AI-Powered Drone Innovation for Crop Yield Estimation in the Era of Climate Change

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ABSTRACT

This research is motivated by the scarcity of rice stocks, which has caused rice prices to soar recently. This can occur due to many factors, including climate change, insufficient rice stocks, and many crop failures. Furthermore, technology is currently advancing very rapidly, and one of the most widely used technological products is drones. Drones are devices that are currently used to assist human work in agriculture, photography, and hobbies. Drone technology has also advanced very rapidly, with the installation of several components such as sensors and cameras, enabling current drones to be developed by implementing machine learning and artificial intelligence to accomplish specific tasks.

Based on the above problems, the researcher wants to create a smart drone innovation that can overcome agricultural problems, particularly in the field of harvesting. The drone innovation to be developed will utilize Artificial Intelligence technology to estimate the amount of harvest based on image data obtained from the drone. Research on drones that utilize artificial intelligence, such as Deep Learning, Machine Learning, Optical Flow, and other methods, has been widely conducted. The focus of this research is for drones to estimate the harvest in rice fields based on image data of the rice fields taken from the drone.

There is currently no AI-based Drone innovation technology that focuses on agriculture, particularly in estimating crop yields. This is important because Indonesia is currently experiencing an increase in rice prices and a shortage of rice stocks. To estimate crop yields, a data source is needed in this case in the form of image data of rice fields taken from drones. Then, an artificial intelligence method will be implemented to capture the color of the rice plants in the rice fields using the camera's field of view (FOV) method...

Keywords— Agricultural technology, AI/Artificial Intelligence, Crop yield estimation, Drone, Rice harvest, Image data/analysis.

I. INTRODUCTION

Indonesia, as an agrarian country, faces significant challenges in maintaining national food security. The current crisis of rice stock shortages has resulted in a significant price hike, burdening the wider population. This issue is caused by various complex factors, such as extreme climate change, supply shortages due to crop failures, and inefficient inventory management. This situation threatens food stability and demands innovative solutions to address these challenges.

Amid the Industry 4.0 revolution, drone technology has become an increasingly popular tool in various sectors, including agriculture, photography, and hobbies. With continuously evolving capabilities through the application of sensors, cameras, machine learning, and artificial intelligence (AI), drones have the potential to provide solutions to enhance agricultural productivity and address food security issues. Previous studies have shown that drones can be utilized to monitor crop growth, identify pests and diseases, as well as optimize fertilizer application and irrigation. However, there is currently no specific solution focusing on accurately and efficiently estimating crop yields.

This research aims to develop an innovative AI-based smart drone capable of estimating harvest quantities based on aerial field image data. By leveraging machine vision and deep learning technology, this drone will analyze field images to identify areas ready for harvest and accurately calculate productive acreage. Accurate harvest estimates provide crucial information for farmers and governments in managing food supplies, determining marketing strategies, and maintaining price stability in the market.

Various AI methods have been applied in previous research, such as Deep Learning, Machine Learning, Optical Flow, and other techniques. However, this research will focus on implementing the Camera's Field of View (FOV) and Grayscaling methods to efficiently process field image data. The FOV method will convert image data into the actual acreage of the field, while Grayscaling will separate the acreage of the field into yellow (ripe rice) and green (unripe rice) areas. By combining these two methods, accurate estimates of productive field acreage can be calculated.

Furthermore, estimates of productive field acreage will be converted into harvest weight estimates using conversion factors established based on historical data and previous research. The final result of this process will provide important information about harvest production estimates in a region, which can be used to support decision-making in national food security strategies.

