Mustard Plant Growth Monitoring System Using Artificial Intelligence in Aquaponics

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Abstract

Modern agriculture increasingly relies on technology to increase efficiency and productivity.Aquaponics, a sustainable farming method that combines fish and plant farming, is emerging as a promising approach.To maximize yield in an aquaponics system, it is very important to monitor plant growth.In this context, artificial intelligence (AI) provides innovative solutions for monitoring and optimizing plant growth in real time.Artificial intelligence-based aquaponics technology is designed to be portable, allowing you to grow plants both inside and outside your home.AI-based aquaponics technology uses cameras to monitor plants in real time.The camera data is processed and analyzed by the AI system, allowing automatic monitoring of the plant-growing environment within the system.If you get results that show whether the leaves are still fresh or not, the leaves will die quickly.This technology, which utilizes CNN's deep learning techniques, will improve the efficiency of resource management and contribute to sustainable food production.This system can increase productivity and strengthen food security in the face of future challenges.This aquaponics technology can make a significant contribution to the development of sustainable agriculture and provide guidance and inspiration to those in the agricultural and food industries.By optimizing food production through AI-based aquaponics systems, communities can address global food security challenges and find greener, more efficient, and sustainable solutions for the future.

1. Introduction

Today, with a growing global population and a changing climate, the world faces interrelated challenges related to agriculture, the environment, human resources, and resources.(Efendi & Sagita, 2022)In addition to the high demand for mustard, Indonesia also produces a lot of these vegetables.According to data from the Central Bureau of Statistics (BPS), Indonesia's mustard production in 2022 will be 706,305 tons. This was a 29% decrease compared to the previous year's 727,467 tonsGiven that Indonesia's trade sector still relies on the agricultural sector, the decline of the agricultural sector has serious implications for Indonesia's economic growth.The decline in agricultural growth in Indonesia is one of the causes of the effects of climate change, so

effective aquaponics is needed to grow plants in closed and open environments. (Badan Pusat Statistika, 2022)The next problem is that vegetable crops are staple foods with many benefits. both as a source of nutrition and as an appetite enhancer.Therefore, vegetables are essential for everyone. (Aak, 2017) However, the Republic of Indonesia has released the results of the 2022 Indonesia Nutritional Status Survey (SSGI), according to the Ministry of Health.The findings not only provide data on the yearly trends in stunting rates in Indonesia but also provide details on stunting rates in each province of Indonesia.The data showed that Indonesia saw a 28% reduction in stunting rates from 2021 to 2022 This success rate is in line with the target of approximately 27% per year, set by the Ministry of HealthAccording to an FAO report, insufficient intake of vegetables and fruits is one of the top 10 causes of high mortality rates worldwide. (UPK KEMENKES RI, 2022)One of the vegetable plants is mustard (Brassica juncea L). Mustard greens are an economical and nutritious leafy vegetable.Indonesia's mustard production is 602,468 tons, with an average productivity of 991 tons/ha in 2014It is still low compared to the productivity, which reaches 10–12 tons/ha.Crop productivity remains low due to cultivation techniques, especially fertilization, which is not utilized to its full potential (Karim et al., 2020).However, in addition to the high demand for mustard in Indonesia, these vegetables are also produced in large quantities.According to data from the Central Bureau of Statistics (BPS), Indonesia's mustard production in 2022 will be 706,305 tons. This was a 29% decrease compared to the previous year's 727,467 tons (Monavia Ayu Rizaty, 2023) Recently, a unique type of agriculture has emerged: aquaponics, which combines fishing and farming to create a stable ecosystem rotation.The application of aquaponics farming is still relatively new in Indonesia, as the area is decreasing. Cultivate two different types of goods.According to a study conducted by Nur Ayini et al.titled “Supporting the use of home garden land through aquaponics technology in the Uwedaka village community," due to the problems previously faced in small houses, vegetable gardening and the activities of communities that grow other crops may be restricted.You can also consider growing vegetable crops using aquaponics methods.One of the goals of aquaponics is to provide vegetable crops on a household scale. (Lalu, 2022) In addition to the results obtained, aquaponics also allows you to produce plants in the form of vegetables that are much fresher than conventional farming methods since the use of chemicals is completely eliminated.Some researchers have attempted to resolve these issues.For example, the study by Nur Prihatiningsih et al. The company, titled "Aquaponic Vertical Cultivation System for Organic Vegetables as Farmland Utilization," is developing aquaponics technology, but it also uses artificial intelligence (Prihatiningsih et al., 2020)to enable people to grow crops inside and outside their homes.is not used.This technology uses mustard leaf discoloration detection cameras installed in aquaponics to monitor mustard growth.The cameras are processed and analyzed by an AI system, and the growing environment of plants within the system can be automatically monitored in real time.This technology also uses aquaponics, which uses fish waste as fertilizer.Fish waste replaces water nutrients and supports the growth of mustard greens.

