Augmented Reality Based Vision System for Network Based Mobile Robot

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Abstract. The human machine interface is an essential part of intelligent robotic system. Through the human machine interface, human user can interact with the robot. Especially, in tele-robotic environment, the human machine interface can be developed with remarkable extended functionality. In this paper, we introduce a tele-presence vision system for monitoring of a network based mobile robot. The vision system is a vision part of human machine interface with augmented reality for the network based mobile robot. We synchronize head motion of human user and the camera motion of the mobile robot using visual information. So user of the mobile robot can monitor environment of the mobile robot as eyesight of mobile robot. Also, the system partially creates a panoramic image to solve a pose latency problem. In this paper, we evaluate and compare panoramic images from two different methods. One is pattern matching method which is simple and fast, the other is Scale Invariant Feature Transform (SIFT) which is complex and slow. Finally, proposed vision system provides high resolution and wide Field Of View (FOV) to user who is wearing a Head Mounted Display (HMD).

Keywords: Tele-operation, Tele-presence, Augmented reality, Human Machine Interface, Head Mounted Display.

1 Introduction

Many researchers have been tried to make a robot more intelligent and serviceable. Consequently, robot system will be used widely in various fields and become more important in our daily life. But, up to now, most robotic systems are not fully intelligence and these are leading the necessity of human machine interface(HMI) which are conducted by many researchers. As a result, human machine interface forms an essential part of successful robotic system.

Owing to advent of computer network and internet, environment of industry and human's lifestyle are extensively changed. Robot system is also affected by these trends. Many robot developers are carrying out research on network based robot which is combined computer network and robot system into one methodology. Especially they have paid much attention to the human machine interface.

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We can check the essential role and importance of the human machine interface in the field of tele-presence technique. Tele-presence is the paradigm that user who is in a certain place will feel as if he/she is at another place and receives environment stimuli.

For tele-presence, panoramic images are used frequently[2][3]. To create panoramic images, there are various techniques such as omni-directional camera, multiple-camera, and revolving single camera. However, low resolution and narrow field of view(FOV) are problem[2][3][5] to be solved in the methods stated above.

In this paper, we propose a vision system which is an essential part of human machine interface with augmented reality for the network based mobile robot[1]. This system synchronizes human and mobile robot using visual information. In other words, motions from user's head and camera in mobile robot are identical. So user can monitor surroundings of the mobile robot as eyesight of the robot. In addition, the proposed system creates a partial panoramic image to solve a pose latency problem[2][3] and provides high resolution and wide field of view(FOV) to the user wearing a head mounted display(HMD).

In section 2, we introduce proposed network framework for network based mobile robot. Vision system to be targeted will be followed in Section 3. Finally we made conclusions in Section 4.

2 Network Framework for Network Based Mobile Robot

Figure 1 shows interaction between human and a mobile robot through the network and human machine interface.

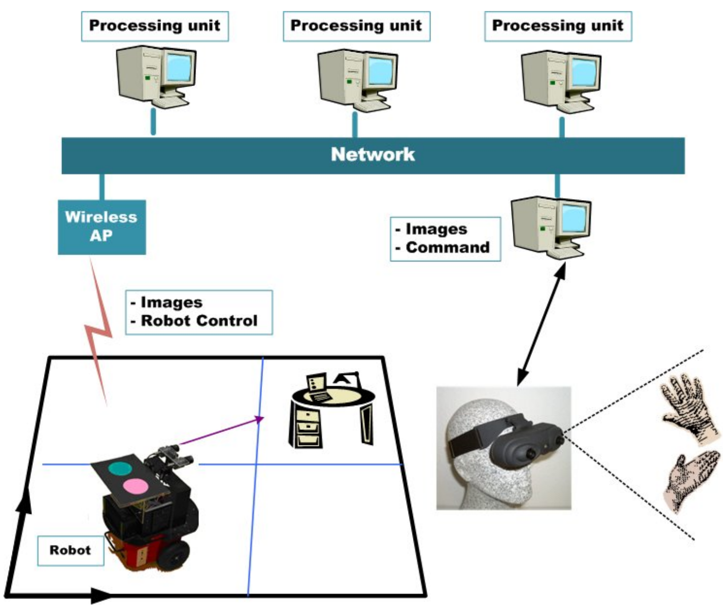

Fig. 1. System overview

In this system, all resource such as vision system, the mobile robot and processing units are connected via network. A low performance PC which has main roles of sensory data collection and control of mobile robot is equipped in the mobile robot. User can interact with the mobile robot more easily and intelligently displaying all information from HMD in Fig. 1.

To manage network connection, The Common Object Request Broker Architecture(CORBA) is used as middleware in our system. The Common Object Request Broker Architecture(CORBA) is a widely recognized middleware standard for heterogeneous and distributed systems. We used the public domain implementation of CORBA, called The Adaptive Communication Environment / The Ace Orb (ACE/TAO), as a middleware for the proposed system[6].

