A Novel Automatic Detecting System for Cucumber Disease Based on the Convolution Neural Network Algorithm

NGO Quang Uoc[1,2], NGO Tri Duong[2], LE Anh Son[3], and BUI Dang Thanh[4,*]

ARTICLE INFO

Article history:
Received: 13 April 2021
Revised: 31 May 2021
Accepted: 14 June 2021

Keywords:
Cucumber
Disease
YOLO
AI

ABSTRACT

The paper presents research on the convolutional neural network algorithms (CNN) applied to the determination of downy mildew and powdery mildew diseases in cucumbers in Vietnam. Three separate areas for growing cucumbers were deployed: the first with a natural crop that was free of diseases, the second area is a cucumber tree with downy mildew and the final area in the cucumber area that was contaminated with powdery mildew. An automated system was developed to collect images of cucumber leaves in the three areas above, classify them and put them into a database. This dataset was then trained according to the CNN and imported into the system to give real-time alerts to farmers. A total of 7640 pictures collected in three areas during three months will be used for automatic detection of disease based on artificial intelligence (AI). The results indicated that CNN has achieved more than 80% accuracy. That has good performance with high accuracy, and it can automatically detect and sent the message to the farmers based on our system. The results open various opportunities for new research to enhance the accuracy as well as to add other diseases for detection.

1. INTRODUCTION

Vietnam is an agricultural country, with the key exporting products that are rice and vegetables. Cucumber is a popular plant in Vietnam. Vietnamese people plant it everywhere, especially concentrated around the Red River Delta and Mekong Delta. The area which is used to plant cucumbers are net houses and it increases every year [1]. In recent years, applying new technology for cucumber is one of the key points to improve the quantity and quality of cucumber such as net house technology, environment monitoring technology, artificial technology, and so on.

An algorithm based on the convolution neural network (CNN) model to detect, identify, and classify objects in real-time is called YOLO. It was developed by Joseph Redmon et al. in 2016 by a combination of convolutional layers to extract the feature and connected layer to detecting [2]. The YOLO is developed through four versions to make the model faster and more accurate [3-5].

For agriculture, YOLO is also applied in various applications. In 2020, Achuyut applied YOLO v3 for detecting some diseases for plants such as apple, corn, tomato with the database from Plant Village. On the other hand, Dihua Wu focused on faster detection using YOLO v4 for real-time but the accuracy was reduced [6]. By applying the Support Vector Machine (SVM), Lili Zhu can find the error in the banana of 96.4%. In addition, some other researchers have also used YOLO for detecting diseases but mostly for apple and tomato [7-10]. Some scholars focused on size measurement; fruit recognition based on computer vision techniques. However, there has been limited study on cucumber diseases, which affects remarkably the farming and producing works of Vietnamese farmers.

Fig. 1. Cucumber plant in Vietnam.

[1]*Institute for Control Engineering and Automation, Hanoi University of Science and Technology, Hanoi, Vietnam.*
[2]*Faculty of Engineering, Vietnam National University of Agriculture, Hanoi, Vietnam.*
[3]*Faculty of Vehicle and Energy Engineering, Phenikaa University, Hanoi, Vietnam.*
[4]*School of Electrical Engineering, Institute for Control Engineering and Automation, Hanoi University of Science and Technology, Hanoi, Vietnam.*
**Corresponding author:* BUI Dang Thanh; Tel.: +84 24 3868 3518; E-mail: thanh.buidang@hust.edu.vn.

With the development of mechatronics, nowadays Vietnamese farmers grow cucumbers in net houses with a very large crop area. The need for automatic disease detection and warning to support people in taking care of cucumbers is very urgent. To solve this problem, we propose a system that can automatically classify the cucumber diseases, will be investigated and developed.

The system was created by using real-time detection under natural conditions based on YOLO v4. First of all, the data will be collected to make the trained dataset. Then, the YOLO v4 object detection model was applied for accurate and fast detection of cucumber diseases. Finally, based on the result of YOLO v4, the message will automatically be sent to the farmers for warning.

In order to create a completed solution for the farmers for automatic cucumber disease detection, we investigated and selected two diseases for cucumber including downy mildew and powdery mildew, then applied YOLO for training data. The trained data will be used for automatic detection and give feedback to the farmers.

