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Design of a Smart Car based on Wireless Image Acquisition Technology

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Abstract. Design of a smart car based on wireless image acquisition technology is introduced. The smart car is controlled by MCU MC9S12DG128. It receives control commands to carry a camera to different sites to capture images. There is a CMOS camera and a ZigBee RF module installed on the smart car. The CMOS camera can obtain static images. Then the acquired image data are stored in MC9S12DG128. And the image data are transferred to a remote monitor on PC through wireless ZigBee RF module based on IEEE 802.15.4/ZigBee protocol. Finally, the smart car can be used to capture and send images of special environments, such as toxic environment and narrow spaces, to a remote monitor center.

Keywords: Smart car, CMOS camera, ZigBee, Image acquisition

1. Introduction

In recent years, lots of disasters occurred on the earth. But in the rescuing sites, rescuers can't get access to dangerous environments because of radiation, poisonous gas, or narrow spaces. The Fukushima Daiichi nuclear disaster led to global panic, which is nuclear meltdowns and releases of radioactive materials at the Fukushima I Nuclear Power Plant, following the Tohoku earthquake and tsunami on 11 March 2011. At that time, rescuers could not get close to the disaster site in fear of the nuclear radiation. To solve the problem, a smart car based on wireless image acquisition technology was constructed. It can be used to acquire and send images of special environments though wireless ZigBee network to a remote monitor center.

2. System Analysis

The wireless image acquisition system is composed of several parts. The main controller is based on Freescale MC9S12DG128 [1], which is a 16-bit micro controller and has enough peripherals, such as PWM, UART and so on. A keyboard is connected as the I/O device. A PWM module output to the servo to control the direction of front-wheel. Another PWM module is outputted to the MC33886 driver to drive the DC motor at the rear-wheel. The photoelectric encoder installed in the rear-wheel is used to measure the velocity for a feedback control [2, 3]. There is a CMOS camera OV7620 controlled by OV529, capturing pictures. The wireless ZigBee module CC2530, connected to the UART interface of the MCU, is used to send image data to the remote monitor and receive commands from it. The interconnection among these modules is shown in Figure 1.

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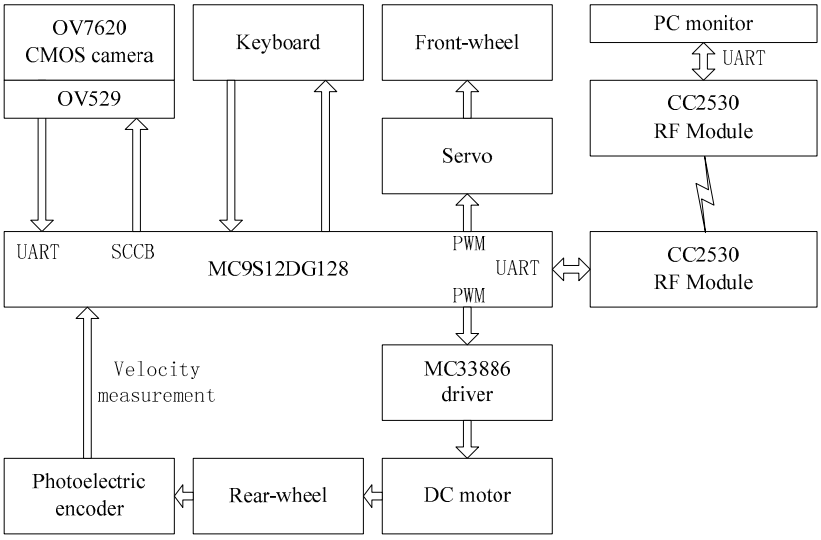

Fig. 1: The structure of the wireless image acquisition system

3. Hardware Design

In order to complete the system's function, hardware circuits for CMOS camera [4], ZigBee RF module and smart car was designed.

3.1. CMOS Camera

The image sensor module for our platform is OmniVision OV7620 combined with embedded DSP OV529. The OV7620 image sensor is a low voltage CMOS sensor that provides the full functionality of a single-chip VGA camera and image processor, as shown in Figure 2. The OV7620 provides full-frame, sub-sampled or windowed 8-bit images in a wide range of formats, operating at up to 30 frames per second (fps), controlled through the Serial Camera Control Bus (SCCB) interface [5]. The OV529 Serial Bridge contains an Embedded JPEC CODEC and controller chip that can compress and transfer image data from the Camera Sensor to an external device [6]. The OV529 performs all imaging function like white balance, downsizing and compressed image to JPEG format. And the image sensor module connects with the processor through UART.

