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Environmental Lighting towards Growth Effect Monitoring System of Plant Factory using ANN

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ABSTRACT

Malaysia is currently driven to become another most developed country in the world. Among other priority sector is Food Sustainability. Along the process, our vegetable supply-demand keeps increasing by year. Compared to traditional systems, closed systems or its other name called hydroponic is getting more important for plant production, with artificial light which has many potential advantages, including better quality transplants, shorter production time and less resource use. To gain full profit from it, the quality of vegetables needs to be controlled efficiently. Climate conditions, especially temperature and light intensity, have a significant impact on vegetable growth and yield, as well as nutritional quality. Plant growth and development are influenced by a variety of environmental factors, the most important one is light intensity. Among the problems to be tackled in this research are plant growth manual observation, light intensity variation and abundance of growth-related data to be evaluated manually. Therefore, to solve these problems, the specific type of vegetable used here is lettuce. The proposed methods are, observation of plant growth conducted automatically round the clock in intervals of 15 minutes for the whole month (estimated mature period of lettuce), using images captured. At the same time, the proposed light intensity which is red & white to the ratio of 2:1 (optimum ratio recommended by previous researchers) will be used. The issue of data to be evaluated manually will be solved using Artificial Neural Network (ANN) architecture, in specific Deep Learning. Concisely, the results & analysis shows the research is successfully developed for plant growth monitoring by using artificial neural network which, reached 80% to 90% accuracy in the training and validation session that made the architecture sufficient for determining the growth of the said vegetable. This is indeed foreseen, will highly assist the farmer in better monitoring the growth rate of the plant.

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1. Introduction

When compared to traditional systems, closed systems or its other name called hydroponic is important for plant production, with artificial light which has many potential advantages, [1] including better quality transplants, a shorter production time, and less resource use. To gain full profit from it, the quality of lettuce needs to be controlled frequently. This will increase the profit as the quality of the lettuce is controlled to the best. Hardware development is stages where all hardware of this research has been assembled [2]. This research is to determine the growth rate of lettuce. This research was done to find the gaps in the existing research and viable solutions to overcome these gaps in the future [3].

However, there are a few problems that will prevent the smoothness in doing this research which is first growth of lettuce is difficult to be monitored manually as it takes time to grow [4]. Next, humans have their limit in differentiating when the lettuce keeps growing as they only show a littledifference [5]. Humans also cannot spend every 15 minutes observing the plant for 24 hours straight.

Next, there is a various spectrum and intensity of light. The different intensities of Photosynthetic Photon Flux Density (PPFD) and photoperiod will produce different growth of lettuce [6]. There are some refinements based on this method [7]. There is the specific value of PPFD and photoperiod that will make the quality of lettuce increase however there is also the value of PPFD, and photoperiod will make the opposite [8]. Another problem is that there is too much data to manage or verify manually by humans as there are several values of light intensity of PPFD that need to be supplied to the lettuce [9]. This may cause difficulty in observing the data as it will produce a lot of data. The quality of lettuce was evaluated by measuring several physiological indexes [10]. The value of PPFD and photoperiod will determine the lettuce growth [11].

The hardware and software are done and integrated together to successfully finish the prototype [12]. MATLAB software and Deep Learning, used to simulate the data obtained from the growth of lettuce. Deep Learning can be thought of to automate predictive analytics [13]. The ANN used is Convolutional Neural Network (CNN) as this is the most effective neural to adapt with image. CNN will memorize every image detail given and the architecture can spit out which is the correct one. This method may seriously affect the diagnostic process and its outcome, especially if an automatic computer-based procedure is used to derive diagnostic parameters [14]. CNN is one of deep learning architecture which is used to enhance traditional Multi- Layer (ML) by adding “depth” (complexity) to the model and changing the data using various that hierarchically allow data representation, across many levels of abstraction. This approach is simple, however very effective [15]. Deep Learning solutions will require a vast collection of pictures. The number of pictures, image dimensions, number of channels, and number of levels per pixel is the most common image data input parameters. deep learning architecture. This architecture contained the input layer, hidden layer, and lastly output layer. The hidden layer will consist of a few types of a layer such as convolution layer, etc. [16].

