

A nursing support system for connecting PCs with the real world

-Proposal of a real-world cursor-

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Abstract— We developed a life support system for connecting PC with the real world. This system has seamless interface between the personal computer (PC) world and the real world, we have been studying a method for teaching a caregiver robot and a caregiver person. The interface proposed here allows a user to intuitively direct a robot's motion via a graphical user interface of the sort typical in the PC world. One issue with that system, however, was that the size of the laser spot captured by the camera would be smaller for distant objects, making them difficult to recognize in some environments. To solve this problem, we propose a “real-world cursor” that allows clear indication of the laser spot location, and experimentally demonstrate its effectiveness.

Keywords— Real-world clicking, Caregiver robot, Real-world cursor

I. INTRODUCTION

Recent advances in robotics have led to increased research into and development of caregiving robots [1–3]. Although developing technologies for robot hardware is important, interface methods that allow for simply and accurately issuing commands are another important consideration. One recently proposed interface method is for the use of laser pointers [4–7], which provide a highly intuitive means for indicating objects and thereby supplying robots with operational instructions. Against this background, we previously proposed a system by which handicapped persons can simply and accurately express to caregivers or caregiving robots their needs for nearby objects [8]. One issue with that system, however, was that the size of the laser spot captured by the camera would be smaller for distant objects, making them difficult to recognize in some environments. To solve this problem, we propose a “real-world cursor” that allows clear indication of the laser spot location, and experimentally demonstrate its effectiveness.

II. CONVENTIONAL SYSTEM

A. Overview

Figure 1 shows an overview of the caregiving system we are developing. The system comprises a caregiving robot equipped with an arm, and a pan-tilt actuator equipped with a laser pointer and a camera. Figure 2 shows the system in use, showing

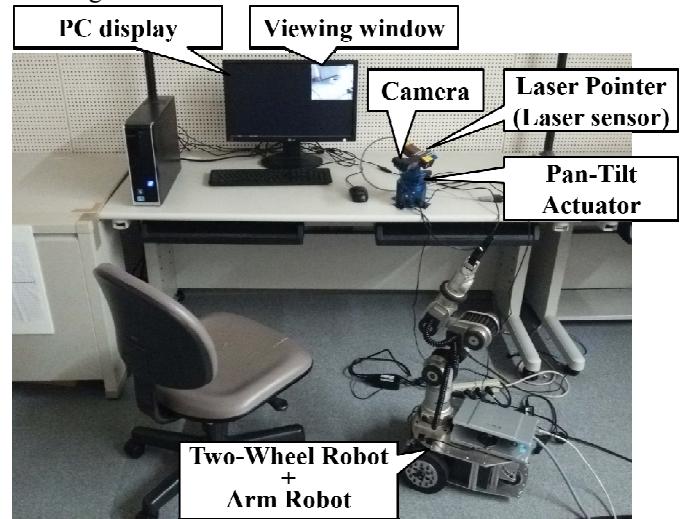


Fig. 1 Our real world clicking system

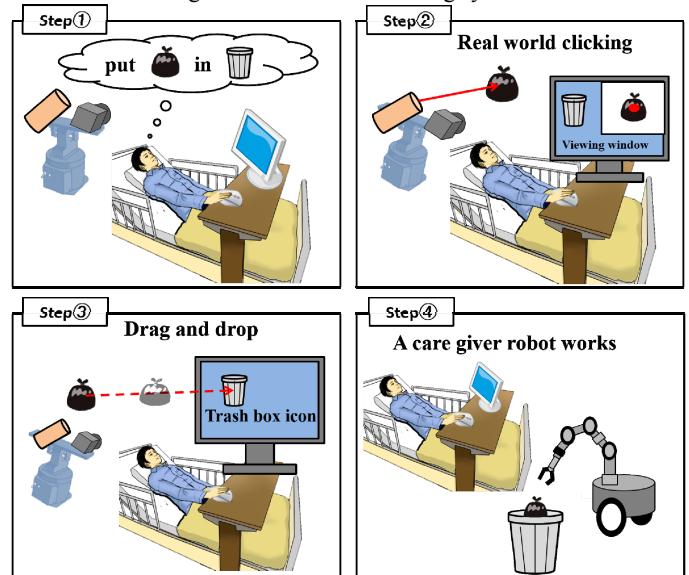


Fig. 2 A conceptual usage scene of our system

picking up of trash that has fallen on the floor and throwing it away in a trashcan as an example operation. The user first views the trash by using a personal computer (PC) and then shines the laser beam on the trash to select it. The PC screen represents the trash as an icon, which can then be moved to a trashcan icon, using a drag-and-drop gesture to instruct the robot to throw away the trash. In the following, we describe important characteristic features of the system.

