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Visualisable and Adjustable Command Spaces for Gesture-based Home Appliance Operation System via HoloLens2

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***Abstract*— We deal with a visualisable and adjustable gesture-based system for operating home appliances with gestures that can be easily operated and adjusted by anyone. The system uses "Command Spaces" in which commands for home appliance operation are tied to a space. These command spaces are constructed using body-relative coordinates using gestures at the start of the operation, which enables operation regardless of the posture and location of the operator. Different manners people are comfortable performing gestures in different postures. Gestures vary from person-to-person. In this paper, we construct a system that visualizes them using Mixed Reality via the Microsoft HoloLens2. This allows the operator to freely visualize and adjust them, improving the usability of the appliance operation system. Comparative experiments showed that operation time, operation accuracy, and usability were improved when the system was used. This shows that the system facilitates learning about home appliance operation.**

I. INTRODUCTION

Nowadays, there are various products that integrate the real world and cyberspace. For example, in Japan, a program to implement "Society 5.0" was defined by the 5th science and technology basic plan[1]. In Society 5.0, every element of society is constructed as a digital twin in cyberspace. As one such technology, several systems have been constructed to interact with surrounding devices and operate home appliances without the use of remotes.

For example, Kano et al.[2] and Yan et al. [3] constructed a home appliance operation system using "Command Spaces", i.e. locations in three-dimensional(3D) space where gestures can be performed. These Command Spaces basically act as "virtual 3D buttons" to which various home appliance operation commands are tied. By placing ones hand in any one of these spaces, the corresponding "button" can be pressed and the specified operation can be triggered, as shown in Fig. 1. The use of several Command Spaces can allow multiple operations. These Command Spaces were fixed at specific locations in a room. They can also be constructed relative to the operator's body. However, gestures and Command Spaces that are fixed in the real world are not easily understood by user as they are invisible. Each operator also performs hand gestures in different ways, necessitating customization and adjustment. In this paper, we propose user-friendly, customizable Command Spaces for home appliance interaction that can be visualized and adjusted by the operator as necessary.

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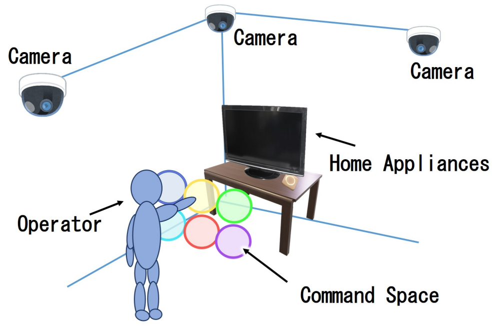

Fig. 1: Home appliance operation system using command spaces. The user can operate the TV (upto 6 actions) by placing their hand in the 3D locations of any of these 6 spheres.

The objective of this study is to build a system that allows anyone to easily operate home appliances using gestures performed in customizable Command Spaces. We propose a system that uses the Microsoft Hololens 2, a Mixed Reality (MR) headset, to enable this. Using our proposed system, Command Spaces can be visualized and adjusted as the user desires.

II. RELATED WORKS

Most previous studies on gesture recognition focus on hand gestures[4]-[11]. Verdadero et al. used deep learning to learn hand shapes to enable gesture recognition[4]. Wu et al. recognized hand trajectories and enabled operation according to the shapes drawn by the hand[5]. There have been other studies of gesture recognition using Android smartphones[6][7]. However, all of these require the user to be close to the device, which can be inconvenient. In contrast, in our proposed system, Customizable Command Spaces can be constructed and operated anywhere in the room, regardless of location.

There are also studies on capturing the entire body to enable the operation of home appliances regardless of location. Li et al. recognize the trajectory of the arm and enable home appliance operation by arm movements[8]. Bhat et al. used hand trajectories to write letters and used to control a drone[9]. However, since different gestures are tied to each operation, they need to be memorized. With our proposed use of customizable Command Spaces, the operator simply needs to place their hand in the space designated for the desired command. We achieve this with the help of a Mixed Reality (MR) headset as a tool to visualize and adjust them as desired.

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As for visualization with MR headsets, Chen et al. visualized facial pressure points in 3D to facilitate technique learning[12]. Peng et al. reduced errors by visualizing procedures for operations in hazardous environments[13]. Xiao et al. visualized the simulation of a spacecraft[14]. These results show that MR visualization offers many advantages.