2. Methodology

2.1 Introduction

This research will all be managed by Artificial Intelligence (AI), Arduino, MATLAB, and WIFI to get the result. For the first phase, the research is well drafted to ensure that the research will be conductedcorrectly according to the flow. So, the flowchart has been made to make things easier and all work will go according to the flow of the flowchart. Hence, the flowchart must be followed precisely. Figure 1 shows the flowchart of the overall research. The literature review is about the

background study of the research, and it contains all the data and the background of this research. This part is more focused on obtaining information about lettuce.

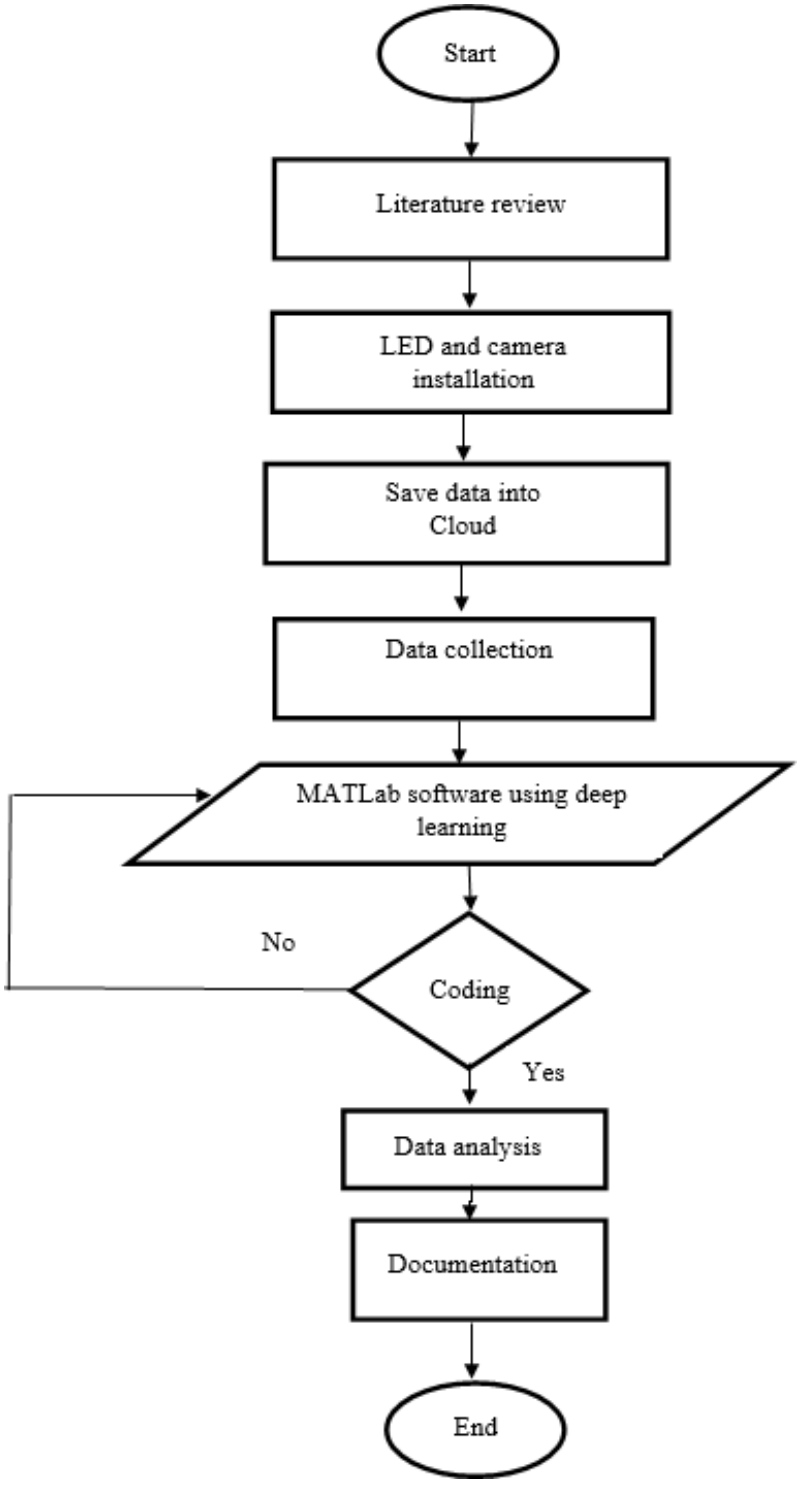

Fig. 1. Flowchart of the Research

Next, the camera has been selected which is able to connect to WIFI and it will be installed at the hydroponic plant. This camera will capture the image every 15 minutes in 24 hours and save it in the cloud. After that, when the system is complete, MATLAB software is used to run the coding. If the coding is successful, it will continue to show the data graph. If coding is not functioning, it will repeat the previous step.

Finally, all the data will be collected and analysed. All the data obtained will be documented in this paper.

2.2 System Design

The hydroponic was designed to plant lettuce. Material selection mainly depends on howeasily they can be shaped [17]. The hydroponic system here will use IoT to operate the fan using Blynk App. Then, a camera will be installed to capture the image of the hydroponic plant every 15- minute using ESP-Cam 32 which operates with Arduino Ide. The coding of Arduino will make the camera capture images every 15 minutes and send it to cloud storage using Wi-Fi. The image will be recorded for 30 days straight. This is because the lettuce growth rate is about 6-8 weeks [18]. After that, the image will be gathered and be used in deep learning for image processing using MATLAB coding whichthen will produce a graph to see the training and validating accuracy of the image. So, by using deep learning, it will recognize the growth pattern of the plant from the training session and be able to tell if the plant is growing perfectly or not. This will be performed by testing other images from the training to evaluate the accuracy of the training phase.

The hydroponic system in Figure 2 uses is two here, as for the first one, the system will be installed with the fan to make the system have airflow within it and the second system will not have airflow.

