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The Detective of the Obstacle by Using the New System Called Horizon View Camera

Ayami Iwata, Kunihito Kato, Kazuhiko Yamamoto
Department of Information Science, Faculty of Engineering, Gifu University
aya@yam.info.gifu-u.ac.jp

Abstract

In this paper, we proposed a new camera system called Horizon View Camera (HVC). It is possible to install it in the small size robot. The HVC is the system in which the optical axis of a camera is directed to the horizon by using a mirror. The obtained image consists only objects without the ground. Therefore, the HVC system has a feature that distinction of the object from the ground becomes very easy. We presented the effectiveness of the HVC with experiments of the detection of the distance to the object by using feathers of the HVC.

1. Introduction

Now a day, many researches of autonomous robots have been proposed. According to it, the visual information by a camera is useful for the autonomous robot [1]. The autonomous robot has to recognize surrounding situation using the visual information. For example, when the robot moves, the robot has to recognize the object such as obstacles that limit the action.

In the method of detecting the object, the single camera or the stereo camera is usually used. However, these methods have some problems. In the case of using the stereo camera, two cameras and more are needed which increases the cost [2][3]. On the other hand, in the case of using the single camera, cost becomes low because only one camera is needed. But it is necessary to keep the camera at a higher position in order to acquire higher accuracy [4]. Therefore, the height of the system becomes big inevitability. So, we proposed a new camera system called Horizon View Camera (HVC) for constructing the small size robot [5].

2. Outline of the HVC System

In the case of using the single camera, it is necessary to keep the camera at a higher position in order to acquire higher accuracy, and this strategy had the problem that the height of the system becomes tall. To solve this, we came across the opposite viewpoint to this method. Our new method is keeping the camera at a low position, that is, the camera is put on the ground. By this method, the obtained image contains only surrounding objects without the ground because the system positions too low. In this paper, therefore, the camera was put on the ground, and the system was made so that the optical axis of a camera was directed to the horizon. This system was named Horizon View Camera. The obtained image by this system contains only objects without the ground. Therefore, this system has advantages that distinction the object from the ground becomes very easy, and the calculation time for that can be reduced. By moving forward, the system can measure the distance easily.

We tried to make the HVC system, but we have to bury half of the cameras in the ground to make the optical axis of the camera direct to the horizon. But it is impossible in actual applications. Therefore, the optical axis of a camera was directed to the horizon by using a mirror. The HVC system is shown in figure 1. The height of the HVC system is decided according to the size of a camera and a mirror. In this paper, the size of the mirror used is 17cm×11.9cm. The range of vision of this camera is about 46 degrees in the vertical direction,

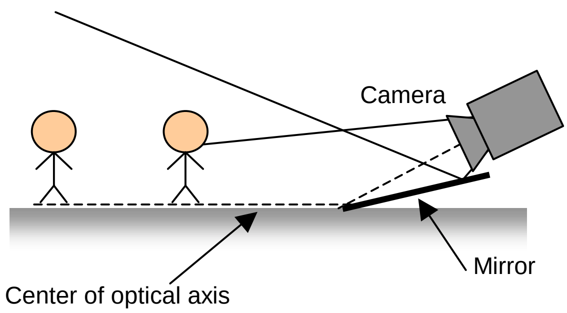

Figure 1. HVC system

and about 60 degrees in the horizontal direction. The HVC system was made with this camera and this mirror. The obtained image by this system is separated horizontally into two parts; the upper half of image is the reflected image by the mirror, and the lower half of the image is the direct image in front of the system. The obtained image by the HVC is shown in figure 2, and figure 3 shows a sequence of the animation which is taken by the HVC. A person who was walking front of the HVC was taken.

3. Features of the HVC System

In this system, every object in the image is considered the obstacle, because the ground is not included in the image of upper part of the horizon. Therefore, the distance to the object is measured with the reflected image only by moving the HVC, without detection of the object.

The images obtained by the HVC system have a feature for its emission point of the optical flow which is formed by the movement of the system. The emission point of the upper half of the image is located on the horizon in the image. Moreover, when the HVC system moves forward, the emission point is existed at the center of the horizon. The optical flow is discharged from the emission point to outside. Figure 4 shows the optical flow of the HVC system. If the optical flow is not discharged from the emission point, that part of the image can be recognized as a moving object.

