

## Study on route setting and movement based on 3D map generation by robot in hydroponics managing system

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### ABSTRACT

We propose an efficient hydroponics management system where farmers (users) can cultivate their fields by operating a mobile robot in remote locations. This system can reflect users' requests, thus this system can provide high efficient crop management and high quality crops. However, in order to put this system into practice, we need to develop the robot that can move in the field by users' remote control. In the previous research, the robot created a 3D map using RGB information. However, in this function misalignment occurs at the time of alignment when the similar RGB information is contained in the image taken by a RGB camera, making it difficult to create 3D map. Therefore, in this research, we generate maps using ArUco marker to enable generation of maps even in the place with similar RGB information.

### KEYWORDS

hydroponics, robot, ArUco marker, 3D map generation, hydroponics managing system.

### 1. INTRODUCTION

In recent years, hydroponic culture is attracting attention in the agricultural field. As one of the reasons why hydroponic cultivation attracts attention, a culture solution is used instead of soil as shown in Fig 1. In addition, as shown in Fig 2, it is possible to cultivate crops in a multistage manner, so the yield per unit area is high. In the cultivation methods using soil, there is a possibility that crops may cause disease or an insect damage due to soil bacteria. On the other hand, hydroponic culture is not affected by pests and soil because it uses culture medium.

Hydroponic cultivation methods are used in plant factories. A plant factory is a cultivation facility capable of stable crop management throughout the year through cultivation by controlling the light,

temperature and humidity, nutrients, and moisture necessary for plant growth. Hydroponic cultivation in a plant factory has the following merit.

- Crops can be grown all year round without receiving external factors such as insects and weather.
- Since cultivating crops indoors, introduction of environmental sensors and robots is easy.

From these advantages, a hydroponic culture management system using a machine using environmental sensors such as a temperature sensor and a humidity sensor has been proposed. Machine management creates breeding patterns according to crops and manages crop plants using environmental sensors, so it is not necessary to hire many workers and labor costs can be reduced. However, since good quality crop production requires delicate management of environmental conditions, it is still difficult to cultivate good quality crops by fully automated machine. Therefore, in this laboratory, by conducting delicate crop management using the experience of the farmer (user) as shown in Fig 3, it is possible to cultivate good quality crops, place robots on multiple farms, We have proposed a hydroponic cultivation managing system that can manage multiple farms by one person[1]-[4]. With this system, users can manage environmental conditions and operate robots from remote locations, thereby making it possible to realize tasks that require user's experience even on remote farms. Two modes of this system are shown below.

- Automatic management mode: robots check growing state of farm crops automatically.
- Remote control mode: a farmer works from the distant place using robots.

In the automatic management mode, when there is no instruction from the user, the farm temperature, humidity, light amount and the like are automatically managed using a sensor mounted on the robot and management is

performed according to the growing state of the crop.

In the remote control mode, Augmented Reality (AR) as shown in Fig 4 is used in consideration of user operability. AR is a technique to add information created by digital synthesis or the like to real information perceived by a person. In addition, as shown in Fig 5, a head mounted display (HMD) is used as a head mounted type display. By using AR and HMD, the user can look into the farm AR displayed in the real space and monitor it by moving the robot, and it is possible to intuitively remotely operate the robot by gripping the object become. In the proposed system, it is thought that the robot can manage a large farm alone, because the robot automatically performs many tasks. In addition, since AR can display information corresponding to markers, it is possible to monitor a plurality of farms at the same time, and improvement of production efficiency is expected.

In a previous research, Ide[1] proposed the estimation method for the self-position of the robot based on the surrounding RGB information and developed 3D map generation function using the self-position using SLAM (Simultaneous Localization and Mapping) to realize the route of the robot in the farm in the remote control mode. However, in this function misalignment occurs at the time of alignment when the similar RGB information is contained in the image taken by a RGB camera, making it difficult to create 3D map. Therefore, in this research, we generate maps using ArUco marker[5] to enable generation of maps even in the place with similar RGB information..