1.1 Literature Review

Many researchers have done research related to monitoring plant growth using artificial intelligence. One of the studies that has been done is disease detection in mango plants with digital images.

1. Research was conducted by (Marifatul Azizah et al., 2018) that investigated related surface defects in mango fruit. The study, titled "Mangisi Fruit Surface Defect Detection Using Deep Learning Method with Multilayer Convolution", uses a machine learning method that can be used to classify an object's image, the Convolution Neural Network (CNN). This method is used to solve data classification problems because its use has a relatively fast computational process, so this study can produce the detection of defects on the surface of mango fruit based on image processing, which can help in improving the quality of mango fruit.
2. The research carried out by (Ulla Delfana Rosiani et al., 2020), who investigated related diseases in corn leaves, is titled "K-Means-based Segmentation on Imaging Imaging of Leaf Diseases of Corn Plants", In this study, using the K-Means method on the imaging of leaf diseases of corn plants, the results of the testing of imaging imagery of disease of corn leaf plants, i.e., leaf hawar and leaf spotted leaves, that have been performed have obtained a system test presentation of 90%.
3. Research conducted by (Rasywir et al., 2020) that investigates related palm diseases, The research is entitled "Analysis and Implementation of Disease Diagnosis Sawit with the Convolutional Neural Method Network (CNN)" in this study can He diagnosed 11 types of palm disease in his journal and

obtained the highest accuracy of 89%, the lowest of 83%, and an average of 87% of 2490 palm coconut images tested using the Convolutional Neural Network CNN method.

4 Research conducted by (Fitrianingsih & Rodiah, 2020) who researched related to the classification of types of mango leaves. The research is entitled "Classification of Types of Mango Leaf Images Using Convolutional Neural Network", this study classifies the type of manga leaf in its research using a total of 1585 images of different types of mango leaves (three types of manga sheets) and can identify 1585 manga leaf images correctly. From this, it can be inferred that the accuracy value of the model in identifying The training set totaled 97.72%.

2. Research Methods

This study aims to detect the health of green saffron plants based on holes and scratches caused by pests using the deep learning method. (Convolutional Neural Network) Technical detection of the characteristics of green sawmills affected by pests is done through image data obtained from webcam cameras installed on Akuaponik technology. Click or tap here to enter text. Here are the preprocessing stages to detect pest-affected salvia leaves:

1. Resolution and image size: This is intended to help in computing efficiency and ensure consistent results. Then the pixel normalization process is carried out.

2. Pixel Normalization: Pixel normalization on image data is done with a range of 0 to 1 or -1 to 1. It aims to help with faster convergence when training models.

3. Data Augmentation: This process aims to help in increasing data variation and making models more resistant to position and angle variation.

4. Noise Removal: It aims to remove or reduce noise, such as dust or noise.

5. Object detection and cutting: This is used to detect objects and perform cutting to isolate objects that want to be identified.

6. Color Scale Modification: This is intended to adjust the color scale of the image due to the model being sensitive to light spacing.

7. Format Change: This aims to keep all images in a consistent format, such as JPEG or PNG.

8. Duplicate deletion: This is intended to compress and delete the same image from the dataset.

9. Division of Datasets: The datasets are divided into three parts. The data sets are split into training data, validation data, and test data. It's about to train, optimize, and test models. After the preprocessing of the image data, the data is classified using the CNN method. The convolutional neural network (CNN) method divides the image into small pixels that are stacked and reunites them back into an image with clearer features. (Rangarajan et al., 2018)The network architectures used are AlexNet and VGG16. CNN algorithms with AlexNet network model 4 and the performance of the model evaluated give a higher accuracy of 97.49%.

In helping owners detect damaged green mud leaves, they can use AI technology to detect leaves based on images already planted on raspberry pi and give enough light to green mud plants by replacing sunlight with UV light. Monitoring the air temperature and humidity around plants to avoid unstable temperatures that interfere with green mud growth can be done using the website.

