Automated tomato harvesting system using AI

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***Abstract* — In this study, we implemented an automated tomato harvesting system using artificial intelligence technology as an alternative to solve the problem of decreasing labor force due to the aging of Korean agriculture. Tomato is a crop that is sensitive to the environment, easy to be damaged during harvest, and requires a lot of labor due to the short harvest season. The tomato recognition and position control algorithm was designed and implemented by referring to the research of the National Academy of Agricultural Sciences and the Korea Electronics and Telecommunications Research Institute, and further research is needed to see if it can be applied to other crops through learning. The above automation system can contribute to solving the aging problem of agriculture, and automation of smart farms is expected to become an important technology in the agricultural field.**

Keywords—Samrt Agriculture, AI, IoT, Tomato, Algorithm

I. INTRODUCTION

With the introduction of smart farms, modern agriculture is being modernized based on IoT [1]. Due to data collection, analysis, and utilization of data farming, crop yields have increased significantly compared to open field farming. The productivity of agriculture has been greatly improved through smart farms, but convenience needs continuous improvement. Korea's agricultural environment is facing a major problem of decreasing labor force due to aging. In order to solve these environmental factors, this study implemented an automated tomato harvesting system using AI technology.

Tomato is a representative crop that is sensitive to various environmental factors. It requires management of environmental factors such as temperature and humidity, and its thin skin and soft flesh make it vulnerable to pests and diseases, and it is easy to be damaged even at the harvesting stage. In addition, it has a short harvest cycle and requires a lot of labor because it bears multiple fruits. In this study, we aim to solve these problems by automating tomato cultivation using modern technologies such as artificial intelligence, robotics, and IoT sensor technology [2].

In the main body of this paper, we first review the related research and technological trends on automated tomato harvesting systems using AI, followed by the details of the design and implementation of the automation system. Finally, the design and implementation results and performance evaluation are presented, and the conclusion discusses the applicability of the results of this study in local agricultural environments.

II. RELATED RESEARCH

For the design and implementation of the unmanned harvesting system of artificial intelligence tomato in this study, we refer to the research conducted by related organizations such as the Rural Development Administration and the Korea Electronics and Telecommunications Research Institute.

The Korea Electronics and Telecommunications Research Institute conducted a study on developing a location detection algorithm for fruit harvesting. An algorithm was developed to acquire image information of fruit and convert it into real-world coordinates after image preprocessing and object segmentation to obtain image coordinates [3].

The National Institute of Agricultural Sciences implemented a deep learning-based three-dimensional position detection embedded system and studied tomato position detection technology. The YOLOv5 object detection model was used to train tomato images and convert two-dimensional coordinates into three-dimensional coordinates to detect the three-dimensional position of tomatoes [4].

Kang Hyun-Koo and Lee Hye-Min of the Korea Electronics Technology Research Institute conducted research to develop a lidar-based obstacle detection and avoidance system. They developed a lidar-based real-time obstacle detection algorithm and verified its safety through simulation"[5].

III. SYSTEM DESIGN AND TECHNICAL IMPLEMENTATION

A. System configuration

The automated tomato harvesting system using AI is as shown in Figure 1 divided into hardware and software. Hardware consists of robotic arms, eframes, mobile devices, cameras, and IoT sensors, while software elements include a control system to control the robotic arms and eframes, a power supply system to facilitate power supply, a database system to store data collected from sensors and cameras, and

other communication parts. It also consists of other items to check the safety of the attached sensors and equipment. These hardware and software components affect the performance and reliability of the tomato automation system.

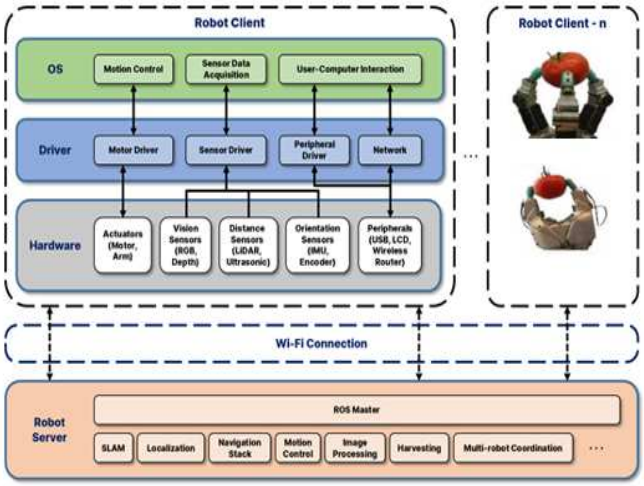

Figure 1 AI-based tomato harvest automation system diagram

B. Developing applied technology algorithms

For the operation of the harvesting automation system, software controls the robot's body, robotic arm, machine vision, etc. and develops algorithms to implement the technology that automatically harvests crops at a specified time and stops when a certain amount is filled [6].

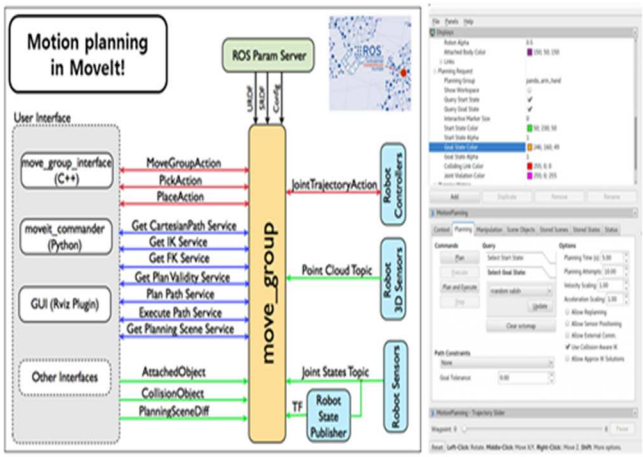

Figure 2 Developing robot arm operating time and motion algorithms

In addition, position and motion control algorithms were developed and applied to ensure the arm's accurate behavior, and obstacle detection and avoidance algorithms were added to increase the system's efficiency so that the arm could move freely in the work environment. These algorithms as shown in Figure 2 are designed to work together to smooth the arm's motion and automatically detect and avoid unexpected obstacles. These control algorithms are compiled into one unified file and run in real-time within the system, allowing the arm to automatically calculate its exact position and perform tasks efficiently and without obstacles.