## 2. PROPOSED METHOD

The appearance of this research system is shown in Fig 6. Place multiple markers on the farm where you want to create the map. The robot consecutively recognizes the marker, compares it with the previously recognized scene at the recognized scene, and acquires the information of the marker recognized, the RGB information, and the depth information when the same marker is recognized. Create point cloud data from the acquired RGB information and depth information, and create a map using marker information.

### 2.1 Hardware configuration

The configuration of the hardware of the robot used in this research is shown in Fig 7. The size of the robot is 640 mm in length, 900 mm in width and 900 mm in height. In addition, Kinect sensor (RGB + D) and PC are installed in the robot. As shown in Fig 8, the Kinect sensor is equipped with an RGB camera and an Depth camera, and by combining these cameras it is possible to acquire three-dimensional information.

### 2.2 Processing procedure

As shown in Fig 9, Kinect should always be able to recognize two or more markers to be installed on the farm. We will explain the whole process according to Fig 10.

#### 2.2.1 Obtaining image

We use Kinect's RGB camera and Depth camera to create point cloud data. When two or more markers are recognized, RGB information and depth information are acquired from Kinect.

#### 2.2.2 Marker recognition

The robot detects and recognizes markers based on the information acquired from Kinect's RGB camera. Since the map is generated considering the angle and position of the marker, the robot acquires the rotation matrix, the translation vector, the marker ID, the two-dimensional coordinates of the four corners and the center of the marker.

#### 2.2.3 Creation point cloud data

We create 3D point cloud data using RGB information and depth information obtained from Kinect.

#### 2.2.4 Map generation

As an example, suppose that there are scene A created at point A and scene B created at point B.

##### 2.2.4.1 Comparison of marker IDs for each scene

When generating the map, it is necessary to match the same data with the point cloud data of each scene. Therefore, the robot searches for the

same marker ID on consecutive scenes, furthermore if same markers are found, the robot calculates rotation matrix and translation vector between scenes.

#### 2.2.4.2 Calculation of rotation matrix and translation vector between scenes

First find the rotation matrix  $R$ . Fig 11 shows how to determine the rotation matrix. We assume  $N_m$  to be the normal vector of the marker. We assume  $N_a$  to be the normal vector of the camera of scene A furthermore  $N_b$  to be the normal vector of the camera of scene B. We denote the rotation matrix  $R_a$  for converting from normal vector  $N_m$  to normal vector  $N_a$ . Similarly, we denote the rotation matrix  $R_b$  for converting from normal vector  $N_m$  to normal vector  $N_b$ . Since the rotation matrix  $R$  is a rotation matrix from scene A to scene B, it is expressed by the following expression.

$$R = R_a^{-1} R_b \quad (1)$$

Next, we calculate the translation vector. Since the translation vector is the same as the movement amount of kinect, it can be obtained from the difference between the center coordinates of the markers for each scene. It is necessary to equalize the angle of the markers between the scenes. This can be calculated using the rotation matrix  $R$  obtained earlier. We assume  $Ac(Ac_x, Ac_y, Ac_z)$  to be the center coordinate of the marker of scene A furthermore  $Ac'(Ac'_x, Ac'_y, Ac'_z)$  to be the center coordinate of the marker of scene A whose rotation is matched with the marker of scene B. The center coordinate  $Ac'$  can be obtained from the following expression.

$$\begin{pmatrix} Ac'_x \\ Ac'_y \\ Ac'_z \end{pmatrix} = R \begin{pmatrix} Ac_x \\ Ac_y \\ Ac_z \end{pmatrix} \quad (2)$$

We assume that the center coordinate of the marker of scene B is  $Bc(Bc_x, Bc_y, Bc_z)$ . Using the result of equation (2), the translation vector  $T(T_x, T_y, T_z)$  can be calculated by the following equation.

$$\begin{pmatrix} T_x \\ T_y \\ T_z \end{pmatrix} = \begin{pmatrix} Bc_x \\ Bc_y \\ Bc_z \end{pmatrix} - R \begin{pmatrix} Ac'_x \\ Ac'_y \\ Ac'_z \end{pmatrix} \quad (3)$$

#### 2.2.4.3 Map construction

Using the result of equation (1) and equation (3), the robot aligns the positions of point cloud of

scene A with the position of the point cloud of scene B. Assuming that the coordinates of the point cloud of scene A is  $P$ , moreover the coordinates of the point cloud of scene A matching the position of scene B is  $P'$ ,  $P'$  is expressed by the following equation.

$$P' = PR + T \quad (4)$$

Every time this map generation process is performed, the point cloud data is acquired to create a map. The created map is shown in Fig 12.