Data collection is a step of data collection that will be used in this research to identify leaf disease in sawi plants. Since this research is a guided study, where the process of classification uses data already existing with the label of each class, the data of sawi leaves used has a label or class that is divided into three, i.e., healthy, immediately leafy, and leaves leached or dead.

Fig 1. Withered mustard leaves

Fig 2. Mustard greens wither soon

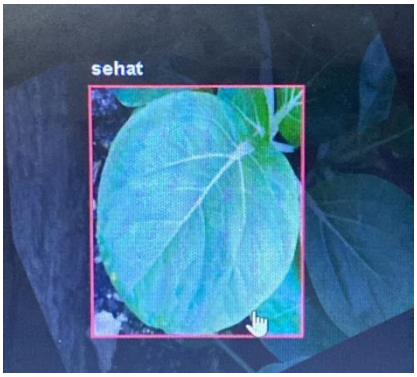


Fig 3. Healthy mustard greens

This dataset is taken from the Roboflow website.

The next step is image classification using the convolutional neural network (CNN) method. The CNN algorithm is included in supervision learning, where image recognition is done by training existing image data and targeting image variables. The CNN convolution layer helps the CNN neural network recognize potato leaves based on their attributes. The neural network is able to recognize the mustard leaf image based on the pixels in the image. Convolutional uses filters to identify attributes in leaf images. In this convolution process, matrix multiplication will be carried out against the filter and leaf image area that can be seen in Fig. 4. Covolution process.

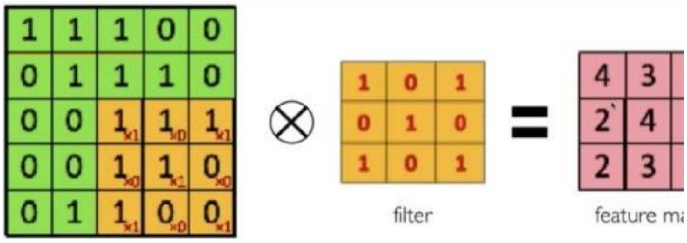


Fig 4. Covolution Process

After the convolution is completed, carry out the maximum collection. Composing here means the process thatis done to get an image with smaller pixels while retaining the information inside the image. As can be seen in Fig. 5, Pooling Process on CNN

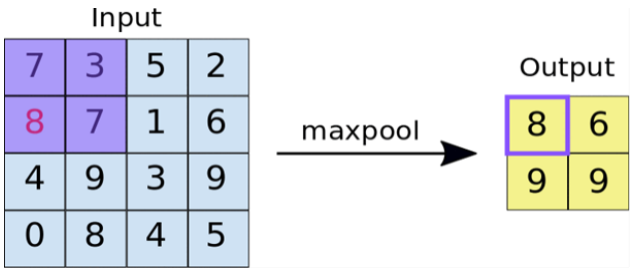


Fig 5. Pooling Process On CNN

Convolutional Neural Network (CNN) is a type of architecture in artificial neural networks commonly used in image processing and other grid-structured data such as video, text sequences, or spatial data. CNNs have several core components that allow them to effectively learn the hierarchical features of the input data.The formulas in CNN can be seen from each component:

1. Convolution Layer:

convolution operation formula that can be seen in Fig. 6. Convolution Formula

$$(f * g)(x, y) = \sum_{i=1}^{m} \sum_{j=1}^{n} f(i, j) \cdot g(x - i, y - j)$$

Fig 6. Convolution Formula

Dimensions that can be seen on Fig 7 : Output Dimension Formula To calculate the output dimensions of the convolution layer:

$$\text{Output Dimension} = \frac{\text{Input Dimension} - \text{Filter Dimension} + 2 \times \text{Padding}}{\text{Stride}} + 1$$

Fig 7. Output Dimension

Where the input dimension is the dimension of the input data, the filter dimension is the filter dimension, the padding is the number of pixels added around the input, and the stride is the step of the filter move.Pooling Layer:

• Max Pooling Operation:

Max pooling takes the maximum value of each discrete region in the input data, reducing the dimension of the data and helping to reduce computing.

Average Pooling Operation:

Average pooling takes the average value of each discrete region in the input data.

