A Method of Providing a Panoramic Image Using Single Image Transmission System

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Abstract -

This paper describes a method of providing a panoramic image using single image transmission system. In recent years, demands for small robots performing inspection work by remote control are expanded. On the remote control of robots, to provide information of environment around the robots is important for operators. Multiple images are usually transmitted to the operators' sides. In some cases, a large or special image generated from multiple images by image processing units is transmitted to the operators' sides. In order to transmit multiple images, multiple image transmission systems are required. On the contrary, generating special images also require a dedicated image processing unit. However, small robots cannot mount such devices due to size limitation. Therefore, we develop a method of providing a panoramic image using single image transmission system. We assume that robots are too small to mount a dedicated image processing unit or multiple image transmission systems. This system is assumed to target cameras with analog outputs. An image which is different from a previously transmitted image is transmitted every transmission. Before the transmission, a special code is added into each frame to distinguish which camera acquires the frame. We develop a tiny processing board to mount the system on small robots. First, we explain a method of spherical projections to generate a panoramic image. Multiple images are transmitted with single image transmission system after adding the code into the images. Availability of our proposed system is shown by an experiment that providing a panoramic image using two cameras.

Keywords -

Small Inspection Robots; Remote Control; Multiple Cameras; Teleoperation; Single Image Transmission System; Analog Cameras

1 Introduction

In recent years, demands for robots for performing the inspection work by remote control are expanded. In some cases, these robots perform the inspection work in a narrow space where people cannot enter. The robots are required to be as small as possible. On the other hand, it is also necessary to provide information of environment around the robot for operators. On the remote control of robots, an image acquired from a camera mounted on the robots is provided to the operator. However, to recognize the environment around the robots is difficult with single camera. Therefore, many remote control robots are equipped with multiple cameras. In some cases, a large or special image is combined from multiple images on the robot. An image transmission system is required to transmit an image to the operator from the robot. In order to transmit multiple images, multiple image transmission systems are required. On the contrary, to generate special images requires a dedicated image processing unit. However, small robots cannot apply these methods due to limitation of sizes. We develop a small hexapod robot which is shown in Figure 1 for the purpose of assisting inspection work[1]. The robot is too small to mount USB cameras or multiple image transmission system. The robot is equipped with multiple cameras with analog outputs. A single image transmission system is mounted on the robot due to limitation of sizes. Similarly, the robot is also not equipped with a dedicated image processing unit. Nevertheless, a method of providing a panoramic image is required for the remote control of the small robot.

In this paper, we describe a method of providing a panoramic image using single image transmission system. In order to transmit multiple images quickly using single image transmission system, following requirements are satisfied.

1). All cameras are synchronized.
2). Cameras are switched at the same time that transmission of just one image is ended.
3). Received images can be separated to each camera's image in operators' sides.

About 1), we assume that all cameras are synchronized. Methods to satisfy 2),3), are described in the following. Availability of our proposed system is shown by an experiment of generating a panoramic image by using two cameras. This paper is organized as follows. Section 2 describes related work about providing information on remote control of robots. A method of generating a panoramic image is described in Section 3. In Section 4, a method of transmitting multiple images by a single image transmission system is described. By transmitting

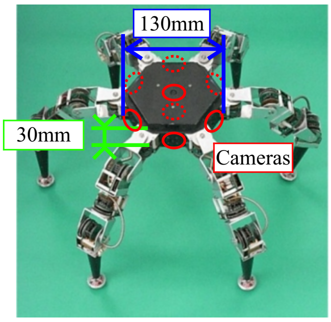
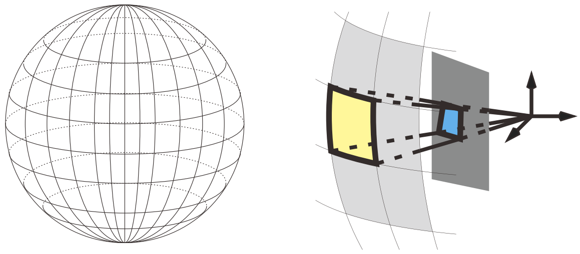


Figure 1. Hexapod Robot



(a) Projection sphere (b) Image projection to spherical surface

Figure 2. Spherical projection

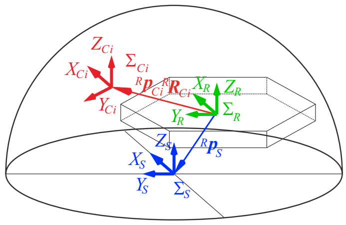


Figure 3. Coordinate system

the images in which added a special code, it is possible to distinguish which camera acquires the frame. Section 5 shows availability of our proposed system by an experiment of providing a panoramic image. Finally, Section 6 presents our conclusions and future work.