Therefore, a home appliance operation system that can be visualized and adjusted using MR and operated from any location would be highly beneficial.

III. PROPOSED METHOD

A. Overview

Our proposed method consists of two systems running in parallel: Command Space visualization and adjustment system and home appliance operation system. In the command Space visualization and adjustment system, Command Spaces are visualized using a HoloLens. The system allows the operator to visualize the location of the Command Spaces, and change their positions and sizes. This enables operation with Command Spaces that match the operator's physique and preferences. The operator is only required to wear the HoloLens for visualizing and adjusting the Command Spaces. Then the operator can interact with the appliances via the home appliance operation system with simple gestures. The home appliance operation system reads the updated location of the Command Spaces that have been changed by the Command Space visualization and adjustment system and performs gesture detection via multiple cameras in order to execute the desired command. The Command Spaces in our proposed system use body-relative coordinates.

B. Home Appliance Operation System

A schematic diagram of the system is shown in Fig.1. In the system, images are captured from four CCD cameras installed in the four corners of the ceiling. OpenPose[15] is applied to the obtained images to extract the operators' skeletal point information. The two-dimensional coordinates of the skeletal points obtained from several images are acquired and their 3D coordinates are obtained by triangulation with multiple cameras. Gesture recognition performed by detecting whether the operator's hand is within a particular Command Space for a set amount of time. We also set a gesture for indicating the start of the operation to avoid accidental triggering.

1) Start Gesture: A gesture to indicate the start of appliance operation is essential to prevent accidental commands. For this, we chose a gesture where the operator's right hand is extended in front of the body. A flowchart for detecting the start gesture is shown in Fig. 2.

In order to detect the start gesture, we define the 3D coordinates of the center point of the right wrist and chest as W(x_w, y_w, z_w), C(x_c, y_c, z_c) respectively. We calculate the distance between the x_w,y_w coordinates of the center point of the chest and the x_c,y_c coordinates of the wrist. If the distance is above 0.4 m for 15 frames (approximately 5 seconds), we consider it a start gesture. After that recognition, when the hand is lowered and the distance is 0.4 m or less, the gesture to start the operation is recognized as completed.

2) Body-relative Coordinate System for Command Space Construction: The Command Spaces are defined in front of the operator for easy operation. However, defining these relative coordinates with respect to the operators' torso does not work as the coordinates rotate as the operator's body twists during operation. Therefore, our proposed method defines a body-relative coordinate system based on the center points of the operator's wrist and chest.

We store the x_C,y_C coordinates of the chest center point, and the x_W,y_W coordinates of the wrist for each frame during the frame count of the start gesture. The respective average values are then obtained. We define the average coordinates of the center point of the wrist and chest over all frames as $W_{Avg}(x_{AvgW}, y_{AvgW}, z_{AvgW})$ and $C_{Avg}(x_{AvgC}, y_{AvgC}, z_{AvgC})$ respectively. The distances between the center point of the chest and the wrist Dis in the x-axis direction x_d and in the y-axis direction y_d are obtained by (1), (2), and (3) respectively.

$$x_d = x_{AvgW} - x_{AvgC} \tag{1}$$

$$y_d = y_{AvgW} - y_{AvgC} \tag{2}$$

$$Dis = \sqrt{(x_d)^2 + (y_d)^2} \tag{3}$$

We define (x, y, z) as the 3D coordinates of the object for which relative coordinates are sought, such as wrist coordinates or Command Space. The rotation matrix between the absolute and relative coordinate systems is R and the relative coordinates $W'(x', y', z')$. We obtain these via Equations (4) and (5).

$$R = \begin{pmatrix} \frac{y_d}{CWdis} & \frac{-x_d}{CWdis} & 0 \\ \frac{x_d}{CWdis} & \frac{y_d}{CWdis} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{4}$$

$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = R \left\{ \begin{pmatrix} x \\ y \\ z \end{pmatrix} - \begin{pmatrix} x_c \\ y_c \\ z_c \end{pmatrix} \right\} \tag{5}$$

The relative coordinates shown in Fig. 3 were thus constructed. In addition, the command space follows the body when the operator moves. This makes it possible to operate home appliances regardless of the posture and location of the user at the time of the gesture to start the operation.

