Intelligent Parking System Based on Nios II

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Abstract— **Intelligent parking system attracted increasing attention of the automobile manufactures in recent years. A reliable parking assistant system could reduce the rate of accident effectively and simplify the operation of the driver. This design takes Nios II as control core, uses camera to collect parking information, installs ultrasonic sensors to achieve ranging capabilities, adopts Ethernet port and wireless router to realize communication with Android smart phone and designs driver circuit to control car. The experiments show that this design can achieve real-time operation of the model car through smart phone to finish parking process. Meanwhile the car can complete parking automatically with the assistance of image and range information.**

Keywords— **Intelligent Parking; Nios II; FPGA; Android; Real time Image Processing**

I. INTRODUCTION

A. Design Intention

With the continuous development of economic level and the improvement of living standards, a growing number of cars lead to serious problems that highway, street and parking lots are increasingly crowded. There are fewer parking spaces for cars. In addition, the gradually increasing number of novice drivers leads to kinds of problems as well. According to the statistical data of the traffic accident database and the insurance company, accidents caused by parking accounted for 44% of all types of accidents[1]. With the development of embedded technology, using various electronic devices to assist parking is also a hot technology researched by major automobile manufacturers in recent years[2]. Therefore, we design this intelligent parking system based on Nios II.

Since Google launched the first Android phone in 2007, just after six years, Android has become the leader in smart phone operating system. What's more, its market share in the country has reached 86%. Currently APP based on Android system has reached 400,000, spreading all over people's work, life and entertainment. Development of Android application has become a hot research by various manufacturers, including traditional non-electronic industry. It's convenience for app development by Android's popularity, anyone with an Android device can access to the equipment to use[3].

We will combine Android operating system and parking system, you can not only observe the image behind car while parking by phone, but also control car, improves the safety and reliability of the parking process[4].

B. Design Scheme

This design using 1:20 car model as platform, FPGA as the processing core, combined with ultrasonic ranging module, camera, optical encoder, achieved intelligent parking assist function. System structure diagram is shown in Fig. 1.

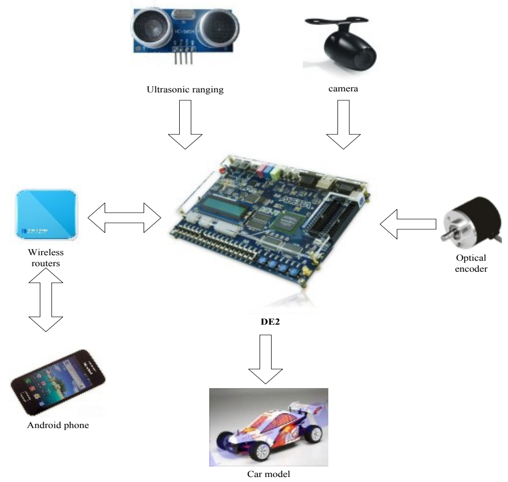

Fig. 1 Intelligent Parking System Structure

The system collects parking spaces information by camera in the process of parking car, at the same time transmits the real-time images to Android phones through wireless router and displayed on the Android phones. The system will send prompt message to drivers when it determined the presence of a valid parking space, if you choose to parking, parking system will update real-time parking space and surroundings information by camera and ultrasonic ranging module, parking car automatically. Besides drivers can also manually control cars by Android phone while parking, it can overcome the limitations of the view in the car when used in real scene, increasing the security.

II. THE HARDWARE CIRCUIT DESIGN

Intelligent parking system hardware block diagram is shown in Fig.2.

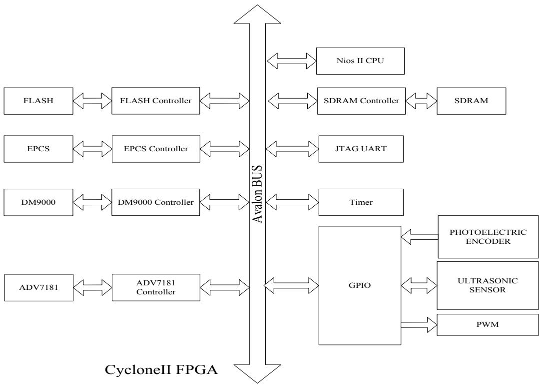

Fig. 2 Intelligent parking system hardware block diagram

The system physical map is shown in Fig. 3.

