Application of Remote-Control Car with Visual Control

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Abstract— **Recently, embedded system has been developed on Internet and mobile devices, such as industrial remote monitoring, 3G video mobile phones and surveillance monitoring for security. Windows CE is an operating system for embedded which is produces by Microsoft. Due to its affinity, real time and it has complete drivers for user to use, it is increasing the market share gradually. With .NET Compact Framework and C# language's outstanding performance in the networking and software development, there are more and more IT engineer are involved in this research. Therefore, we propose the "Application of Remote-Control Car with Visual Control." At first we set up the webcam in front of the control car, we then use webcam to get the image and send it to the rear of embedded systems for real-time computing. After that, the remote-control car will move smoothly to the destination by using stereo visual technology to determine the right direction.**

This paper can be used widely in various industries, For instance, the application of warehousing transportation vehicle system, can reduce the cost of manpower and increase the competitiveness.

Keywords—**Embedded system, Visual Control, Stereo Vision, Windows CE**

1. INTRODUCTION

With the rapid development of electronic circuit, computer and image processing, visual image play an important role in academic research and industrial application. Take electronic circuit testing with high complexity and density as an example; if there has not been the facilitation of the skills of computer image automatic testing, it is impossible for the prosperity of electronic technology. Based on the approach defined by error signals, Sanderson and Weiss (1980) classified visual system into location as basis and image as basis. On one hand, stereo vision based on the location is that the location of pixels on the image plane where objects are projected judge the movement of the objects. On the other, stereo vision based on the features of image is that the features of changes of objects projected into the image plane decide the movement of the objects. The dramatic difference of the both lies in the stereo vision based on the features of the image. Due to the features of the image as essential information, it is necessary to understand the image.

Recently computer technology progresses fast, microprocessors[1] with powerful functions, mini size and low cost are very popular. Nearly all facilities are controlled by the system constituted of the microprocessors. However, the control system constituted of single chip processor and easy electric circuit cannot satisfy the needs of users nowadays. Instead, the compact embedded system which compose the embedded operation system is caught more attention.

Defined by IEE Electronic Library[2], the embedded operation system is the device for controlling, monitoring, or facilitating equipment. It prioritizes the integrated competence of computer hardware and software, aiming to develop for certain specific purposes. In other

words, it is to customize to handle different situations. The daily application of the system is like household appliances which can connect to the Internet and 3G cellphones which can transmit information through the Internet. On the application in the industry, the wind power generation monitoring system[3] in western countries is used to lower the personnel cost via the remote-control of the Internet. In addition, the thriving development of robot industries in Japan is mostly structured on the embedded system. It is not difficult to discover that the application of the system is widely gained and the need of its functions is increased a lot. To industry and academic fields, there is no doubt that the trend attracts more and more excellent researchers to get involved in the research and design of the system.

Our processing platform adopts the embedded system, so over complex algorithm is not used to calculate. In hands-on implement, the approach of using single image to establish stereo vision was adopted. The relevant literature includes the research concerning the stereo vision produced by sequential single image, which was published by department of computer science and information engineering of Tatung University. The research displayed an easier way to design the program of the system but it did not discuss the actual application of the system. The algorithm of the visual image in the present study not only provides a manageable hands-on implement but applies in the embedded system.

So far, there is a large number of research studies concerning the visual control combined in remote-control cars. Tracking and dodging obstacles has been a hot study topic. Up to present, the most accessible approach of integrating the visual control in navigation is that the remote-control cars follow the pre-scheduled sensory lines to proceed. In Cheng et al.'s studies (2006), the central- and side- lines of the roads in outside surroundings were detected[5]. Choi et al. (2006) utilized the algorithm in the freeway conditions[6].

Image construct of stereo vision[7] usually classified into two approaches, first approach is binocular stereo vision that simulated the human eyes with two cameras , its concept like human eyes compute depth of image . The method calculated depth of image with distance of two cameras and focal length, and captured right and left image to lap over its. It can calculate depth information fast; the other approach, via a sequence of measurements collected over time from a moving camera, then it can construct stereo vision. The former is called the binocular stereo vision approach, on the implement is difficult very much, because it has error that two cameras capture image at one time. The latter is called the monocular stereo vision approach , in the way, had a lot of researchers bring up many method , optical flow .The camera made motion of every pixel with relative velocity of environment in sequences image . Optical flow[8] based on construct of stereo vision that the principal advantage do not need to define the characteristic of objects. It is suitable for the widely positioning and o tracing work.