3) Command Space Construction and Gesture Recognition: In previous work [3], Command Spaces were constructed as cubical spaces. However, we noticed a large number of operation errors at the boundaries of the cubes. Moreover, we noticed that operators often misjudged the orientations of the cubes. Therefore, we decided to construct spherical Command Spaces which can be defined only by spherical centers, are orientation symmetric, and separated from each other. In order to detect gestures, we calculate the

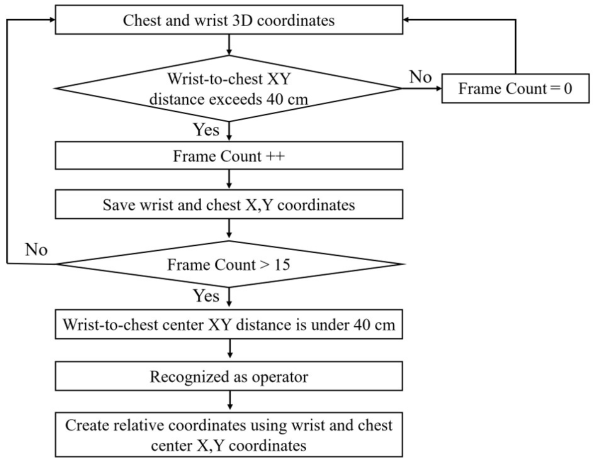

Fig. 2: Flowchart of Gestures for Starting Operation

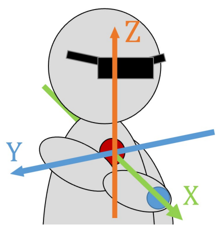

Fig. 3: Construction of relative coordinates

distances between the center coordinates of each spherical Command Space and the operator's wrist coordinates. If the distance is less than the radius of the Command Space for 2 frames, we detect it as a gesture in that space. In the next section, we describe our approach to allow the operator to visualize and adjust these Command Spaces as desired.

C. Command Space Visualization and Adjustment System

Since Command Spaces exist virtually and are not physical entities, it is difficult for operators to grasp their locations, which can be helped by visualizing them. Each operator may also wish to adjust these spaces for comfortable operation. We achieve these through our Command Space visualization and adjustment system.

This system has two components: a Microsoft HoloLens app and a server program to synchronize the Command Space locations with the home appliance operation system. The HoloLens app uses the Microsoft HoloLens2 Mixed Reality (MR) headset to visualise and manipulate the command space. It creates virtual objects in space that can be manipulated by the operator with their hands in 3D, while showing the background. An example is shown in Fig. 6. The server program retrieves and stores the information sent by the HoloLens app. The operator is only required to wear the HoloLens for visualization and adjustment.

1) Process Flow: Initially, the server program is put into standby and connected to the HoloLens app. The operator can adjust the size and position of each Command Space on the HoloLens app. After the adjustment is complete, the radii and center coordinates of the Command Space are sent

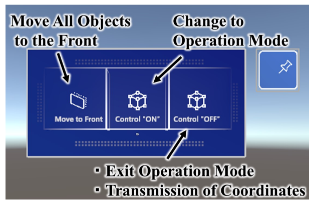

Fig. 4: Control Button

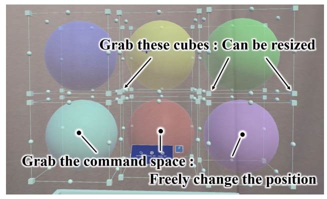

Fig. 5: Adjustment Mode

to the server program and stored. TCP/IP communication is used for communication.

The position and size of Command Spaces can be changed from their initial state in the adjustment mode as shown in Fig. 5. The adjustment mode can be switched via the control button shown in Fig. 4. After the change has been completed, press the button to the right of Fig. 4. This ends the adjustment mode and the data is transmitted to the server program.

D. Simultaneously Moving all Command Spaces

If the initial Command Spaces were created in inappropriate locations (e.g. locations with obstacles in front of the operator), it is quite tedious and difficult to move each space one by one. In cases where Command Spaces completely coincide with obstacles, it is impossible. To deal with this, we introduced a button to easily move all Command Spaces to the control button in Fig.4. The control button automatically follows the operator as it is a HoloLens entity.