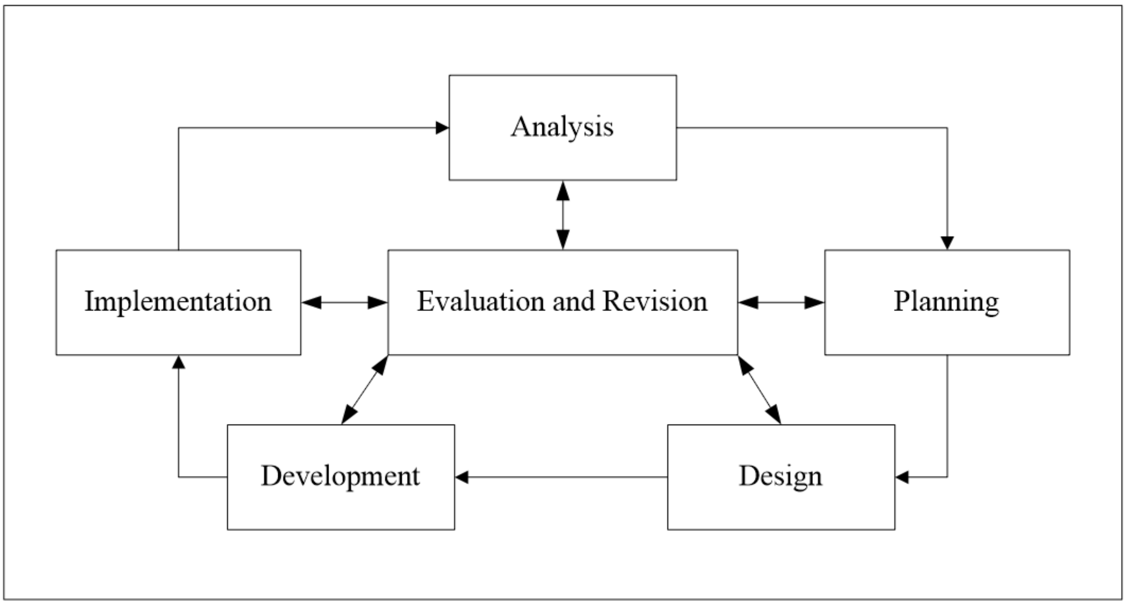


Figure 1 Model of the Instructional Development Cycle

By observing these problems and potential, we conclude that farmers can increase their productivity and minimize losses with technology. So in this study we want to realize our research, namely AHYM (Aerial Harvest Yield Monitor with Drone) as a tool for technological innovation, especially in the agricultural sector.

By leveraging advancements in drone and AI technology, this research is expected to make a significant contribution to addressing the food crisis in Indonesia and enhancing the efficiency and productivity of the agricultural sector. This innovative solution has the potential to be a first step towards digital transformation in agriculture, ushering in a new era of smarter, sustainable, and affordable food management for the wider population.

II. Method And Experimental Details

This section outlines the systematic approach we adopted for our experimental endeavor. To create the application and administer the survey, we followed the model instructional development cycle, a comprehensive framework encompassing multiple phases. Figure 1 illustrates the workflow we employed in developing AHYM (Aerial Harvest

Yield Monitor with Drone), our innovative solution for monitoring crop yields through aerial technology.

The instructional development cycle is an iterative process that ensures continuous improvement and refinement. It comprises several key stages: analysis, planning, design, development, implementation, evaluation, and revision. Notably, the evaluation and revision phases are not confined to specific points but are integrated throughout the entire cycle. These ongoing assessment and refinement activities are woven into each phase, allowing for thorough examination and enhancement of the outputs before advancing to the subsequent stage.

The cycle commences with the analysis phase, where objectives and requirements are meticulously examined. This is followed by the planning phase, during which strategies are devised to meet the identified goals. Next, the design phase translates these plans into tangible instructional materials and activities. The development phase then brings these designs to life, creating the actual resources and tools. Once developed, the solution is implemented, and its effectiveness is rigorously evaluated. Based on the evaluation findings, revisions are made to address any identified areas for improvement, ensuring that the final product aligns with the desired objectives and meets the highest standards of quality.

A. Analysis Phase

The initial phase of our process involved conducting an extensive literature review. This crucial step allowed us to gain a comprehensive understanding of the requirements and considerations necessary for developing a website aimed at predicting rice yields through the utilization of drone technology. By thoroughly analyzing existing research and relevant materials, we were able to identify the specific needs that our solution would need to address.

Furthermore, during this phase, we meticulously assessed the resources and environmental factors that would be leveraged in the development of AHYM (Aerial Harvest Yield Monitor). Through a careful evaluation of the available materials and conditions, we ensured that our subsequent efforts would be well-informed and tailored to the specific context in which the website would be implemented. This comprehensive assessment laid the foundation for the successful integration of our solution into the target environment.

B. Planning

During this phase, we meticulously planned the development of the website, including the selection of the programming language to be utilized. Additionally, we established the specifications and requirements for the AHYM (Aerial Harvest Yield Monitor) system.

After careful consideration, we chose Python as our programming language of choice. Python is a high-level, multi-functional language created by Guido Van Rossum and first released in 1991. It has gained significant popularity in recent years due to its ease of use and versatility.

The decision to employ Python was driven by several factors. Firstly, Python is renowned for its simple and readable syntax, which facilitates efficient coding and collaboration. Secondly, Python boasts a rich ecosystem of libraries and frameworks that cater to a wide range of applications, enabling us to leverage existing tools and functionalities. Furthermore, Python enjoys strong community support as an open-source language, ensuring access to a vast knowledge base and ongoing development.

