A Remote Robot Control System based on AVM using Personal Smart Device

IL-KYUN JUNG, HYO-BIN KIM, WOO-SUNG JUNG, SE-WOONG JEON
Intelligent Robotics Research Center
Korea Electronics Technology Institute
193 Yakdae-dong, Wonmi-gu, Bucheon-si, Gyeonggi-do
SOUTH KOREA
{mickey3d, binth, claude, daniel}@keti.re.kr

Abstract: This paper introduces a remote robot control system that has been developed to provide the operator with intuitive user interface and view in the vicinity of the robot. An AVM (Around View Monitoring) system using four smart cameras is proposed to create surround view and a remote control system with intuitive user interface using personal smart device. Thanks to high speed LTE (Long Term Evolution) network, real-time remote control and monitoring can be realized without any special constraint. The proposed system can make it possible to generate intuitively path of robot and modify the path in real-time. The performance of the remote control system is proven by experimental results with a smart pad and the wrap around view system equipped on a mobile robot.

Key-Words: smart camera, AVM, LTE network, intuitive user interface, personal smart device

1 Introduction
As researches of remotely operated or autonomous mobile robots have recently been developed as a focus within the robotics community [1]~[3], where a kernel problem is to intuitively detect the surrounding environment by various sensors, so as to make proper decisions to fulfill a given task. With the rapid development of image processing, control theory, computer vision and visual image plane feedback control, visual servoing or vision-based control[4]~[7] has been introduced into robotic systems to increase intelligence and flexibility of robot. These systems usually comprise of a camera and pan module for yaw motion. Visual servoing with the vision module, if the feature points are always in the middle(or center range) of image plane, the following issues are to maintain. As pointed out frequently, current visual servoing system still confront with several key drawbacks, such as oversensitivity to camera calibration error, image noise, difficulty of keeping the target in the field of view, i.e., the so-called FOV problem: low visual servoing efficiency, failure of path planning in complex environments and so on. As for remote robot control system, it is the most important capability that a human can direct the navigation of a remotely located robot using an intuitive interface, which provides controls, both status and environment information.

This paper focuses on both remote control with personal smart device and AVM (Around View Monitoring) system equipped on a mobile robot in which four cameras are used to feedback image plane and track the planar motion of mobile robot in real 3-dimensional workspace. For these purposes, the smart KETI-CAM system and AVM system are firstly proposed, then remote robot control system with personal smart device. The main advantage of both systems is that using the image information around the robot, users can easily operate with personal smart device via LET network.

The paper is organized as follows. Section II describes smart KETI-CAM cameras and AVM system with them. In Section III, the intuitive user interface for remote robot control with AVM is presented. In next section, experimental results are shown and its implication is depicted. The conclusions is finally given in Section V.

2 AVM System
The AVM system comprise of four embedded cameras, which called "smart KETI-CAM", that have the capability of processing images by itself. Thanks to this ability, the computation bundle of main MCU can be drastically reduced.

2.1 Smart KETI-CAM
The figure 1. described the developed the smart KETI-CAM module. This system consists of a total of three boards. The core board is the image processing part which is consisted of the Analog
Device’s BlackFin core and memory. BlackFin core is utilized for image capture and image translation. The camera intrinsic and extrinsic parameter is ported and self-side wrap-around view is configured by the following sequence. By the CMOS sensor, the image is captured on 320x240 pixels or 640x480 pixels. The given image is calibrated by camera two parameters. Thus the original lens distortion is corrected this processing. In figure 2, camera mounting and image processing procedure are introduced. The obtained result image plane with lens distortion correction, is converted by the homography matrix. As shown in the figure 2, the camera side view is converted on top-ward view. The detail homography matrix is omitted because it depends on mount location of mobile robot. The homography matrix contains the translation and rotation information between the current and desired robot coordinate systems.

