SUGISAKA MASANORI

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Research Article

Industrial Robot Introduction through Augmented Reality System

Takuya Matsumoto[1], Eiji Hayashi[2], Sakmongkon Chumkamon[2], Ayumu Tominaga[3], Abbe Mowshowitz[4]

[1]Department of Intelligent and Control Systems, Kyushu Institute of Technology, 680-4, Kawazu, Iizuka-city, Fukuoka, 820-8502, Japan

[2]Department of Mechanical Information Science and Technology, Kyushu Institute of Technology, 680-4, Kawazu, Iizuka-city, Fukuoka, 820-8502, Japan

[3]Department of Creative Engineering Robotics and Mechatronics Course, National Institute of Technology Kitakyushu College, 5-20-1 Shi, Kokuraminamiku, Kitakyushu-city, Fukuoka, 802-0985, Japan

[4]Department of Computer Science, The City College of New York, 160 Convent Avenue, New York, NY 10031, USA

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ABSTRACT

In this research, we developed an application that allows AR simulations to check safety ranges and operation details. Furthermore, we created a user-friendly GUI, suitable for individuals with limited knowledge in robot development. This application was developed using ARCore in Unity. By establishing communication between ROS (Robot Operating System) and Unity to control virtual robots, we achieved visualization of ROS-based robots in the AR environment. With this AR application, the need for physical safety design and verification of safety ranges during the introduction of robots in small and medium-sized enterprises has been significantly reduced. As a result, cost reduction in the implementation process can be expected, and it offers a potential solution to the labor shortage issues in such enterprises. In conclusion, the effectiveness of the AR application developed in this research has been confirmed.

1. Introduction

In recent years, the issue of labor shortages has become increasingly critical for small and medium-sized enterprises (SMEs). In particular, the food service industry faces challenges in finding adequate labor to meet its demands. To address this, automation using robots is seen as a promising solution to improve productivity and cope with the scarcity of available workforce. However, the high costs associated with robot introduction, including design, parts, and integration expenses, present significant barriers, especially for SMEs with limited financial resources.

In this context, this study explores the potential of Augmented Reality (AR) technology as a means to support SMEs in robot introduction. AR technology superimposes virtual information onto the real environment through devices like smartphones or AR glasses. By operating a virtual robot model in an AR environment, SMEs can assess food preparation processes and safety ranges within their factory without the need for physical robot installations and operational tests. This approach is expected to considerably reduce overall introduction costs, encompassing design and system integration expenditures.

The primary focus of this research is the development of an AR application tailored for SMEs to evaluate the safety range of robots during their introduction phase. The application is designed with the assumption that its users may not have prior experience in robot development. Consequently, we have prioritized user-friendliness and ease of operation during the application's development. This paper presents the

Corresponding author's E-mail: matsumoto.takuya130@mail.kyutech.jp URL: http://www.kyutech.ac.jp

details of the application's design, evaluation, and verification process.

2. Application Details

2.1. *AR System Configuration*

In this study, we utilized three primary technologies for the development of the AR application. Specifically, we integrated the ARCore SDK into Unity, enabling the utilization of ARCore, a software dedicated to AR development, for creating the application. Fig. 1 presents a schematic diagram illustrating the AR system.

Fig. 1. AR System Configuration

2.2. *AR Application*

The application has two main parts. One part is for AR simulation, and the other part is for AR simulation. The other part is for grasping with a real robot. This application is to operate a real robot after AR simulation. The real robot part is explained in Chapter 3. Robot System.

2.2.1. Simulation Part in AR

The application flow is depicted in Fig. 2, proceeding in the following order: (a), (b), (c), and (d).
(a) Select Object Scene
Users select the type, quantity, and placement position of solidified food by dragging and dropping within the application. After making selections, they transition to the simulation screen where AR robots conduct the simulation by pressing the "Plan" and "Execute" buttons. Additionally, users have the option to start over from the beginning by pressing the "Reset" button.
(b) Simulate Scene in AR
By pressing the "SetObject" button, the selected virtual object in (a) is placed at the same real-world coordinates. Users can then use the "Pick" and "Place" buttons to instruct the AR robot to perform pick-and-place actions.
(c) Start Real UTRA Robot Scene
After the AR robot simulation is completed, buttons to control the real robot's movements appear. By pressing these buttons, the real robot performs pick-and-place actions with the same objects as used in the AR simulation.
(d) End Scene
Once the real robot's actions are completed, a message indicating the end of the process will be displayed.