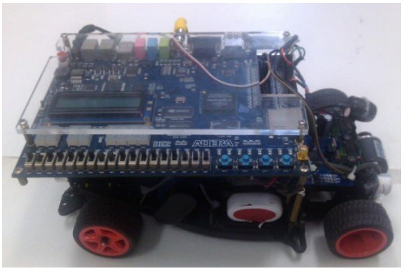

Fig. 3 The system physical map

A. Hardware Performance Parameters

1) DE2-70 Performance Parameters

- FPGA：CycloneII2C70 FPGA, 70000LEs
- Memory ： SDRAM(two 32-Mbyte SDRAMs), SRAM (one 2-Mbyte SRAM), Flash memory(8-Mbyte Flash memory)
- Altera EPCS16 EEPROM
- Transmission interface：10/100MHz Ethernet port
- Clock input：50MHz Oscillator,28.63MHz Oscillato

2) Si Bo Electronics A type model car G768 Performance Parameters

- Motor：RS-380SH-5025
- Actuator：FUTABA3010
- Size of car：27cm×16cm

3) Wireless Router TL-WR702 Performance Parameters

- Wireless protocol：802.11b/g/n
- Wireless rate：150Mbps

4) 185A Camera Performance Parameters

- Working voltage：12V
- Sensor type：CCD
- Signal standard：PAL
- Resolution：720×576

5) Ultrasonic Sensors HC-SR04 Performance Parameters

- Working voltage：5V
- Sense angle<15
- Detection distance：2cm~450cm
- Accuracy：1cm

6) Omron 500 Line Optical Encoder Performance Parameters

- Working voltage：5V
- Line number：500
- Diameter ：3cm

B. H-bridge driver circuit design

H-bridge circuit is a typical DC motor control circuit, as shown in Fig.4. The motor will be in a forward or reverse state, when the diagonal pair of MOS transistor is turned on.

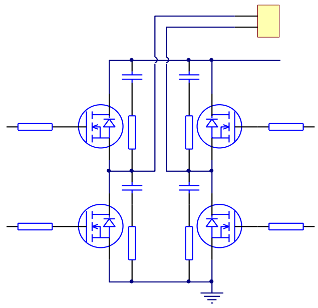

Fig. 4 H-bridge driver circuit

The MOS transistor used in this design is IRF3205, its maximum working current is up to16A. Add 74LS02 circuit to signal input terminal, as shown in Fig.5, which is used to choose input signal. The output of this circuit is low when forward and backward signal are both high or low, only when one of these signals is high, the output is high. Thus avoiding the upper and lower half-case of the H-bridge circuit are simultaneously turned on, to ensure the motor work normally.

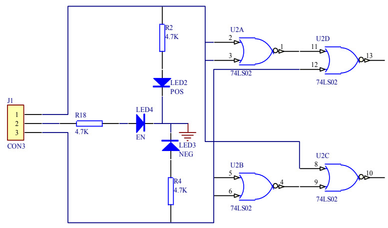

Fig. 5 NOR circuit schematics

C. User-defined Component

The system designed four user-defined components as follows according to functional requirements, accomplishing data interaction with Nios CPU through the AVALON bus.

1) The Image Data Read Module

Using ADV7181 as image acquisition circuit, depositing the changed image data to a FIFO module, when the data is full of 256 units, sending an interrupt signal to CPU, reading data into Nios II for processing through the RD_DATA module.

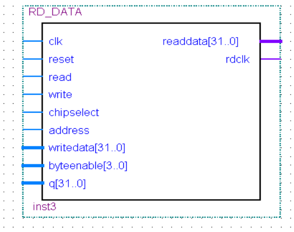

Fig. 6 The Image data Read module

2) PWM Module

To control the operation of car, designs a PWM signal module in FPGA, three channel signal output control motor turn forward and backward and steering respectively. If only the specific information is written to the appropriate address, it can output a fixed period, variable duty cycle square wave signal, to control the car.