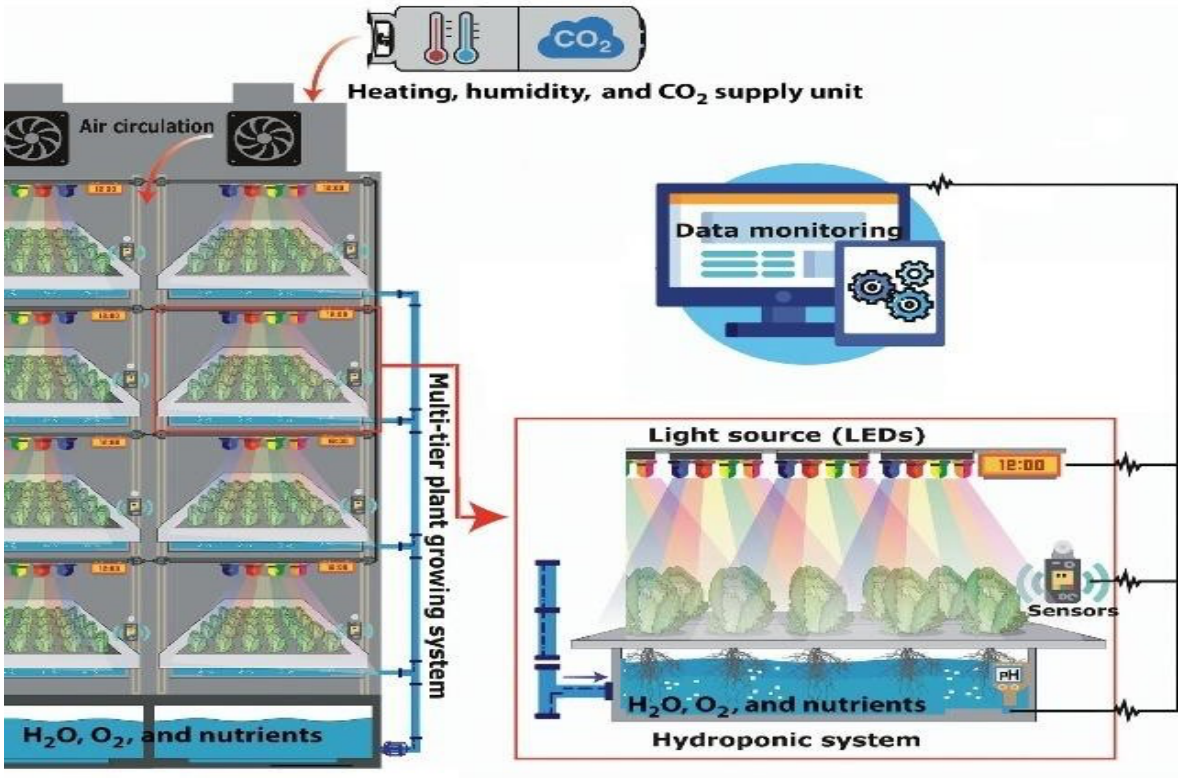

Fig. 2. Hydroponic System

The pot used for every hydroponic system is four pots which means the total pot will become eight. In this experiment, the same step has been taken from previous assessment [19]. The total image taken for the whole research would become approximately 23040 images to be used in the deep learning training. The image will be split into a few phases. A phase will contain all images for a week and will be labelled according to their growth. Then the process will continue until the expected result is obtained at the end of the research. The lighting was installed about 9-12 inches above the

lettuce as the calculation of the light intensity was done and the result was 9-12 inches. This is because the lighting installed is 590nm to 695nm of the spectrum. When converting the spectrum to distance, the value is 9-12 inches is the perfect range to apply between the light and plant [20].

3. Results

3.1 Phase 1

The image collected is from week one which is called phase 1. Figure 3 shows the image from this phase.

Fig. 3. Plant 50mm

The total images collected for this phase is approximately four hundred. It is seen that the average highest growth of the plant in phase 1, is 50mm in height on day seven.

3.2 Phase 2

