Mobile Sensor Platform (MSP) v5.0

Zhifei Zhang, AICIP
Electrical Engineering and Computer Science, UTK
E-mail: zzhang61@vols.utk.edu

Date: 12/17/2014
Contents

1 Hardware 2
   1.1 Motherboard: Raspberry Pi ............................................. 2
   1.2 Power: Adapter and Driver ............................................. 2
   1.3 Sensor: Camera and Sonar ............................................. 3
   1.4 Memory and WiFi ..................................................... 3
   1.5 Car Model .......................................................... 3

2 Assembly Guide 4
   2.1 Motherboard ....................................................... 4
   2.2 Motor Driver ....................................................... 4
   2.3 Sonar and Servo ................................................... 4

3 Software 7
   3.1 On-board Software .................................................. 7
   3.2 Sever Software ..................................................... 8

4 Appendix 9
   4.1 Videos of Motion Test ............................................... 9
   4.2 Installation Recommendations ..................................... 9
   4.3 Part List ........................................................... 10

List of Figures
   1 Hardware design ...................................................... 2
   2 Raspberry Pi (Model B) ............................................... 2
   3 Power modules ........................................................ 3
   4 Sensor modules ........................................................ 3
   5 Memory and WiFi ..................................................... 3
   6 Car model ............................................................. 4
   7 The mobile sensor platform ......................................... 4
   8 Connection of motherboard ......................................... 5
   9 Connection of GPIO (denotations are listed in Table 1) ......... 5
   10 Connection of the driver module .................................. 6
   11 Connection of the sonar module ................................... 6
   12 Connection of the servo ............................................. 6
   13 Structure of on-board software modules .......................... 7
   14 GUI of the server software ......................................... 8

List of Tables
   1 Meaning of denotations in Fig. 9 ................................... 5
   2 On-board software modules ......................................... 7
   3 Commands sent from the server ..................................... 8
   4 Part list of MSP v5.0 ................................................... 11
1 Hardware

Generally, design of hardware is shown in Fig. 1.

1.1 Motherboard: Raspberry Pi

Raspberry Pi (model B) is used as the motherboard, which is shown in Fig. 2.

CAUTION: Never supply a voltage above 5.2V to Raspberry Pi.

1.2 Power: Adapter and Driver

Fig. 3 shows the adapter and driver modules. The adapter modules converts 7.2V DC to 5V DC. Since the adapter module is adjustable through a variable resistance, the output should be calibrated to 5V ± 0.2V. The driver modules mounted with L298N is supplied with 7.2V DC, and it can be controlled by PWM signal. Exactly, a pair of PWM signals control one motor, thus the motor can achieve two-way rotation.
1.3 Sensor: Camera and Sonar

Fig. 4 shows the camera and sonar modules, both of which need 5V DC power. Here, we use PiCam that is specifically designed for Raspberry Pi, and SRF05 sonar module is used to detect distance. Plenty of document related to these two modules can be found online.

1.4 Memory and WiFi

Micro SD card and USB WiFi adapter are adopted, which are shown in Fig. 5.

1.5 Car Model

The car model is shown in Fig. 6, which is much smaller than previous version. It consists of two motors, two wheels, an omni-wheel and a plastic holder. The motors are supplied by 5V DC and 120mA at most.
2 Assembly Guide

Assembling all parts, the mobile sensor platform is shown in Fig. 7.

2.1 Motherboard

Fig. 8 shows the connection of motherboard. The detailed connection of GPIO is shown in Fig. 9, and the denotations are listed in Table 1.

2.2 Motor Driver

Connection of the driver module is shown in Fig. 10. The pin denoted as VCC on board connects to 7.2V.

2.3 Sonar and Servo

Connection of the sonar module is shown in Fig. 11. We only need to connect 4 lines: 5V—SN+, 0V—SN−, Echo—SN_E and Trigger—SN_T. Note that the voltage of SN_
Figure 8: Connection of motherboard

Table 1: Meaning of denotations in Fig. 9

<table>
<thead>
<tr>
<th>Denotation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM&lt;sub&gt;n&lt;/sub&gt;</td>
<td>the nth PWM signal for the left motor</td>
</tr>
<tr>
<td>RM&lt;sub&gt;n&lt;/sub&gt;</td>
<td>the nth PWM signal for the right motor</td>
</tr>
<tr>
<td>SV</td>
<td>PWM signal for the servo that controls the sonar</td>
</tr>
<tr>
<td>SN</td>
<td>connect to the sonar: power (+), ground (-), trigger (T) and echo (E)</td>
</tr>
<tr>
<td>L</td>
<td>connect to LED light: positive (+) and negative (-)</td>
</tr>
</tbody>
</table>

Figure 9: Connection of GPIO (denotations are listed in Table 1)

pin on Raspberry Pi is 3.3V that lower than required 5V. But it can still work normally in practice.