This was done using a hierarchical structure where an empty object as the parent of all objects. This causes all objects to move with respect to the empty object when the coordinates of the empty object are changed. The relative frontal direction of the entire system relative to HoloLens and the relative coordinates of the empty object are acquired and stored when the system starts. When a control button is operated at an arbitrary position, the stored relative coordinates of the frontal direction and the empty object are recalled. They are then reconstructed on the current relative coordinate system. In addition, the control button is created at a fixed height to prevent the command space from being created at awkward positions. The methods enable the Command Space to be adjusted and manipulated regardless of location.

E. Methods of Obtaining Command Space Coordinates

We constructed a HoloLens app as shown in Fig.6. A center mark was placed at the point (x,y,z)=(0.3, 0, 0)[m] on the HoloLens relative coordinates at the start of application. The coordinates of the Command Space were obtained in relative coordinates with reference to the center mark. In addition, a standing platform, fixed to the ground, was installed to inform the operator of their initial position. The position where the toe touches the stand is the operating position. This enables the operator to return to the same operating position after moving once. The relative coordinates are obtained by adding the distance between the center mark and the HoloLens to the relative coordinates of the center mark reference. In addition, the HoloLens coordinate system is

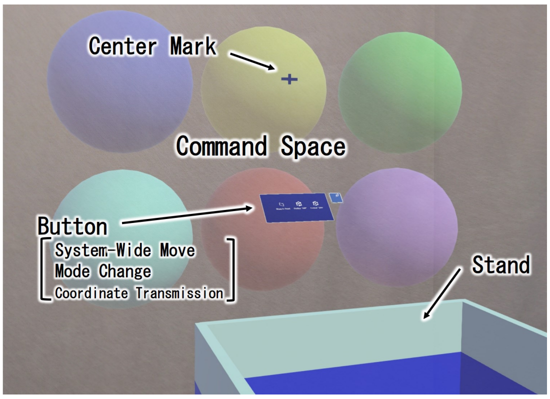

Fig. 6: HoloLens Application

aligned with the user's eye position, whereas the coordinate system for the home appliance operation system based on based on skeleton keypoint detection is aligned with the chest. Since the distance from the eyes to the chest varies minimally among individuals, the coordinate systems were synchronized by pre-measuring the height difference and inputting this value into the system. The above made it possible to transmit accurate coordinate data regardless of posture.

IV. COMPARATIVE EXPERIMENT

A. Experiment Overview

A comparative experiment was conducted to verify whether Command Space Visualization and Adjustment was effective in improving the ease of learning the use of our home appliance operation system. The experiment was conducted on twelve male subjects in their 20s who had no experience using the system. Two experiments were conducted. In Experiment 1, the participants practised using the system without wearing the HoloLens and then conducted home appliance operation. In Experiment 2, the participants practised wearing the HoloLens and then conducted home appliance operation. The operation time, and operation accuracy in the production operation were compared. After each experiment's production operation, a questionnaire using the NASA-TLX[16] and a structured interview were administered to evaluate usability.

This allowed us to compare the usability of each experiment. In the experiment, the subjects were divided into two groups, and Experiments 1 and 2 were performed in different orders for each group.

(This experiment was approved by the ethics committee at Chuo University.)

B. Investigating Operation Time and Accuracy of Operation

In Experiment 1, the Command Space arrangement was communicated to the subjects using diagrams. Subsequently, home appliance operation was practised using gestures only. Feedback on recognition completion was given by presenting an image showing recognition completion on a PC screen and by verbal communication. Practice was conducted until the participants had a sufficient understanding of the location of the Command Space and how to operate it, without setting a time limit. In Experiment 1, the Command Space was arranged in the same initial layout for both groups. In Experiment 2, in which the subjects practiced operation wearing the HoloLens, they adjusted the Command Space such that it was easy for them to operate. After the adjustment was completed, the subjects practised while wearing the HoloLens. The actual operation experiment was conducted without HoloLens to ensure the same conditions in the two experiments. The actual operation was carried out in a different body orientation from the practice in order to simulate operation without being restricted by location. This also ensured that the subjects had to be aware of the Command Spaces relative to their body. Command space operation instructions were given in a random order. The time from the operation instruction to recognition and whether the correct Command Space was recognized were measured. The number of misses was added up as the number of misses if the Command Space was not detected for more than 10 seconds or if a different Command Space was recognized. When the number of misses in one Command Space reached three, recognition was deemed impossible.