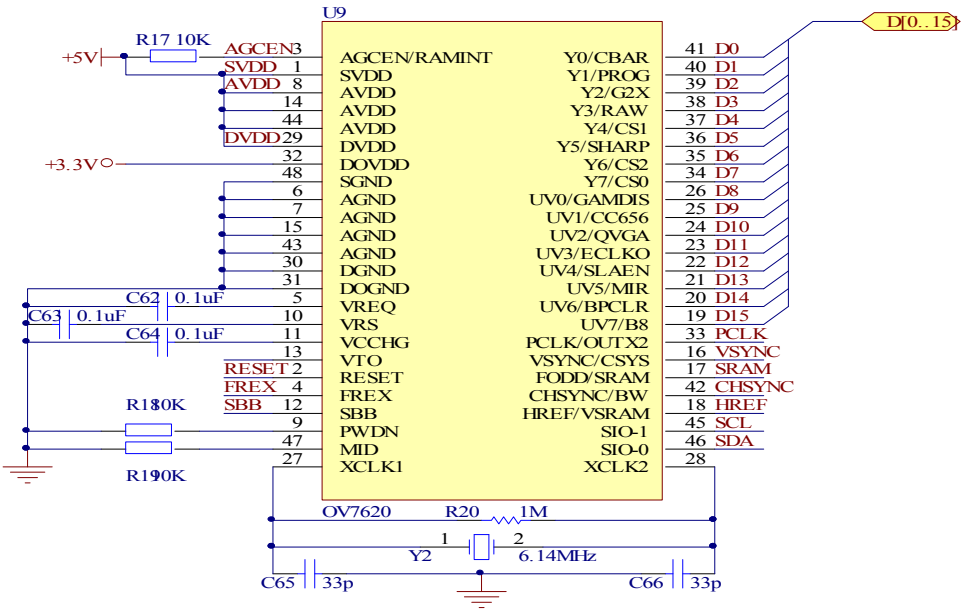

Fig. 2: The schematic of the CMOS camera

3.2. ZigBee Module

A ZigBee transceiver, CC2530, was used as a RF module to communicate with the PC. Thus, the car model can transmit image data to the PC. And the PC also can send control commands to the car model. The

CC2530 is a true system-on-chip (SoC) solution for IEEE 802.15.4, Zigbee and RF4CE applications. It enables robust network nodes to be built with low costs. The schematic of CC2530 is shown in Figure 3.