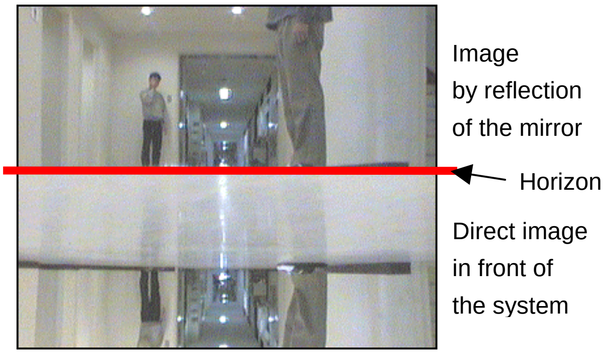

Figure 2. Obtained image of the HVC
(320×240 pixels)

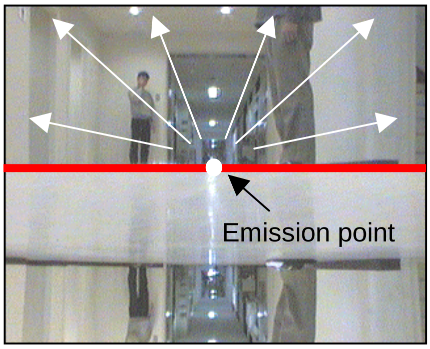

Figure 4. Optical flow of the HVC

The HVC also has a feature that the object on the center of the optical axis does not move in the image when the HVC moves forward.

Moreover, we transformed the image from the HVC to the log-polar coordinate [6][7]. The transformed image has an interesting feature. When the HVC system moves forward, the optical flow is discharged to upward direction. Also if the optical flow is not discharged to upward direction, the object of that image can be detected as a moving object like the optical flow of the original image.

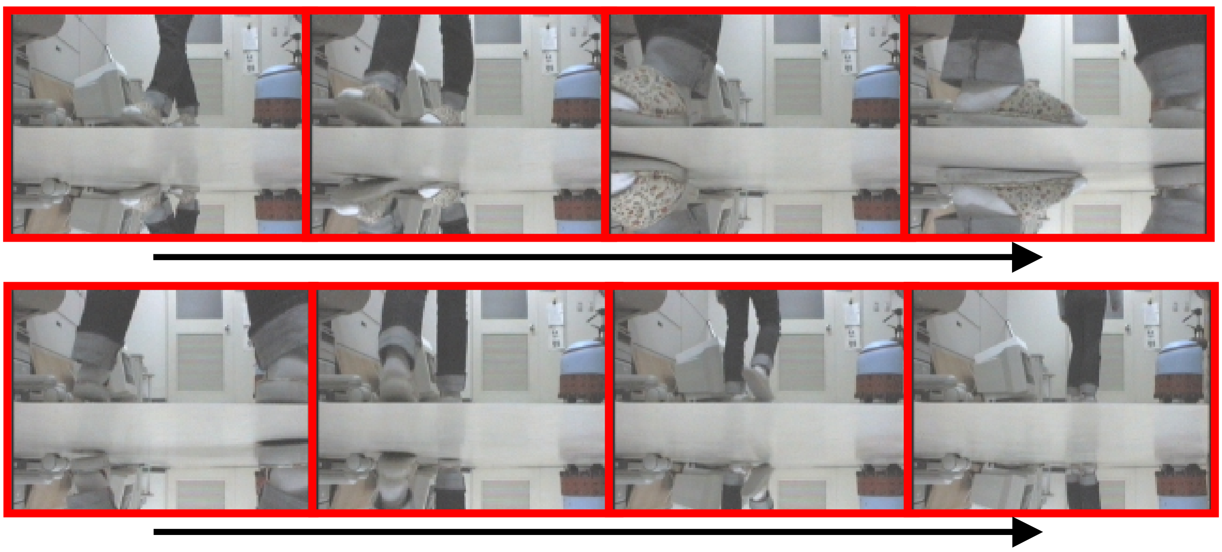

Figure 3. The animation from the HVC

Generally, since the image by the HVC is transformed to the log-polar coordinate, we have to fix the origin to the same position exactly in every image. This is a seriously problem in the applications using the log-polar coordinate transform. But the origin is always fixed in the center of the horizon by the HVC. Therefore, we can transform to the log-polar coordinate easily.

We explain the detail of the log-polar in chapter 4. We called the obtained image by the HVC as X-Y image, and the transformed image by the log-polar as log-polar image.