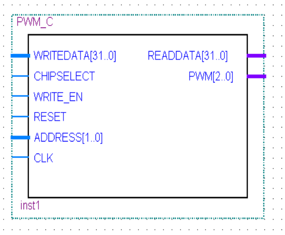

Fig. 7 PWM module

3) The Speed Measuring Module

To measure the car speed, installing an optical encoder on the rear drive shaft. By counting the encoder output pulse, the current speed can be calculated indirectly, as shown in Fig.8.

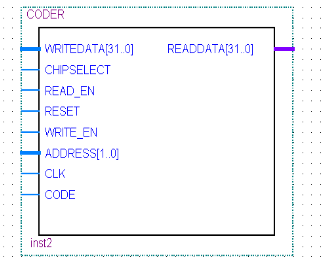

Fig. 8 The speed measuring module

4) The Speed Measuring Module

In the process of car parking, by ultrasonic sensors installed on the front and rear of the car that can determines whether there is an obstacle in the track and respond promptly. Sending a high level trigger signal to ultrasonic ranging module last for 10us, counting the reflected signal received and converting it into the corresponding time, then we can calculate the actual distance.

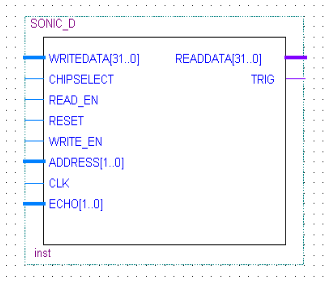

Fig. 9 The Ultrasonic Ranging module

D. FPGA Resource Usage

Fig. 10 shows the use of FPGA.

Flow Status	Successful - Thu Jul 18 14:58:26 2013
Quartus II Version	9.0 Build 132 02/25/2009 SJ Full Version
Revision Name	DE2_TV
Top-level Entity Name	DE2_TV
Family	Cyclone II
Device	EP2C35F672C6
Timing Models	Final
Met timing requirements	No
Total logic elements	6,763 / 33,216 (20 %)
Total combinational functions	5,002 / 33,216 (15 %)
Dedicated logic registers	4,519 / 33,216 (14 %)
Total registers	4587
Total pins	428 / 475 (90 %)
Total virtual pins	0
Total memory bits	107,520 / 483,840 (22 %)
Embedded Multiplier 9-bit elements	4 / 70 (6 %)
Total PLLs	1 / 4 (25 %)

Fig. 10 FPGA resource information

III. SOFTWARE DESIGN AND PROCESS

A. Nios II Software Design

According to the system design demand, the system software can be divided to the following modules: system initialization, reading and processing of image, Ethernet communication, car control. Each module to achieve the following functions:

System initialization: Initializes the hardware devices and global variables.

Reading and processing of image data: To read image data stored in FIFO, one frame each time, with which to finish parking recognition and confirmation of driving track.

Ethernet communication: To assemble image data to certain format according to system demand and send to smart phone through Ethernet port and vice versa.

Car control: To realize real-time operation based on instructions sent by smart phone in manual mode.

Overall system flow is shown in Fig.11.

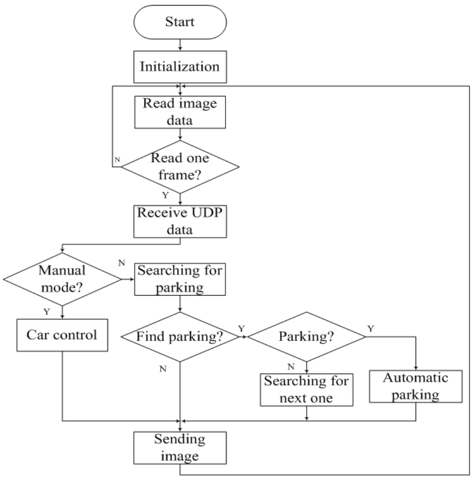

Fig. 11 Overall system flow

1) *Ethernet Communication Design*

FPGA and Android smart phone establish UDP communication model by configuring Ethernet control chip DM9000A.