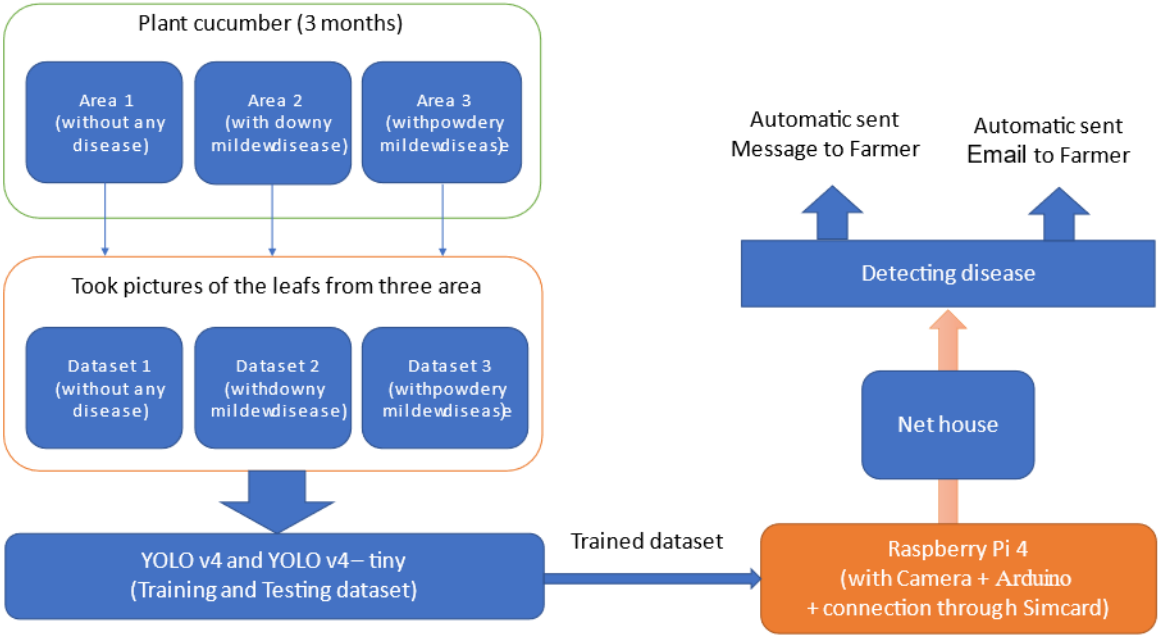

Fig. 2. Data flow Diagram.