The servo is shown in Fig. 12.
Figure 10: Connection of the driver module

Figure 11: Connection of the sonar module

Figure 12: Connection of the servo
3  Software

A specially designed OS—Raspbian—is installed. Raspbian is a free operating system based on Debian optimized for the Raspberry Pi hardware. In addition, OpenCV (section 4.2.1) and its related package are also installed to support image processing work.

The on-board software can be divided into five parts: camera control module, GPIO control module, WiFi control module, image processing module and motion planning module. Currently, a mobile platform is designed as a terminal that can communicate with the server, which can communicate with multiple terminals (mobile platforms). Thus, all terminals can cooperate with each other indirectly through the server. Note that the sever can be a PC or MSP (section 4.2.2).

3.1  On-board Software

All on-board software modules are listed and described in Table 2. They are all written in Python 2.7.

Table 2: On-board software modules

<table>
<thead>
<tr>
<th>Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera control module</td>
<td>Open and close the Pi camera module, control capture rate (frame/second)</td>
</tr>
<tr>
<td>GPIO control module</td>
<td>Initialize GPIO, set PWM and IO pins, modify PWM duty and IO state in order to control the motors, servo, sonar and LED</td>
</tr>
<tr>
<td>WiFi control module</td>
<td>Connect Raspbian Pi to the server via WiFi (UDP), do identification and communication</td>
</tr>
<tr>
<td>Image processing module</td>
<td>Embedded in the camera control module, process image for certain specific purpose</td>
</tr>
<tr>
<td>Motion planning module</td>
<td>Call all of above modules:</td>
</tr>
<tr>
<td></td>
<td>1. Collect feedback of all sensors and receive command from the server</td>
</tr>
<tr>
<td></td>
<td>2. Control the motors and servo according to collected information</td>
</tr>
<tr>
<td></td>
<td>3. Send current state to the server</td>
</tr>
</tbody>
</table>

Fig. 13 shows the structure of on-board software modules.

Figure 13: Structure of on-board software modules
3.2 Sever Software

The server software is written in Python 2.7, and it is only tested on the Windows 8 system. The GUI is shown in Fig. 14.

![GUI of the server software](image)

Figure 14: GUI of the server software

Currently, the software is still in the primary stage, the commands need to be sent from the server are listed in Table 3.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>auto/.</td>
<td>Default mode, change to automatic mode, the manual control panel is locked</td>
</tr>
<tr>
<td>manu/.</td>
<td>Change to manual mode, the manual control panel is unlocked</td>
</tr>
<tr>
<td>sonar/d</td>
<td>Under manual mode, control the sonar, $d$ corresponds to rotation angle (degree)</td>
</tr>
<tr>
<td>$n_L/n_R$</td>
<td>Under manual mode, control the motors, $n_L$ and $n_R$ corresponds to rotation speed of the left and right motor respectively</td>
</tr>
</tbody>
</table>
4 Appendix

4.1 Videos of Motion Test

Video1: Fixed motion test
Video2: Motion planning test using sonar

More related works on MSP can be found from AICIP Wiki

4.2 Installation Recommendations

Installation instructions of OS, OpenCV, on-board and server software can be found from the Dropbox, where also includes all Python code.

Hopefully, one can build a MSP by following these instructions even though s/he has no related experience. In order to well organize the whole installation procedure, we strongly suggest the following installation order:

1. Mount the PiCam and USB WiFi adapter to Raspberry Pi
2. Install OS to Raspberry Pi (need a HDMI monitor and a USB keyboard)
3. Access Raspberry Pi to Internet
4. Install OpenCV to Raspberry Pi
5. Install SSH to PC (make it easy to transform files between Raspberry Pi and PC)
6. Copy on-board software to Raspberry Pi, and copy server software to PC
7. Build the mobile platform
8. Connect Raspberry Pi and PC to the same LAN
9. Test the hardware and softwares

4.2.1 OpenCV

OpenCV (Open Source Computer Vision) is a library of programming functions mainly aimed at real-time computer vision. It is written in C++ and its primary interface is in C++, but there are now full interfaces in Python. After fully compiling, OpenCV (v2.4.9) will take about 500MB static storage space, which is not a problem for current storage devices. The SD card we used on MSP is 32GB.