4. Method of Measuring the Distance to the Object

4-1. Method of Measuring the Distance by X-Y Image

We used the optical flow for detecting the distance to the object [8]. When the camera is moved forward, the object whose distance between the camera and the object is short moves greatly in the image. On the other hand, the object whose distance is long does not move so much. Moreover, the distance of the movement also differs by the distance between the object and the center of the optical axis. If the object is located far from the center of the optical axis, moves greatly. If the object is located near the center of the optical axis, it moves a little. By using this difference, the movement vector of the object in the image before and after the camera's movement can be calculated. We can measure the distance by the direction and the size of each movement vector to the object.

In this paper, we used the template matching to detect the optical flow [9]. So, the distance to the object is measured by the optical flow. The distance to the object is calculated by the triangulation, because the angle from the camera to each pixel of the image is constant, and the moved distance of the camera is already known.

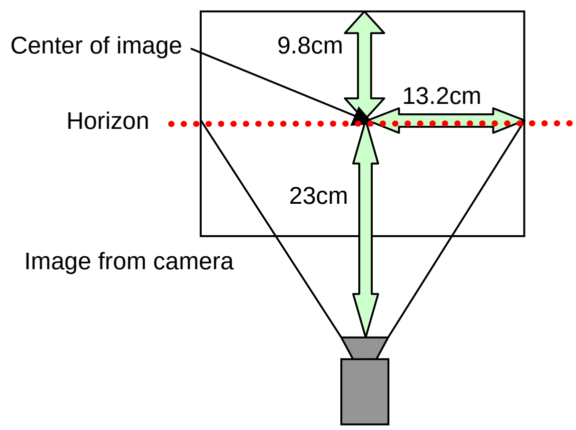

Figure 5. Camera parameters

To measure the distance from the camera to the object, we have to know the camera parameters. Then the angle corresponding to each pixel is given. We present the calculation of the camera which is used here. Since the camera was located from the wall by 23cm, we got the image about 9.8cm high and 26.4cm wide. Figure 5 shows the camera parameters. The value of θ that is the angle in each pixel from the camera is decided by using these values.

Since the center of the horizon is on the origin, (x, y) is calculated by eq.(1) in the case of the resolution of 320×240 pixels.

$$(I, J) = \left((x-160)\times\frac{13.2}{160}, (120-y)\times\frac{9.8}{120}\right) \quad (1)$$

$(x=0\sim320, y=0\sim120)$

Obtained (I, J) is an actual position in a place away from the camera by 23cm. Figure 6 shows how to calculate the angle of each pixel in the image. Therefore, the angle of each pixel from the camera is calculated by eq.(2). So, the angle from the camera of each pixel is calculated.

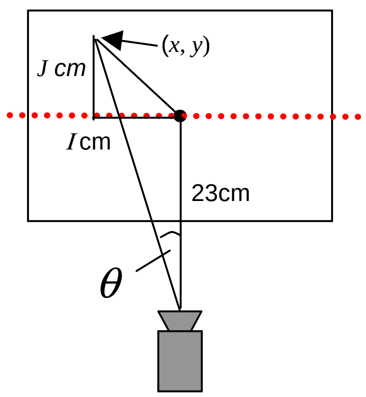

Figure 6. The angle of each pixel

$$\theta = \tan^{-1}\frac{\sqrt{I^2+J^2}}{23} \quad (2)$$

Where d is the movement distance of the camera, and D is the distance to the object, the distance to the object is calculated by eq.(3) using the value of θ_1, θ_2 calculated for each pixel. Figure 7 shows the method of calculating the distance. The value of θ_1, θ_2 for each pixel and d have already been known.