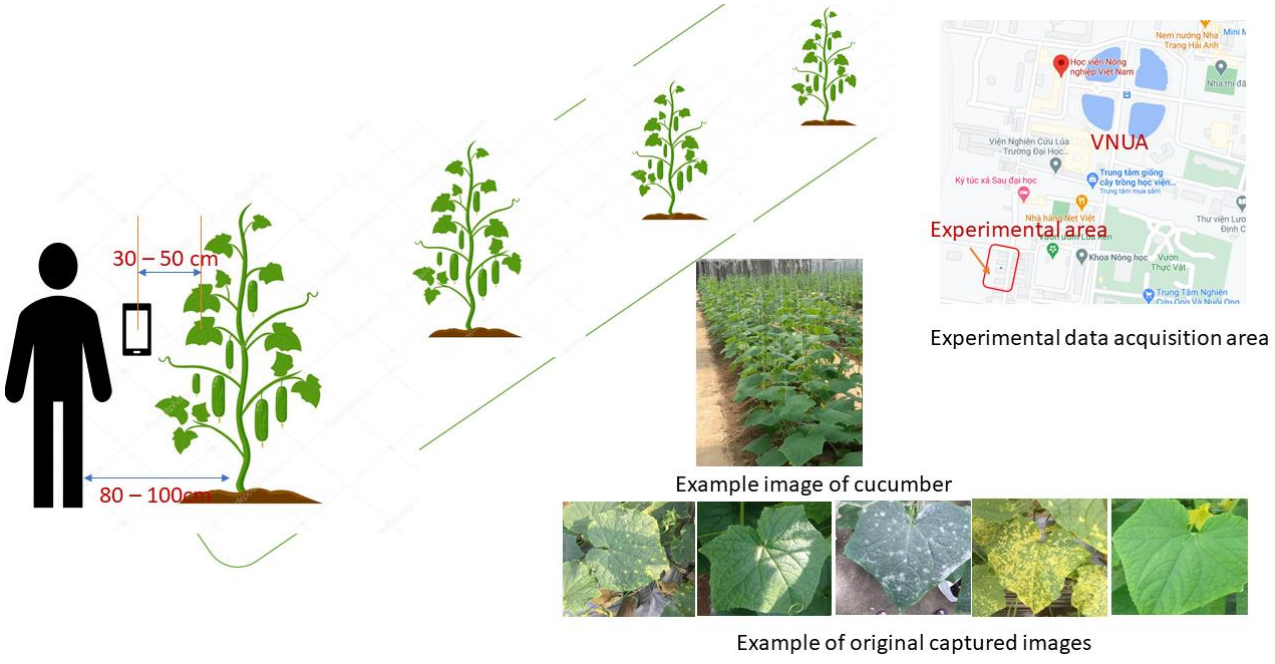

Fig. 3. Sample collection.

2. METHODOLOGY

The Procedure

In order to build a dataset on the diseases of cucumber plants, three separated areas will be used to plant the cucumbers, in which the first area is the place to grow cucumbers naturally without any disease, the second area plants the cucumbers with downy mildew, and the last area plants the cucumber with powdery mildew. To collect the dataset for YOLO v4, pictures were taken in three areas and then preprocessed by resizing and labeling. 80% of the dataset will randomly be selected to train using YOLO v4 and YOLO v4-tiny while the rest 20% of the data set was mixed and used for the testing model.

After having the trained dataset, the model will be confirmed by test data and then applied to the real cucumber net house for detecting the disease as well as verifying the function for automatic email and message sending to the farmers. The detail of the procedure is shown in Fig.2.

Sample collection

In this research, 75 cucumber trees infected with powdery mildew, 100 cucumber trees infected with downy mildew, and 110 healthy cucumber trees were collected from the Vietnam National University of Agriculture (VNUA). The images of these samples were captured from October 2019 to December 2020 under various day time and weather conditions and labeled. A total of 7640 images were collected including 2949 images with powdery mildew, 2199 images with healthy cucumber, and 2492 images with downy mildew. The detail of the collection method is shown in Fig. 3.

CNN Algorithm

The algorithm exploited in this study for realizing the accurate and rapid detection of cucumber disease in a natural environment. Therefore, the data will manually be labelled and trained using YOLO v4 (Fig.4). Because of the ease of applying on Raspberry Pi, the YOLO v4-tiny was also applied in this study (Fig.5) [11].