- How DM9000A[5] Works

Once the system powered on, FPGA would configure net control register (NCR), interrupt register (ISR) and so on through bus to finish initialization. Subsequently, DM9000A enters a wait state for data transceiver.

FPGA has to assemble data into UDP format before sending it to Ethernet, and deliver it to data sending cache of DM9000A byte by byte through 8bit bus or 16bit bus. Then write the necessary information such as data length into the correlative register and send enable command. Finally DM9000A will combine data with frame information to form MAC frame and send it out.

After receiving net data package, DM9000A will check the validity of data frame and abandon it if any frame header flag or CRC error exist. Otherwise store it in internal RAM and inform processor through interrupt after which processor will deal with received data.

- UDP Package Format[6]

The system adopt UDP package to finish data communication, its format is shown Fig.12.

There are two types of package in this design. The first one is sending package, which is shown in Fig.13.

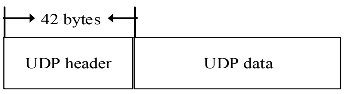

Fig. 12 UDP data package format

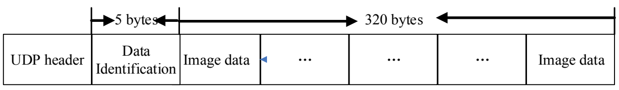

Fig. 13 Sending package format

The resolution of image used in the system is 320*200 and each send package contains 320 bytes namely a row image.

The second type is receiving package, which is shown in Fig.14.

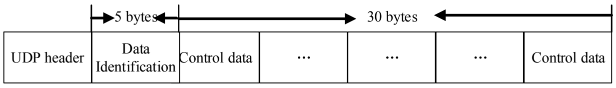

Fig. 14 Receiving package format

- Ethernet Communication Procedure

After powered on, DE2 send ARP package continuously to get MAC address of smart phone, once connection is finished, DE2 and smart phone can exchange data at any time.

Ethernet communication procedure is shown in Fig.15.

2) *Car Control Design*

System follows the orders sent by smart phone to write control construction to PWM module to control car movement under manual mode. In automatic mode, in order to finish parking with stable low speed, system need PID algorithm based on feed-back control.

The speed control used in this system is incremental PID algorithm, which can be described as equation (1).

$$\Delta u(n)=kp\times[e(n)-e(n-1)]+ki\times e(n)+kd\times[e(n)-2\times e(n-1)+e(n-2)] \quad (1)$$

Wherein $\Delta u(n)$ represents output at time n, kp is proportional amplification factor, ki is integral amplification factor, kd is amplification factor of the differential, $e(n)$ is the deviation of time n, $e(n-1)$ is the deviation of time n-1, $e(n-2)$ is the deviation of time n-2.

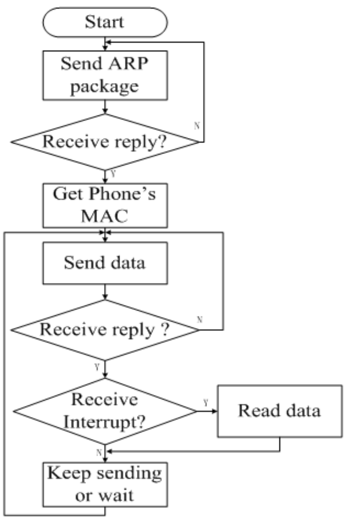

Fig. 15 Ethernet communication procedure

Here is how the incremental PID algorithm works: Using the deviation of the real speed and expected speed and the latest two deviations as inputs of PID controller at time n, n-1, n-2. After calculated PID controller outputs the specific value to control motor. Each factor has to be debugged repeatedly to achieve a smooth adjustment effect.

