Backward Recognition System For Wheelchair User Using RGB-D Sensor

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***Abstract*— Wheelchair user has a difficult problem to confirm backward in their life. In order to support backward movement of the wheelchair user, this paper proposes a method presenting the information such as obstacles and stairs behind the user in an easy-to-understand way. Obstacles and steps are detected by installing the RGB-D camera directly above the wheelchair user. Also the distance between wheelchair and obstacles are calculated by using respective three-dimensional coordinate position.**

Keywords—Wheelchair user support; RGB-D camera; Backward recognition; Image processing;

1 INTRODUCTION

In recent years, as the development of technology and the thinking of diversity is expanding, the barrier-free of society is progressing. Therefore, there is a tendency for wheelchair users to act outside. When a wheelchair user moves outdoors or indoors, it is very important to know information about their surrounding obstacles and steps. It is difficult for wheelchair users to know surrounding information sufficiently because there is a lower eye level than a healthy person and there is a limitation on the movement of their body. In an autonomous of an electric wheelchair, Uratsuji conducted a recognition of obstacles and steps in front of a wheelchair user by using laser sensors and infrared sensors [1]. On the other hand Utaminingrum had developed a smart wheelchair system that facilitates obstacle detection in front and human tracking based on computer vision [2]. There is also a research that uses stereo camera to avoid obstacle for power assisted wheelchair [3]. Our research pays attention to backward recognition. The purpose of this research is to recognize the surrounding environment behind the user by information obtained from above the user. Also to support movement by presenting the state of the recognized surrounding environment to a tablet terminal or smartphone owned by the user. This paper proposes a method to estimate the surrounding environment behind the wheelchair user based on three-dimensional information and color information, and a method to present distance between the wheelchair and obstacles or steps.

2 PROPOSED METHOD

To detect obstacles and steps behind, we use color images and depth images (Figure 1) obtained from RGB-D camera installed above the wheelchair user. The white parts of the depth images have depth information. Depth images are mainly used for the detection, but only with this information the detection accuracy is not good enough. There are parts that depth information cannot be obtained by the camera because of their material. For that, we use color images to extract those parts like edges of the wall and wheelchair's tires.

First the depth image is segmented into floor areas and other object areas. Then, obstacles and steps are detected by using depth information of other object areas and edge information extracted from color image. Finally, the distance between the wheelchair and detected obstacles and steps are calculated from the respective three-dimensional coordinate position and displayed on a mobile device.

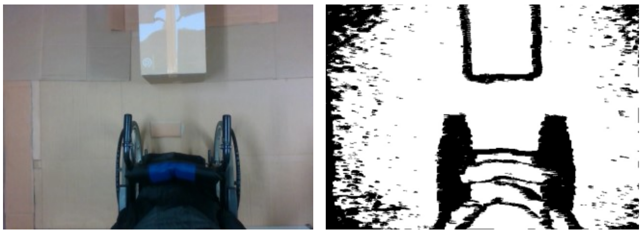

Fig. 1. Color image and depth image

2.1 SEGMENTATION

In detecting wheelchair and obstacles, the depth image is first segmented into floor areas and other object areas. The depth data is obtained by the tilted RGB-D camera with respect to the floor as shown in Figure 2. From the obtained data in camera coordinate system, it is difficult to obtain information on the height direction with base to the floor. For that, the data in the camera coordinate system is converted to the data based on the floor in the world coordinate system. To obtain the transformation matrix, checkerboards as shown in Figure 3 are put on the floor in advance. The transformation matrix is calculated using the least squares method by preparing plural sets of the corner points of the checkerboard in the camera coordinate system and corresponding points in the world coordinate system. By applying the calculated transformation matrix to the depth data obtained from the RGB-D camera, data in the world coordinate system with the floor plane set to $z = 0$ is obtained. By using this data, we segment the depth image into floor areas and other object areas. When the wheelchair user moves backwards, a step larger than 5 cm will become an obstacle. So data up to ± 5 cm from the floor is segmented as floor areas. Figure 4 shows an example of segmentation result.

The image of the obstacle candidate is used to detect wheelchairs and obstacles in the next step.