2 Related Work

In order to recognize environment around robots, multiple cameras are usually mounted on the remote control robots. However, it is difficult for operators to recognize environment around robots by multiple images. A method of combining multiple images to generate one special image has been studied. As a special image, there are panoramic images[2, 3, 4]. The panoramic images can be viewed omnidirectionally from the location of acquisition. Therefore, it is easier for the operators to recognize the environment around the robots by special images than by multiple images. Recently, there are omnidirectional cameras which can acquire panoramic images with one camera. However, the image resolution per viewing angle of these cameras is low. Another special image is a bird's-eye view image[5, 6]. An image looking down the robots is generated by combining multiple images. A bird's-eye view image helps operator to recognize the environment around the robots. In many studies, images generated with combining multiple images are provided on the remote control of the robots.

3 Generating Panoramic Image

3.1 Overview

This section describes a method of generating a panoramic image from multiple images. Multiple images are combined into a single image by projecting the images to a spherical surface. The spherical surface where images are projected on is divided by latitude and longitude. The images are projected to the spherical surface after images are segmented and transformed to accommodate various regions of the spherical surface.

3.2 Coordinate System

As shown in Figure 3, three coordinate systems, which are orthogonal and right-hand ones, are defined for calculation. The robots coordinate system Σ_R is fixed to the center of figure of robots' body. The cameras coordinate system Σ_{Ci} is attached to the camera mounted on the robot. Note that the subscription "i" means the camera number. The projection sphere coordinate system $\Sigma_{section}$ is fixed to the center of the sphere. The vector from O_R to O_{Ci}, expressed in Σ_R, is denoted as ${}^R\boldsymbol{p}_{Ci}$. The vector from O_R to O_S, expressed in Σ_R, is denoted as ${}^R\boldsymbol{p}_S$. The rotation matrix from O_R to O_{Ci}, expressed in Σ_R is denoted as ${}^R\boldsymbol{R}_{Ci}$. In this case, ${}^R\boldsymbol{p}_{Ci}$ and ${}^R\boldsymbol{R}_{Ci}$ is already known according to the specification of the robots.

3.3 Spherical Projection

Image planes are placed at a distance of focal length f_i from cameras. The vector from O_{Ci} to image planes expressed in Σ_{Ci}, is denoted as ${}^{Ci}\boldsymbol{p}_{0i} = [0, 0, -f_i]^T$. Then, normal vector of the image planes, expressed in Σ_{Ci}, is denoted as ${}^{Ci}\boldsymbol{n}_i = [0, 0, -1]^T$. Considering camera attitude and defining vector ${}^{Ci}\boldsymbol{p}$ as any position in 3 dimensions, an equation of image planes is as follows.

$$\boldsymbol{n}_i^T \cdot ({}^{Ci}\boldsymbol{p} - \boldsymbol{p}_{0i}) = 0 \tag{1}$$

The vector of position on the spherical surface ${}^{Ci}\boldsymbol{p}_F$, expressed in Σ_{Ci}, is calculated by Equation (2).

$${}^{Ci}\boldsymbol{p}_F = {}^{Ci}\boldsymbol{R}_R({}^S\boldsymbol{p}_F - {}^R\boldsymbol{p}_S) - {}^R\boldsymbol{p}_{Ci} \tag{2}$$

A vector of three-dimensional position on the spherical surface ${}^S\boldsymbol{p}_F$, expressed in Σ_S is calculated by Equation (3)

Radius of projection sphere r, latitude θ and longitudeϕ is necessary before the calculations.