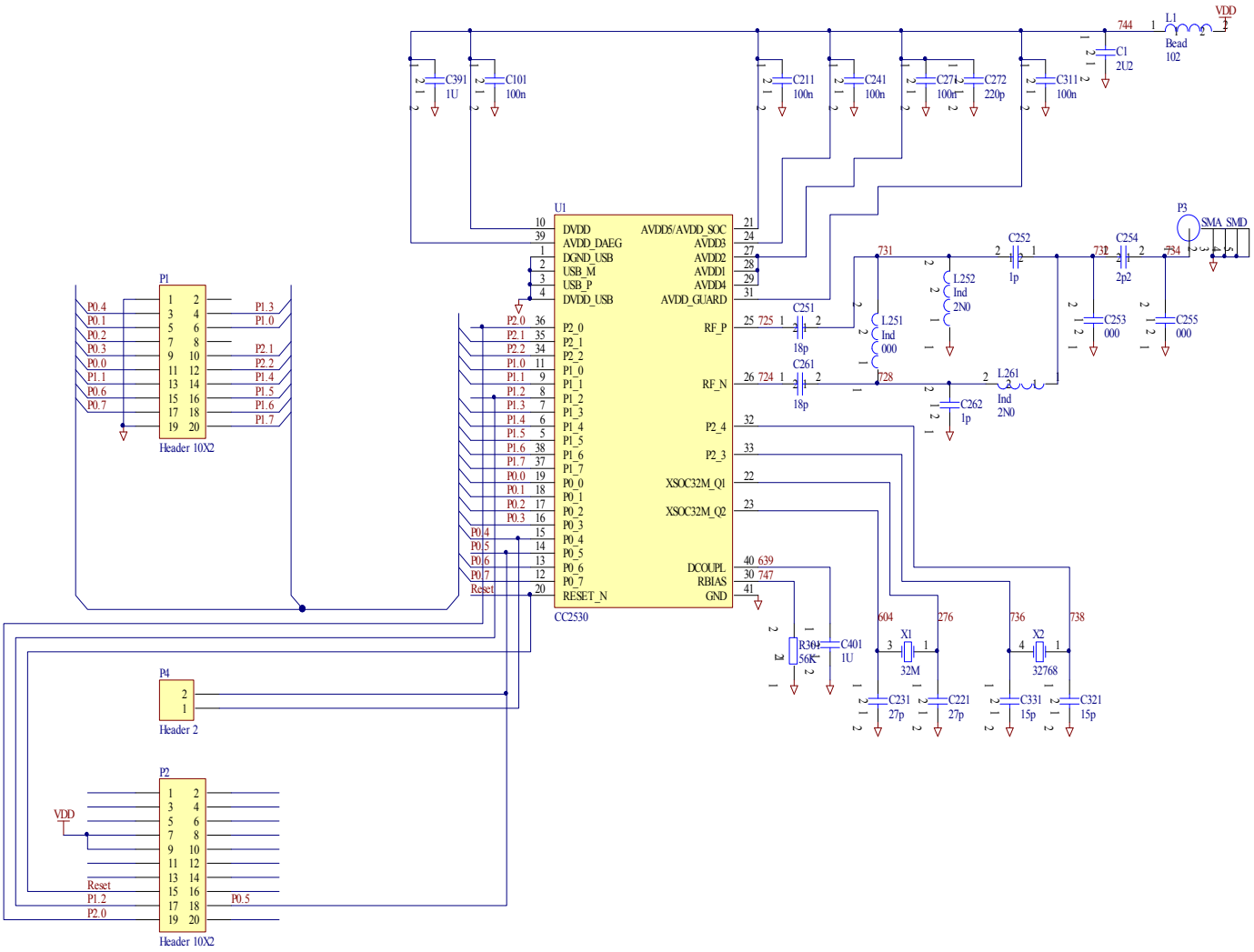

Fig. 3: The schematic of CC2530

3.3. Motor Driving Module

The smart car is driven by a DC motor in the rear-wheel; its direction is controlled by a servo in the front-wheel [7].

To obtain a stable speed of the motor, feedback mechanism PID was used to eliminate environment interference such as non-stable battery voltage and uneven road friction. So an integrated photoelectric encoder was used to get the speed of the motor. The signal is connected to PT7 of the MCU.

RS-380SH motor was used. It works at voltage 7.2V and no-load current 0.5A, whose specified rotating speed is 16200 r/min. MC33886 is a monolithic H-Bridge ideal for fractional horsepower DC-motor and bi-directional thrust solenoid control. Two chips of MC33886 are paralleled to drive the motor, which can provide greater driving force. And the MC33886s are controlled by a PWM from the MCU. Changing the duty cycle of the PWM, then the speed of the motor was adjusted [8]. The schematic of the driving circuit is shown in Figure 4.

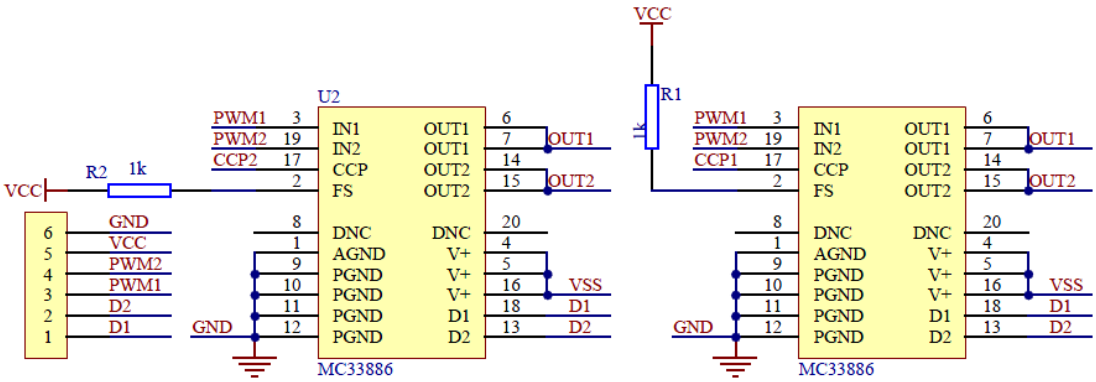

Fig. 4: The schematic of the motor driving circuits

4. Software Design

To achieve the system, 3 types of specified software were developed. One on CC2530 was the ZigBee protocol stack to communicate between the smart car and the remote controller; one was the smart car control software based on MC9S12DG128; another one was the PC monitor developed with Microsoft MFC. A set of protocol of commands were specified so that the PC monitor and the smart car must obey with it to communicate with each other accurately.