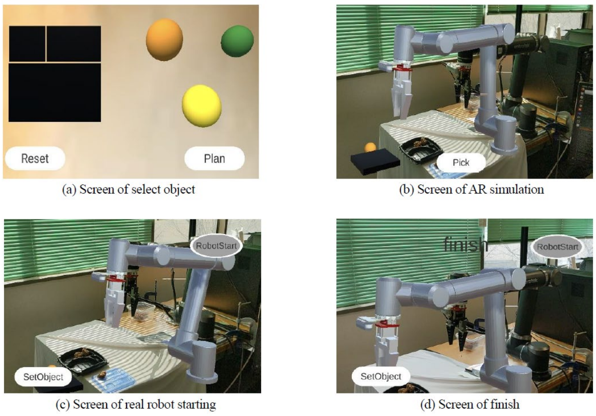


Fig. 2. The Display of AR Simulation

3. Robot System

This chapter describes the Real Robot itself, the image recognition system used for it, and the operation flow of the Real Robot.

3.1. *Robot Configuration*

In the foodservice industry, robots are required to perform tasks equivalent to those of humans, necessitating more human-like and flexible movements. Therefore, to achieve a certain level of high freedom of movement, a 6-axis vertically articulated robot is employed. The model used for this purpose is the UmbraTek UTRA6-850. Fig.3.1 shows the appearance. Furthermore, at the robot's end-effector, as shown in Fig.3.2, an RGB-D camera was equipped for object recognition purposes. Additionally, a stepper motor was used for the gripper to enable grasping of solid food items. The stepper motor allows the gripper to open and close, facilitating the handling of solid food products.

Fig. 3.1. Appearance of UTRA6-850

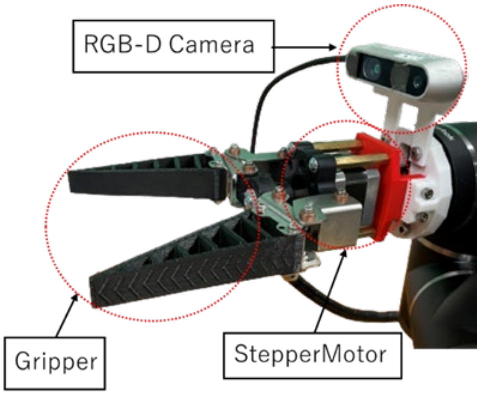


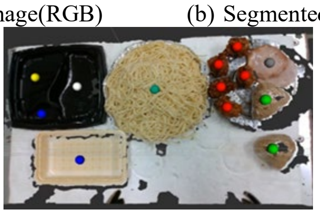
Fig. 3.2. Appearance of the End Effector

3.2. *System Configuration*

During the gripping and serving process, it is essential to identify the position of the solidified food. For this purpose, an object recognition system was employed. Initially, the information of the object RGB Image is captured using an RGB-D camera situated on the robot's tip, and instance segmentation is conducted. Subsequently, the two-dimensional coordinates of the center of gravity are computed based on the generated segmentation image. Additionally, depth information is acquired to determine the 3D center-of-gravity coordinates for the object. Moreover, a microcon is utilized to control the grippers' opening and closing motions via a PC. Fig. 4 showcases both the image acquired from the RGB-D camera and the corresponding processed image

(a) Original image(RGB)

(b) Segmented Image



(c) Image with marked centroid coordinates

Fig. 4. The information from the RGB-D camera and the processed images after each step

3.3. *Real Robot Grasping part*

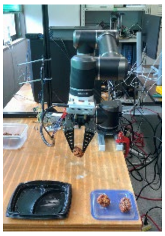
Next, we describe the motion flow for grasping solidified food using the robot, hardware, and image recognition system. The operation phase is divided into six phases from (a) to (f). The motion is performed in the order of (a) to (f). Fig.5 shows the robot in each phase.