3 Vision System

We propose a synchronization scheme for pan and tilt positions between camera in mobile robot and HMD to ensure wide range of field of view.

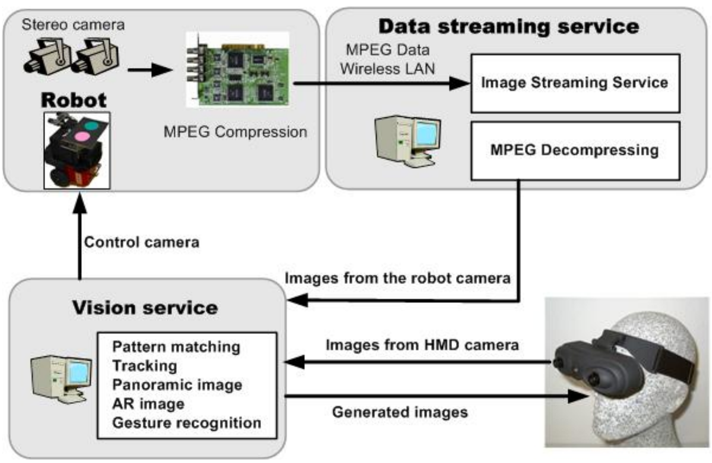

Fig. 2. Vision system

Figure 2 shows proposed vision system. In this system, captured images from camera in the mobile robot and HMD are sending to data streaming service region and vision service region, respectively.

Two images from robot camera and HMD camera are gathered into vision service region. In addition, panoramic images and augmented reality(AR) images for user who is wearing the HMD are created in the service region. Using the augmented reality and gesture recognition system, user can control the mobile robot more intelligently.

3.1 Augmented Reality and Synchronization of Mobile Robot and HMD

The vision system in Fig. 2 receives images from a robot camera and a HMD camera. Then it calculates each motion factor of the HMD and the robot camera. If the motion factor calculated is different from each other, the vision system tries to synchronize these motion factors by controlling pan, tilt position of robot camera.

We simply applied pattern matching technique. An image is divided as several blocks in the vision system and each block is comparing and matching with previous images. If the vision system found the most matched block, then it will be a base block. Using the base block the motion factor will be calculated from vision system. Example of the pattern matching method is shown in Fig. 3. The vision system calculates motion factor based on the base block.

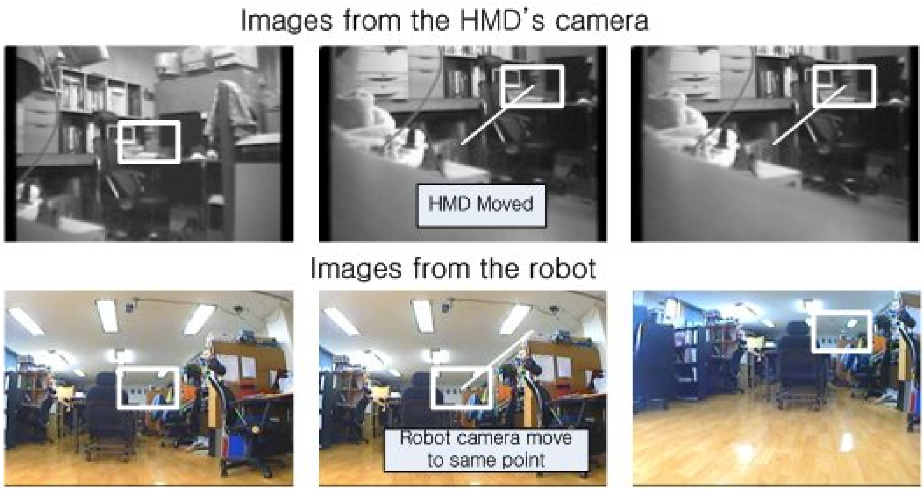

Fig. 3. Calculation of motion factor using pattern matching and tracking

As augmented reality, if the user's gesture or environments are recognized, then virtual interfaces on the HMD will be generated like in Fig. 4.