Some of the Python libraries that we planned to incorporate into our project include Streamlit for building interactive web applications, OpenCV (cv2) for computer vision and image processing tasks, NumPy for numerical computations, and Matplotlib for data visualization. These libraries would provide us with the necessary tools and capabilities to develop a robust and feature-rich website for predicting rice yields using drone technology.

C. Design

The utilization of drones in agriculture offers significant advantages, particularly in the context of large-scale farming operations. Drone possess the capability to cover vast agricultural areas with remarkable speed and efficiency, enabling comprehensive monitoring of even the most expansive and remote fields.

This technology proves invaluable for farmers, as it eliminates the need for manual, plant-by-plant inspection to assess the readiness of crops, such as rice, for harvesting. Instead, drones can be programmed to conduct regular monitoring missions, ranging from daily to weekly intervals.

This frequent and systematic observation allows for continuous tracking of plant growth and field conditions, providing farmers with up-to-date information crucial for informed decision-making.

Furthermore, drones offer accessibility to areas that may be challenging or impractical to reach through conventional means. By leveraging this cutting-edge technology, farmers can gain a comprehensive understanding of their entire agricultural landscape, regardless of the terrain or size of the farming operation. This level of detailed monitoring and data collection was previously unattainable, making drones a game-changer in the realm of precision agriculture..

D. Development

In this phase, we develop the AHYM. Also, during this phase, we divide tasks among each member of the team. This process took two months. At this stage, we also receive guidance from our mentor, Arda Surya Editya, to supervise our work and provide tips on our research.

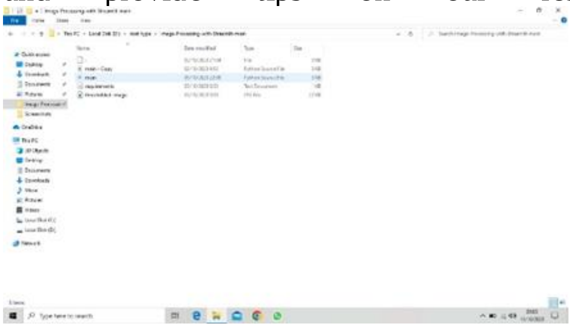


Figure 2 The folder where the web code is stored

The program imports necessary modules such as Streamlit, PIL (Pillow), OpenCV, NumPy, and Matplotlib. In Figure 2, start by opening the file, then select the folder where the web code is stored.

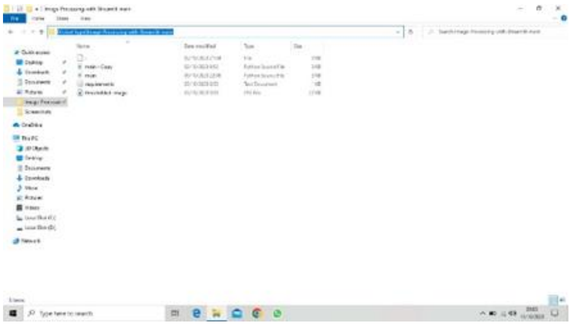


Figure 3 Copy the file name

In Figure 3, after navigating to the location where the web code is stored, copy the file name as indicated in Figure 2. Then proceed to delete it..

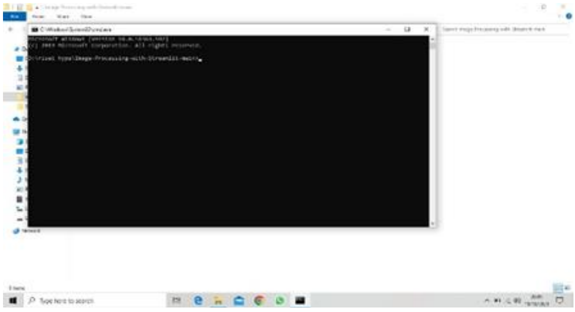


Figure 4 Cmd window display

In Figure 4, the CMD window will appear. Then, type "python -m streamlit run main.py" (adjusting the name of the file that stores the code), followed by "main.py," which is the name of our website file..

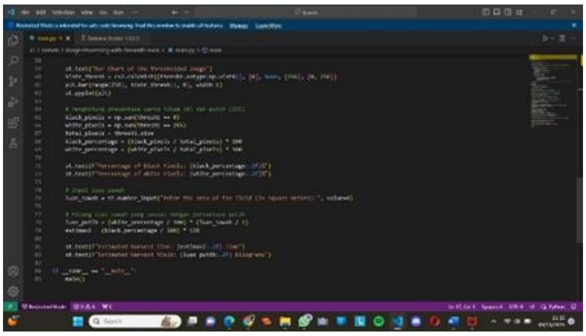


Figure 5 Website code in Python

Based on Figure 5, the main() function serves as the primary function that executes the application. It begins by displaying the title of the application and providing options for the user to select the image source: either uploading an image or capturing one from the webcam. If the user opts to "Upload Image," they can proceed to upload an image, which will then be displayed. Alternatively, if they choose "Capture from Webcam," the application will show the webcam view, allowing the user to capture an image by clicking the "Capture Image" button.

