

Augmented Control for Mobile Robot using PocketPC

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Abstract - This research presents a design of an augmented control for a mobile robot using PocketPC via wireless communication under the Microsoft Windows Mobile operating system. The system is specially designed for non-expert users to control the robot using softkey command, touch screen speed control, and fully graphic display for sensor fusion. The computer server combines augmented data of sensors with video streaming and sends data packet to PocketPC. Furthermore, target tracking and distance estimation with single camera are implemented. The system is also able to detect human movement using image processing. Moreover, fuzzy system is implemented to enhance the performance of robot for obstacle avoidance. The results indicate that the proposed system assists user to control a mobile robot more effectively and intuitively.

Index Terms - PocketPC, Mobile robot, Augmented data, Fuzzy logic

I. INTRODUCTION

In recent years, robot control using mobile devices has been widespread implemented [1][2][3]. The advantages of mobile device such as PocketPC are compactness, light weight, and portability. End-user communication with robots is usually provided either by PC-based interfaces or by simple button-based controls. Generally, PocketPC are used for data management or entertainment. Actually, it can be programmed like ordinary computer.

Outdoor robot operation is a challenge problem in term of an interaction between robot and user. It needs a simple and intuitive user interface with a minimum of training required to run the system. This could be solved by using a small device like a PocketPC. Furthermore, augmented reality can complement mobile computing on wearable devices by providing an intuitive interface to a three-dimensional information [4][5].

Hence, this research proposes a new method of tele-mobile robot control with augmented reality on a PocketPC. The proposed system offers both touch-based and stylus-based interfaces because stylus-based interaction is not practical for all situations such as walking or running. The system is designed for remote driving in unstructured and unknown environments. The user receives augmented graphic data in order to control a mobile robot easily and intuitively. The system also provides both manual and automatic control modes which are appropriate for an outdoor task especially military, reconnaissance, surveillance, and rescue missions.

II. SYSTEM DESIGN

In Fig. 1, a mobile robot consists of multiple sensors that transmit all data to be processed at a computer server via Bluetooth communication. All augmented data will be superimposed on video streaming processed by the computer server. A PocketPC is connected to the server via wireless network communication. The mobile robot receives commands from the operator and returns augmented information the status of robot and environment.

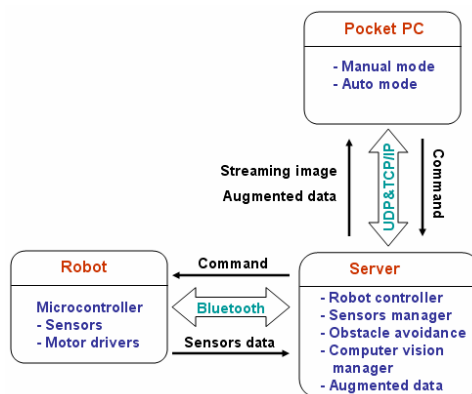


Fig. 1 System overview

This mobile robot can be tele-operated in unstructured and unknown environments. Thus, the system are implemented into two modes which are manual and automatic modes. In manual mode, user can manually control directions and speeds of the mobile robot. In automatic mode, it allows user to define waypoints for moving the robot to the target. There are 2 main sections of system which are hardware and software sections.

A. Hardware section

1) *Mobile robot*: A mobile robot consists of 6 wheels driven by 24V DC motors with 110 RPM and 10 kilogram payload capability.

2) *Electronic devices and Sensors*: All electronic devices as shown in Fig. 2(a) are interfaced with a microcontroller. Ultrasonic and Infrared distance sensors fixed on a servo motor are used for object detection. The servo motor is located in the front of the robot and it rotates with 0-180 degrees all the time. A encoder is used to calculate the distance along the robot's path. A digital compass is necessary to determine the robot's direction. The electromagnetic fields from spinning motor affect the accuracy of the digital compass so appropriated position needs to be determined. A bluetooth module is used to transmit all data to the computer server. The last device is

a wireless camera which is mounted in the front of the robot and it is also connected to the computer server. It can take snapshots of 320x240 pixels at 25 fps. All video signals are transferred through the RF wireless system as shown in Fig. 2(b).