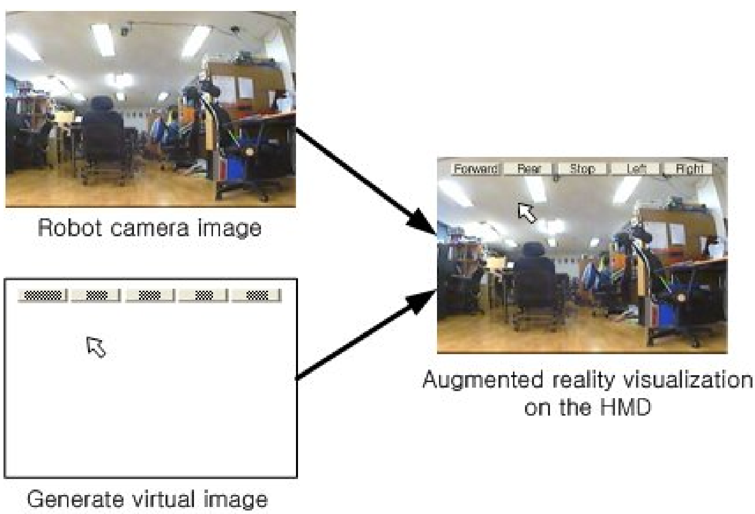

Fig. 4. Augmented reality

3.2 Generation of Panoramic Images

For a virtual absorption in an augmented reality environment, pose latency problem must be solved[2][3][5]. To handle the problem, researchers use panoramic images. However, it is difficult to create panoramic image with high resolution at real time.

In proposed system, panoramic image will be used to find the base block when the vision system fails to contact the position of the HMD camera. Considering pose latency problem, already calculated motion factor will be employed and position of the robot camera will be displayed into the HMD before the camera of the robot synchronizes that of the HMD.

After synchronization is completed between cameras of the HMD and the robot, the panoramic image used is useless any more. This is why we don't need whole panoramic image. Therefore, the vision system partially creates panoramic image. Fig. 5 shows partially generated panoramic image.

Fig. 5. Partially generated panoramic image

Using the revolving robot camera, panoramic image is generated partially and changed its displaying area slowly. In this paper, two methods, pattern matching and scale invariant feature transform(SIFT), are employed to generate panoramic images.

To generate a panoramic image, already calculated motion factor of each image block is used in Fig. 6(a). Using the calculated motion factors stated before, current image blocks are attached to the corresponding positions in the panoramic image plane directly. This method is very fast and easy to create panoramic image, but it has low precision than another method. This method takes the average of 10 ms at the Pentium IV 3Ghz computer.

When the scale invariant feature transform(SIFT) method is used, the result is shown in Fig. 6(b). After calibrating received images, matching point of current image and already generated panoramic image are found using SIFT algorithm. After finding matched points, homographies and warping parameters are found and current image are projected to the panoramic image plane using these parameters.

This method can make highly accurate panoramic image but it takes too much time to generate a panoramic image. This method takes the average of 15 seconds at the same computer.

(a) Panoramic image from pattern matching

(b) Panoramic image from SIFT

Fig. 6. Panoramic image from pattern matching and SIFT method

3.4 Vision System Flow

Using the current poison of the HMD, position of the panoramic image in which an image is displaying on the HMD is calculating. At the same time, images from a robot camera and current position of the panoramic image are updating continuously. Based on the above process, every new image is checked for motion factor and synchronization.

When a center position of the HMD goes out of the base block region, view point is expanded and new panoramic image is generated using information from current panoramic image and current received image from robot camera and HMD camera. Proposed algorithm flow for vision system is as follows.

a. Set initial position. Create panoramic image plane for images from a HMD camera, and panoramic image plane for images from a robot camera.
b. Receive images from the HMD camera and the robot camera.
c. Calculate motion factors from the HMD image and the robot image. If those motion factors are different, send control signals to the robot to synchronize those motion factors(Fig. 3).

d. During vision system try to synchronize positions of the HMD camera and the robot camera,
   1. Check both motion factors. If those factor over a threshold, following statement execution. Otherwise, go to step 5.
   2. Create panoramic images.
   3. Calculate position of panoramic image plane of the robot using current position of panoramic image plane of the HMD.
   4. Get an image that calculated position of panoramic image plane of the robot.
   5. Receive augmented images from augmented reality service(Fig 4).
   6. Merge and display the image on the HMD.
   7. Update current image to panoramic image plane.
   8. Loop. Go to step b.

4 Conclusion and Future Work

Designing a good human machine interface(HMI) is the key to the successful robot system. In addition, Building an infrastructure and a base framework for augmented reality are very complex task. However, it is essential technique for HMI.

In this paper, we have attempted to build an augmented reality based vision system for the network based mobile robot. Proposed vision system uses revolving single camera to generate a panoramic image instead of an omni-directional camera or multiple cameras configuration. We implemented a very fast and simple method to create partially the panoramic image using revolving single camera and simple pattern matching method. This method can generate the panoramic image at real time. In addition, we implemented another method using SIFT to create high quality panoramic image. Both algorithms can be used without time constraint on our vision system. The vision system uses the panoramic image to synchronize a HMD camera position and the robot camera position. Also, the vision system uses the panoramic image to solve pose latency problem. Proposed vision system provides wide range of FOV and high resolution images.

In our future work, we will update our HMI system. Especially, we intend to project the panoramic image plane to a cylindrical and a spherical projection plane for a virtual absorption in an augmented reality environment.

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