4.1. CC2530 Software

In a ZigBee network, there are 3 types of nodes; they are coordinator, router, and end device [9]. Each node can be configured as one of these above. So the node connected to the PC was configured as a coordinator; the one installed on the car was configured as an end device.

When powered on, the coordinator set up a ZigBee network, and then the end device enters the established network. Since then, the PC monitor sent commands to the smart car to take pictures or move around; the smart car controlled the camera to take a picture and sent the image data to the PC monitor. As is specified [9], packet size of ZigBee is 127 Bytes; despite for necessary controlling bytes, the payload of each packet is less than 100 bytes. As a result, we separated the image data into 64 bytes per packet to transfer. The flowchart of the wireless communication procedure is shown in Figure 5.

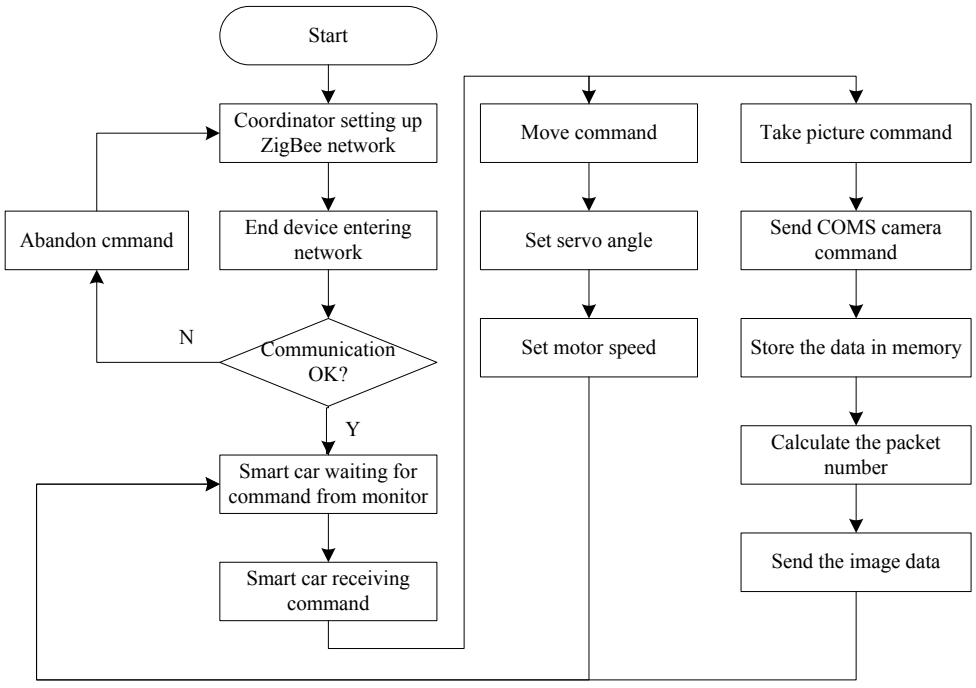

Fig. 5: The flowchart of the wireless communication procedure

4.2. Smart Car Control

The car receives the commands through the wireless ZigBee CC2530 module. According to different commands, the car moves can move back and forth, turns around, takes pictures and sends image data.

First of all, the length of the servo rod was adjusted to an optimal value. Thus, the servo has the most extent of sensibility. The servo is controlled by PWM. And the servo's rotation is proportional to the pulse width. However, the relationship between the turning radius of the car models and steering angle of the servo is nonlinear [10]. The relationship between them was obtained through lots of experiments, and then the data was plotted in MATLAB, as shown in Figure 6. They were stored in the memory as a table. When the car is set to a specified turning radius, the MCU will search the table for the corresponding PWM duty cycle and outputted it.

Traditional PID control strategy was adopted to control the speed of the motor [11]. Compared to open-loop control, the PID feedback control can keep the motor maintaining a stable speed. The PID parameters were tuned through lots of experiments.