$$^{S}\boldsymbol{p}_F = [\ r\sin\theta\cos\phi,\ \ r\sin\theta\sin\phi,\ \ r\cos\theta]^T \tag{3}$$

Then, a point which line from camera fixed position to the spherical surface intersects an image plane is calculated. A vector of position on image planes corresponding to position on the spherical surface $^{Ci}\boldsymbol{p}_p$ is able to be calculated from at a point which a line intersects an image plane.

$$t = \frac{\boldsymbol{n}_i \cdot {}^{Ci}\boldsymbol{e}_F}{\boldsymbol{n}_i \cdot \boldsymbol{p}_{0i}} \tag{4}$$

Therefore, a vector of position on image planes $^{Ci}\boldsymbol{p}_p$ is as shown in Equation (5).

$$^{Ci}\boldsymbol{p}_p = t \cdot {}^{Ci}\boldsymbol{e}_F \tag{5}$$

These processes are performed in all regions on the spherical surface. Then, images are projected on regions on the spherical surface. Conditions of $^{Ci}\boldsymbol{p}_p = \left[{}^{Ci}x_p, {}^{Ci}y_p, -f_i\right]^T$ within image planes is,

$$\begin{cases} -\dfrac{w_i}{2} \leq {}^{Ci}x_p \leq \dfrac{w_i}{2} \\ -\dfrac{h_i}{2} \leq {}^{Ci}y_p \leq \dfrac{h_i}{2}, \end{cases} \tag{6}$$

where w_i is the width of image planes, h_i is the height of image planes. When Equation (6) is not satisfied, $^{Ci}\boldsymbol{p}_p$ is removed.

4 Transmission System of Multiple Images

4.1 Overview

This section describes a method of transmitting multiple images via a single image transmission system. One image is able to be transmitted by using the single image transmission system. Another image which is different from previous transmitted image in every transmission is transmitted to transmit multiple images. On the other hand, the received image cannot distinguish which camera acquires the one. A special code is added into the image to distinguish cameras. First, the output signals of analog cameras are described. Then, the timing of exchanging images which are transmitted is shown. Finally, the special code is added into the images.

4.2 Composite Video Signal

This study targets cameras which output the composite video signal. There are some kinds of type. These video encoding processes are different. However, there are not large differences in the structure of the video signals. In the

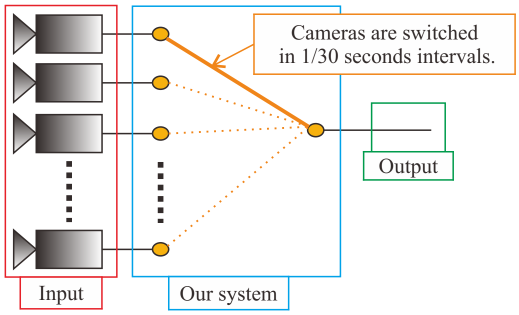


Figure 4. A system of transmitting multiple images using single image transmission system

subsequent processing, any type can be applied by changing parameters. In the following, our system is explained by NTSC system which is widely used in Japan. The composite video signal is composed of a video signal and a synchronization signal. The synchronizing signal includes a vertical synchronizing signal, a horizontal synchronizing signal, and a color synchronizing signal. Using synchronizing signals, one frame of images is distinguished.

4.3 A Method of Exchanging the Images

Figure 4 shows that a system of transmitting multiple images. Multiple images are transmitted by switching images which is transmitted in 1/30 seconds intervals. For example, we describe a method of exchanging images by using camera with an NTSC signal. In NTSC system, one image is composed of two fields which are even field and odd field. Each field has 262.5 scanning lines so that one image has 525 scanning lines. One scanning line has one horizontal synchronizing signal. In other words, one image has 525 horizontal synchronizing signal. On the one hands, a vertical synchronizing signal is changed in swapping odd field and even field. After switching the vertical synchronization signal from HIGH to LOW, 525 horizontal synchronization signals are counted to exchange the images.