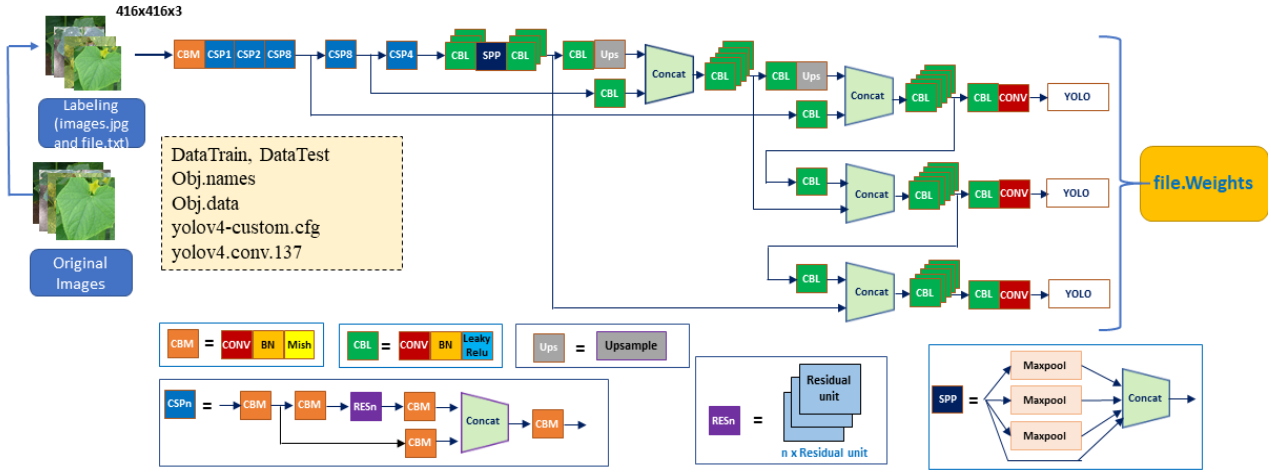

Fig.4. YOLO v4 mathematical algorithm.

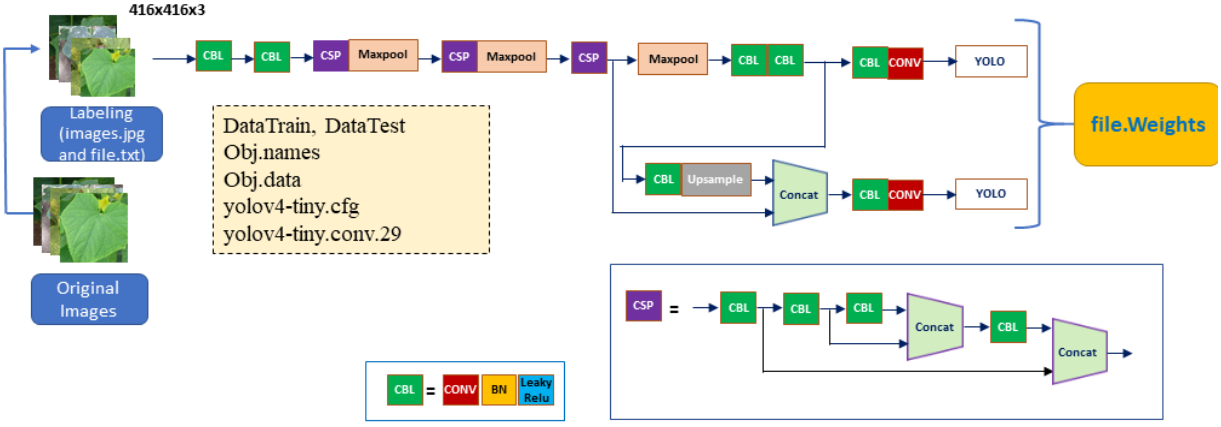

Fig.5. YOLO v4-tiny mathematical algorithm

For checking the performance of the YOLO v4 and YOLO v4-tiny, the precision, recall, mAP, IoU, and F1-score (1) – (5) are used to evaluate here: TP (true positive), FP (fault positive), TN (true negative), FN (fault negative); R is the detected area of the object bounding box, R' is the actual area of the object bounding box; the *mAP* is the average value of the average precision (AP) when a cucumber leaf is detected.

$$precision = \frac{TP}{TP + FP} \times 100\% \quad (1)$$

$$recall = \frac{TP}{TP + FN} \times 100\% \quad (2)$$

$$mAP = \frac{\sum_{c=1}^{C} AP(c)}{C} \quad (3)$$

$$IoU(R, R') = \frac{|R \cap R'|}{|R \cup R'|} \quad (4)$$

$$F1 - score = 2 \times \frac{precision \times recall}{precision + recall} \quad (5)$$

Table 1 shows the detailed parameters for training the model for YOLO v4 and YOLO v4-tiny.

Table 1. Parameter

Parameters	YOLO v4	YOLO v4-tiny
Input size	416 x 416	416 x 416
Learning rate	1.1×10^{-3}	2.61×10^{-3}
Batch_size	64	64
Classes	3	3
Iterations	8000	8000
Filters (before each of the [YOLO] layers)	24	24

3. RESULTS AND DISCUSSION

YOLO v4 and YOLO v4-tiny

To classify the two types of cucumber diseases by YOLO v4 and YOLO v4-tiny, 1484 data test images were used. By changing the iteration, the model shows good performance with high accuracy at 4000 iterations for YOLO4 and 8000 iterations for YOLO v4-tiny. The detail of the results is shown in Table 2 and Table 3.