Once an image is displayed or captured from the webcam, the application proceeds with the thresholding process on the image. This involves converting the image to grayscale, performing thresholding with a threshold value that can be set by the user, and displaying the resulting thresholded image along with its histogram. Additionally, the application calculates the percentage of black and white colors in the thresholded image and estimates the harvest time and yield based on this information and the area entered by the user.

The estimation calculation is performed as follows:

Estimation calculation = ((((black_pixels/total_pixels)*100)/100)*120

(120 is the threshold value) Harvest prediction calculation = (((white_pixels / total_pixels) * 100)/100)*(area_sawah / 2)

Finally, the application checks if the code is run as the main program and calls the main() function. It will then automatically display the AHYM website, prompting the user to click "Browse File" to select the image for prediction.

E. Implementation

In this phase, we utilize information from journal databases, highlighting the challenges faced by rice farmers during the harvest process, which often result in significant losses. These challenges stem from various factors, including a lack of knowledge and techniques, particularly the absence of technological advancements. To combat these hurdles, we employ the Citra development system and the Python programming language. Subsequently, we integrate an informatics system into drones, enabling us to predict rice harvests using technology.

The drone transmits camera data to the PC via a Wi-Fi network. Subsequently, the PC application processes the image, converting it into a binary format through a thresholding process. The program then computes the percentage of the rice-planted area based on this binary image. Additionally, with user input regarding the rice field's area, the program estimates the harvest yield in kilograms. While the estimated harvest time is initially calculated as a fixed value, it ideally should be determined based on actual plant growth data and environmental factors. Ultimately, the program furnishes both the estimated harvest time and yield.

F. Evaluation and Revision

This phase is an integral part of every stage we undertake. Within the Instructional Development Cycle Model, each stage necessitates evaluation and revision to ensure the creation of a system with optimal performance and user comfort. The evaluation and revision processes are overseen by our mentor, Arda Surya Editya. With each revision, we address identified issues and seek approval from our mentor before proceeding.

III. RESULT AND ANALYSIS

In this section, we will present both our research findings and an analysis thereof, which will be segmented into three parts. Firstly, we will delve into the performance evaluation of the website we developed. Secondly, we will discuss the methodologies employed in the website creation process. Lastly, we will examine the outcomes of the survey conducted among our users..

A. Website AHYM Performs

The website or system utilized programming and image processing techniques to predict the harvest yield in rice fields..

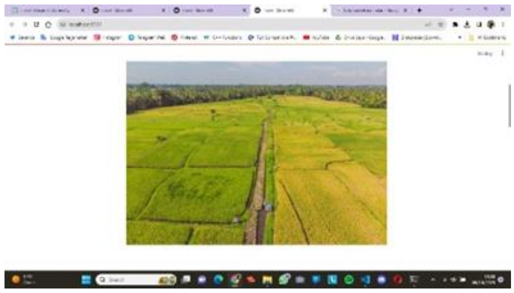


Figure 6 Upload photos from the drone

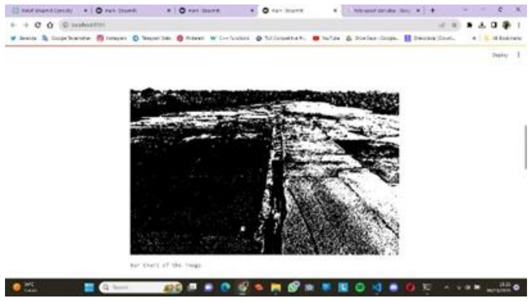


Figure 7 Satellite image processing results using the AHYM Website.

In Figure 6, the result depicts a photo captured using a drone. Figure 7 illustrates that the rice is not yet ready for harvest, indicated by the black color. Conversely, if the rice appears green in Figure 6, it signifies readiness for harvest, depicted by the white color in Figure 7. Additionally, if the rice appears yellow in Figure 6, it indicates an intermediate stage of readiness for harvest.