$$D = d \times \frac{\tan\theta_1}{\tan\theta_2 - \tan\theta_1} \quad (3)$$

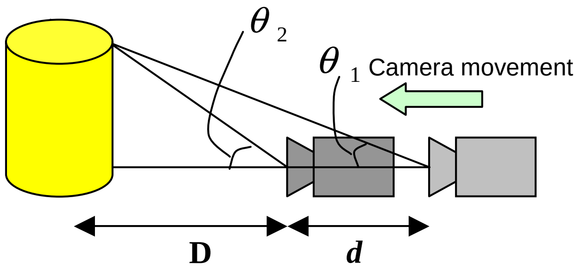

Figure 7. Measurement of the distance to the object

4-2. Method of Measuring the Distance by Log-Polar Image

The upper half of the image obtained by the HVC is easy to transform to the log-polar coordinate image as shown in figure 8. This log-polar image has useful properties. The X-Y image is transformed to the log-polar image by eq.(4). In the general equation to transform to the log-polar coordinate, objects detached from the center of the horizon become small to transform. Therefore, when we detect the optical flow, the reliability of the measuring distance become low because the size of each vector is small. According to it, we regulated the increasing rate of "log" by using the value of k in this paper. So, we can detect the optical flow which is possible to measure the distance with enough accuracy by eq.(4). Figure 9 shows the X-Y image and the log-polar image.

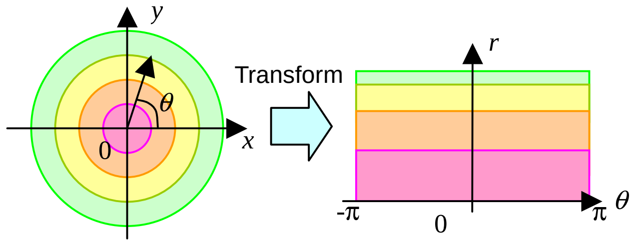

Figure 8. Transform to the log-polar coordinate

$$\begin{aligned} r &= \log_a \left\{ k \times \sqrt{x^2 + y^2} + 1 \right\} \\ \theta &= \tan^{-1} \frac{y}{x} \end{aligned} \qquad (4)$$