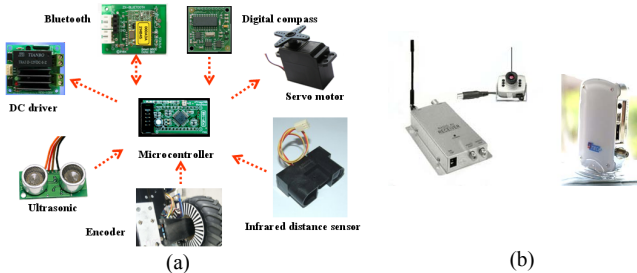


Fig. 2 (a) Electronic devices (b) Wireless video camera system

3) *Computer server*: Laptop computer is used as a server, which takes care of computer vision, obstacle avoidance, and sensor fusion. It also receives user's commands and sends them to the robot controller.

4) *PocketPC*: The ASUS PocketPC can display with a resolution of 320x240 pixels. It runs on Intel Xscale Processor working at 520 MHz. The operating system (OS) and development tool are Windows Mobile and Microsoft Visual Studio .NET Compact Framework [6], respectively. It communicates with the computer server via Wi-Fi network.

B. Software sections

Software section can be described into 6 topics which are computer vision manager, robot obstacle avoidance, sensor manager, user interface, robot controller, and communication as shown in Fig. 3.

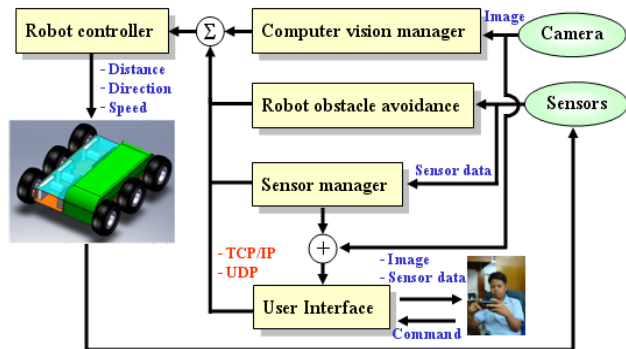


Fig.3 Software section

1) *Computer vision manager*: It is responsible for three image processing procedures which are path defining, target tracking, and object classification. OpenCV.Net Library [7] is used for image acquisition with 320x240 pixels in JPG format at 25 fps. Before processing, image is enhanced with anti-aliasing for smoothing graphic, gamma correction for true color, and interpolation with high quality Bicubic algorithm as shown in Fig. 4.

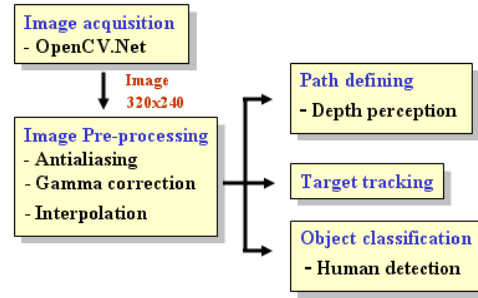


Fig.4 Computer vision process

Stylus-based is used to define movement of robot in automatic mode. A steady image is first captured and waypoints are assigned on the PocketPC screen. The waypoints are collected in an array list and then sent to the robot controller. Those waypoints will be calculated for the distance and direction control. The robot is then moved along calculated path as shown in Fig. 5.

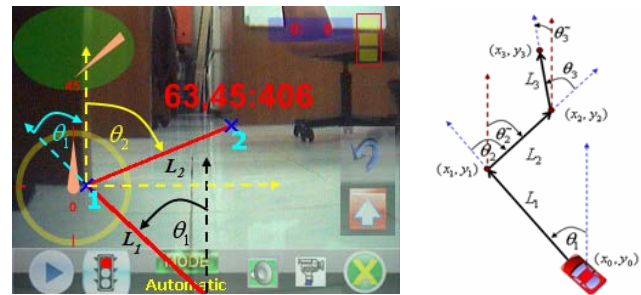


Fig.5 Path defining

All distances are estimated by using a single camera installed in the front of mobile robot. The image depth using a single camera is calculated based on an interpolation using a set of image distances between base line and object with their corresponding real world distances. This interpolation can be described into 3 following steps. First, the camera is located in a position with a specified height and a tilted angle. If the object is far from the robot, one changed pixel provides a large distance because a PocketPC screen height is limited to 240 pixels. If image resolution is larger like 640x480 pixels or 1280x960 pixels, an image depth can be calculated more accuracy. With the limitation of PocketPC screen resolution, a specified region is cropped and zoomed to fit into the PocketPC screen as show in Fig. 6.