The image collected is from week two which is called phase 2. Figure 4 shows the image from this phase.

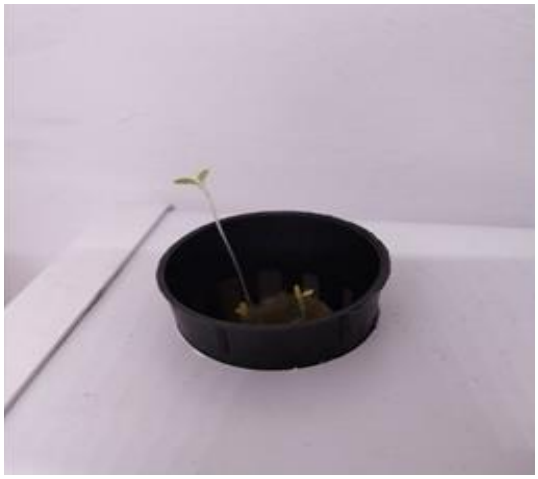

Fig. 4. Plant 61mm

The total images collected for this phase is approximately 2520. It is seen that the average highest growth of the plant in phase 2, is 61mm for day eleven.

3.3 Phase 3

The image collected is from week three, which is called phase 3. Figure 5 shows the image from this phase.

Fig. 5. Leaf sprout 40mm

The total images collected for this phase is approximately 1600. It is seen that the average highest growth of the plant in phase 3, is 40mm for day fifteen. It is also observed that the plant died after day eighteen on week three.

3.3.1 Layer used in deep learning

The deep learning architecture was created in MATLAB Software and the coding will be run to train the data given to it and it will produce the actual result. Variation between data will make deep learning be able to differentiate features, characteristics and perform accurate classification. The layered uses for basic deep learning are the 2-input layer, sixteen convolution layer, sixty-four hidden layer, and 4 output layers. The same procedure is done for modified designs in the analysis software [21]. In this paper only Phase 1 growth of the plant is presented, because the other three phases are the repetitive of Phase 1 in Deep Learning method.