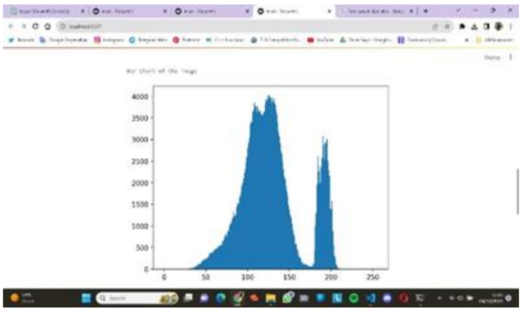


Figure 8 Diagram view of the figure 6

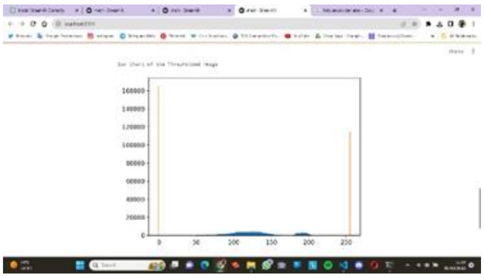


Figure 9 Diagram view of the figure 7

In Figure 8, the presence of blue indicates that the uploaded image in Figure 6 contains colors other than green and yellow. Moving to Figure 9, the number 0 represents the color black, indicating that the rice is not yet ready for harvesting. Conversely, the number 250 represents the color white, signifying that the rice is ripe and ready for harvest. The blue color in Figure 9 signifies that Figure 7 contains colors other than black and white..

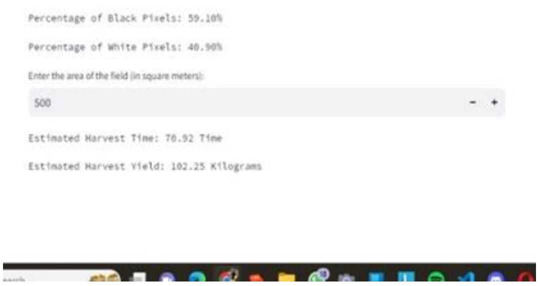


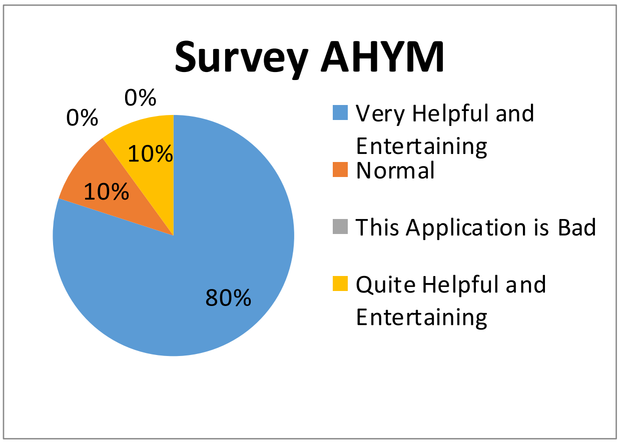
Figure 10 Prediction of rice harvest time in days and total rice yield in kilograms

In Figure 10 "Enter the area of the field" is used to input the area of the field.

B. Make A AHYM Website

The program imports the necessary modules, such as Streamlit, PIL (Pillow), OpenCV, NumPy, and Matplotlib. In Figure 2, begin by opening the file, then select the folder where the web code is stored. Moving on to Figure 3, after entering the location where the web code is stored, copy the file name as indicated in Figure 2. Proceed to delete it. In Figure 4, the CMD window will appear. Based on pictures numbered 5, 6, and 7, the website will run the program.

C. Survey Result



In this section, we present the results of a survey compiled from various journals. The survey indicates that 80% of respondents found the AHYM app to be very helpful, while 10% regarded the AHYM website as quite helpful. Additionally, another 10% of respondents reported that the AHYM website functions normally.

IV. CONCLUSSION

In this research, we have developed a website named AHYM, designed for predicting rice yields using drones. This innovative platform leverages artificial intelligence technology to gather data through drones. The application serves as a valuable tool for farmers, aiding in the determination of optimal harvest times to mitigate crop failures or losses arising from harvesting too early or too late.

AHYM website is built using the Python programming language, incorporating essential modules such as Streamlit, PIL (Pillow), OpenCV, NumPy, and Matplotlib. The integration of these modules enhances the functionality and effectiveness of the website.

The significance of this website is underscored by the results of surveys conducted among respondents and published in several journals. According to the findings, 80% of respondents deemed the AHYM website to be very helpful, while 10% found it helpful, and another 10% considered it to function normally.

Looking ahead, we envision further development and enhancement of this application. We aspire to explore cutting-edge technologies and devices to deepen its capabilities. Specifically, we aim to integrate advanced data collection methods, such as gathering image data from drones, and employing artificial intelligence algorithms with satellite imagery for more precise predictions and analyses..

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