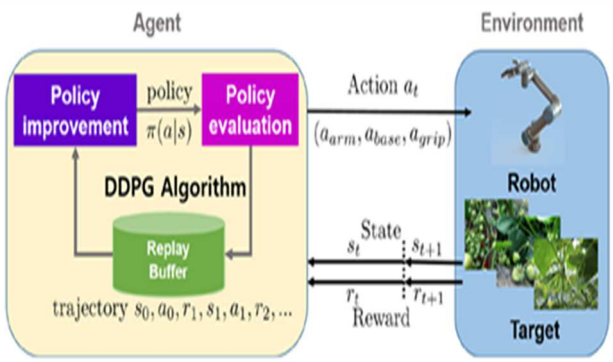

Figure 3 Develop a control algorithm for reinforcement learning for a robotic arm

The system as shown in Figure 3 was dynamically modeled with control state vector St, control action vector At, and reward Rt to reinforce deep learning, and agents (DDPG, PPO, A3C) suitable for continuous control were configured.

For communication, we used Bluetooth, which is relatively low in production cost and uses small range communication, considering the size of the greenhouse and the operating radius of the robot arm. It also provides compatibility in that it uses the same communication method for future user PC and mobile application interworking.

C. Implementation results

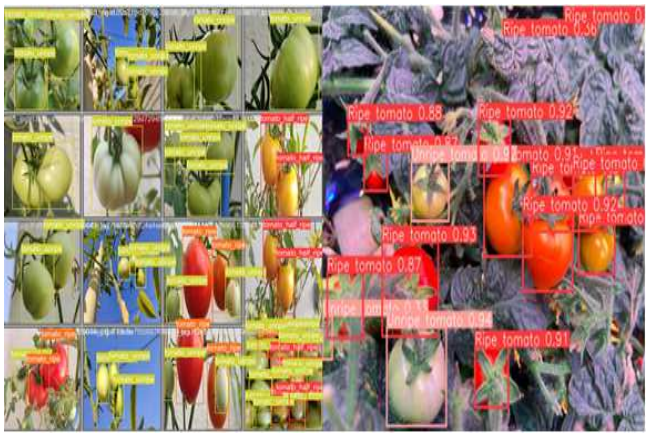

Figure 4 Learning outcomes using the YOLOv5 model

To apply the developed algorithm, we conducted an experiment as shown in Figure 4.

First, we conducted a test to check the tomato recognition rate using the YoloV5 model using public datasets, and later developed the algorithm on the testbed for 5 days.

We trained the model using public datasets and realized an accuracy rate of about 91%, and evaluated it on the testbed in terms of safety, model accuracy, and robot arm accuracy.

The safety of determining crop damage, model accuracy of determining harvestable tomatoes, and the success rate of the robot arm were evaluated, and the results showed 86% safety, 90% model accuracy, and 79% success rate.

IV. CONCLUSION

In this study, we designed and implemented an automated system for harvesting tomatoes in a greenhouse, which demonstrates the practicality of how an automated harvesting system can be applied in a real-world agricultural environment. This system can be improved to become more accurate and efficient through continuous learning, and such improvements will contribute to the convenience and productivity of workers in actual agricultural environments. In addition, the system proposed in this study is expected to be applicable to other crops such as cucumbers and paprika, and we plan to examine the feasibility of its use in various crops and implement it in practice through future follow-up studies. As the aging agricultural environment and decreasing labor force are expected to become more serious in the future, automation of agriculture using advanced technology will become an increasingly important technology. Against this background, this study is an important basic research on how smart farm automation can revolutionize the agricultural sector, and it is expected that further research and advancement will contribute to maximizing the efficiency of the agricultural environment.

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REFERENCES

[1] Kim, Hyeong-Ja, "Science Technology - Agriculture is also on the cutting edge! Urban 'Smart Farm' is on the horizon," Telecommunications Technology Association, 2018.

[2] [Patil, Shashank, et al. "Smart Farm: An Automated Farming Technique Using Robot." PCE JCE_ 6.1 (2017): 42.

[3] Minkyu Kim, Byungil Han, Yunsoo Jung, Eunchang Choi, and Cheolho Won, "Development of Position Recognition Algorithm based on the Robot Vision for Fruit Harvest Robot," in Proceedings of the National Conference of the Association for Control Robot Systems, 2012, pp. 164-165.

[4] Ki-Beom Lee et al. "Implementation of 3D Location Detection Embedded System for Tomato Harvesting Robots," The Journal of Korean Institute of Communications and Information Sciences, vol. 47, no. 11, pp. 2007-2019, 2022, doi: 10.7840/kics.2022.47.11.2007

[5] Hyun-Koo Kang and Hye-Min Lee, "Development of LiDAR-based obstacle detection and avoidance system for autonomous driving of orchards," in Proceedings of the National Conference on Control Robotics Systems, 2024, pp. 559-560.

[6] [Tsai, Y. C., and A. H. Soni."An algorithm for the workspace of a general n-R robot." (1983). pp: 52-57.