B. Real-world pointing

Users use the PC mouse to manipulate a standard cursor within the display, and perform real-world pointing by using the mouse to operate the external pan-tilt actuator to aim the laser beam at objects of interest. The display and the real world are temporally and spatially connected without interruption, using the cursor and the laser beam to cross the boundary. Specifically, when the cursor moves beyond the edge of the screen, the laser is aimed as if the cursor had transitioned from the screen into the real world. Conversely, when the laser beam is brought within the screen's boundary, control is returned to the cursor. Objects within the PC and in the real world can thereby be pointed at without restriction. When real-world objects are situated in proximity to the PC display, the position of the laser spot can be verified by the naked eye; when the object lies outside the range of vision, the laser spot can be viewed with a camera image positioned next to the laser pointer.

C. Real-world clicking

“Real-world clicking” refers to using mouse-click operations to trigger measurement of the three-dimensional (3D) coordinates of the object at which the laser beam is pointed. In the present system, this 3D coordinate measurement is achieved by a high-precision encoder installed in the pan-tilt actuator to realize measurements of the beam length by the time-of-flight (TOF) principle. The laser pointer used in this system is thus a laser sensor capable of TOF-based distance measurements.

D. Real-world drag-and-drop

Similar to drag-and-drop operations in a standard graphical user interface (GUI), “real-world drag-and-drop” refers to dragging the icon for an object (selected via real-world clicking) and dropping it onto a PC icon or an icon representing another real-world object.

E. Problems

One of the problems with conventional systems is that it is easy to lose track of the laser spot in the viewing window. Figure 3 shows an example of pointing at a real-world object through the viewing window. The origin for the coordinates as shown in the viewing window is set to the window's bottom left, and the user can arbitrarily set the window size and position. As that figure shows, the laser spot is extremely small, and there are many cases in which the background color and brightness make it hard to find. The spot's position also changes within the viewing window. Figure 4 shows a typical example of this. In the figure, measurement examples (1) and

(2) can be seen, with real-world pointing scenes in each showing viewing windows with laser spot coordinates (x_{lp}, y_{lp}) and L , the distance to the

