A Situational Training System for Developmentally Disabled People Based on Augmented Reality

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SUMMARY

Nowadays, many interface devices or training systems have been developed with recent developments in IT technology, but only a few training systems for developmentally disabled people have been introduced. In this paper, we present a real-time, interactional and situational training system based on augmented reality in order to improve cognitive capability and adaptive ability in the daily lives of developmentally disabled people. Our system is specifically based on serving food in restaurants. It allows disabled people wearing the HMD attached with camera to conduct the training to cope with a series of situations safely while serving customers food and drinks and take the training session as much as they want. After experimenting on our presented system for 3 months, we found that they actively participated in the training and their cognitive abilities increasingly went faster through repeated training, resulting in the improvement in their cognitive ability and their ability to deal with situations.

key words: developmentally disabled people, situational training, augmented reality, hand recognition, situational awareness

1. Introduction

Developmentally disabled people often require special care for their everyday lives since they have cognitive impairments compared to normal people. Even if their mental age reaches that of infants, the environment that they should cope with is the same as the environment of adults. Thus, to improve their cognitive and social function they have to experience various different situations and practice them over and over. For example, they must be trained about handling dangerous tools such as hot or fragile objects, ordering or serving food in restaurants or kitchens, or crossing the street at crosswalks. However, the existing special education for people with disabilities is conducted under teacher instructions for a certain amount of time and in space. For this reason, iterative learning is difficult. Especially, the education with real tools or the training to be enforced in the field needs a lot of money to build the environment. In addition, the possibility that safety incidents occur to them is far higher than to normal persons. Therefore, it is difficult to implement training in reality.

Augmented reality technology solves the problem mentioned above. It also enables them to learn how to handle tools difficult to use without the help of teachers or to have training repeatedly based on augmented reality in order to experience the environment difficult in the field.

Recently, many research works have been attempting to apply augmented reality technology to education with the recent development in IT technology \([1]–[3]\). But, only a few systems have been introduced for developmentally disabled people \([4]–[6]\). Richard E. et al. proposed the cognitive training designed to find the same model as the one in a marker book and to match them \([4]\), whereas Claudio K. et al. presented another cognitive training planed to find the pattern that generates the same image as the image of the cell designated using a 3-sided cells and physical pointers with markers \([5]\). However, these researches focus on cognitive training only, so it is difficult to find augmented reality based situational education cases. The situational education using augmented reality-based technology enables one to one learning and experience. Thus, it can make a great contribution to minimizing the experience of failure that people with developmental disabilities may encounter in daily life and expanding the successful experience.

In this paper, we propose a real-time, interactional, and situational training system for developmentally disabled people based on augmented reality. It is specifically based on serving food in restaurants. It allows a disabled man wearing a camera-attached HMD to conduct the training to cope with a series of situations while serving customers food and drinks. In addition, the proposed system induces the developmentally disabled people to perform correct training when they have to cope with unforeseen situations during training. To attract users and improve their cognitive ability, we also present the virtual hand control technology as an input interface and the situational awareness technology to monitor users’ abrupt behaviors and their incorrect performing of the training. Furthermore, we make it possible to provide the tailored-individual training with various situational scenarios according to the level of disability within one system by providing scenario reconstruction function and thus enabling special education teachers easily to edit the scenarios.

2. A Situational Training System for Serving Food in Restaurants

2.1 Scenario

The proposed situational scenario in Table 1 is designed by a special-education-school teacher. A trainee becomes a restaurant waiter or waitress. And he or she is trained to serve food stage by stage under conditions that closely resemble a real restaurant.
### Table 1: Food serving scenario.

| Stage                  | Direction                                      |
|------------------------|------------------------------------------------|
| 1. Give a bow          | Give a bow to a guest                         |
| 2. Take an order       | Serve water and menu board to the guest and    |
|                        | take an order                                 |
| 3. Serve food          | Put foods on a tray and serve them to the guest |
| 4. Wash dishes         | Wash dishes                                   |
| 5. Give the change     | Calculate the change and give it to the guest  |
| 6. Give a bow          | Give a bow to the guest and clean the table    |

#### 2.2 System Environments

Figure 1 shows the proposed overall situational training system environments. This marker-based training system provides trainees to experience various different situations safely and take the training session under any circumstances. The trainee can see the overlay of the virtual imagery on real world when he or she is wearing the HMD attached with camera. For example, three-dimensional virtual food objects appears on the plates on the real kitchen table and a three-dimensional virtual guest character appears in front of the real guest table. The trainee moves the plates; the virtual food objects move with them and appear to be attached to the real object. The trainee comes and goes easily between the kitchen table and the guest table by following the voice instructions and tries the situational scenario stage by stage in Table 1. The cameras mounted on each table are used to recognize and monitor the trainee’s actions. The monitoring and management programs of the training session are also provided for teachers or parents.

#### 2.3 Virtual Hand Control

In order to increase interest and to develop cognitive ability, our system also provides virtual hand interface for selecting a menu and taking an order (in stage 2), virtually washing dishes (in stage 4), and calculating the change (in stage 5) programs, as shown in Fig. 2. They recognize a trainee’s hand and show the 2D virtual hand image, instead of the real hand, to select or move an object in the virtual reality programs.

We can utilize the movement of a trainee’s hand as an input interface for the virtual hand to select and move an object. Figure 3 shows the proposed hand recognition algorithm. An input image is transformed into the HSV color space from the RGB color space, and the hand area is segmented using double thresholds of H and S values and connected component analysis. Subsequently, the centroid of gravity of the hand area can be calculated by 0 and 1 moment implementations of the segmented area. Since the centroid of gravity is positioned onto the center of the hand, the pixels that are further apart from the centroid among the pixels in the segmented hand area can be recognized as fingertips. Finally, the axis of the hand is obtained as the vector of the centroid of gravity and the furthermost fingertip. In order to increase recognition stability, we used a history buffer that accumulates and averages fingertips in consecutive frames, and in order to enhance the speed, we performed the algorithm for the bounding box of the hand region neighborhood using temporal coherence.

#### 2.4 Situational Awareness

It is important to monitor whether or not the trainee acts well because developmentally disabled people often go or look the wrong way during the course of training. Figure 4 shows the process of situational awareness. First, interest points for the surrounding environment images are selected and represented by the descriptor vectors for finding the
same physical interest points under different viewing conditions. Next, the descriptor vectors are matched between the HMD input image and the surrounding environment images to recognize where the trainee is and what he or she is looking for. Finally, if the trainee looks or goes in wrong direction, the system guides him or her to take a train session well by voice instruction, as shown in Fig. 5.

Our system detects interest points and constructs the descriptor vector based on the SURF (Speeded Up Robust Features), which is a novel scale-and rotation-invariant interest point detector and descriptor [7]. SURF has relatively high cost since it uses a 64-dimensional floating point vector as a descriptor. The proposed method converts a 64-dimensional floating point vector to a 16-dimensional integer vector, and then the 16-dimensional integer vector to a 4-dimensional integer vector for fast matching. Using the fact that similar descriptor vectors are clustered as the dimensions of the descriptor vector are being reduced, we use the integer descriptor as an index for fast matching. Figure 6 shows the proposed multi-level index structure.

In order to match features between the input image and surrounding images, candidate descriptors are searched by top-down traversing in the multi-level index structure. Then, the Euclidean distance between the input descriptor and each candidate is compared. The shortest one is retrieved.

3. Experiments and Results of the Situational Training System

We used ARToolkit [8] and DirectX 9.0 libraries for building the situational training system based on augmented reality. Experimental results showed that our system was capable of 60 frames per second at a resolution of 640 × 480 pixels on i5 2500 PC with 4 GB RAM.

The proposed system was tested and directed at the students of three groups including one elementary school group (the low level group determined to find it difficult to study and live by themselves), one middle school group (the medium level group with low immature language and life skills), and one high school group (the high level group with basic communication and life skills), as shown in Fig. 7. Each group consisted of six students. The weight of the HMD attached with camera was 850 g and the extent of the training room was 355 sq. ft. The results of performing the training according to their individual level showed that the high level students were well adapted as the training repeated. The medium level students gradually adapted with the help of the voice guidance provided from the system when they could not perform the training within a certain period time. The low level students lacking in a learning ability seemed to be difficult to be adapted to the training by themselves, but carried out the training with the help of a teacher.

Figure 8 shows a graph of the average time that the students, who had participated in the training, were required to perform the steps of each scenario. It took a lot of time to perform each step because they could not follow the progress of the program at the beginning of the training, in spite of the help of a teacher. But, as they paid attention to
the voice instructions and became accustomed to the virtual hand control using hands, the awareness of food menu, and the comparison of bowls to be served and bowls to be removed, the execution time of each step was gradually shortened. It was observed that while performing the training, the students developed communication skills through paying attention on others, interaction skills, and computation skills, and significantly improved the accuracy of operation results through performing repetitive tasks.

It was also found that they had no reluctance to wear the HMD and that they continued to be trained very interestingly rather by immersing themselves into the augmented reality environment. In addition, we obtained special education teachers’ evaluation that this system is a highly effective training system to students with autistic developmental disabilities who are difficult to develop sociality, due to its characteristics of the stability, repeatability, and uniformity that may benefit from the situational training courses, and also their feedbacks on the students who performed the training, as shown in Table 2.

4. Conclusions

We presented a real-time, interactional and situational training system based on augmented reality in order to improve cognitive capability and adaptive ability in daily lives of developmentally disabled people. It is specifically based on serving food in restaurants. They are able to look around with the HMD and experience various different situations and practice them over and over. Thus, it can make a great contribution to minimizing the experience of failure that people with developmental disabilities may encounter in daily life and expanding the successful experience. After experimenting on our system for 3 months, we obtained special education teachers’ evaluation that this system is a highly effective training system to students with autistic developmental disabilities.

Our presented system can be expandable to not only serving food in restaurants but also other daily activities. Furthermore, it can be used for children or elderly people as well as developmentally disabled people who need to improve cognitive capability and adaptive ability.

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