Table 2. Detection results of cucumber disease by YOLO v4

Iteration	AP powdery mildew	AP healthy	AP downy mildew	mAP	Size/ resolution	precision	recall	F1-score	average IoU
1000	76.67%	76.38%	50.56%	67.87%	416x416x3	0.56	0.73	0.64	42.49%
2000	83.51%	79.96%	69.49%	77.65%	416x416x3	0.58	0.85	0.69	47.08%
3000	83.09%	83.17%	70.68%	78.98%	416x416x3	0.7	0.78	0.74	58.56%
4000	84.48%	84.95%	72.84%	**80.76%**	416x416x3	0.66	0.83	0.73	56.60%
5000	78.61%	82.16%	68.75%	76.51%	416x416x3	0.6	0.83	0.69	49.72%
6000	83.43%	85.21%	69.91%	79.52%	416x416x3	0.6	0.84	0.7	51.88%
7000	82.52%	83.29%	74.96%	**80.26%**	416x416x3	0.66	0.82	0.73	**57.27%**
8000	79.33%	84.11%	73.61%	79.01%	416x416x3	0.67	0.8	0.73	58.89%

Table 3. Detection results of cucumber disease by YOLO v4-tiny

Iteration	AP powdery mildew	AP healthy	AP downy mildew	mAP	Size/ resolution	precision	recall	F1-score	average IoU
1000	72.31%	70.85%	57.10%	66.75%	416x416x3	0.56	0.67	0.61	39.76%
2000	81.93%	82.80%	73.19%	79.31%	416x416x3	0.55	0.83	0.66	45.16%
3000	80.68%	84.19%	70.49%	78.45%	416x416x3	0.59	0.81	0.69	49.63%
4000	81.46%	85.66%	72.66%	79.93%	416x416x3	0.57	0.83	0.68	48.07%
5000	82.45%	85.10%	73.75%	80.43%	416x416x3	0.57	0.83	0.68	47.86%
6000	83.28%	85.11%	74.23%	80.87%	416x416x3	0.62	0.79	**0.7**	**52.22%**
7000	83.18%	85.56%	74.92%	81.22%	416x416x3	0.58	0.83	0.68	49.95%
8000	83.61%	85.68%	75.75%	**81.68%**	416x416x3	0.59	0.83	0.69	50.43%