4.4 Adding a Special Code into Images

A special code is added into images by using active video in composite video signal. Any line of an active video is replaced with the special code. By using the code in the images, a camera which acquires the image is distinguished. The code is composed of two colors which are white and black. By dividing a line into N parts, one line has the values of range from 1 to 2^n. In NTSC system, width of an image is 640 pixels. One line has the values of range from 1 to 2^{640}. Figure 5 shows relation between the code and the numerical value (N = 3). A process of adding binary code into images is shown in Figure 6.

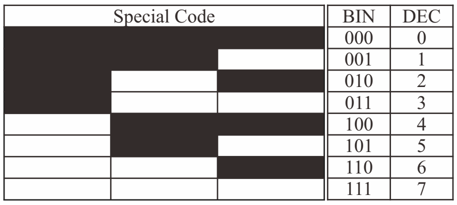


Figure 5. A special code and numerical values corresponding to the code (N = 3)

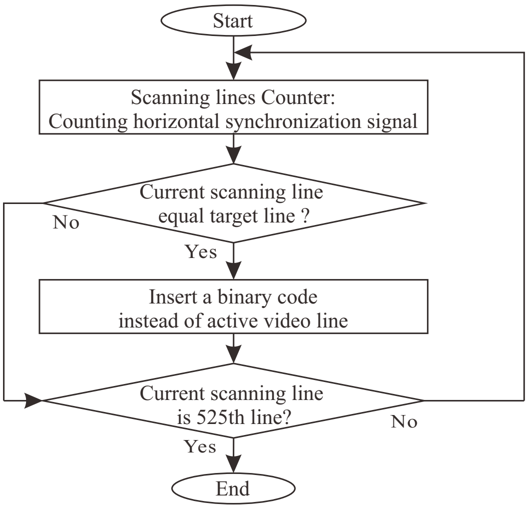


Figure 6. The process of adding a binary code into images

For example, the code is added into the first line of the image. 480 of 525 scanning lines are displayed as images. From 1 to 45 scanning lines are used for different purpose such as subtitle, vertical synchronization. Therefore, the first horizontal line in images can be changed to the special code by swapping 46th scanning line and the code. Figure 7 shows an image which added the code into the 100th scanning line. As a result, the special code in the images have been confirmed.

5 Experiment

5.1 Overview

Being able to provide a panoramic image is confirmed by using our proposed system. In an experiment, two images are transmitted to computer via single image transmission system. Prior to transmitting, the binary code is added into the images by using an experimental equipment. On the computer, the received images are combined into a panoramic image. As a result of the experiment, availability of our proposed method is verified. Problems of generating a panoramic image are also revealed.

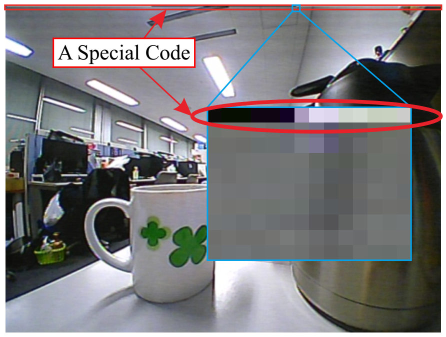


Figure 7. The image which added binary code

Table 1. The specification of computer

OS	Windows 10 Pro 64bit
CPU	AMD Ryzen™7 1700
GPU	NVIDIA®Geforce GTX-1060 6GB
RAM	16GB
Capture Device	PCA-DAV2

Table 2. The specification of cameras

Product name	MINI CCTV CAMERA 205M-WD
Resolutions	640 x 480
FPS	30
Horizontal view angle	about 110 degrees
Vertical view angle	about 95 degrees

5.2 Environment

Figure 8 shows a prototype device which is developed for the experiment. The device is composed of the video signal extractor, the camera exchanger, and the signal counter. The video signal extractor is made by referring to an article[7]. PIC is used for adding binary code and exchanging cameras. Two camera are synchronized before making the experiment. In this case, the two cameras are synchronized by means of injecting a clock signal which created by one crystal into two boards after removing the crystal on cameras boards. If using more than two cameras, clock signals which generated from a clock generator are injected in order to synchronize all cameras. Using the device, a binary code is added into images acquired from two cameras. Images outputted from the equipment are captured in the computer by a capture device. The panoramic image is generated from two images after separating the images. In this situation, one of codes added into the images is black line and the other is white line. Figure 9 shows a simplified image of experimental equipment. The cameras that used in the experiment are shown in Figure 10, and the specification of the cameras and the computer are shown in Table 2. The cameras are fixed to an experimental equipment as shown in Figure 11.