C. Usability Survey Methodology

In the experiment, a questionnaire using the NASA-TLX[16] and a structured interview was administered after the end of the production run of each experiment. This assessed the sense of use. The NASA-TLX[16] is a subjective assessment method of mental workload, consisting of the following six subscales: intellectual and perceptual needs, physical needs, temporal demand, effort, frustration and work performance. Each is rated on a 0-100 visual analogue scale (VAS). The overall evaluation is represented by the weighted workload, which is calculated by multiplying the score of each subscale by its corresponding weight and then summing the results. The NASA-TLX[16] scores for each of the two patterns were calculated and compared.

For the structured interviews, all responses were collected in a descriptive format. Q1-4 were conducted after each experiment. Q5-8 were conducted after all experiments were completed. The structured interviews were as follows.

Common questions to be asked in each experiment

Q1. What was the basis for learning the Command Space?

Q2. How well did you know the Command Space during practice?

Q3. Did you feel anxious when operating the real appliance operation system?

Q4. Were there any obstacles in the operation?

Comprehensive questions asked at the end of the experiment.

Q5. Did the adjustment of the Command Space make the operation easier?

Q6. Which experiment was easier for you to memorise the Command Space?

Q7. When using the system for the first time, which method did you feel was more appropriate to your needs?

Q8. Which of the experiments did you find easier to perform?

V. Experimental Result and Evaluation

A. Operation Time and Accuracy

The experimental results of the operation time and operation accuracy for each experiment are shown in Table I. The average detection time was 3.48s in Experiment 1 and 3.20s in Experiment 2. The average number of failures was 1.03 in Experiment 1 and 0.82 in Experiment 2. The recognition failure rate was 25% in Experiment 1 and 28% in Experiment 2.

The above results show that the average detection time and the average number of failures are better in Experiment 2, using the HoloLens. However, the proportion of recognition failures increased in Experiment 2. The reason for this was that they set the Command Spaces too far or in difficult-to-reach positions. Therefore, although the average number of failures decreased, the proportion of recognition failures increased.

TABLE I: Experimental Results on Operation Time and Accuracy

	Mean Time to Detect	Mean Number of Operating Errors	Percentage not Recognised
Experiment 1	3.48 s	1.03	25 %
Experiment 2	3.20 s	0.82	28 %

B. NASA-TLX

The mean NASA-TLX[16] scores for Experiment 1 and Experiment 2 respectively are shown in Table.II. Intellectual and perceptual need was 45.9 in Experiment 1 and 41.2 in Experiment 2. Physical need was 53.9 in Experiment 1 and 44.1 in Experiment 2. Temporal demand was 21.6 in Experiment 1 and 26.0 in Experiment 2. Effort was 61.8 in Experiment 1 and 52.5 in Experiment 2. Frustration was 55.9 in Experiment 1 and 42.2 in Experiment 2. Work performance was 52.7 in Experiment 1 and 33.1 in Experiment 2. Weighted workload was 55.7 in Experiment 1 and 45.7 in Experiment 2. The variability of the data is shown in Fig.7.

The results show that the values of attributes other than temporal demand decreased after wearing the HoloLens. The reason for the increase in temporal demand in Experiment 2 was because of the pressure felt by the operators for not being able to execute commands in Command Spaces adjusted on their own. However, the decrease in the other five items and weighted workload indicates that the workload decreased in total by practicing with the HoloLens.

C. Structured Interview

The results of the common structured interviews conducted in each experiment are shown in Table III. In Q1, about the basis for learning the Command Space, 33% of the subjects said that they learned by visual information, even if they were wearing HoloLens. This shows that many people tried to learn not only by visual information, but also by feeling, assuming that they would be in the actual situation.

In Q2, how well did they grasp the location of the Command Space during practice, the number of respondents

TABLE II: Average NASA-TLX Score

	Experiment 1	Experiment 2
Mental Demand	45.9	41.2
Physical Demand	53.9	44.1
Temporal Demand	21.6	26.0
Effort	61.8	52.5
Frustration	55.9	42.2
Performance Demand	52.7	33.1
Weighted Workload	55.7	45.7

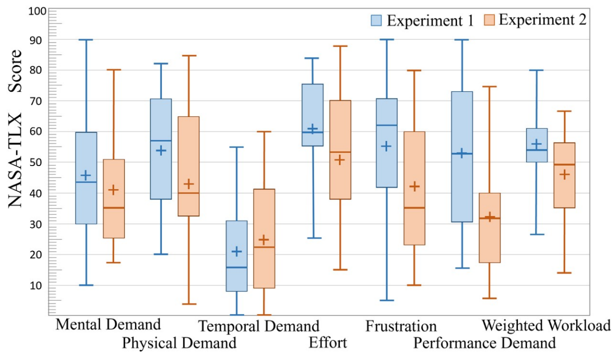

Fig. 7: NASA-TLX Score

who answered that they were able to perfectly memorise the Command Space increased when they could clearly see its location.