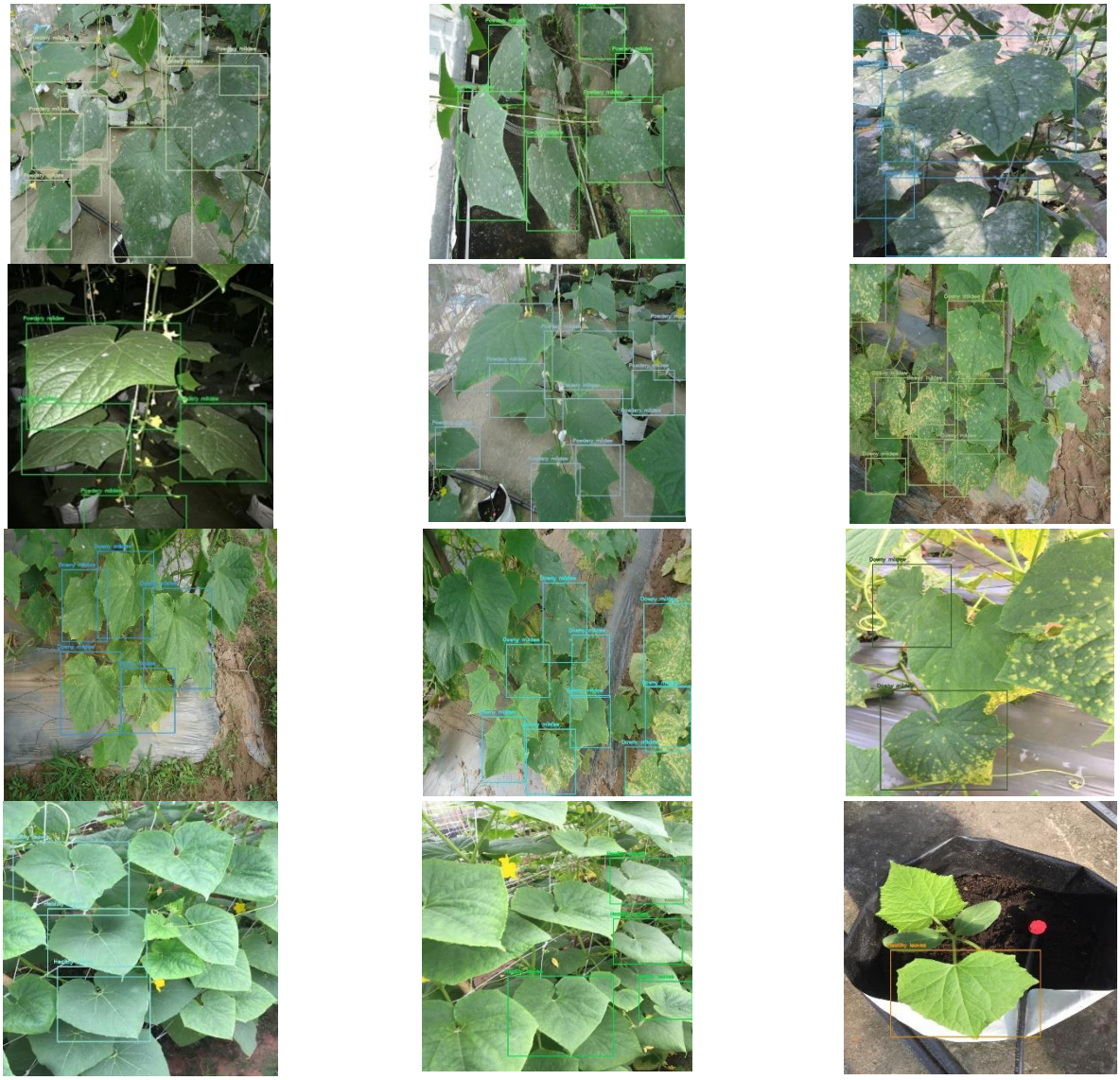

Fig. 6. Performance of YOLO v4-tiny at 8000 iterations

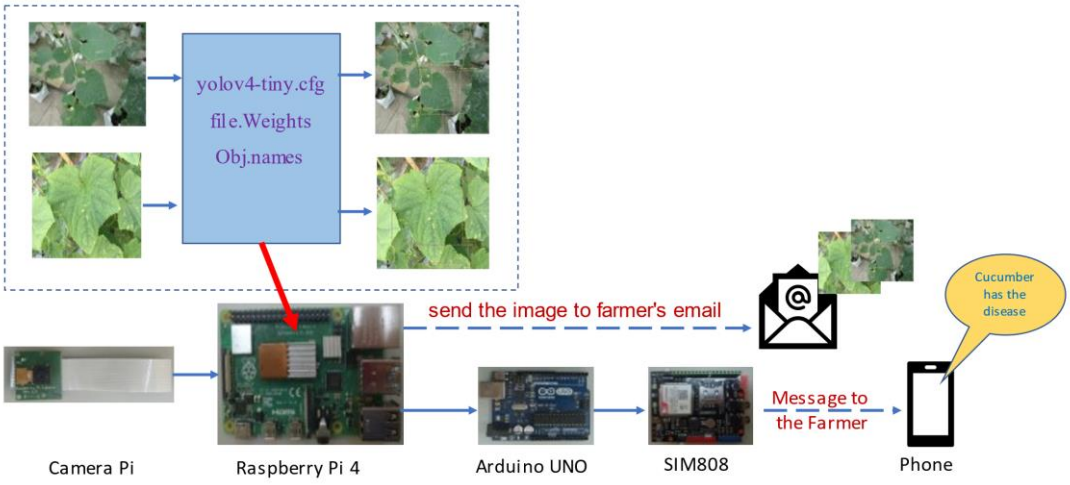

Fig. 7. Auto detecting cucumber disease system with Raspberry Pi 4.