(a) Home:
Placement for visualization processing at the home position before and after grasping.
(b) Pre-pick (Previous pick):
Motion before grasping the object
(c) Pick:
Motion to grasp the object
(d) Post-pick (Postpone pick):
Motion to lift the grasped object up once
(e) Pre-place (Previous place):
Motion before placing the object on the plate
(f) Place:
Placing an object on the table

(a)Home

(b)Pre-Pick

(c)Pick



(d)Post-Pick

(e)Pre-Place

(f)Place

Fig. 5. Each motion phase of a real robot

4. Experiment

4.1. *GUI Evaluation Experiment[1]*

The AR application is intended for small and medium-sized industrial robots. They are not familiar with robot development and are therefore not familiar with how to operate the application. The application cannot be used if the operation method is complicated. Therefore, the GUI application was designed to be simple enough to be used by first-time users. Therefore, the following experiments were conducted to confirm that the GUI is simple enough to be used by first-time users of the application.
First, gather 10 subjects and divide them into two groups, A and B, with 5 subjects in each group. 2.
Next, the five subjects in Group A were given a full explanation of how to use the application, and asked to

use the application. The other five participants in Group B will be asked to use the application without any explanation of how to use it. If the subjects were able to perform the sequence of operations from "(a) the object selection screen" to "(d) the display of the serving results", they were able to successfully use the application.

However, if the subject is unable to complete the operation due to the user's operation or comprehension of the operation method, the subject is considered to have failed. In this case, the subject is considered to have failed. For example, the user could not press the start button even though the start button was displayed on the actual device. This means a case in which the functions installed in the application were not fully usable. In other words, when it stops in an emergency due to danger, it is not regarded as a failure, and the process is restarted from the beginning.

The percentage of successes in each of the above groups is calculated and compared. Table 1 shows the results.

Table 1. The results of user success or failure using the application

	Successful	Total	Rate of successful [%]
Group A	5	5	100
Group B	3	5	60

4.2. *Discussion*

Experiments 4.1 were conducted to assess the usability of the developed application. The results from 4.1 revealed that while the application can be utilized effectively with proper guidance, it proved challenging for first-time users. Particularly, a significant number of users encountered difficulties when they want the AR Robot to grasp the virtual objects. To address this issue, future improvements could involve developing an application that prevents the acceptance of subsequent operation commands while the virtual robot is in motion. By doing so, it is anticipated that the number of failures during this stage will be reduced.

5. Conclusion

In this research, we developed an application that allows AR simulations to check safety ranges and operation details. Furthermore, we created a user-friendly GUI, suitable for individuals with limited knowledge in robot development. This application was developed using ARCore in Unity. By establishing communication between ROS and Unity to control virtual robots, we achieved visualization of ROS-based robots in the AR environment. With this AR application, the need for physical safety design and verification of safety ranges during the introduction of robots in small and medium-sized enterprises has been significantly reduced. As a result, cost reduction in the implementation process can be expected, and it offers a potential solution to the labor shortage issues in such enterprises. In conclusion, the effectiveness of the AR application developed in this research has been confirmed.

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Authors Introduction

Mr. Takuya Matsumoto

He received bachelor degree in Engineering in 2022 from intelligent and Control Systems, Kyushu Institute of Technology in Japan. He is currently a Master student at Kyushu Institute of Technology and conducts research at Hayashi Laboratory.

Prof. Eiji Hayashi

He is a professor in the Department of Intelligent and Control Systems at Kyushu Institute of Technology. He received the Ph.D. (Dr. Eng.) degree from Waseda University in 1996. His research interests include Intelligent mechanics, Mechanical systems and Perceptual information processing. He is a member of The Institute of Electrical and Electronics Engineers (IEEE) and The Japan Society of Mechanical Engineers (JSME).

Dr. Sakmongkon

He received Doctor of Engineering degree from Kyushu Institute of Technology in 2017. He was a postdoctoral Guangdong Technology Presently he is a postdoctoral researcher in Kyushu Institute of Technology since 2019. His research interests include factory automation robots and social robots.

Prof. Abbe Mowshowitz

He received the Ph.D. degree from University of Michigan in 1967. He has been professor of computer science at the City College of New York and member of the doctoral faculty at the Graduate Center of the City University of New York since 1984. His current research interests lie in two areas are organizational and managerial issues in computing, and network science. In addition to teaching and research, He has acted as consultant on the uses and impacts of information technology (especially computer networks) to a wide range of public and private organizations in North America and Europe.

Projected Assist. Prof. Ayumu Tominaga

He is a professor in Department of Creative Engineering Robotics and Mechatronics Course at National Institute of Technology Kitakyushu College. He received the Ph.D. (Dr. Eng.) degree from Kyushu Institute of Technology in 2021. His research interests include Intelligent mechanics, Mechanical systems and Perceptual information processing