The current trend of the technology has a great influence on the evolution of the study; the purpose of the study hopes to develop a set of visual operating system which can make the remote-control cars proceed smoothly, and to further apply the system to real life. A camera was used to capture image and a platform by means of the embedded system was utilized for data analysis.

The paper is organized as follows: the second section introduces the hardware structure of our own system, the third section describes the hardware structure, the fourth illustrates the analysis of the research results, and the fifth is the conclusion of the study and suggestions for future studies.

2. HARDWARE ARCHITECTURE OF SYSTEM

The hardware architecture of system include three parts: firstly, the embedded system, ICOP Ebox-4300[9], it is responsible for all system operation; next, it is connected by remote control-car with 89S51[10][11] signal chip as kernel made of the control electronic circuit; finally, a webcam is equipped in front of the remote-control car, to capture sequences image. The hardware architecture of system is illustrated in Fig. 1, and we will explain the processing flow of the system in detail.

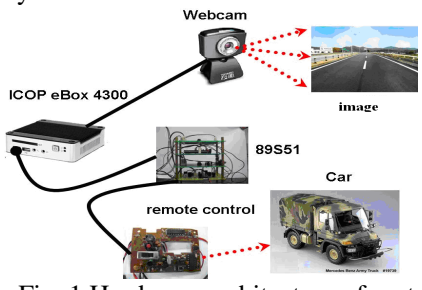

Fig. 1 Hardware architecture of system

In the beginning, the webcam captures image to the embedded system, which has using the platform of windows CE. The decision algorithm in the embedded system can determine. Then the judgment results will be transmitted the signal through RS232 to the 89S51 signal chip as kernel control circuit. Last, signals processed by 89S51 control circuit will output the command of forward, backward, left and right to remote-control car and drive it to move. All the 89S51 control circuit exception the signal chip transmitting the signal has the voltage-stabilized power, which transforms 9V output power into 5V power.

Next is the RS232 control circuit, it transmits the control signal from eBox-4300 to 89S51 control circuit. Finding, it's TC4066BP[13], it is a switch IC, is responsible for receiving signals from the 89S51 control circuit, let remote-control car to execute the movement of forward, backward, left, and right. Fig. 2 shows the control flowchart based on 89S51 control circuit.

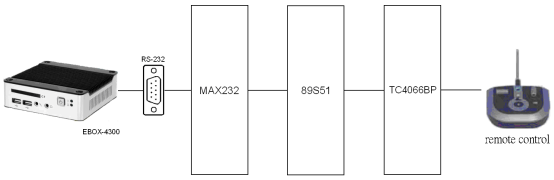

Fig. 2 A control flowchart based on 89S51 control circuit

3. SOFTWARE ARCHITECTURE OF SYSTEM

The software architecture of system flowchart is shown in Fig. 3. First, the embedded system captured a sequence of image from webcam, then we use the technology of obstacle detection to determine whether the remote-control car showed drive or not. The judgment result signal is transmit to 89S51 control circuit, and drive remote-control car to move. The sequence image is continually captured from the webcam, and the judgment of movement is constantly made to dodge obstacles.