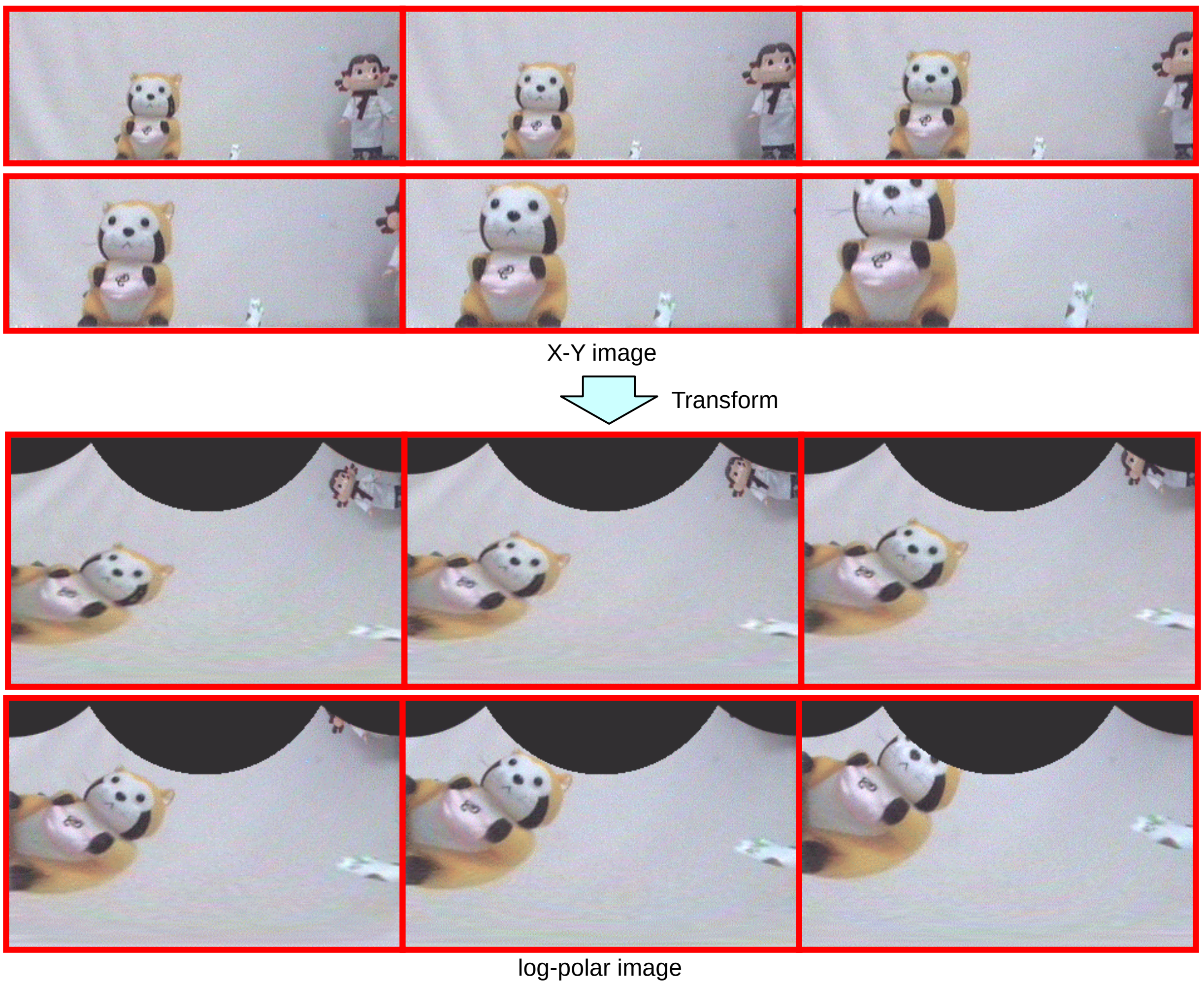

Figure 9. Transform to the log-polar image

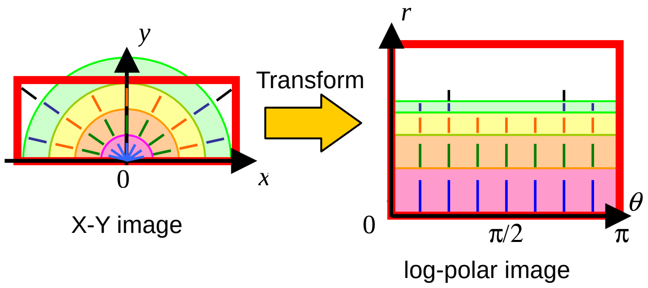

Figure 10. Optical flow of X-Y image and log-polar image

In the log-polar image, the optical flow of standing objects is discharged to upward direction constantly, as shown in figure 10. By using this property, a process of detecting the optical flow becomes very easy, because the searching area of the template matching is limited to a small area, and the computation cost is reduced.

Moreover, by using the log-polar image, we think that the optical flow is detected correctly and the accuracy of the measuring distance can be improved. Because the feature of the object which has the straight line and the texture is changed into complex feature. In the X-Y image, objects are moving to outside from the center of the horizon. In the log-polar image, objects are moving to upward direction as shown figure 9.

In order to detect the distance, we substituted eq.(4) to eq.(1), and we expected θ by substituted obtained (I, J) to eq.(2). We obtained the distance to the object D by substituted the angle of each pixel θ to eq.(3). So, we can measure the distance to the object in the log-polar image by eq.(5). In eq.(5), (r_1, θ_1) and (r_2, θ_2) are coordinate values of the object in the log-polar image before and after movement. In the log-polar image, θ_1 and θ_2 are not change if the HVC moves forward. Because the optical flow is discharged to upward direction constantly. Therefore, θ_1 and θ_2 are not included in eq.(5). d is the movement distance of the HVC and known value.

$$\boldsymbol{D} = \boldsymbol{d} \times \frac{\boldsymbol{a}^{r_1} - 1}{\boldsymbol{a}^{r_2} - \boldsymbol{a}^{r_1}} \qquad (5)$$

5. Experiments

We made the comparing experiment of the accuracy of measuring the distance to the object by using the X-Y image and log-polar image of the HVC. In this experiments, we detected only a standing object. Therefore, the calculated optical flow is discharged from the center of the horizon to outside in the X-Y image. The calculated opical flow is discharged to upward direction in the log-polar image. If an unexpected movement vector is obtained, it was considered a mistake of the template matching and this

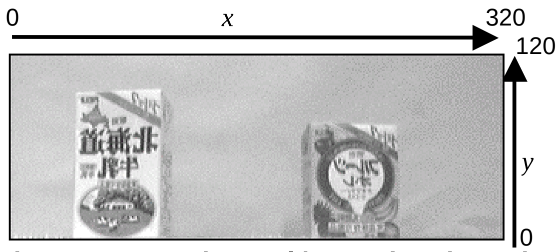

Figure 11. Experimental image (X-Y image)