3.3.2 Phase 1

The image collected in this phase is less than the other phases as the image can be taken after the lettuce shows the divergence of the growth which is day seven. The image taken in this phase is aboutfour hundred images.

3.3.2.1 Data split to 4 classes according to their growth

Figure 6 shows the randomized image from the overall image taken in the folder. The image was split into four classes is 34mm, 40mm, 45mm, and 50mm.

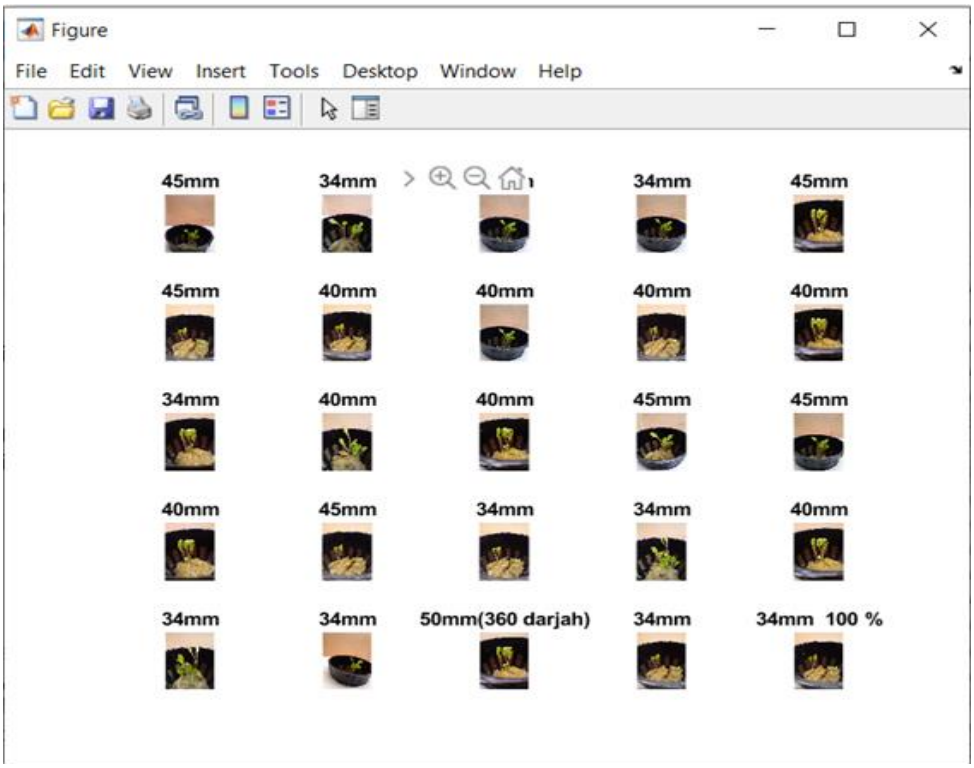

Fig. 6. Image from Every Class for Phase 1

This is the growth measured in length of all plants inthe first phase and the lowest growth is 34mm while the highest growth is 50mm. This figure shows that the network successfully read the image per class that has been constructed.

3.3.2.2 Training and validation graph

Figure 7 shows the training progress from processing the image for every class that has been created.