3) Image Processing Design

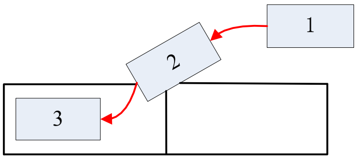

Fig. 16 Parallel parking procedure

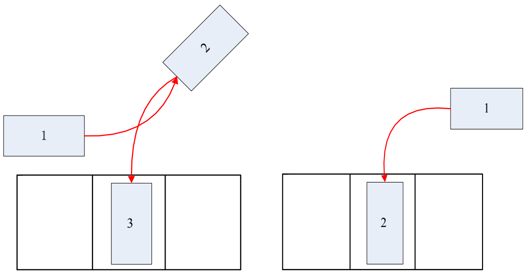

Fig. 17 Vertical parking procedure

Fig.16 shows the parallel parking path and Fig. 17 shows the two common vertical parking methods. Since the model car used in this system can't reach the performance of a real car, which can turn a corner in a smaller radius, the left method is selected.

The binary image captured by camera installed in the back of car is shown in Fig. 18. Effective parking space can be found and the distance between car and parking can be calculated through software processing, then parking path can be estimated according to parking procedure[7].

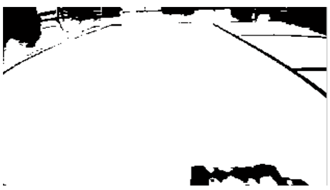

Fig. 18 Binary image

Taking vertical parking as example, the real-time image can be captured, which is shown in Fig. 19. Estimates the relative position between car and parking space by image processing and makes real-time adjustment to accomplish parking[8].

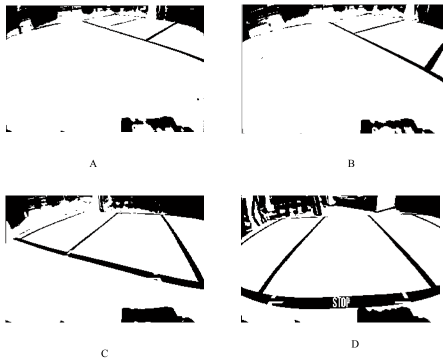

Fig. 19 Real-time image

B. *Android Smart Phone Software Design*

This system chooses Android as platform and uses eclipse to finish software development.

According to demand, the function of smart phone can be divided to receiving message and transmitting message, both of them are realized by UDP protocol. The task of receiving message is to obtain the status of car and the real-time image; For transmitting message, it has to send the control instruction such as moving forward, moving backward, turning around to car. The smart phone interface is shown in Fig.20 and Fig.21.

Fig. 20 Phone interface

Fig. 21 Car control interface

Software procedure of Android is shown in Fig.22.

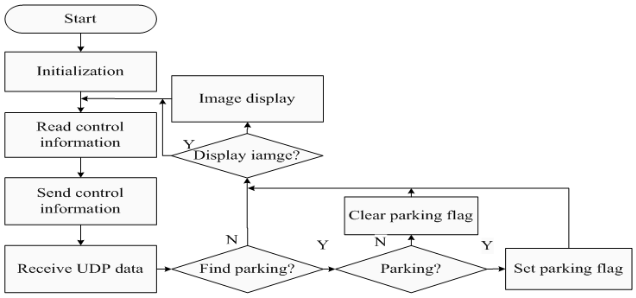

Fig. 22 Software procedure of Android

IV. SYSTEM TESTING

A. *Parking Space*

We design two parking modes—vertical parking and parallel parking. A common vertical parking space is shown in Fig.23, common parallel parking spaces shown in Fig.24.

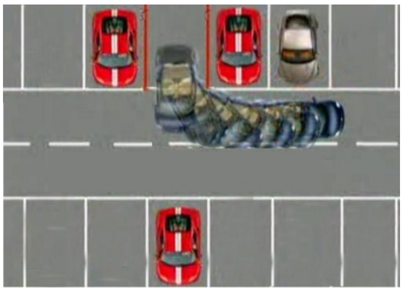

Fig. 23 Vertical parking sketch map

The general size of the vertical parking space in daily life is 6m * 2.5m.The Ford Focus, whose size is 4.5m * 1.8m, is used as the reference in our system. The size of our car model is 27 cm*16 cm. So the length-width ratio is 1:16 and 1:11. The equal ratio parking space size is 37cm * 22cm.

