Marker Recognition System for Localization of the Rover on the Lunar Space

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Abstract

This paper proposes a marker realization system for rover localization in the Lunar environment. CPU used in the space environment is not as sensitive to changes of the surrounding environment differently from normal CPU, but it has a lower performance. So it is necessary to use an algorithm reduced amount of computation. In order to reduce the amount of computation on the rover, we propose a rover driving algorithm based on marker recognition. It makes possible to explore the Lunar by using the low- performance CPU. For implementing this algorithm, we performed a marker detection test, and then extracted the center point coordinate of the marker by using Canny Edge Detection and Circular Hough Transform.

Keywords: rover, Lunar space, marker, localization.

1. Introduction

The universe is a vast, still unknown space, and an environment that requires continuous exploration. For stable exploration in specialized environments, many techniques required like a rover localization and obstacle avoidance. So exploration rovers have various sensors, but generally use a vision sensor because it can directly obtain images. Vision sensor usage is various depending on which camera used, how many cameras used, where attached in rover, which algorithm used.

The image processing algorithm for localization in the space environment was mainly used Visual Odometry method using Optical Flow. In this algorithm, feature points are extracted from previous image and matched feature points extracted next image. Matching is the process of searching for the same feature points from two images. The movement amount and direction of rover was measured through position changing of the detected feature points on the image. This method has an advantage that it can localize with only the front images. However, because this algorithm uses difference of previous and current images, if the rover moves too fast or the time interval for taking pictures is too long, the numbers of identical feature points presented in both pictures decrease, so matching accuracy is reduced. For preventing this, it is necessary to take pictures at a short time interval and to process them. It leads increment of computation amount, and as a result, high performance CPU is required.

CPUs used in space have very low performance and capacity compared with general CPUs. Nonetheless, people use CPU for space because it is insensitive to environment changes. General CPUs are extremely sensitive to change of the temperature, and weak to radiation. Lunar and Mars have intensive difference of

temperature more than 100℃. Also, Lunar doesn't have atmosphere, and Mars has very little. So Lunar and Mars will receive the solar radiation much more directly than Earth. In this way, the space has many environmental changes. It is the reason that people use the CPUs for space. But its performance is very poor and expensive. Improving the performance and capacity of CPU for space becomes a costly burden, so an algorithm with a small amount of computation is required.
In this paper, we propose a new rover driving algorithm using a low-performance CPU and marker.

2. Rover driving algorithm based on marker recognition

Rover driving algorithm proposed in this paper is possible to localization and obstacle recognition nevertheless using low-performance CPU. Because of using a low-performance CPU, the vision computation is not processed on the rover itself, but on the earth after transmitting. Then, a rover movement command is transmitted from the earth to the lunar. In this process, a communication delay of about 7 minutes occurs. So it is impossible to perform rover's moving and transmitting at the same time. Also, distance of moving command should not be short. Therefore, the proposed rover driving algorithm needs image processing algorithm that is not affected by previous images.

In this paper, localization algorithm using marker recognition is proposed. It can recognize the marker and get the coordinate of the marker from only current image. By using the position which the marker is attached and depth value obtained by the stereo camera, the horizontal distance between lander and rover can be known. And by using the number of pixels between two points extracted by the marker and the actual distance between two points, it is possible to know the angle between the rover and the marker.

But this method also has a problem. Rover drives in direction far from lander, but rover needs to see the lander for taking pictures of the marker. In other words, the direction of the camera is opposite to the direction of the rover's driving. In this case, it can't confirm whether the obstacles are present forward. In order to solve this problem, we propose a method that the camera shoots 360 degrees at intervals of 15 degrees while rover is stopped. After shooting, pictures are transmitted to the earth and processed on the earth. In order to shoot 360 degrees, it is possible to confirm the presence of obstacles by grasping the situation of the front and the surroundings and to acquire the current position through marker recognition from backward image both.
For implementation this algorithm, first, marker detecting process and extracting process of the coordinates are required. Second, It is required that the process of obtaining the horizontal distance between lander and rover by acquiring the depth value using the stereo camera. Third, it needs to integrate the coordinates of the images and the coordinates of the rover. In the next chapter, we will deal with the image processing algorithm that we used for detecting and recognizing the marker.

3. Image Processing Algorithm

In this paper, edges are detected from the image and the marker is detected by recognizing a circle in the edge image. Marker detecting algorithm used in this paper consists of Canny Edge Detection and Circular Hough Transform.

3.1. *Edge detection*

Canny algorithm used in this paper is widely used for practical edge detection. Canny algorithm process consists of 5 steps.