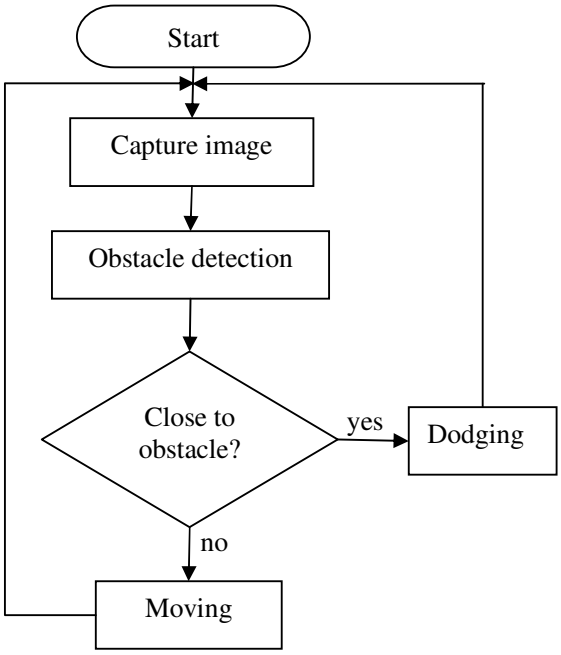

Fig. 3 Software architecture of system flowchart

Fig. 4 shows, the control flowchart of control circuit systems with 89S51 as the kernel. The series port is initially setting, and then baud rate is established. Next, UART is started to prepare to receive data. In the content of 89S51 RI=1, this is the data will be transmitted to the 89S51 SBUF, we have to judge in which model the data were. We adopt the switch…case syntax in the programming. When the signal judged are determined 1, it transmits control signal to drive the remote-control car forward, and eliminated the RI=0; when the signal judged are determined 2, it transmits control signal drive the remote-control car backward, and eliminated the RI=0; when the signal judged are determined 3, it transmits control signal drive the remote-control car right, and eliminated the RI=0; when the signal judged are determined 4, it transmits control signal to drive the remote-control car left, and eliminated the RI=0; when the signal judged are determined 5, the transmission control signal makes the remote-control car stop, and eliminates the RI=0. If any judgment cannot be established, the loop will repeat the following step as above until the judgment can be established.

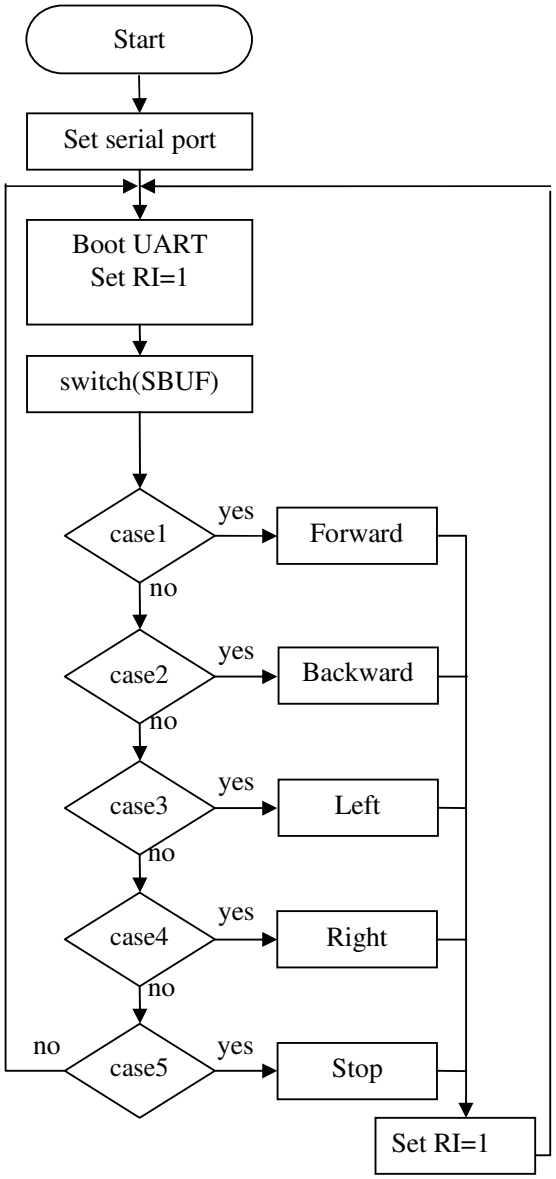

Fig. 4 89S51 signal control flowchart

The obstacle detection flowchart is shown in Fig. 5, image are captured by the webcam for detection. Then, we analyse the obstacles in terms of the position of the image. Two features, color and area of the obstacles, are used to facilitate us to make judgments. In capturing the colors of the obstacles, RGB color space is used to detect the feature of the feature color of the obstacles. In addition, the Sobel edge detector is used to find the edge of the obstacles in the image. Eventually, the calculation of logic AND operator can combine two results to find out the centroid coordinate and the area measurement of the obstacles, and obtain resulting the relative position and the distance between the obstacles and the remote-control car. Therefore, the progression of the remote-control car is determined, and minimizes the opportunities of crash to the obstacles.