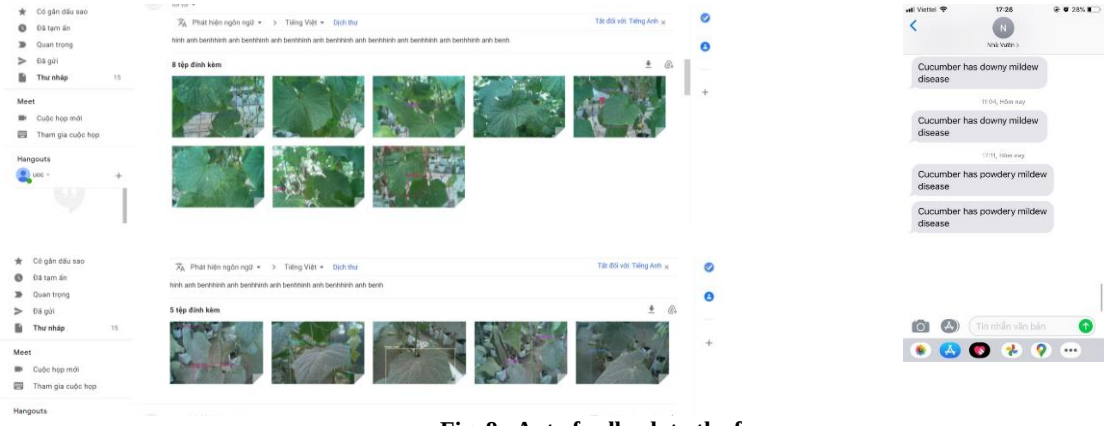

Fig. 8. Auto feedback to the farmers

Based on the results of Table 2, 3, the YOLO v4-tiny shows very good performance at 8000 iterations with the mAP of 81.68%, F1 score of 0.69, recall of 0.83, and average IoU of 50.43%. Furthermore, YOLO v4-tiny works well on the Raspberry Pi, which has an acceptable price for the farmers. Therefore, the YOLO v4-tiny with 8000 iterations will be selected for making the system for automatic detect cucumber disease. The results of detection in the real situation are shown in Fig. 6.

The automatic detecting cucumber disease system

Based on the results of detection, the Rasberry Pi 4 Model B Rev 1.1, Ram 1GB with camera board v1.3 5MP, together with SIM808 module for internet communication through Simcard, the system was created and installed for checking the performance. The completed system is shown in Fig. 7. The system shows good performance with the feedback to the farmers in two methods: email and message (Fig. 8).

4. DISCUSSION

Cucumber is one of the most popular and important vegetables for human beings. Therefore, the applying techniques for helping the farmers play a very important role for plant and it may help to reduce a lot of effort while planting a tree. Some researchers focus on the nutrient for cucumber [12] or some focus on finding the reason for the disease [13-15]. However, automatic detection of disease also becomes a hot topic while artificial intelligence contributes a lot to agriculture. In 2019, Ke Lintriesy uses deep learning and convolution neural networks for segmentation and qualification powdery mildew [16], the results show high accuracy from 72.11% to 96.08%. Pan Zhang also doing the recognition of cucumber disease under a natural complex environment by efficientNet-B4-Ranger [17] with 97% accuracy. However, both Ke Lin and Pan Zhang using a very complex mathematic algorithm so it needs a very powerful computer for running, which is not the suitable price for applying in the real situation, especially in poor countries such as Vietnam.

In our research, a low cost, artificial intelligence and Raspberry PI computer-based disease detection system for cucumbers has been implemented. The initial accuracy has reached 80%, if the data sets increase, the accuracy of the model will be increased and become a good solution to help farmers.

5. CONCLUSION

This paper presents a method using the convolution neural network model algorithm (YOLO v4) for detecting cucumber disease. We have successfully developed downy mildew and powdery mildew dataset in the cucumber plants in Vietnam. Applying artificial intelligence according to YOLO v4, the obtained accuracy is more than 80% compared to the standard data set. These are very positive initial results in the application of artificial intelligence in smart agriculture in general and in monitoring and care of cucumbers in particular.

Furthermore, our scientific contribution also includes a complete solution for detecting cucumber diseases and it can help other researchers in:

- using the database of cucumber disease, which can be applied for other research in the future to reduce the time for collecting the data.
- expanding the system and adding other measurement parameters to monitor the health of cucumber plants in Vietnam.