In Q3, when asked whether they felt anxious when operating the appliance operation system, 75% in Experiment 1 felt anxious because they did not have a clear understanding of the location of the Command Space. In contrast, in Experiment 2, 66% said that the difference between the practice and the live environment made them unsure whether they could remember correctly and what gestures they had performed during practice.

In Q4, whether there were any challenges or obstacles during the performance or practice, 50% in Experiment 1 struggled with understanding the location of specific Command Space. In Experiment 2, in addition to the same reasons as in answer to Q3, 33% said that it was difficult to correctly execute gestures in the Command Space locations set by them.

The results of the comprehensive interview conducted after the experiment are shown in Table IV.

In Q5, whether the Command Space adjustment made the operation easier, 75% of the respondents answered that it was easier, while 25% answered that it was harder. As reasons for this, 41% answered that it had become easier by changing the settings to match their arm length or by positioning the commands closer together to reduce the burden on their arms. On the other hand, 25% answered that it had become difficult because they had made mistakes in the placement of the Command Space.

Q6, 7 and 8 asked questions comparing Experiments A and B respectively. 83% of the participants in Q6, 100% in Q7 and 83% in Q8 stated that Experiment 2 was better. The

TABLE III: Results of Structured Interview Q1-Q4

	Experiment 1	Experiment 2
Q1	Memorized based on arms (50%) Memorized centre of the body (33%)	Memorized by visual information (33%) Memorized on the basis of arms (25%)
Q2	Memorized perfectly (42%) Memorized more than half (50%)	Memorized perfectly (92%) Memorized than half (8%)
Q3	Had some anxiety (75%) Did not have any anxiety (25%) (Reason: Command space location could not be comprehended (50%))	Had some anxiety (66%) Did not have any anxiety (34%) (Reason: Differences in environment from practice (25%))
Q4	There were obstacles (75%) There were none (25%) (Reason: Command space could not be manipulated successfully (50%))	There were obstacles (58%) There were none (42%) (Reason: Adjusted command space was difficult to opesrate (33%))

TABLE IV: Results of Structured Interview Q5-Q8

	Result	Reason
Q9	Easier to operate (75%) Harder to operate (25%)	(E) Can be adjusted to suit your body size (41%) (H) The arrangement was difficult to operate (25%)
Q10	Experiment A (17%) Experiment B (83%)	(A) Visual understanding of the command space (75%) (B) There was no difference between practice and performance (17%)
Q11	Experiment A (0%) Experiment B (100%)	(A) Visual understanding of the command space (67%) Reduced physical load (25%)
Q12	Experiment A (17%) Experiment B (83%)	(A) Visual understanding of the command space (67%) (B) There was no difference between practice and performance (17%)

reason for this was that 75% said they had a better visual understanding of the Command Space. Another 8% said that the adjustments made it easier. On the other hand, 11% said that Experiment 1 was better as there was less difference between the practice and the actual operation.

D. Discussion

The experimental results showed that the average operation time and the average number of failures improved using the Command Space visualization and adjustment system. The results of the NASA-TLX[16] and the comprehensive interviews also showed that Experiment 2 was better overall. Based on the above, it can be said that the Command Space visualization and adjustment system was effective in improving the ease of learning the appliance operation system. However, there is an issue of reduced operating accuracy due to the large difference between practice and real operation. Another remaining issue was that not everyone was able to arrange the Command Spaces appropriately.

VI. Conclusions and Future Work

In this paper, a gesture-based home appliance operation system was made user friendly by incorporating a HoloLens-based Command Space visualization and adjustment method. Experiments showed that the ease of learning improved by using the Command Space visualization and adjustment system.

In the future, we aim to develop a system with enhanced usability to reduce the burden on the operator. Additionally, while the current system is designed for home appliance operation, we plan to explore its application to various other devices, including robots.