Fig. 2. Setting of RGB-D camera

Fig. 3. Checker board

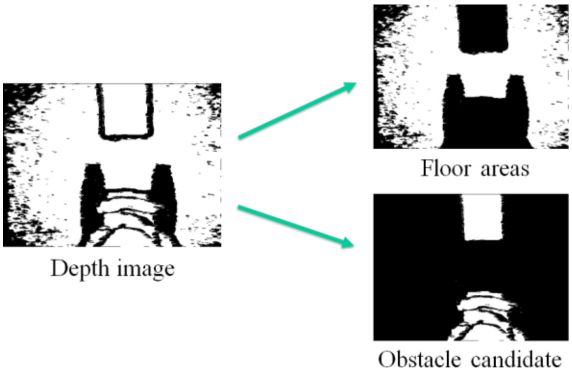

Fig. 4. Segmentation result

2.2 EDGE EXTRACTION

The image of the obstacle candidate shown in Figure 4 is not suitable for object detection, because like the depth of the tire area of the wheelchair has not been acquired. Therefore, by generating an edge image from a color image, the area where the depth cannot be acquired is complemented. We use the canny algorithm for edge extraction. Figure 5 shows the edge extraction results. The right image is the generated edge image and it is confirmed that the boundary of the tire area of the wheelchair can be detected.

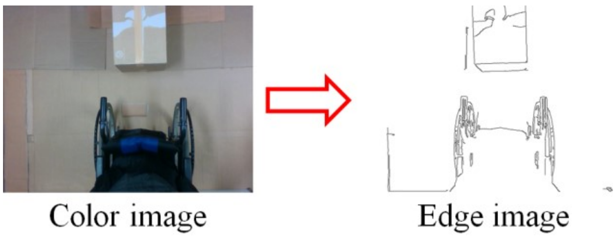

Fig. 5. Edge extraction result

2.3 COMBINING EDGE IMAGE AND DEPTH IMAGE

Next, the edge image and the depth image of wheelchair and obstacles are combined. Since we want to display objects other than the floor area as combining result, edges overlapping with the floor area are eliminated during combining. Figure 6 shows the combining result.

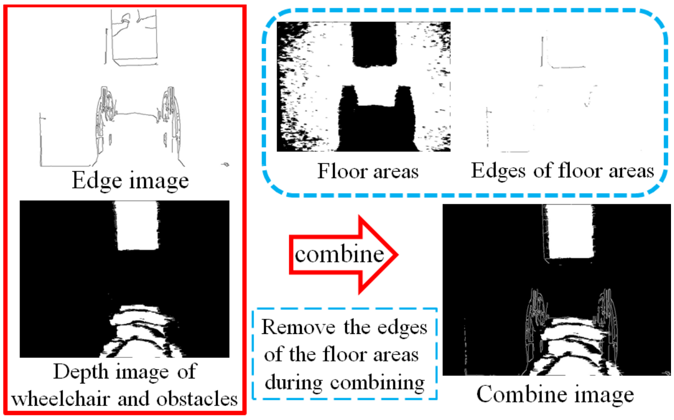

Fig. 6. Combining result

2.4 LABELING

After generating combine image, closing process is performed before labeling process. The closing process fills the area between the obtained candidate area using depth information and the edge of the wheelchair or obstacle, so that the contour and the inner area of the object are labeled as the same. After the closing process, labeling process is performed on the image and so the object detection is performed. Among the labeling results, small areas are removed as noise. Figure 7 shows the labeling result. The right image is the labeling result after noise removal.

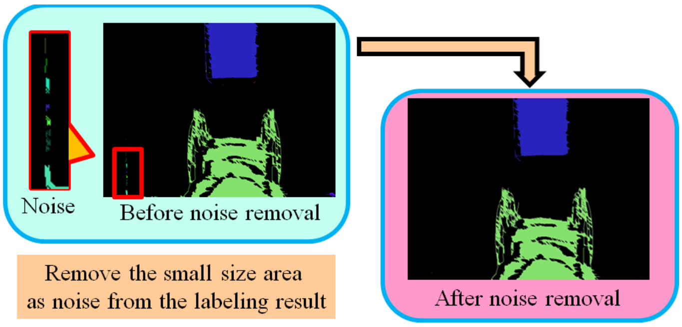

Fig. 7. Labeling result

2.5 DISTANCE CALCULATION

At last, the distance between the wheelchair and detected obstacles are calculated. This time, the wheelchair is displayed as a rectangle. The end of the rectangle is set on the rear wheel part which may actually collide with the obstacle. The shortest distance between the rectangle and detected obstacles are calculated from three-dimensional coordinate position, and displayed on the screen.

3 Experiments

In experiments, we use a PC with Core i7-6500U 2.50 GHz CPU, 8 GB of memory. Input images are 640 × 480 pixels captured by a RGB-D camera (Intel RealSense Camera SR300). Calculated distance between the wheelchair and detected obstacles are compared by the actual distance. Figure 8, 9 and 10 show the results of the proposed method in each process when the distance between the wheelchair and obstacle was 30cm. It can be confirmed that the calculation result shown in the right image of Figure 10 has only an error of 0.2 cm as compared with the actual distance. Figure 11 shows results of comparing in other 3 cases of obstacle. In each case, we were able to estimate the distance between the wheelchair and the obstacle in high accuracy. However there were problem that some area of the floor was detected as obstacle. This has happened because there is a problem of measurement accuracy in RGB-D camera. Depth information which exist at the edge of the image are difficult to acquire accurately. And there are also influence of noise generated by the camera when the data were obtained.