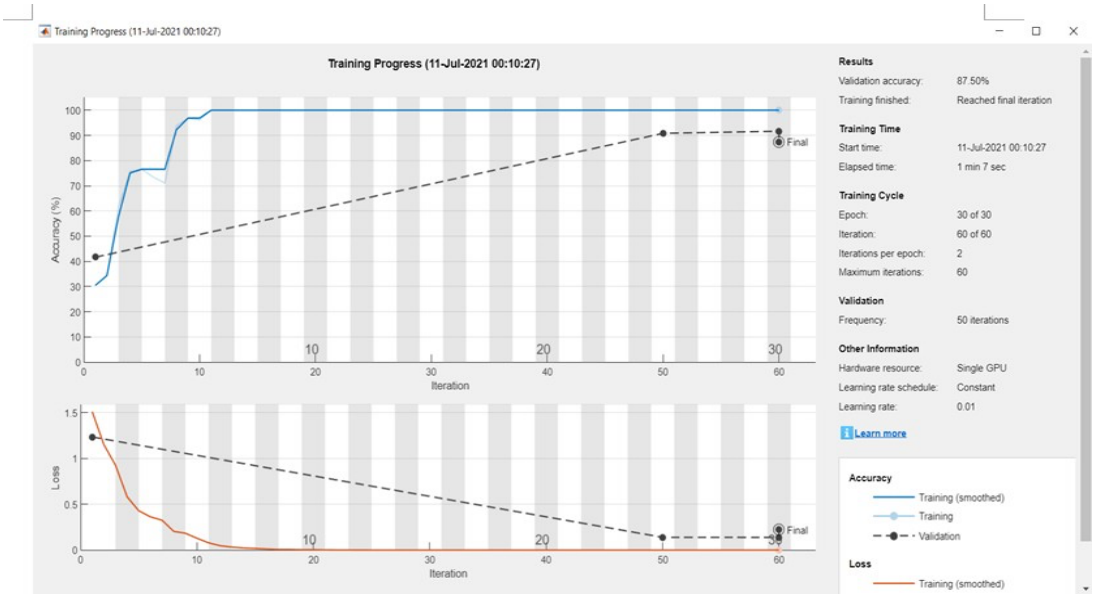

Fig. 7. Training and Validating Graph for Phase 1

By having 87.5% accuracy, the loss will be nearly zero. However, the deep learning architecture is still not perfect yet as the accuracy is not 100%. The blue line shows the training accuracy of the data, while the red line shows the loss of accuracy. The black dot line shows the validation accuracy.

3.3.2.3 Training and validation accuracy

Figure 8 shows epoch, iteration, mini-batch accuracy, and validation accuracy.

```
Training on single GPU.
Initializing input data normalization.
|=========================================================================================================================|
|  Epoch  |  Iteration  |  Time Elapsed  |  Mini-batch  |  Validation  |  Mini-batch  |  Validation  |  Base Learning  |
|         |             |   (hh:mm:ss)   |   Accuracy   |   Accuracy   |     Loss     |     Loss     |      Rate       |
|=========================================================================================================================|
|       1 |           1 |       00:00:04 |       21.09% |       26.67% |       1.4074 |       1.3880 |          0.0100 |
|      25 |          50 |       00:00:56 |      100.00% |      100.00% |  3.5695e-05  |       0.0111 |          0.0100 |
|      30 |          60 |       00:01:08 |      100.00% |      100.00% |  2.6226e-05  |       0.0084 |          0.0100 |
|=========================================================================================================================|
```

Fig. 8. Training and Validation Accuracy Phase 1

The training and validation accuracy depends on the mini-batch accuracy, epoch, and iteration. Iteration per epoch is the number of training samples divided by minibatch size. The network is being trained with thesame data thirty times.

3.3.2.4 Testing the deep learning architecture

Figure 9 to 12 shows the test result from the deep learning architecture and all the result obtained was correct according to the training data.

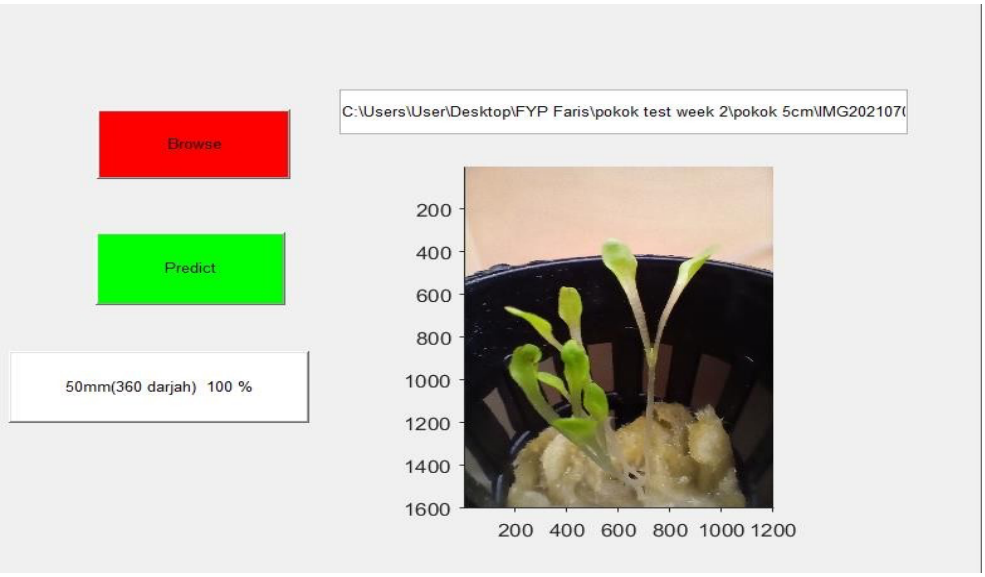

Fig. 9. Test 1 (day 7)

This image shows the Test 1 unit of the plant which has grown to 50mm as displayed through Deep Learning ANN processing architecture. This is the 50mm class.

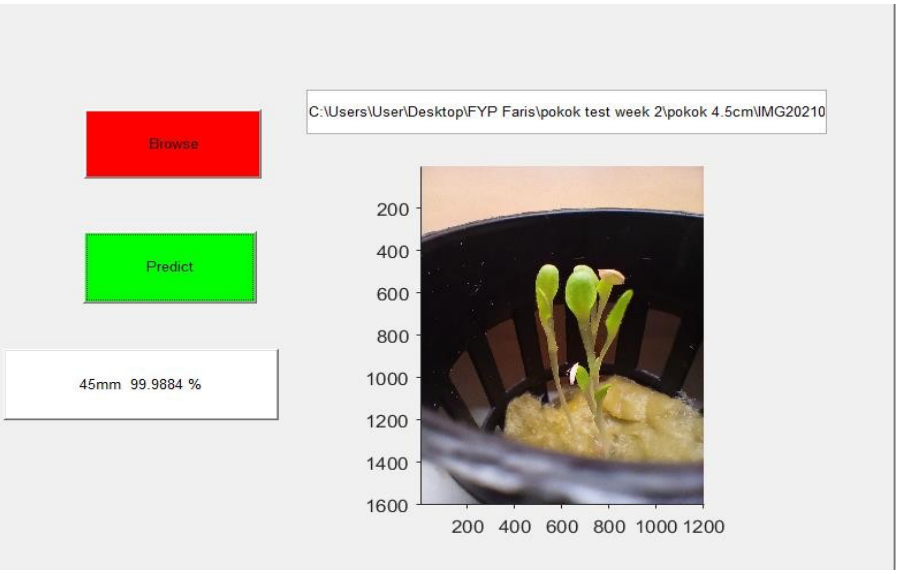

Fig. 10. Test 2 (day 7)

Whereas this image shows the Test 2 unit of the plant which has grown to 45mm as displayed through Deep Learning ANN processing architecture.