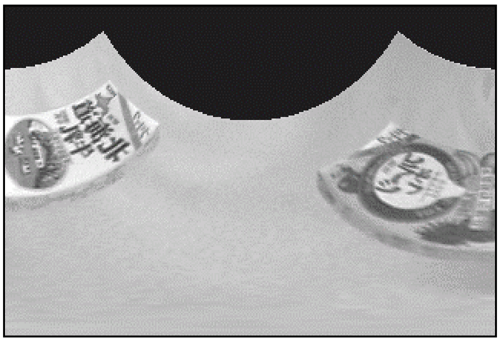

Figure 12. Experimental image (log-polar image)

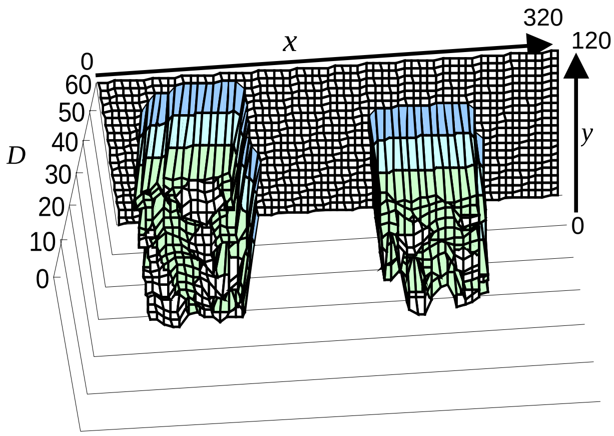

Figure 13. Result of the detected the distance (X-Y image)

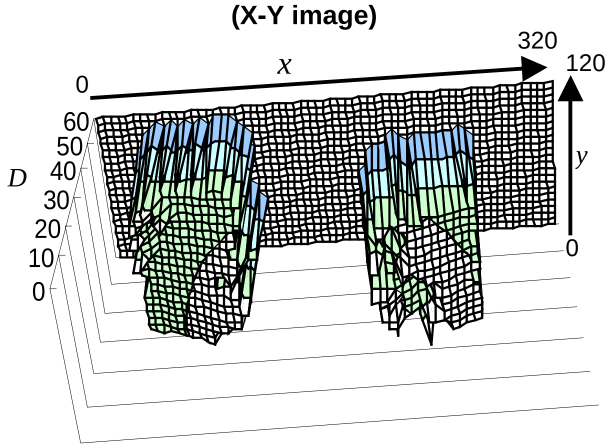

Figure 14. Result of the detected the distance (log-polar image)

movement vector was not used to measure the distance.

In this paper, templates were made on the feature points in the image, and then the camera was moved forward. Then the template matching was executed for the image after moving. The optical flow in the image of the object was calculated by difference of positions of the template.

In the situation of the single background, we put two objects which have the flat surface in the same position. The camera was moved forward by changing the distance as a constant value, and the image was taken every distance. The distance between the camera and objects had been changed from 55cm to 15cm by a 1cm step. Using the obtained image, we measured the distance in the X-Y image and the log-polar image, and we expected the accuracy of the measuring the distance in each images.

Figure 11 shows the X-Y image, and figure 12 shows the log-polar image used in the experiment. Figure 13 shows one of the result of detected the distance using the X-Y image, and figure 14 shows one of the result of detected the distance using the log-polar image. In the image of figure 11, 12 and the result of figure 13, 14, the actual distance to objects from the camera is 30 cm.

By the experimental result, the average error by the X-Y image was 2.93 cm, and the average error by the log-polar image was 1.64 cm. The reason of this result why the template matching became easy by using the log-polar image, and the mistake of the matching was reduced. Therefore, using the log-polar image, we obtained the result of the measuring distance with higher accuracy.

6. Conclusion

In this paper, we presented the effectiveness of the HVC, which is constructed by a mirror and a camera for a small robot system. Moreover, by using the property of the HVC like the log-polar image, the HVC can measure the distance to the object with higher accuracy, and we consider that the HVC is very useful for the small robot system.

At present, we used only the upper half of the image taken by the HVC. But the obtained image has another half of the image. Therefore, we think that using two parts of images gives us more various information. For example, the accuracy of measuring the distance becomes better, and objects are detected by the different method.

For the future, we are going to install the HVC in the cleaning robot. By using the lower half of the image, the HVC can see the state in the front of it. By using the upper half of the image, the HVC can know around it. Therefore, the robot can find garbage and obstacles by using the obtained image easily.

7. Reference

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