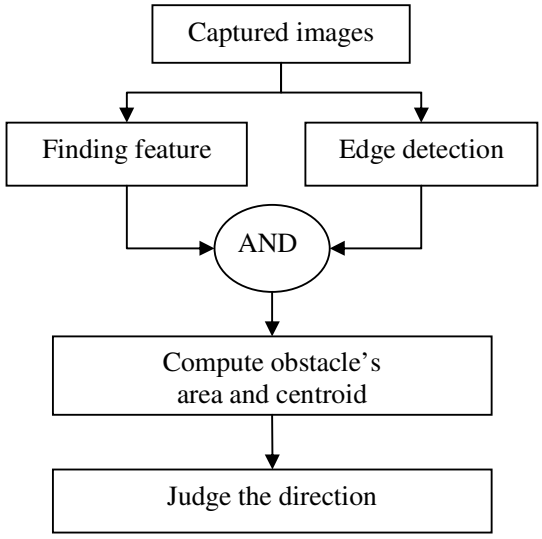

Fig. 5 Obstacle detection flowchart

In the finding feather color phase, based on RGB color space, we can find the obstacle color in the captured image. Due to obstacle color is bright and clustered together, RGB color space is proper to find correction position. The feature colors of the target obstacles can be found via the two sets of RGB in Equation (1) and (2). In this paper, obstacles are classified into red and blue two colors. If the feature color of the obstacles is red, the feather color is defined as the equation (1).

$$\begin{aligned} 106 \le R \le 255 \\ 0 \le G \le 90 \\ 0 \le B \le 90 \end{aligned} \quad (1)$$

If the obstacle feature color is blue, its color rang is defined as equation (2).

$$\begin{aligned} 106 \le B \le 255 \\ 0 \le G \le 90 \\ 0 \le R \le 90 \end{aligned} \quad (2)$$

We employ the Sobel edge detector to discover the image edge. We use a group of 3×3 Sobel operator, comprised of the vertical and horizontal calculation, to perform the plane convolution with the image. Hence, the image

edge is obtained. The Sobel operator are shown in equation (3).

$$Gx=\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} * I \ and \ Gy = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} * I \quad (3)$$

In the equation (3), Gx and Gy represents the Sobel operator of horizontal and vertical direction respectively, I represents the raw image, and * represents the convolution operator. The results of the horizontal and vertical calculation will be combined together in order to obtain complete a image edge. The combination method is as follows:

$$G = \sqrt{Gx^2 + Gy^2} \quad (4)$$

After combining the feature color of the obstacle with the result of the Sobel edge detection, we can find the obstacle's position in the sequential image. Therefore, the centroid and the area of the obstacle can be calculated. The calculation equations are as follows.

$$X = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} j \times w(i,j)}{\sum_{i=1}^{n}\sum_{j=1}^{m} O_a(i,j)} \quad (5)$$

$$Y = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} i \times w(i,j)}{\sum_{i=1}^{n}\sum_{j=1}^{m} O_a(i,j)} \quad (6)$$

The $\sum_{i=1}^{n}\sum_{j=1}^{m} O_a(i,j)$ stands for the obstacle area, (X,Y) represents the obstacle centroid, n is the image width, m is the image height, $w(i,j)$ for the value weight of individual pixel element (with obstacle is 1; without obstacle is 0), $O_a(i,j)$ represents obstacle position in image (with obstacle is 1; without obstacle is 0).

Finally, we obtain three results. First, it is centroid position and area of obstacle. Next, it is the relation position between the obstacles. Finally, it is relation position between the obstacle and remote-control car. When it comes to the progression of the remote-control car, the first step is to find the closest obstacle by the remote-control car, and then to judge if the relative position of the closest obstacle lies in the straight line of the remote-control car progression. If not, the remote-control car will revise its progression routing. When the remote-control car detects a certain distance from one obstacle, it will dodge the obstacle and move to the other obstacle which is the closest one relative to the first obstacle

4. EXPERIMENTAL RESULTS

This paper uses ICOP Ebox-4300 as kernel processor, the built-in 500MHz microprocessor, memory 512MB, 10/100 Mbps LAN network card, 2 RS-232 port, three USB 2.0 port, the software platform is Windows Embedded CE 6.0 R2. And we use Microsoft Visual Studio 2008, as development tool.

The remote-control car's forward, backward, left and right, which add needed control controller's copper when touch, then remote-control car can act. The present paper adds TC4066BP, as Switch IC, had four groups switch to control the signal, shown as Fig. 6. Fig. 7 is shown 89S51 control circuit's fin product. This control circuit divided into 4 constructions, from top to bottom is the TC4066BP electric circuit, 89S51 control circuit, RS232 transmission electric circuit and the voltage-stabilized source 5V output. All power is provided by the lowest level of voltage-stabilizer circuit. RS232 transmission electric circuit will receive the signal, then to get the 89S51 control circuit judge the signal. After the 89S51 chip analysis the data, if has command of movement, will transmit to the TC4066BP, to open the switch; If it not receives command of movement, 89S51 will close the switch. So then can .control control-remote car to direction of movement. As Fig. 8 shown that capture obstacle flowchart. Then calculate the obstacle the centroid coordinate and the area.