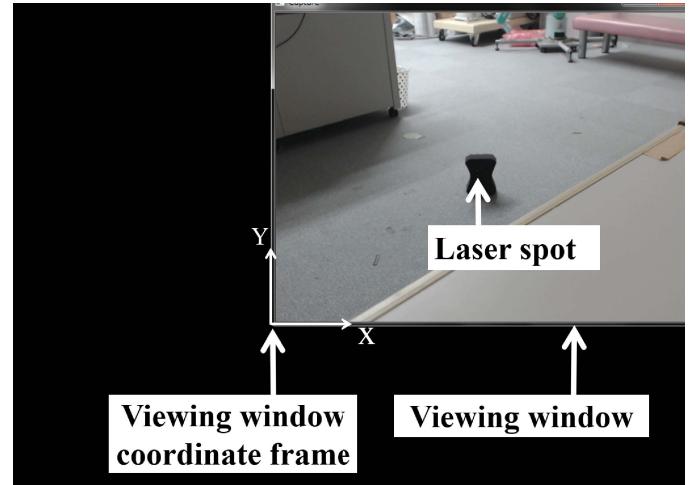


Fig. 3 PC display with a viewing window

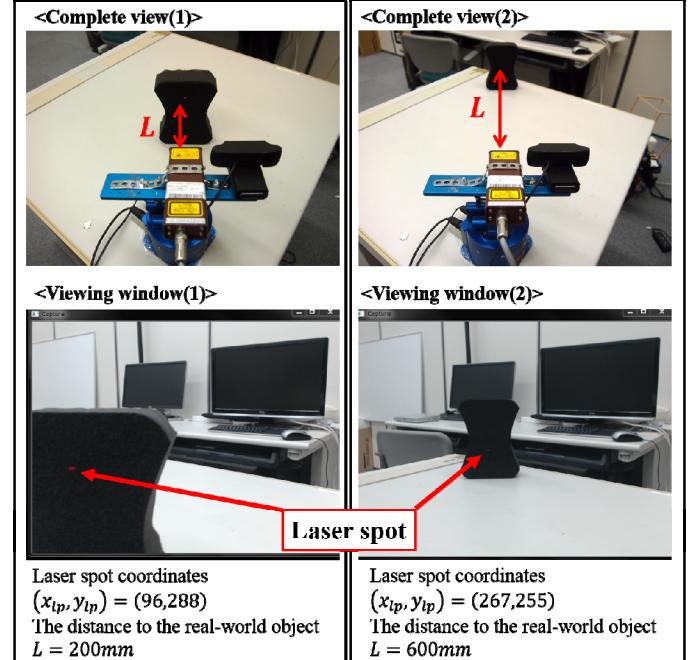


Fig. 4 Laser spot position depending on the distance to the object

real-world object. We can see that (x_{lp}, y_{lp}) varies as the distance to the real-world object changes. When the laser traces a path through a complex environment, the distance to the target can rapidly change due to surface irregularities, making it easy for the user to lose track of the laser's position.

III. PROPOSED METHOD

To solve the above-described problem, we propose a cursor (the “real-world cursor”) that clearly shows the location of the laser pointer in the viewing window. By viewing the real-world cursor, the user should be able to easily verify the laser position,

regardless of room brightness, background color, and target distance. Accurate display of the real-world cursor requires some method for measuring (x_{lp}, y_{lp}) . As for measuring y_{lp} , installing the camera lens and laser beam on the tabletop pan-tilt actuator such that the central horizontal axes are at the same height allows y_{lp} to remain fixed, regardless of environmental influences. It should be noted that there is a slight difference between the two measured values of y_{lp} (288,255) in Fig. 4, which is due to an error in assembling the camera and the sensor. We thus focus on measuring x_{lp} in the following proposed methods.

A. Method 1

The first method of measuring x_{lp} uses camera parameters and target distance measurements. Figure 5 shows a top-down view of the laser distance sensor and the camera used for real-world pointing at objects. Note that the optical axis of the laser distance sensor and the central axis of the camera lens are parallel. This is known to allow advance measurement of the distance D between the laser distance sensor and the camera and the bisecting angle θ of the angle of view. Then we can calculate x_{lp} by Eq. (1),

$$\begin{aligned} x_{lp} &= (W'/W) \cdot n_{xpixel} \\ &= (L \tan \theta - D/2L \tan \theta) \cdot n_{xpixel}, \end{aligned} \quad (1)$$

where W is the field of view, W' is the width from the field of view edge to the laser spot, and n_{xpixel} is the maximum pixel value in the x -direction.

B. Method 2

The second method does not use the target distance measurement or camera parameters, but, rather, focuses on image processing of quantitative features of the laser spot image to recognize the laser spot and calculate x_{lp} . This method calculates x_{lp} by first performing binarization, converting RGB values of the camera image in the viewing window that exceed a threshold value to white and others to

black, and then finding the centroid of the white region.