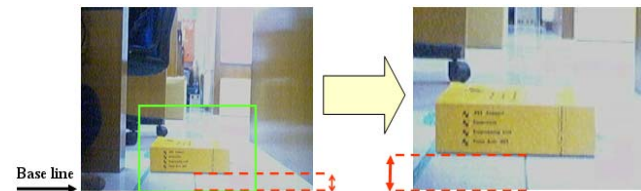


Fig. 6 Cropped and zoomed region

Second, all necessary data for an interpolation function are collected based on height and tilted angle of the camera.

Third, Bezier interpolation function with Bernstein polynomials is used for non-linear data estimation [8]. This method divides data into a number of segments and each segment will be approximated by a cubic curve so that the error can be minimized. All four necessary data will be analyzed per a segment as shown in Fig. 7(a). Hence, an interpolation curve can be obtained corresponding to a relationship between distance and pixel on PocketPC screen as shown in Fig. 7(b).

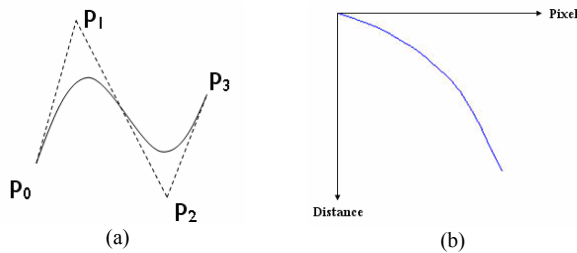


Fig. 7 (a) Bezier curve (b) Interpolation curve

The operator can specify a target by using stylus to select that target on PocketPC screen image. The robot will track that target based on its color automatically. In fact, the size of an image data would be up to 76,800 pixels and it needs to be divided into 768 image blocks of 10x10 pixels as shown in Fig. 8. The RGB color of each block will be averaged and the target color will be searched in real time as shown in Fig. 9(a) and 9(b), respectively.

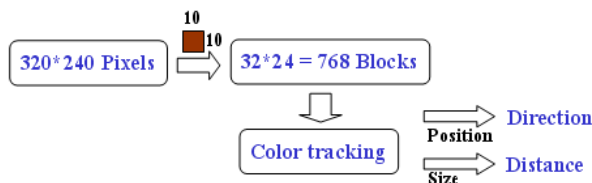


Fig. 8. Tracking process

Once a target is found, the location and size of the object will be calculated. The computer vision manager will compute a direction and distance of target before sending them to the robot controller. The robot is moved to the target with a half of distance between robot and the target for each step. The rest of distance will be recalculated and the robot will be moved to the target until it reaches its destination. The target in this system is assumed to be a fixed size bomb. The robot can automatically stop in front of target after it detects the corresponding size of the target.



Fig.9 (a) No target (b) Found target

Since this robot system is developed for bomb detection or suspicious object removal in any places

including living area, it would be good if it can detect human in such an area. Hence, the computer vision manager is responsible for detecting the human movement in real time using 6 analysis procedures which are slope, walk, height, leg, head, and shape analyses as shown in Fig.10. The analysed image is segmented into a binary format with zeros represent a human region and ones show non-human region. All noises are removed using a filter. Image resolution of 320x240 pixels will be quantized into one of 32x24 pixels. This reduces image processing time significantly. If conditions of all procedures are true, the system will report the human movement.

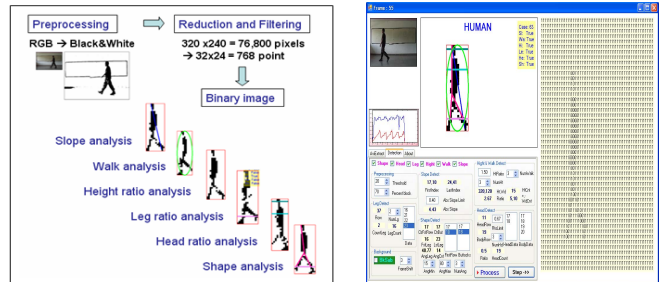


Fig. 10 Human movement detection

2) *Robot obstacle avoidance*: This paper also presents the design and simulation of a fuzzy logic to control the mobile robot to avoid obstacles. Data from the ultrasonic and infrared distance sensors are used as inputs of fuzzy system, which is able to handle ambiguity and uncertainty of sensed data. It can avoid the collision between the robot and the nearest object based on a specified fuzzy rules as shown in Table 1.

TABLE 1
FUZZY RULES

Dst \ Dir	Left	Center	Right
Near	Right	Center	Left
Medium	LittleRight	Center	LittleLeft
Far	Center	Center	Center

The membership functions of fuzzy inputs, which are distance and direction of obstacle, and output, which is an angle of robot moving direction, are shown in Fig. 11.

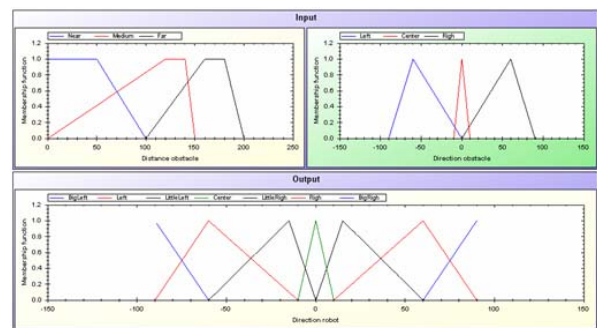


Fig.11 Fuzzy membership functions

3) *Sensor manager*: Sensor manager is responsible for filtering noises from data obtained from ultrasonics, digital compass, and infrared sensors. The big noises in Fig. 12(a) can mislead the robot into the dangerous state and result in

stopping the robot movement while no obstacle is there. This problem can be solved by a filter and the result can be shown in Fig. 12(b). Furthermore, the sensor manager is able to record data and generate a graph for displaying on the PocketPC.

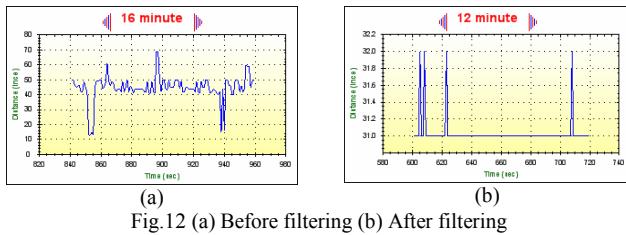


Fig.12 (a) Before filtering (b) After filtering

4) *User Interface*: The main user interface is based on touch screen interaction which is easy to command the robot by dragging a screen from bottom to top for increasing speed or pushing a softkey for direction control as shown in Fig. 13. There are two function modes which are a robot control mode and auxiliary function mode such as camera control, sensor control, or video recording.



Fig. 13 User interface

OpenCV.Net Library provides some image processing and graphic overlay function but it does not support transparent graphic function. The transparent graphic function is then provided by Graphic Device Interface Plus (GDI+) library [9] which enables applications to use two-dimensional vector graphics and formatted text on the video display. Moreover, GDI+ from the Dot NET Framework can handle animation format and image manipulation.

Touch-based interfaces require graphic user interfaces (GUIs) that are large enough to accommodate human finger. GUIs are designed to display feedback sensor data with graphic symbols as shown in Fig. 14. The screen employs virtual graphic symbols that represent ultrasonics sweeper as a radar for object detection, digital compass for robot's direction, and vertical progress bar for speed level. The image flickering is reduced by a double buffering technique. Fullscreen image can be displayed in either 90 degrees clockwise or counter clockwise in horizontal, therefore the operator can control the PocketPC with left or right hand.

The graphic display of virtual radar based on data from ultrasonic and infrared distance sensors can enhance the user's perception beyond video image from the camera. This allows the operator to control the robot even the robot is in a small area that contains many objects and obstacles.



Fig. 14 GUI on PocketPC

The operator can zoom an image while controlling a robot as shown in Fig. 15. The process will enlarge an image in a cropping area using digital zoom technique. All functions, which are run in the computer server, are controlled from the operator.