We have also performed experiments at where there are down stairs. Figure 12 shows color image and depth image of down stairs behind the wheelchair. Figure 13 shows the segmentation result of down stairs where the depth data is lower than -5cm from the floor. By comparing the segmentation result with the color image, we can see that the steps behind the wheelchair are segmented almost correctly.

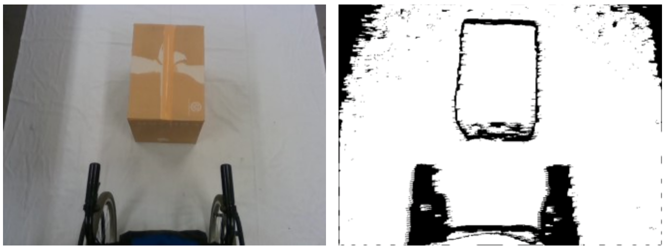

Fig. 8. Result of color image and depth image

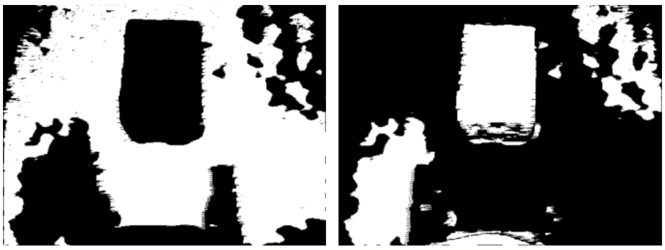

Fig. 9. Result of floor areas and obstacle candidate

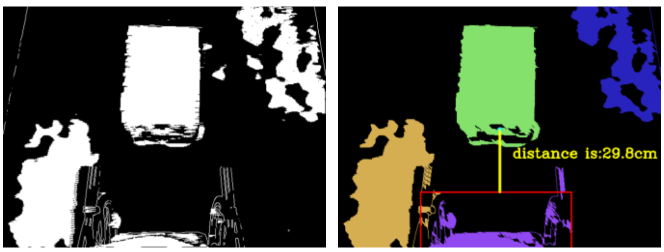

Fig. 10. Result of combine image and labeling image

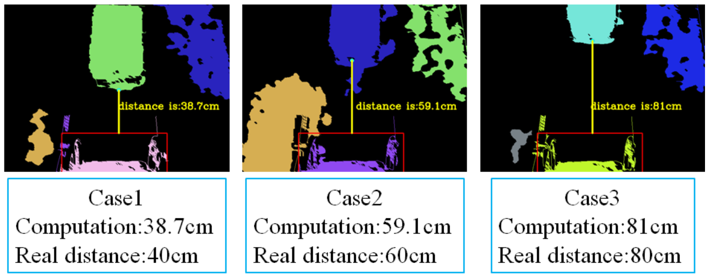

Fig. 11. Distance between wheelchair and obstacle

Fig. 12. Color image and depth image of down stairs

Fig. 13. Segmentation result of down stairs

4 Conclusion

To support backward movement of the wheelchair user, we installed the RGB-D camera above the user, which made it possible to detect obstacles and steps behind, and calculated the distance between the wheelchair and obstacle. In the future, we will consider a method which improves detection precision of obstacles and steps, and accuracy of distance calculation. We will also calculate the distance between the wheelchair and down stairs and perform comparative experiment with the real distance.

References

[1] Yuki Uratsuji, Daisuke Hukuyama, and Tadahiro Kaneda, "Research on automation of electric wheelchairs" Journal of the Japan Association for College of Technology, vol. 16, pp. 5-10, July 2011.

[2] Fitri Utaminingrum, M Ali Fauzi, Randy Cahya Wihandika, Sigit Adinugroho, Tri Astoto Kurniawan, Dahnial Syauqy, Yuita Arum Sari, and Putra Pandu Adikara, "Development of Computer Vision Based Obstacle Detection and Human Tracking on Smart Wheelchair for Disabled Patient" Computational and Business Intelligence, 2017 5th International Symposium on Computational and Business Intelligence (ISCBI), pp.1-5, 2017

[3] Naoki Oda and Toshiaki Izumi, "Experimental Evaluation of Vision-based Obstacle Avoidance Function for Power Assisted Wheelchair" 8th Europe-Asia Congress on Mecatronics, pp. 303-307, 2014