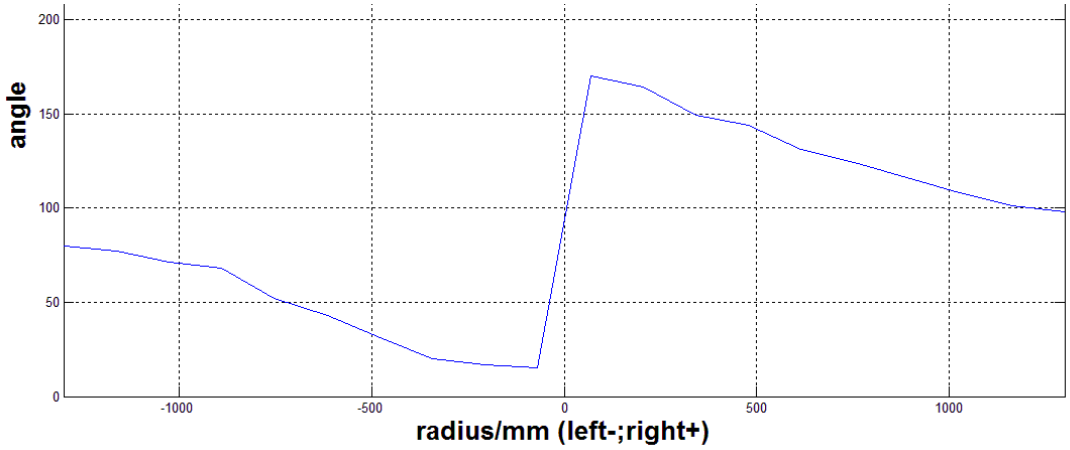

Fig. 6: The relationship between turning radius and servo angle

4.3. PC Monitor Center

A monitor program was developed with the Microsoft MFC, as shown in Figure 7(Image Captured in our Lab.). The upper right combo list and button were used to control the COM port; the middle two buttons were used to take and show pictures, acquired by the smart car; the bottom right 4 buttons were used to control the movement of the car. Then the bottom box showed the state of the program dynamically. Because the image is JPEG format, there is a decoder module in the program.

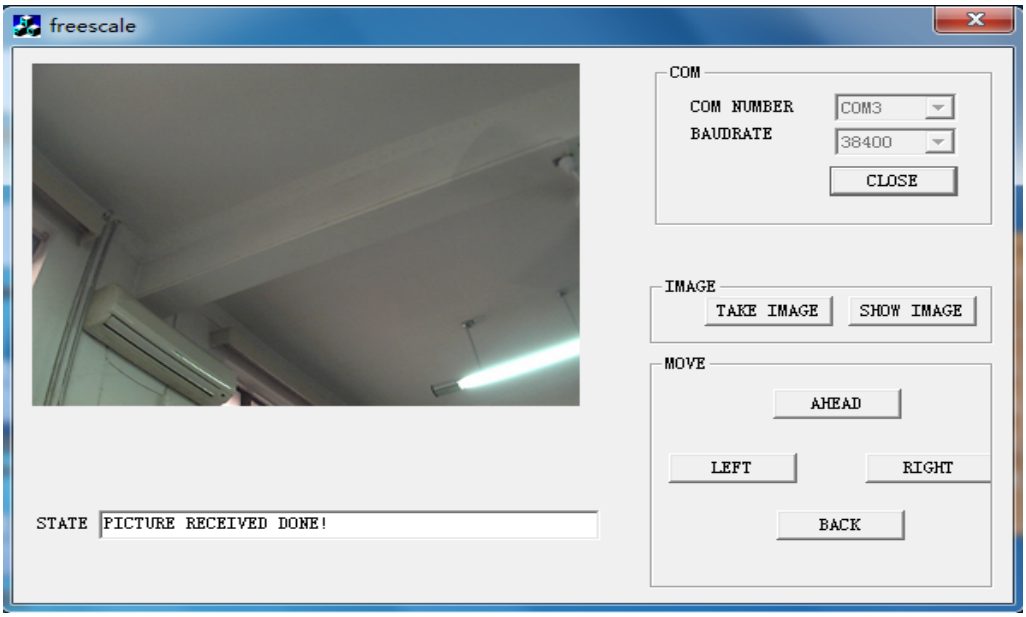

Fig. 7: The MFC monitor program

5. Conclusions

By designing the CMOS camera, wireless ZigBee module and smart car control module, a wireless image acquisition system was developed. In experiments, as the car moved around, it can acquire and send image of its surroundings to the PC monitor to display.

6. Acknowledgements

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