![Fig. 1, KETI-CAM smart cameras](image1)

**2.2 AVM system**

When Smart KETI-CAM converts the video images recorded by four cameras, which are mounted in the front, rear, and on the left and right sides of the mobile robot. Figure 3 describes the AVM system equipped a mobile robot platform. The conversion and synthesized images into Top view can be achieved via projection conversion which is calculated by the transformation and rotation homography matrix. The images are projected onto a flat surface equivalent to the floor surface. Although this system is effective for visualizing object around the robot, it has a systematic drawback since the images are projected on a flat surface, the shape of objects far away from the robot platform tends to be blurred. The image plane from the individually the smart KETI-CAMs are projected or converted onto a virtual 3-D curved surface and the images on that surface are converted into those seen from any desired point of view using the technology of 3-D virtual projection and point of view conversion.

![Fig. 2, KETI-CAM mount and image processing](image2)

![Fig. 3, AVM(Around View Monitoring) system](image3)

In figure 3, AVM process is also described. In smart KETI-CAM, image calibration, distortion correction and homography transformation and In a MCU of AVM system, simple image mosaic: just copy the processed four images onto an AVM image plane. Thanks to the image processing ability of smart KETI-CAM, the computation of a main MCU of
AVM system is not expensive. Hence, AVM system can be realized in robot main controller without using another MCU dedicated to AVM system.

3 Remote robot control
Our remote robot control system consists of a smart pad for intuitive user interface not with joystick but touch pad and AVM system with four smart KETICAM and a AVM main controller which collects the four images transferred from the cameras.

3.1 Intuitive user interface
As shown in figure 4, conventional PC based user interface is neither user friendly nor intuitive. To direct robot path in real-time by user or operator, intuitive user interface like touch and drag/drop is indispensible. So as to realize the interface, A smart-PAD controller is engaged of which control application can describes the visual information around the robot. The AVM system can cover a field of view of 360 degree with top-ward.

Figure 5 shows a smart PAD-GUI and real image plane. The navigation and reference trajectory are used as inputs from the user. The input methods are click and drag/drop on the touch-screen of smart-PAD. As robot moves in real world around view image on the screen is updated in real-time.

3.2 Remote robot control system
We have been developed a remote robot control system with a smart PAD using LET network. From AVM system, around view image is transferred to smart PAD via LTE network. After updating the transferred image, user make the navigation path on the touch screen of the smart PAD with drag and drop inputs. The generated path is interpolated and transferred to AVM MCU, then redirected to mobile robot controller. Figure 6 describes the proposed remote robot control architecture.

Figure 7 shows the proposed remote robot control system with a smart PAD and mobile robot on which AVM system is equipped. To utilize LTE network, LTE modem should be plugged.
4 Experimental results
In our experiments, the non-holonomic robot navigates between rooms in order to reach the target point. We engages twenty volunteers for user testing and investigate user preference and controllability.

4.1 Experiment setup
In figure 8, upper images are an indoor space like living room (3x3m on left and 6x6m on right). Control room is located at more than 20m distance. lower left image shows an user with smart PAD, center with joystick and right images is the mobile robot with the AVM. LTE network speed is 20Mbps.

![Fig 8., Experiment setup](image)

4.2 Results
In user testing, we have seen that both controllability and user convenience are enhanced successfully applying the proposed remote robot control system. Through these tests, it was proven that total time to reach at goal be shorter and user preference be higher with smart PAD than with joystick.

![Fig. 9, Total navigation time (left 3x3m, right 6x6m)](image)

5 Conclusion
In this study, the AVM system was proposed for the fee-collision, monitoring and easy intuitive remote control of a mobile robot platform. The robot equipped with AVM system can be tracked the complex environment in which there are many obstacles. From our experiments, the following conclusions are obtained:
1) The position of obstacles and object is not uniquely related to the robot pose but depends on the camera view.
2) The remote robot mobile control is intuitively steerable and operated with image plane of around robot.
In user testing it has been validated that users could control a robot at remote distance with the smart PAD modifying the robot navigation path in real-time.

References: