K. Suneetha, M. S. R. Sekhar, U. Yedukondalu / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 4, Jul-Aug 2013, pp.2324-2328

# Operation Improvement of an Indoor Robot by Using Hand Fingers Recognition

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## ABSTRACT

**Processing Real-Time image sequence is now possible because of advancement of technological developments in digital signal processing, wide-band communication, and high-performance VLSI. Recently, the demand for the indoor robots has increased. Therefore, increased opportunities for many people to operate the robots have emerged. However, for many people, it is often difficult to operate a robot using the conventional methods like remote control. To solve this problem, we propose a robot operation system using the hand gesture recognition. Our method pays attention to the direction and movement of the hand. We were able to recognize several gestures in real-time.**

## I. Introduction

Recently, the demand for the indoor robots, such as auto cleaning and transporter robots has increased. However, the indoor robots have two problems. First, it is usually not easy for many people to operate them because the operations are often difficult and confusing. Second, safety of the robots while operating in the real environment. In this work, we focused on solving the robot operation problem.

In order to solve the problem, we thought it is necessary and desirable to construct an easy operation system for everyone. Therefore, we proposed a robot operation using hand gestures. This is because hand gestures are easy to understand and intuitive for many people. We recognize the hand gesture divided into motion and hand direction. We used optical flow for hand motion recognition and Harris operator for hand direction recognition. Related works include also using the hand gesture to operate a robot.

This work uses camera and ultrasonic wave sensors to recognize hand gesture. However, our work uses only a camera for easy Application and to construction of a simple system. Moreover, in, an input interface for the computer by the hand gesture is proposed. Our work estimates hand motion by finger position. However, we need to recognize gestures even when we cannot extract a large hand area in an image. In this work, we propose a method to recognize gestures at a distance of 1 to 2 meters from the robot.

Digital Signal Processors (DSPs) and Field Programmable Gate arrays (FPGAs) are two choices under the category of semi custom hardware devices. These devices give a balanced solution for performance, flexibility and design complexity. DSPs are best suited to computationally intensive applications. FPGA has been chosen for our application because of its various properties. FPGAs are reconfigurable devices, which enables rapid prototyping, simplifies debugging and verification. Its parallel processing characteristic increases the speed of implementation.

In section 2 the enviranment of this system is presented. In section 3 proposed method is discussed. In section 4 we provide the results. The discussion of the implementation is concluded in the last section

## II. Environment

### 2.1 System Requirements

In constructing an indoor robot, we thought that it should meet the following requirements:

1. It can operate in real time.
2. User friendly.

Therefore, we have developed a robot system as shown in Fig.1. Autonomous robot operation is realized by computer image processing results. High-speed image processing becomes possible because the main processing is done by a computer. We can then send the control commands from the computer to the robot.

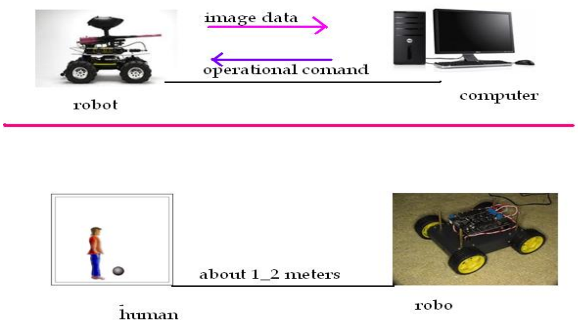



Fig. 1: Robot System

### 2.2 Camera and Computer Spec

In this section, we describe the specifications of the camera and computer. Camera can obtain the images at 640x480 pixels and at 30 frames per second. The video format is Motion JPEG. In this work, we use 320x240pixels image at 15 frames per second. The specifications of computer used for image processing are: The CPU of the is Core2Duo (3.0GHz) processor and the memory is 2[GB].

### 2.3 Definition of Gesture

In this section, describe the gestures used this paper. We define the four gestures to direct the operation of the robot. These are ”Go straight”, ”Stop”, ”Turn Left” and ”Turn Right”. The starting home position is a shown in Figure 2. The gestures are shown in Figures 3, 4, 5 and 6 respectively.

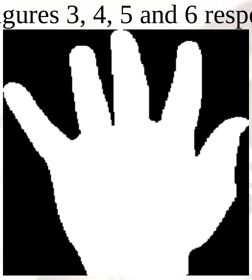


Fig.2 Home position


Fig.3 Down

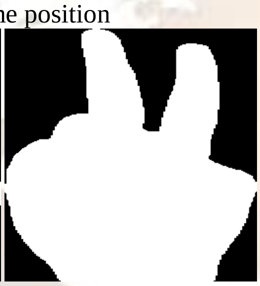


Fig.4 Stop

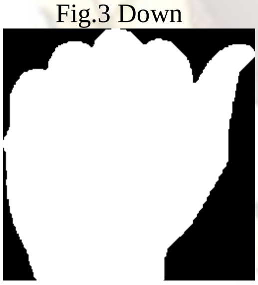


Fig.5 Right

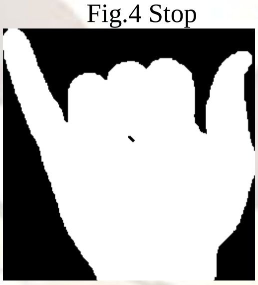


Fig.6 Left

Using these gestures, the following two operations can be defined.

1. Which direction the hand moved
2. The final direction of the hand

This work proceeds by setting these two conditions. In the following sections, we will explain how to achieve these conditions. The complete block diagram of this system is as shown in fig 7.

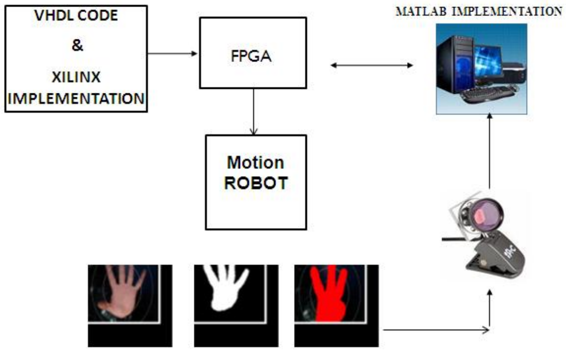


Fig.7 Block diagram

## III. Proposed Method

### 3.1 Flow of Method

The flow of the proposed method is shown in Figure 8. This work consists of two stages, hand motion detection and final direction estimation.

At first, skin color regions are extracted from the input image. The moving parts are considered the hands. Next, on the extracted hand areas, features are extracted and using the features, the hand final direction is detected. Then, based on the final direction of the hand, the gesture is recognized. The details are as follows.

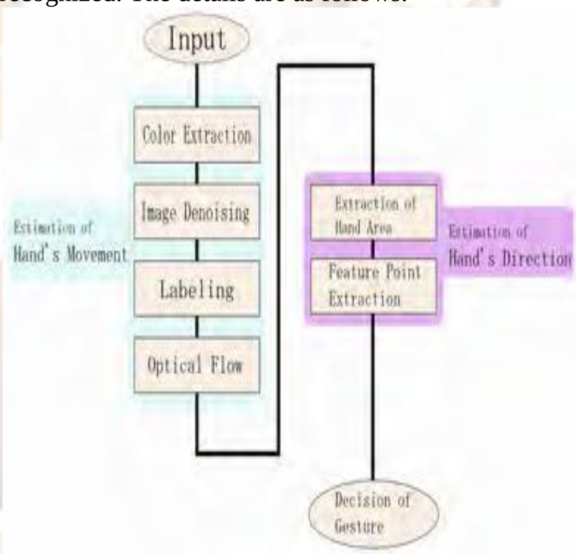


Fig.8 Flow Chart

### 3.2 Estimation of Hand's Movement

#### 3.2.1 Color Extraction

To detect the human hand, we extract skin c area. The raw data provided by the camera is in the RGB format. However, detecting skin color is difficult using the RGB format, because the format is greatly influenced by changes in brightness. Therefore, we use the YCrCb color space. Y is the luma component. Cb and Cr are the blue-difference and red-difference chroma components. YCrCb format is roboust to brightness changes. The color space was used because the human skin color has individual differences. The conversion from the RGB format to YCrCb format is performed using the following equations.

$$Y = 0.229 \times R + 0.587 \times G + 0.114 \times B$$
$$Cr = 0.500 \times R - 0.419 \times G - 0.081 \times B$$
$$Cb = -0.169 \times R + 0.332 \times G + 0.500 \times B$$


Fig.9 Input Image

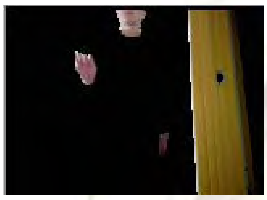


Fig.10 Extraction

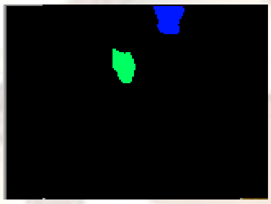


Fig.11 Labeling

The result of extracting skin color regions from Fig.9 are shown in Fig.10. Moreover, to remove the noise, the dilation and erosion processing is done. As shown Fig.10, it is understood that in addition to the hand, the face and a part of background are also extracted. Therefore, labeling is performed on the extracted area. The area of each area is calculated at the same time. The distance between the person performing the gestures and the robot is between 1 and 2 meters. Therefore, very large areas, for example the face, can be deleted because at this distance, they are too large to be hands. Moreover, obviously small areas (less than 40pixels) are likewise removed as noise compared with the hand. The result is shown in Fig.11.

### 3.2.2 Optical Flow

We now explain the technique for detecting the moving regions. The features are first detected from the input image, and are pursued by using optical flow. The Harris filter is used to capture the features. The Harris filter is one of the techniques for detecting edges, an effective characteristic for the tracking. The Lukas-Kanade algorithm was used for the tracking of the feature. This algorithm pursues a feature around the image. High-speed tracking is effective for the robotic operation if possible and real time processing is necessary. When the movement of the feature is detected, the image the result and the labeling result are compared, and the features region is assigned and recorded.

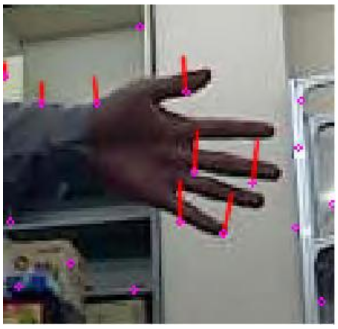


Fig.11 Optical Flow

### 3.3 Estimation of Hand's Direction

### 3.3.1 Feature Point Extraction

In this section we introduce how to estimate the direction of the hand. We assume that the estimated hand area to have a motion which we extract using optical flow. However, the hand area is small as shown in Fig.12. In the example of Fig.12, image size is 320x240[pixels] and hand area is about 50x40[pixels]. It is difficult to extract feature points. Therefore, we expand the area that contains the hand, to detect feature points thereafter.


Fig.12 Hand

We use the Harris operator as feature point's extractor. It can detect fingertips, because, it can detect corners. Hand area is enlarged to 300x300pixels to get more feature points. Fig.13 shows the result of extracted Harris feature points.

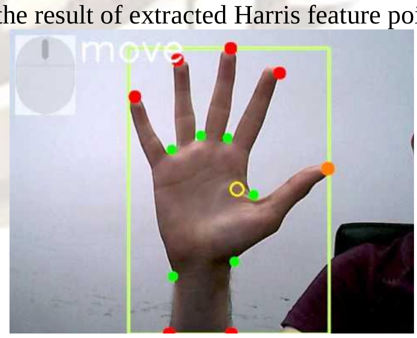
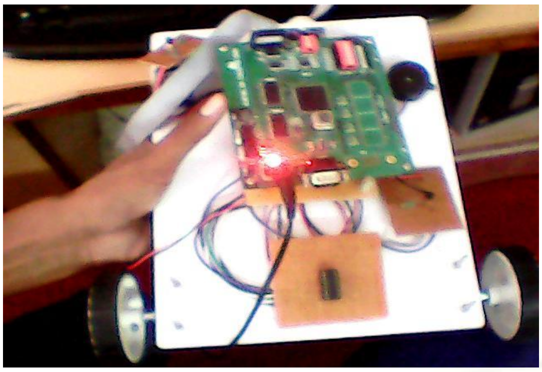


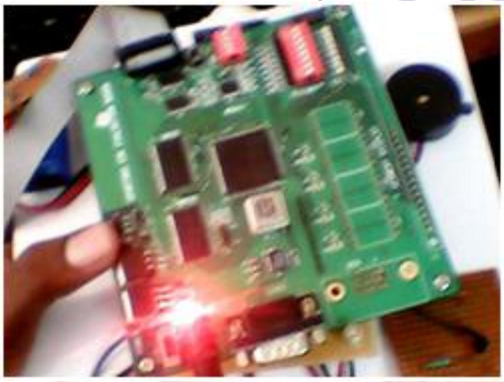
Fig.13 Feature Points

## IV. Results and Discussion

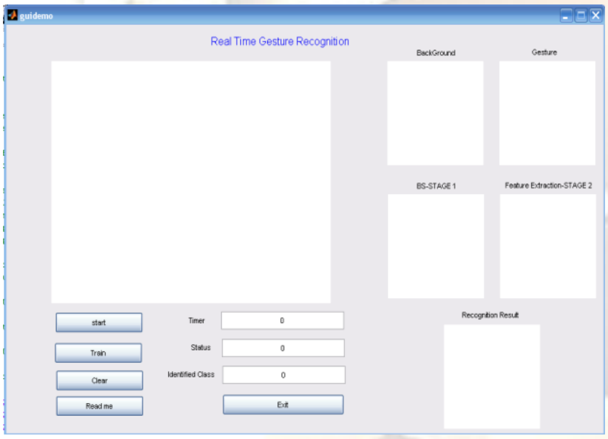
We conducted experiments to verify the effectiveness of our method.



These are the overview of the finger robo frontview.

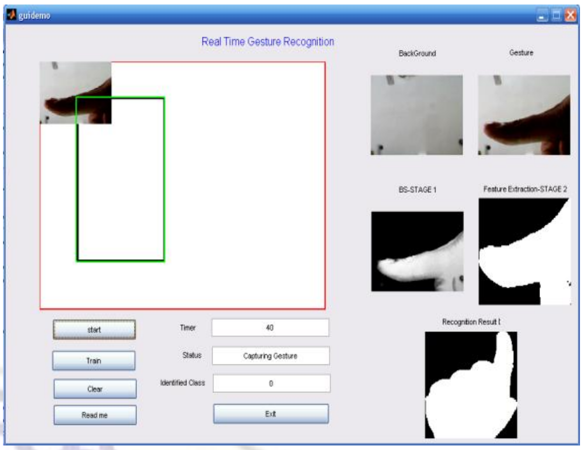


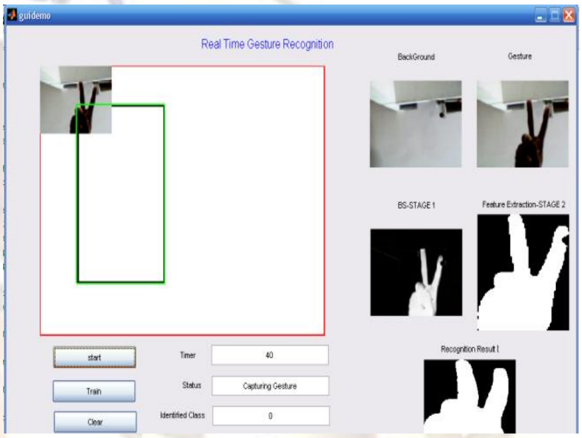
The FPGA SPARTAN3E kit which runs accornding to the command .




The gesture recognition window where the feature points are extracted and functions accordingly.

The below windows describes the fingers extraction which indicates the movement of the robot




## V. Conclusions

In this paper, we proposed a simple operation method for a mobile robot using gesture recognition. We recognized hand gestures divided into motion and hand direction. We used optical flow to estimate the motion of the hand and distribution of feature points to estimate the hand direction. This method can be used to operate the robot in real time. However we encountered several problems. The first problem is color extraction. It is difficult to detect hand area when there is overlapping occur with the skin area in the background and the hand. The second problem is the feature points. In several images, we could not detect the feature points between the fingertip and fingers. In future, we must find solution to these problems and increase the types of gestures to enable complete robot control in a real environment.

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