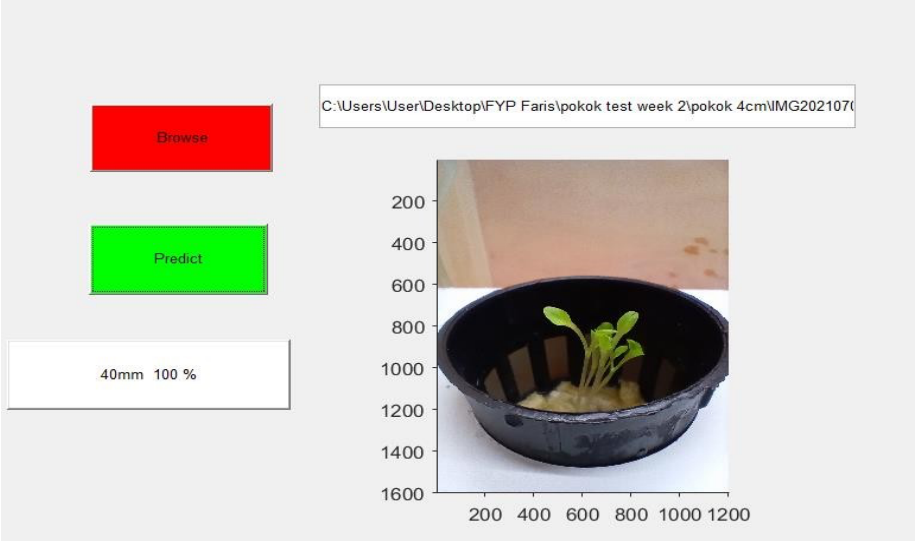

Fig. 11. Test 3 (day 7)

In the meantime, this image shows the Test 3 unit of the plant which has grown to 40mm as displayed through Deep Learning ANN processing architecture.

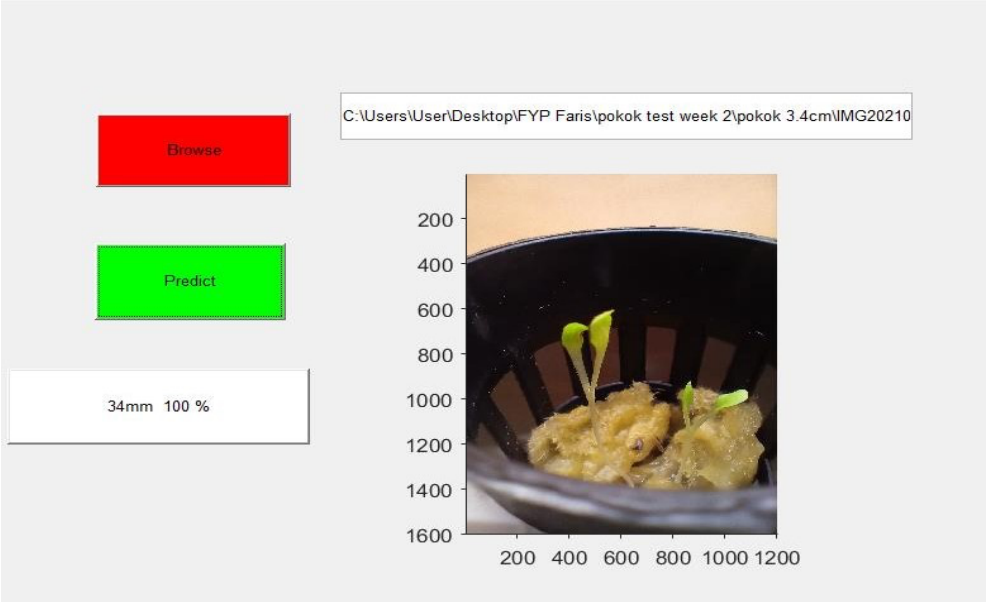

Fig. 12. Test 4 (day 7)

The images used as the test set are different from the images used as the training set image. This proves that Deep Learning is successfully created. Figure 9 to 12 shows the test prediction by inserting other images from the training data to the training network to be recognized. All the data has been collected and documented in this paper [22].

4. Conclusions

Finding the lowest ideal light intensity is crucial for commercial lettuce production in a regulated indoor setting since doing so will result in a yield that is satisfactory while using the least amount of energy. Thus, according to the progress, effectiveness, and energy needs were proved that lettuce may be produced commercially. In artificial light plant factories, LED light sources provide benefits in terms of energy usage and lettuce quality, and they can totally replace fluorescent lamps. However, it is important to assess the effectiveness of LED light sources using efficiency, quality, attenuation properties, and life expectancy of the light source. Its impact on plant culture and performance evaluation should be subjected to proper testing and evaluation. It may be important to do more research on the impact of different LED light combinations to further improve lettuce growth and quality. Finally, this research has achieved the objective successfully and went well. The deep learning architecture was successfully done as the accuracy obtained from training result is 80-90% andthe testing part was able to gauge the height of the lettuce.

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