Step 1: Color conversion
Step 2: Gaussian smoothing
Step 3: Calculation of the image gradient
Step 4: Non-maximum suppression of the grad value
Step 5: Edge determination and connection

In step 1, color of the image was converted to the gray image. In step 2, filtering processing is performed with the converted grayscale image. This filtering is Gaussian smoothing. It is necessary to smooth images for removing the noise before edge detection. In step 3, calculating the gradient is performed. To calculate the image gradient, Canny edge detection algorithm selects a 2×2 neighboring area to get the magnitude and direction the gradient. In step 4, in order to get sharper edges, Non-maximum suppression is performed. Canny method use the 3×3 neighboring area to compare a pixel with its two adjacent pixels along the gradient direction. If a pixel is

bigger than the two adjacent have, the pixel will not change. Otherwise, the pixel will change to 0. In step 5, the edges are finally determined and connected.
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3.2. *Circular Hough Transform*

Hough Transform (HT) is usually used for the recognition of contour and shapes from the images.
Circular Hough Transform (CHT) is one of the effective approaches used nowadays for the detection of circles arcs and finding the center of the circles. CHT normally use geometric and Hough region as shown in Fig. 1. Every point in the geometric region of the original circle edges generates a circle in a Hough space region. The circles in the Hough region meet most at a point (x', y') that will correspond to the point (x, y) in the geometric region of the original images. In other words, the point that overlap most in the Hough region is (x', y'), and this point is center point of circle.

The parametric equation for circle in the (x', y') space is shown in Eq. (1).

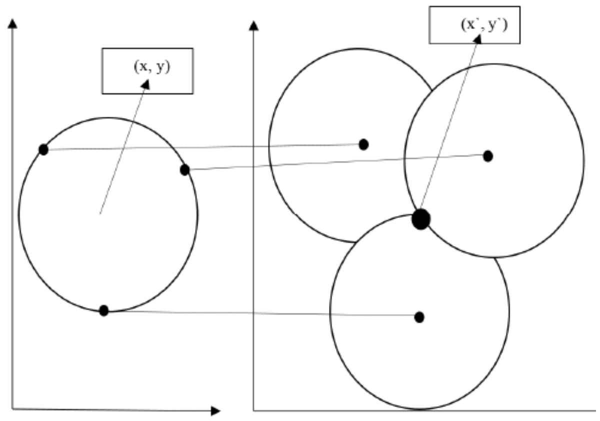

Fig. 1. Geometric region(x, y), Hough Region(x', y')

$$\left(x - x'\right)^2 + \left(y - y'\right)^2 = r^2 \tag{1}$$

If edge point in the geometric region is (a, b), radius is shown in Eq. (2).

$$\sqrt{\left|x' - \mathrm{a}\right|^2 + \left|y' - \mathrm{b}\right|^2} = r \tag{2}$$

4. Marker Detection Experiment

Marker detection experiment executed in this paper was performed to confirm that the marker detection doing well and that coordinates can be acquired from images in normal circumstances. We use the small marker with H written in a circular frame. The thickness of the marker line is 1cm, and the radius of the circle based on outer boundary is 7.5cm (radius of the circle based on inner boundary is 6.5cm). Fig. 2. indicates the shape and size of the marker. Please provide a shortened running head (not more than four words, each starting with a Capital) for the title of your paper. This will appear with page numbers on the top right-hand side of your paper on odd pages.

The image was taken at a distance of 3m in the corridor of the building. And the marker was attached to the wall

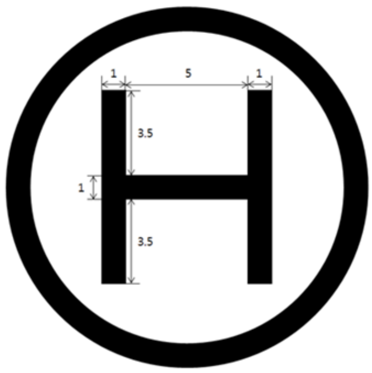

Fig. 2. The shape and size of the marker

surface. Fig. 3. indicates the captured image and the imaging area of camera is 1024×768 pixels. Edge detection was performed from the captured image by using Canny algorithm. Then marker was found from the detected edge image by using Circular Hough Transform and extracted the center coordinate. Fig. 4. indicates result image of Canny Edge Detection. Fig. 5. indicates result image of Circular Hough Transform. Table 1. indicates extracted center coordinate of the marker.

Fig. 3. The captured image

Fig. 4. Result of Canny Edge Detection

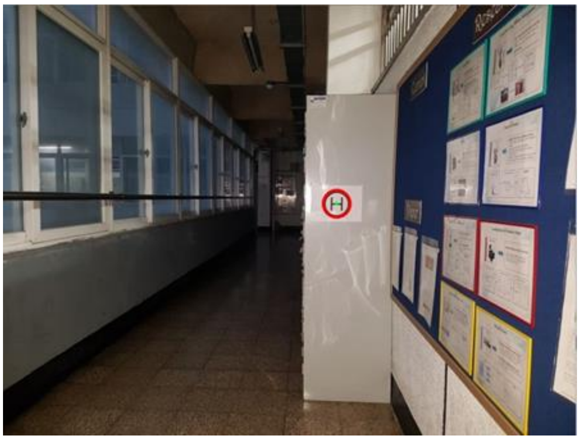

Fig. 5. Result of Circular Hough Transform

Table 1. Extracted center coordinate of the marker

	x	y
extracted center coordinate	596	354

5. Conclusion

In this paper, we propose a driving algorithm of Lunar exploring rover though marker recognition using low-performance CPU. We carried out the marker detecting experiment and extracted center coordinate of the marker. As a result of the experiment, it was confirmed that the marker was well recognized at a distance of 3m even for small size marker. Since it is possible to attach a large marker to the actual lander, it is expected to be able to recognize at far distance.

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