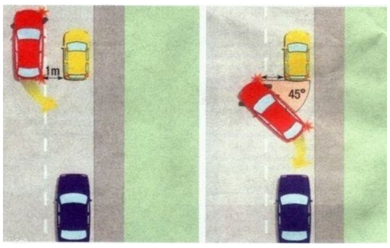

Fig. 24 Parallel parking sketch map

According to the parallel parking test standard, the length of parking space is 1.5 times of car's length add 1m and the width is 0.8 m add car's width. According to the aspect ratio relationship model and the reference model, can calculate out the simulation scenario for parking is 45cm*24cm.

B. *The Procedure Analysis*

The system is in manual mode by default. As long as we open the phone software, we can control of the car in real-time. The same as the real situation, you first need to drive the car to near the parking space and keep parallel, as shown in Fig.25.

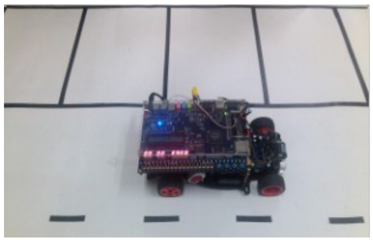

Fig. 25 Initial position

You can switch the mode to automatic parking mode and the car start searching parking space. When the car find parking space, you will be asked whether to parking. If you choose parking, the car will adjust its trajectory with the help of real-time image information and distance sensors and eventually stop smoothly into the car parking spaces. Vertical parking process is shown in Fig.26 and the parallel parking process is shown in Fig.27.

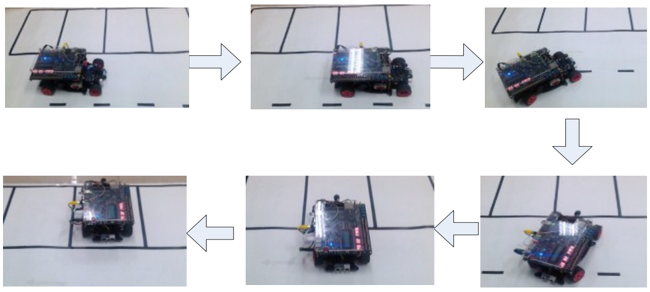

Fig. 26 Vertical parking procedure

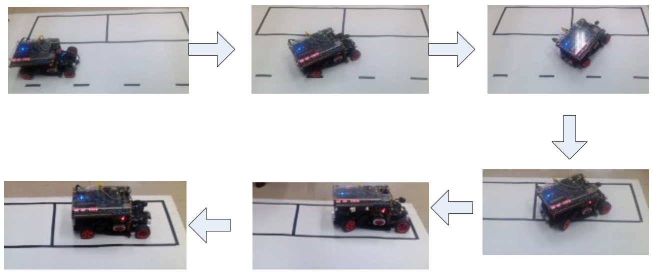

Fig. 27 Parallel parking procedure

Choosing automatic parking mode, the car can park by itself without the driver's intervention. Only in the case of encountering barrier will the car stop. You can switch to manual mode and control the car.

V. CONCLUSIONS AND DESIGN FEATURES

A. *Combining Image Processing with Ultrasonic Ranging*

At present, most of parking assistant system is based on ultrasonic sensors, which is not helpful for the parking space with parking line. What's more, the main function of the camera, installed in the rear of the car, is providing real-time image and its function is not made full of. The image processing can help us identify the parking space and the parking path. The ultrasonic ranging can judge live traffic. So we make a combination of these two sensors to ensure the safety and reliability in the process of parking.

B. Combination with Android

Traditionally, the driver is in the car and his vision is limited. So the driver is unable to get environmental information completely. We combine embedded system with Android mobile in the system and it allows you to park outside of the car. It's a new choice comparing with automatic parking. Moreover, the popularity of Android devices makes extra hardware device for control unnecessary, which reduces the cost of development greatly.

C. The Efficient SOPC Solution

SOPC(system-on-a-programmable-chip) integrates the Nios II processor, memory and I/O port and so on, into FPGA and build it into a system on a programmable chip. What's more, SPOC contains flexible custom peripherals, which can satisfy the requirement of complex design.

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