• Fully Connected Layer:

There is usually no specific formula in this layer. However, the common operations performed are: Output = Activation (Input × Weights + Bias)

Output = Activation(Input×Weights+Bias)

Inputs are multiplied by weights, added by bias, and then activated by the activation function.

• Backpropagation: Gradient Descent:

Apply chain rules to calculate gradients of errors and change the weight and bias of each layer according to the gradient, using methods such as stochastic gradiant descent (SGD) or other variants such as Adam, RMSprop, etc.

CNN uses these layers to hierarchically extract features from data, from simple features like edges or angles to more complex features like facial patterns or more abstract objects. These formulas form the basis of operations that take place in each layer of CNN to study representations of input data.

3. Result and Discussion

The study is as follows:

1. Restrictions on Real-Time Health Monitoring of Sage Plants and Fish: From the results of the study, it can be concluded that society still does not have the technology capable of monitoring the health of sage plants and fish in real-time. This can affect the fertility and productivity of salmon crops as well as the health of fish in the breeding system. This limitation may make it difficult to detect rapid changes in the conditions of plants and fish, making responsive action difficult to take. A possible implementable solution is the development of tools or applications that enable continuous monitoring of the health of plants and fish so that problems can be identified early and corrective measures can be taken in a timely manner.

2. Sub-optimization of the land of the home page: Based on the results of the study, it can be concluded that most communities have not optimized the available land of their home. This may be due to a lack of knowledge or motivation to use the land efficiently, both for agricultural and fish farming purposes. The impact of this suboptimization of land includes the potential waste of land resources that can actually be utilized to increase household food production. Possible solutions include educating and training the public on how to make productive use of land and providing successful examples of urban farming practices. Based on observations carried out in the village of Perlang Bangka Belitung and previous research conducted by Erika dkk entitled "Environmental Management through Aquaponic and Hydroponic Culture Education as an Alternative Solution for the Utilization of Land for the Community of the Village of Bangka Perlang Belitung," the problem of the aquaponic system is the management of the environment through aquaponics and hydroponics. Culture education as an alternative solution to the use of land for the rural population of Perlong Bangka Middle is an educational activity to give insight to the community in managing the environment. (Erika, 2022)

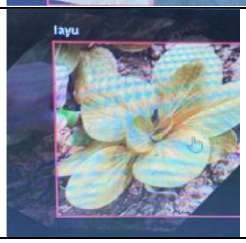
Based on the problems that have been described, the author designed AI-based technology. The application of AI dedicated to this work uses deep learning techniques, namely CNN. According to the research of the Department of Health entitled "Identification of Diseases on Leaf Images Using Convolutional Neural Network (CNN)," the CNN deep learning method can be implemented for the identification of disease images on leaves. The highest accuracy of the training data reached 93% and the highest validation data achieved 99%, so it could be concluded that metoed deep learning CNN can identify disease images on the leaf well. (Lesmana et al., 2022)

The table and discussion below are data from sensors used in AI-based aquaponics technology. AI-based aquaponic technology uses cameras that function to monitor plants in real-time. Data from the camera will be processed and analyzed by the AI system so that automatic monitoring of the plant growth environment in the system can be carried out.

Table 1. 3-Day Research Data

3-DAY RESEARCH DATA

Imagery	Day 1	Day 2	Day 3	Label

	0.12	0.85	0.24	Healthy mustard greens
	0.02	0.76	0.45	Mustard greens wither soon
	0.78	0.44	0.63	Withered mustard greens

Based on research that has been conducted by researchers for 3 days, which can be seen in Table 1, Researchers obtained the following results after collecting research data for three days:Each row represents one image.• Feature 1 through Feature N are feature values extracted from each image.• The label shows the category of the image (healthy mustard, wilted, soon withered). This table of data will later be broken down into training data and test data. The training data will be used to train the CNN model, while the test data will be used to test how well the model can classify new images that have never been seen.

4. Conclusions

This research has investigated the growth monitoring system of sawi plants using artificial intelligence in aquaponics. The results of this study reveal some important aspects that can be concluded and suggested:

1. Aquaponics technology can help the public monitor the health of plants so that they can know the health and well-being of the plants on a daily basis.

2. Aquaponics technology can help communities with the problem of a lack of land to fit plants. Communities can fit plants in their home environment.

3. This future technology will be developed using solar panels as its power source.

4. This future technology will be developed for a variety of other plants.

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