References

[1] Cabinet Office, Government of Japan, "Report on The 5th Science and Technology Basic Plan,"Council for Science, Technology and Innovation, December 18, 2015 [online] Available: https://www8.cao.go.jp/cstp/kihonkeikaku/5basicplan_en.pdf

[2] Takumi Kano, Takuya Kawamura, Hidetsugu Asano, Takeshi Nagayasu and Kazunori Umeda, "Hand Waving in Command Spaces: A Framework for Operating Home Appliances", Advanced Robotics, vol. 32, no. 18, pp. 999-1006, 2018.

[3] Shixun Yan, Yonghoon Ji, Kazunori Umeda, "A System for Operating Home Appliances with Hand Positioning in a User-definable Command Space," 2020 IEEE/SICE International Symposium on System Integration (SII), Honolulu, HI, USA, pp. 366-370, 2020.

[4] Marvin S.Verdadero, Celeste O.Martinez-Ojeda and Jennifer C.Dela Cruz,"Hand Gesture Recognition System as an Alternative Interface for Remote Controlled Home Appliances," 2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), Baguio City, Philippines, 2018

[5] You-Jia Wu; Jian-Jiun Ding,"Real-Time Hand Gesture Recognition Using Depth Information and Path Analysis,"2023 IEEE 5th Eurasia Conference on IOT, Communication and Engineering (ECICE), Yunlin, Taiwan, pp.727-731, 2023

[6] Harshitaa A,Hansini P and P.Asha,"Gesture based Home appliance control system for Disabled People,"2021 Second International Conference on Electronics and Sustainable Communication Systems(ICESC), Coimbatore, India, pp.1501-1505, 2021

[7] Ninad Kheratkar, Sushmita Bhavani, Ashwini Jarali, Aboli Pathak, Shreyash Kumbhar,"Gesture Controlled Home Automation using CNN,"2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, pp.620-626, 2020

[8] Anna Li, Eliane Bodanese, Stefan Poslad,"A trajectory-Based Gesture Recognition in Smart Homes Based on the Ultrawideband Communication System,"IEEE Internet of Things Journal, vol.9, no.22, pp.22861-22873, 15 June 2022

[9] M. Bhat, G. Mahto, S. Kesaria, V. Femandes and K. Arya, "Real-time gesture control UAV with a low resource framework,"2021 International Symposium of Asian Control Association on Intelligent Robotics and Industrial Automation(IRIA), Goa, India, 2021, pp.19-24

[10] Qing Gao, Yongquan Chen, Zhaojie Ju, Yi Liang,"Dynamic Hand Gesture Recognition Based on 3D Hand Pose Estimation for Human–Robot Interaction,"IEEE Sensors Journal, vol.22, no.18 , pp.17421-17430, 15 September 2022

[11] Raihan Kabir, Nadeem Ahmed, Niloy Roy, Md Rashedul Islam,"A Novel Dynamic Hand Gesture and Movement Trajectory Recognition model for Non-Touch HRI Interface,"2019 IEEE Eurasia Conference on IOT, Communication and Engineering (ECICE), Yunlin, Taiwan, 2019, pp.505-508

[12] Xiyu Chen, Hongyu Yang, Yulong Ji, Dongnan Chen ,"3D Real-time Face Acupoints Recognition System Based on HoloLens 2," 2021 7th International Conference on Computer and Communications (ICCC), pp.932-938

[13] Zhengrui Peng, Nianyong Zhou, Chen Zhang,"Application of Electronic Operation Ticket for Intelligent Maintenance of Power Grid via Hololens,"2020 IEEE 2nd International Conference on Civil Aviation Safety and Information Technology (ICCASIT), Weihai, China, pp.407-410, 2020

[14] Jian Xiao, Dawei Zhang, Hongyan Chen, Junwei Wan,"Design of Hololens-based Scene System for Spacecraft Simulation,"2020 5th International Conference on Information Science, Computer Technology and Transportation (ISCTT), Shenyang, China, pp.558-561, 2020

[15] Zhe Cao, Gines Hidalgo, Tomas Simon, Shih-En Wei and Yaser Sheikh, "OpenPose: Realtime Multi-Person 2D Pose Estimation Using Part Affinity Fields," in IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 43, no. 1, pp. 172-186, 1 Jan. 2021

[16] Sandra G. Hart, Lowell E. Staveland, "Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research", Human Mental Workload, pp. 139-183, 1988.