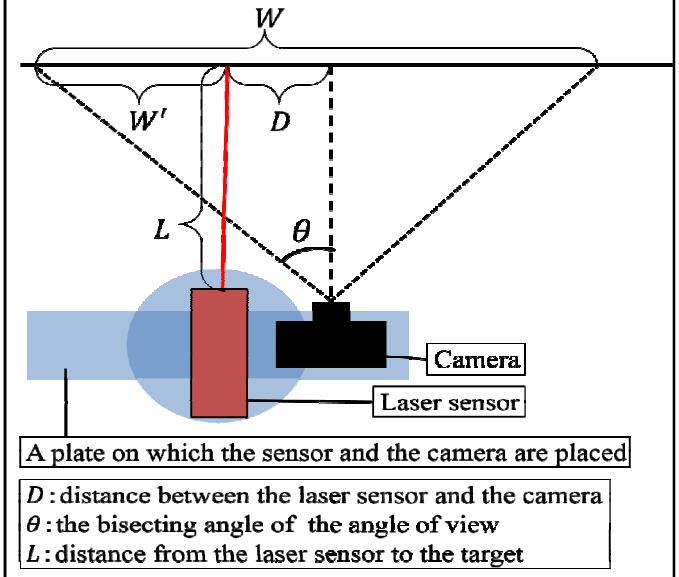


Fig. 5 Geometrical relation between field of view and laser spot

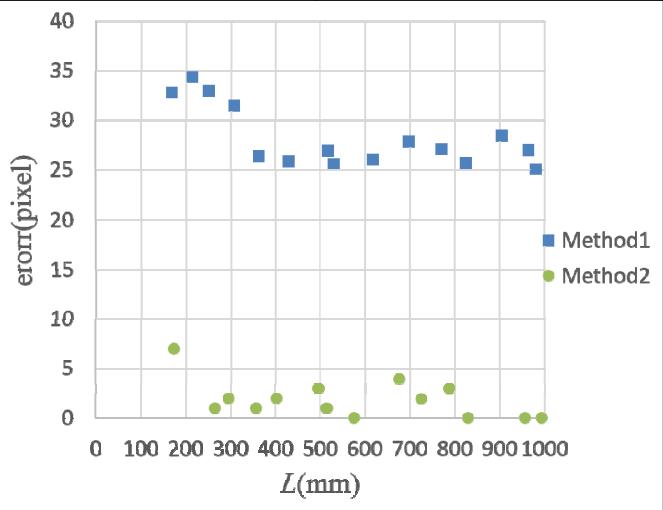


Fig. 6 Laser spot position measurement experimental data

IV. LASER SPOT POSITION MEASUREMENT EXPERIMENT

A. Experiment description

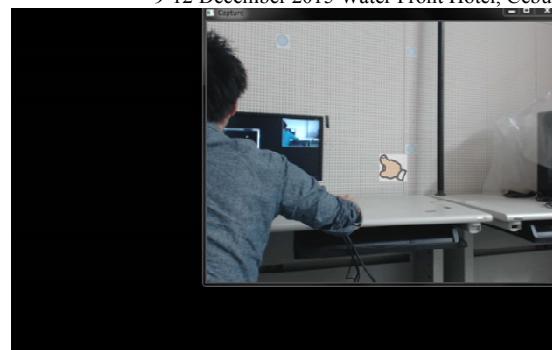
This experiment compares the values obtained by the two proposed methods for measuring x_{lp} . Specifically, as Fig. 4 shows, we place the measured object at random distances between 0 and 1 m along a line between the centers of the measured object and the camera. We performed measurements for each of 15 translational movements. When doing so, the viewing window had dimensions of 640×480 pixels. When using method 2, binarization used a threshold of R-values in excess of 1.2 times both the G- and B-values to determine the white region, and other pixels were considered the black region.

B. Results and discussion

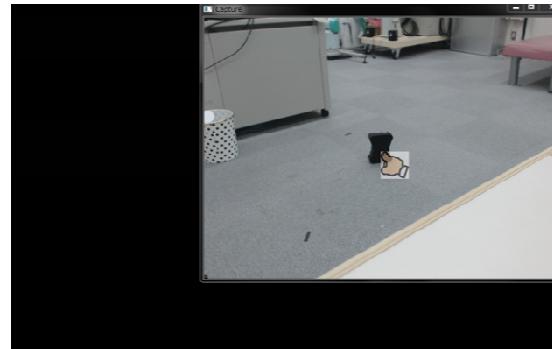
Figure 6 shows the results of the experiment. The vertical axis shows the error (in pixels) of measurement values for both methods, and the horizontal axis shows the distance L (in mm) according to the laser distance sensor. In that figure, the mean error for method 1 was 28 pixels, while that for method 2 was 2 pixels, showing that method 2 has higher accuracy. The error in method 1 was likely due to factors such as errors in the initial angle measurements and errors in the installation of the laser pointer and camera. Another verified problem was an unfocused image due to an inability to use the camera autofocus features because the angle of view had to remain fixed. Errors in method 2 were likely due to an inappropriate threshold value for binarization. Specifically, it can be difficult to isolate the laser spot in the overall image in some cases, such as when the room is bright and when there is a red background, so measurement accuracy will be highly affected by the room environment.

V. IMPLEMENTATION AND DEMONSTRATION OF THE METHOD

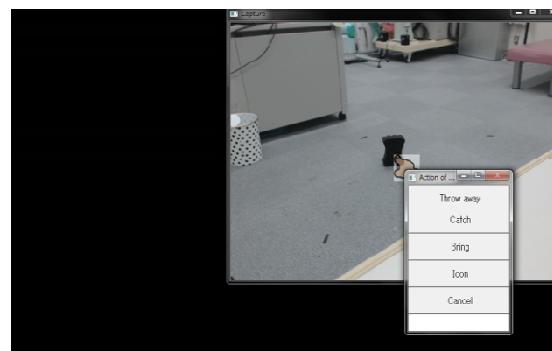
Because of the above results, we adopted method 2. We superimpose a finger shape in the viewing window for use as the real-world cursor. We also added a right-click function to the real-world cursor. This function mimics the de facto standard of



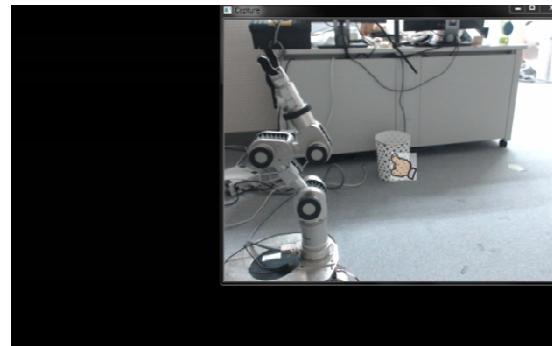
A:Starting the real world pointing



B:Real world clicking to trash



C:Selecting the “throw away” command from the menu triggered by the right-click



D:Real world clicking to trashcan

Fig. 7 A viewing window in which user operates the real world cursor

Fig. 8 Trash dumping task experiment

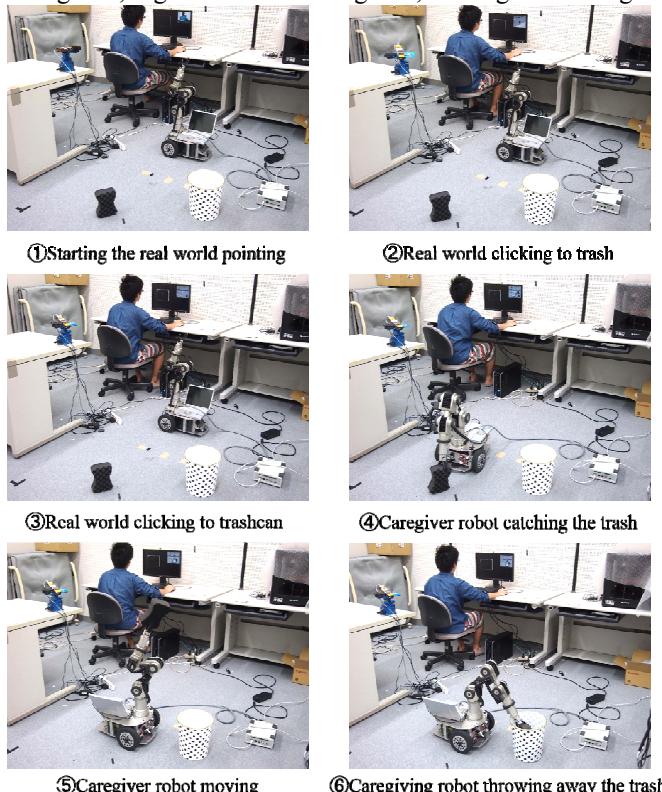
right-click functionality, displaying a context menu at the cursor that allows for selection of physical operations on the object being pointed to. The experimental system was the same as that shown in Fig. 1, using an arm with five degrees of freedom and a gripper at its end. The operation performed in the experiment was the action of throwing away trash as abstractly represented in Fig. 2.

A. Experiment

In the experiment, we instructed a caregiving robot to throw away trash that had fallen on the floor. Figure 7 shows a summary timeline of the viewing window during the experiment. In the experimental procedure, the user first performed real-world pointing from the viewing window to locate arbitrarily placed trash. The user then performed real-world clicking at the location of the trash that the caregiving robot should grasp, and selected “Throw away” from the displayed operational commands menu. Finally, the user performed real-world clicking on the trashcan in which the trash should be thrown away, after which the caregiving robot automatically performed movement and arm control.

B. Results and discussion

Figure 8 shows a summary timeline of operational results during the experiment. As the figure shows, transmission of commands to the caregiving robot to throw away trash placed at an arbitrary location was successful. Figure 7-A corresponds to Fig. 8-1, Figs. 7-B and C to Fig. 8-2, and Fig. 7-D to Fig. 8-3.



Figures 2 and 7-B together show that the real-world cursor served as an indicator for easy visual confirmation of the laser spot.

Furthermore, the right-click function of the real-world cursor allowed issuance of physical commands for real-world objects, in a manner similar to the GUI of a normal PC.

VI. CONCLUSION

We proposed and experimentally demonstrated the effect of a method for easily manipulating real-world objects in a viewing window by using a real-world cursor for clarification of the laser spot position and right-clicking at the cursor location. In future research, we will investigate methods for seamless integration of the real-world cursor with a standard PC cursor.

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