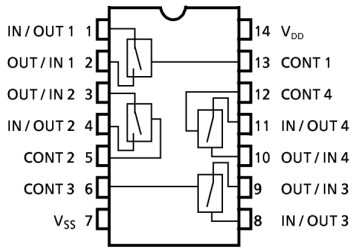

Fig. 6 TC4066BP as switch IC

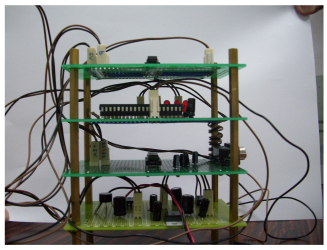

Fig. 7 89S51 electronic circuit

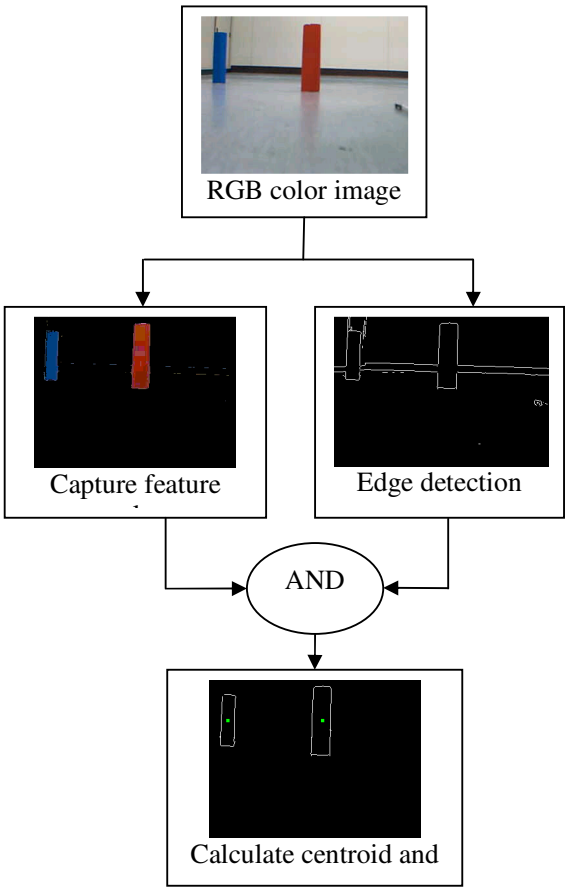

Fig. 8 Capture obstacles flowchart

Due to the problem we met when doing the experiment, the control circuit is unable to control the remote-control car normally. But we then discovered the solution as soon as possible by dividing the control circuit into four molds, 89S51, RS232, TC4066BP, the voltage-stabilizer circuit. This way can test each molds, and operate normally. If one of the mold acts irregularly, we do not need to remake of new one. But it is still by unstable when controlling the remote-control car. We used the bread board to discover the error by adding the LED originally to observe the unstable between control of 89S51 and the TC4066BP, therefore, it can be normal as long as we remove the LED.

When the remote-control car detected the obstacle, due to webcam capture the image's speed lower than the remote-control car's advance's speed, it causes the eBox-4300 on image process to be unable to keep up the remote-control car advance. It causes to be not synchronization when the remote-control car judges sequence image and movement. After improving remote-control car, when process on the obstacle detection, the remote-control car move on the fixed time, the embedded system eBox-4300 enables synchronized with the remote-control car on image processing. After repeating to experiment and the concept by way of the synchronized in operation system, we found can make the embedded system with the remote- control car's synchronizing time. Finally, the control-remote car can dodge obstacle down in not collide obstacles situation.

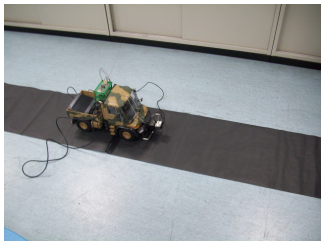

Fig. 9 Remote-control car implementation

5. CONCLUSIONS

This paper is mainly to implement the visual servo embedded systems used in remote-control car navigation technology. By using the webcam we can capture a sequence of image, and use embedded systems as the kernel processor. After using the visual image processing technology to detect obstacles and determine the progression direction, the 89S51 kernel control circuit makes remote-control moving. By the experimental results we found this paper proposed the framework which can be realistic implemented. It is able to dodge the obstacles successfully. We proposes the system which can be used in variety field such as the hospital route guidance can help patients to move to the desired location, or use self-propelled machines in all kinds of harsh environment exploration and the disaster or difficult environment for rescuing to replace the traditional labor.

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