotlin.
4. The Grad-CAM method is implemented in the mobile application by calling an external API server to generate heatmaps, so it is not executed directly on the mobile device.
5. The mobile application is designed to process only inputs depicting rice leaves.