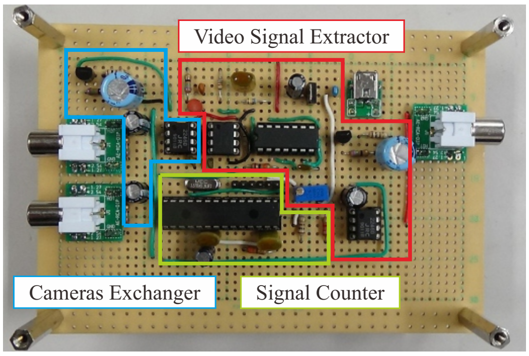


Figure 8. A prototype device to transmit two images using single image transmission system.

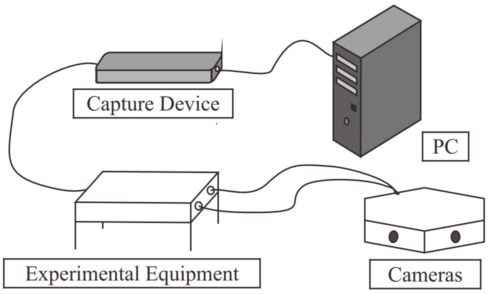


Figure 9. Experimental environment

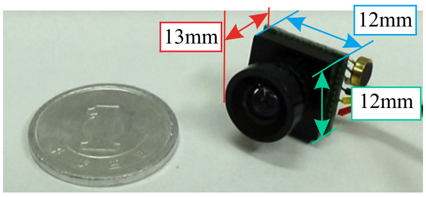


Figure 10. A camera used in the experiment

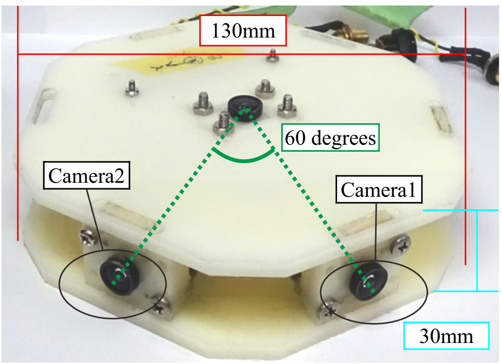


Figure 11. Experimental equipment

5.3 Result

Figure 12 shows the panoramic image which generated by using single image transmission system. It was confirmed that two images can be transmitted quickly and received images are separated to two images. The first line of the image acquired from Camera1 is a black line. Similarly, the first line in Camera2's image is a white line. A special code can be added to the image by using the device. Finally, two images are combined into the panoramic image by spherical projection. Using two cameras, to generating a panoramic image was confirmed. From the above, availability of our proposed method was verified.

5.4 Discussion

The received images are noisier than original images. The image noises might be caused by the video signal amplifier circuit. Our system has two video signal amplifier circuits. In order to reduce noise in images, it is necessary to modify the amplifier circuits. The panoramic image has a problem that a border among the image is not combined continuously. When the camera moves, to generate a panoramic image is difficult due to gap among the projected images. Furthermore, multiple images cannot be acquired from camera at the same time. For this reason, projection position should be changed to combine images correctly. On the other hand, the prototype device which is developed for the experiment is not too small to mount on the small robot. Therefore, to reduce the size of the device is required.

6 Conclusions

This paper presented that the method of generating a panoramic image using single image transmission system. At first, the method of generating a panoramic image with spherical projections was described. Then, multiple images were transmitted using single image transmission system. Prior to transmitting the images, the special code was added into the images to distinguish which camera acquired. Finally, availability of our proposed method was confirmed by the experiment that providing a panoramic image using two cameras.

In future tasks, it is necessary to confirm availability of the our method in the case of wireless transmission. Using more than two cameras, multiple images should be transmitted by the our method. To provide a panoramic image on the remote control, we will develop a remote control system for small mobile robots.

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Figure 12. A panoramic image and separated two images

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