We hope to improve the accuracy of cucumber disease identification by further building the downy mildew and powdery mildew disease data set, to progress to system design for monitoring, warning and spraying eliminate diseases on cucumbers.

REFERENCES

[1] A. Morbekar, A. Parihar, and R. Jadhav. 2020. Crop disease detection using YOLO, *In Proceedings of the 2020 International Conference for Emergency Technology-INCET*, Belgaum, India, 5-7 June.

[2] J. Redmon, S. K. Divvala, R. B. Girshick, and A. Farhadi. 2016. You only look once: Unified, real-time object detection. *In Proceedings of the 2016 IEEE Conference on Computer Vision and Pattern Recognition- CVPR*, Las Vegas, NV, USA, 27-30 June.

[3] J. Redmon and A. Farhadi. 2017. Yolo9000: better, faster, stronger. *In Proceedings of the IEEE conference on computer vision and pattern recognition- CVPR*, Honolulu, HI, USA, 21-26 July.

[4] J. Redmon and A. Farhadi. 2018. Yolov3: An incremental improvement. arXiv preprint arXiv:1804.02767.

[5] A. Bochkovskiy, C.-Y. Wang, and H.-Y. M. Liao. 2020. Yolov4: Optimal speed and accuracy of object detection. arXiv preprint arXiv:2004.10934.

[6] D. Wu, S. Lv, M. Jiang, and H. Song. 2020. Using channel pruning-based YOLO v4 deep learning algorithm for the real-time and accurate detection of apple flowers in natural environments, *Computer and Electronic in Agricuture* 178(4): 105742.

[7] H. Yang *et al.* 2019. Tender Tea Shoots Recognition and Positioning for Picking Robot Using Improved YOLO-V3 Model, *IEEE Access*, vol.7, pp. 180998–181011.

[8] R. Shi, T. Li, and Y. Yamaguchi, 2020. An attribution-based pruning method for real-time mango detection with YOLO network, *Computer and Electronic in Agricuture*, vol. 169.

[9] Y. Zhong, J. Gao, Q. Lei, and Y. Zhou. 2018. A vision-based counting and recognition system for flying insects in intelligent agriculture, *Sensors*, 18(5): 1409.

[10] G. Liu, J. C. Nouaze, P. L. T. Mbouembe, and J. H. Kim. 2020. YOLO-tomato: A robust algorithm for tomato detection based on YOLOv3, *Sensors*, 20(7): 1–20.

[11] Alexey Bochkovskiy. 2020. Darknet: Open-Source Neural Networks in Python. *Available online:https://github.com/ AlexeyAB/darknet.*

[12] A. Alsaeedi, H. El-Ramady, T. Alshaal, M. El-Garawany, N. Elhawat, and A. Al-Otaibi. 2019. Silica nanoparticles boost growth and productivity of cucumber under water deficit and salinity stresses by balancing nutrients uptake. *Plant Physiology and Biochemistry*, vol. 139: 1–10.

[13] H. Wang et al., 2010. Light quality affects incidence of powdery mildew, expression of defence-related genes and associated metabolism in cucumber plants. *European Journal of Plant Pathology*, 127(1): 125–135.

[14] K. N. D'Arcangelo, M. L. Adams, J. P. Kerns, and L. M. Quesada-Ocampo. 2021. Assessment of fungicide product applications and program approaches for control of downy mildew on pickling cucumber in North Carolina. *Crop Protection*, vol.140:105412.

[15] Y. Sun, Z. Liu, G. Lan, C. Jiao, and Y. Sun. 2019. Effect ofexogenous melatonin on resistance of cucumber to downy mildew. *Scientia Horticulturae*, vol.255: 231–241.

[16] K. Lin, L. Gong, Y. Huang, C. Liu, and J. Pan. 2019. Deep learning-based segmentation and quantification of cucumber powdery mildew using convolutional neural network. *Frontiers in Plant Science*, vol.10: 1–10.

[17] P. Zhang, L. Yang, and D. Li. 2020. EfficientNet-B4-Ranger: A novel method for greenhouse cucumber disease recognition under natural complex environment. *Computers and Electronics in Agriculture*, vol. 176: 105652.