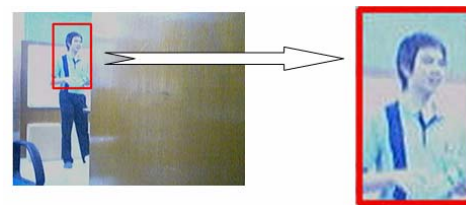


Fig. 15 Zoom area

The sound function is responsible for creating a warning effect of any actions, for example different sounds of pushing buttons to indicate robot's moving direction.

5) *Robot controller*: The mobile robot is connected to the computer server via bluetooth communication. It is controlled by a micro-controller which generates a pulse width modulation (PWM) for speed control. Furthermore, it can determine the robot's movement in 3 states which are safety, warning, and dangerous states respective to the distance between the robot and the obstacle. In the warning state, the speed of mobile robot will be decreased and a warning sound will be generated at the PocketPC. If the obstacle is very close to the mobile robot, the robot state becomes the dangerous state and the robot will be stopped immediately.

6) *Communication*: In this system, a wireless communication network is implemented between PocketPC and the computer server to transfer a data packet of robot's command and video streaming.

Transmission Control Protocol (TCP/IP) is used to transfer any robot commands because it can perform data packet error detection that provides a reliable flow of data between two computers. User Datagram Protocol (UDP) is used to send video streaming between the computer server and the PocketPC. The robot is able to be controlled via internet network or Peer-to-Peer direct link with Ad-Hoc network.

The system utilizes socket network with two ports and multithreaded programming. An augmented data is transferred via one port while robot's commands are sent through another port. The server merges sensor data and image into one packet, compress it with JPEG format,

convert it into a byte array, and then sends streaming data to the client which is the PocketPC. The PocketPC receives streaming data and then converts them into a Bitmap format for display.

The robot will keep performing the last input command until a new command is entered. To handle a situation of wireless out of range, a time-out behavior is integrated to stop the robot.

III. EXPERIMENTAL RESULTS

In this system, augmented data is sent to PocketPC in real time. All graphic and video streaming are displayed on the PocketPC with 25 fps. The advantage of augmented user interface is to provide all necessary information that helps the operator to control the robot easily and intuitively.

For the robot obstacle avoidance function, it is tested and simulated with various situations. The system can provide the valid solutions for robot obstacle avoidance according to fuzzy rules as shown in Fig. 16.

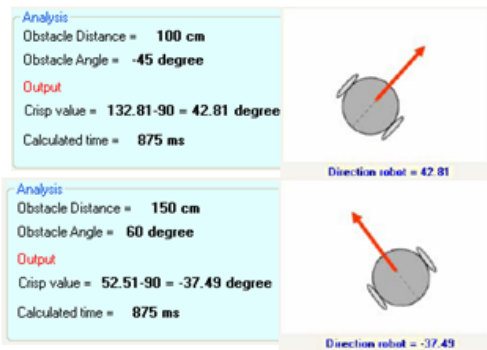


Fig. 16 Robot obstacle avoidance simulation

The results of estimating distance with single camera using Bezier interpolation function show high acceptable estimation with a small computation time. The introduced method has some advantages such as simplicity, accuracy, no extra device need, and no camera intrinsic parameters need. Limitation of this method is the dependency on predefined height and tilt angle of camera. It can provide an acceptable estimated distance with the range of two meters.

Human movement detection provides a high performance under high contrast between human and the background as shown in Fig.17. All image processing procedures are run on the computer server in real time.

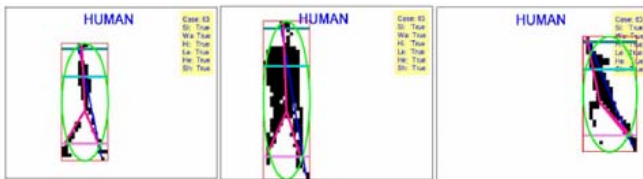


Fig.17 Human movement detection

IV. CONCLUSIONS AND FUTURE WORKS

This paper presented an augmented tele-robot control using a PocketPC. The system provides augmented graphic information superimposed on video image and implements intelligent function to improve the performance of mobile robot control. The augmented graphic user interface enables the operator to remote control a mobile robot intuitively in an outdoor activity.

This system is designed for military and rescue missions. Hence, the system needs to be evaluated under real environments for system performance and usability tests. Finally, some haptic feedbacks could be implemented to enhance the system performance.

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