### 3 Evaluation experiment

In this experiment, we will experiment the accuracy of the map by comparing the map generation function created by Ide, which is a previous study, and the map generation function created in this research. Make the map room in the same place and move the robot manually. In the map generation function of the previous study, as shown in Fig 13, a poster carrying RGB information is pasted on a place where RGB information is scarce and a map is created. In this study, ArUco marker was pasted as shown in Fig 14 and map creation was done. we created a map of the same room and asked 10 subjects to evaluate in 5 stages. Evaluation items are shown below. Figures 15 and 16 show the results of the map.

- [1] Is the map compared with the map generation function of the previous research more reproducible?
- [2] Is the created map reproduce the corner of the room compared to the actual room?
- [3] Are the walls reproduced in the map created compared with the actual room?

The evaluation results are shown in Table 1.

**Table 1: Result of evaluation experiment**

Evaluation item	average	Standard deviation
[1]	4.9	0.30
[2]	4.6	0.49
[3]	4.4	0.49

Because the value of [1] is high, we can see that the map creation of the proposed method has better room reproducibility than the map generation function of the previous research. In addition, since the average value of items in [2] and [3] is also high, the corners of the

room and the walls are highly reproducible, so the usefulness as a map is high.

## REFERENCES

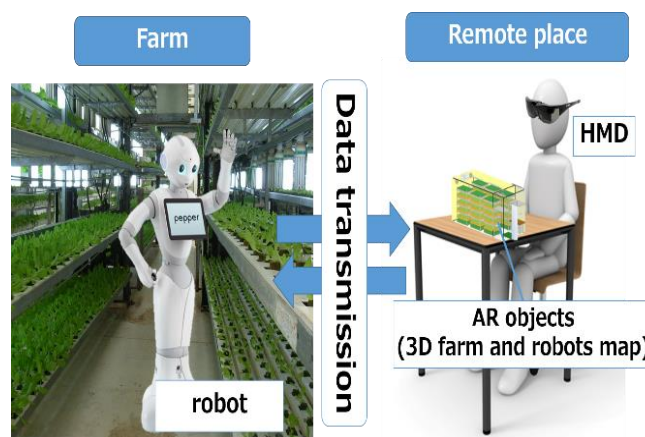
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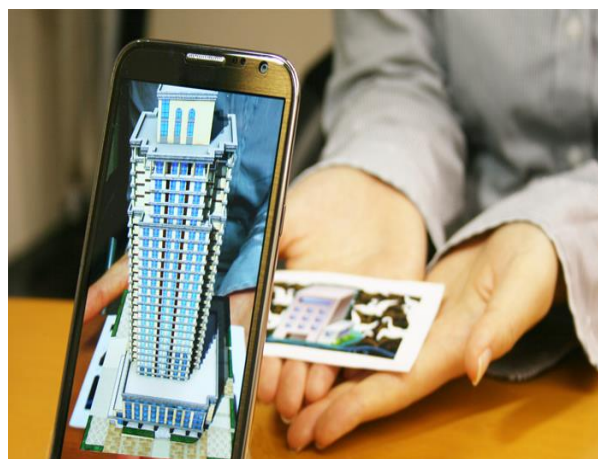
**Figure 1: Cultivation using culture solution**



**Figure 2: Crop cultivation using multistage system**



**Figure 3: hydroponics managing system**

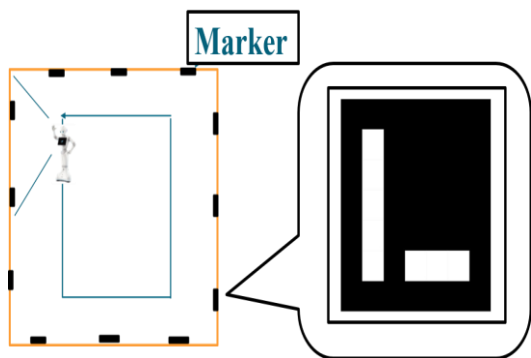


**Figure 4: Augmented Reality**

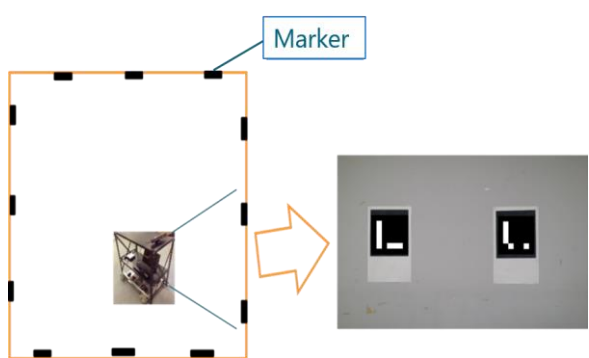


**Figure 5: head mounted display**

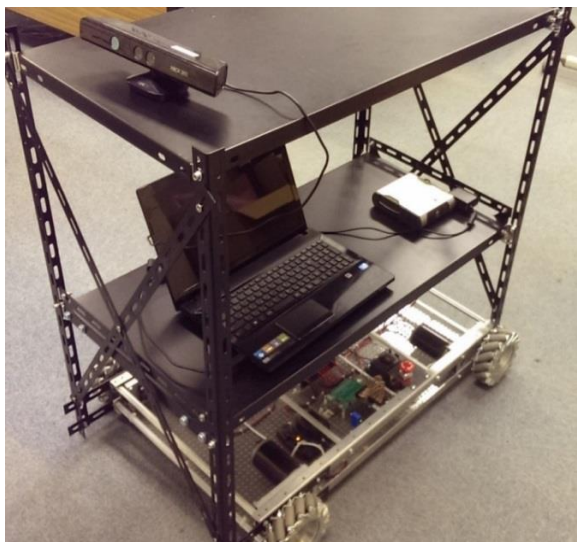




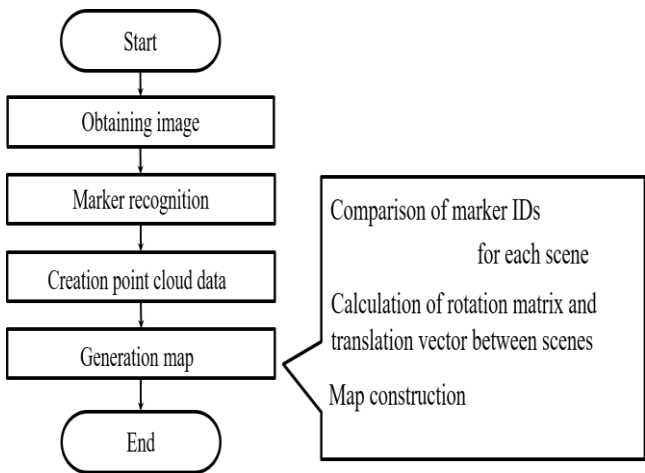
**Figure 6: Outline drawing of system**



**Figure 9: Arrangement of markers**



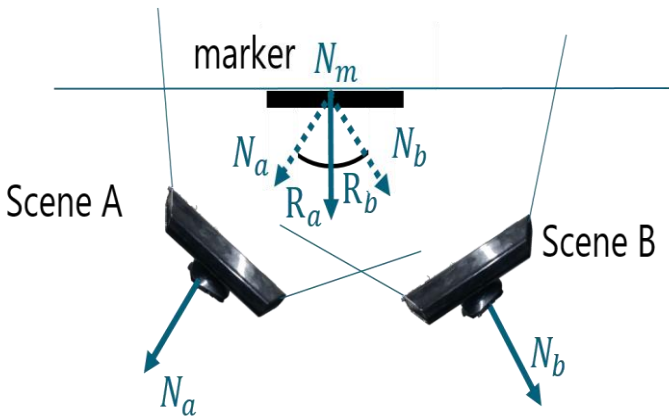
**Figure 7: Hardware configuration of robot**



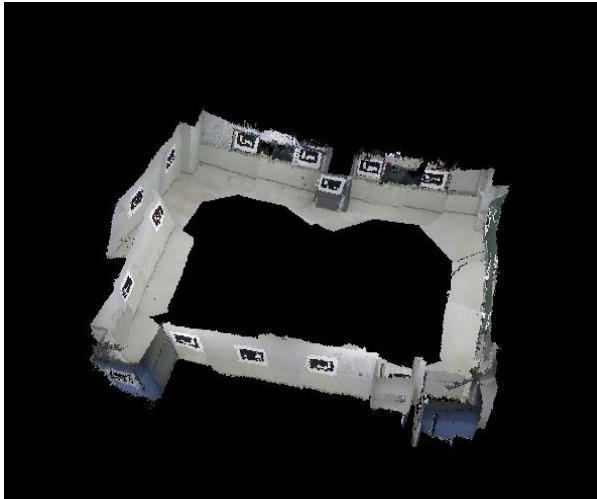
**Figure 10: the flow chart of this system**



**Figure 8: Construction of Kinect**



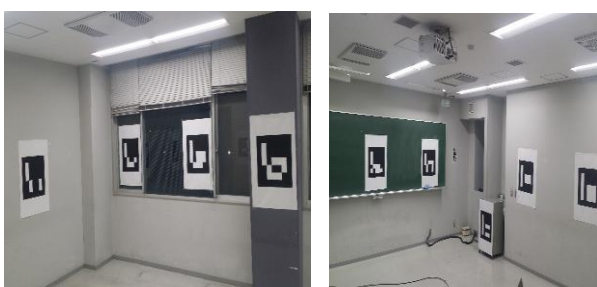
**Figure 11: Description of rotation matrix**



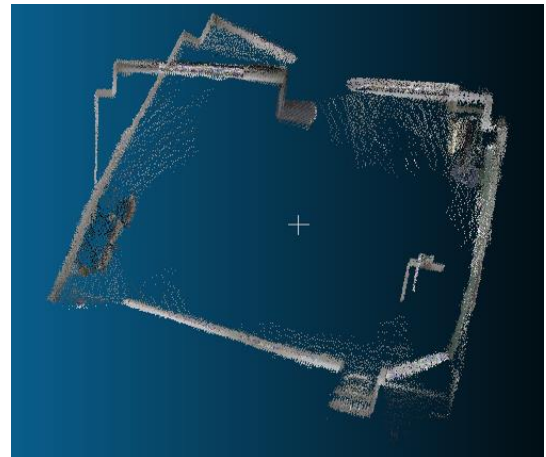
**Figure 12: Map generation result of proposed method**



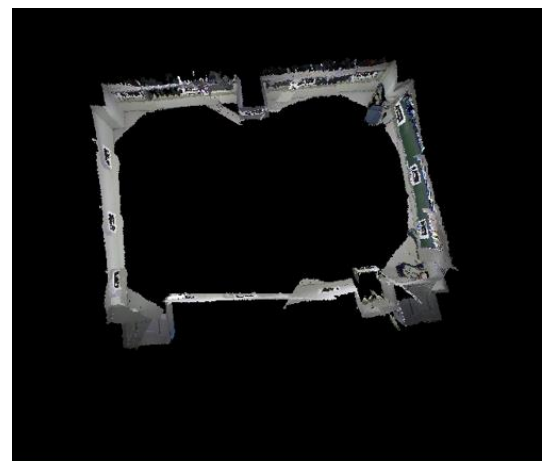
**Figure 13: Experimental environment of previous research method**



**Figure 14: Experimental environment of the proposed method**



**Figure 15: Map of previous research**



**Figure 16: Map of the proposed method**