Usually, only a little part of those library functions are used in a specific application. This makes OpenCV seems cumbersome, but this drawback can be overwhelmed by the optimized code for basic vision infrastructure and state-of-art algorithms. Canny edge detector, for example, one not expert in programming and computer vision can hardly beats OpenCV in running speed and performance. All algorithms in OpenCV is optimized and accelerated, they make the development fast without reinventing the wheel.

Above all, calling OpenCV functions can speed up your code, and it can automatically menage the memory. Here, we may ignore the static storage space that OpenCV takes since even a 8GB hard drive may be enough for installing an OS and OpenCV.
Raspberry Pi has a 512MB RAM (memory), and it can be mounted with a SD card with relatively large storage space. So, OpenCV is not a heavy burden for Raspberry Pi. Actually, the processing ability of CPU (700MHz ARM) is the shortest batten, so code optimization is imperative, which can be easily achieved using OpenCV.

4.2.2 Server

In general, any device with Python compiler and WiFi can be a server. So, a MSP itself can be a server because it runs a kind of Linux system with Python compiler and is mounted with a USB WiFi adapter. In another word, a MSP can be considered as a mobile PC. The only difference between the server and terminals is the program they are running. If a MSP runs the server program, then it is a server. Otherwise, it is a terminal.

Extremely, we can let all MSPs run both server and terminal programs, then everyone is a server and know current state of all the others. Whatever, all MSPs must be in the same LAN, so an access point (router) is always necessary.

4.3 Part List

The part list is shown in Table 4. Total price of the MSP v5.0 is about $230.
Table 4: Part list of MSP v5.0

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Price</th>
<th>Qty</th>
<th>Ship</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAR MODEL</td>
<td>motors, wheels, plastic holder</td>
<td>2WD motor, 1 omni-wheel, 2 wheel and holder</td>
<td>14.88</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>MOTHERBOARD</td>
<td>Raspberry Pi</td>
<td>Raspberry Pi 83-14421 Computer - Model B (512M RAM)</td>
<td>38.49</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>SENSOR</td>
<td>camera</td>
<td>Logitech QuickCam Pro 5000 WebCam</td>
<td>50</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>sonar</td>
<td>Devantech SRF05 Ultrasonic Range Finder</td>
<td>27.95</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>DRIVER</td>
<td>motor driver</td>
<td>L298N Motor Driver Controller Board Module</td>
<td>3.2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>servo</td>
<td>Hitec HS-311 Servo Standard U</td>
<td>7.99</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>COMMUNICATION</td>
<td>WiFi adapter</td>
<td>Edimax 7811,usb adaptive,Supports 150 Mbps 802.11n</td>
<td>9.99</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>POWER</td>
<td>battery</td>
<td>1.2v 12AA, 3000mAh rechargable battery</td>
<td>6.45</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>battery charger</td>
<td>Charger Smart Battery Charger for Rechargeable Batteries</td>
<td>9.99</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>battery holder</td>
<td>6 AA Battery Connector with Snap Connector</td>
<td>2.49</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>PP3 connector</td>
<td>battery snap on clip connector T Type Holder Lead Wire</td>
<td>1.45</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>voltage converter</td>
<td>DC-DC Adjustable Step-up Power supply voltage Converter</td>
<td>1.95</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>MEMORY</td>
<td>SD card</td>
<td>SD card with adapter SanDisk -Ultra 32GB</td>
<td>19.49</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>OTHERS</td>
<td>wire</td>
<td>3 x 40P 20cm Dupont Wire Jumper Cable</td>
<td>7.64</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>PCB board</td>
<td>DIY Prototype Paper PCB, 10Pcs 5 x 7 cm</td>
<td>1.7</td>
<td>1</td>
<td>1.98</td>
</tr>
<tr>
<td></td>
<td>GPIO extension board</td>
<td>Raspberry Pi GPIO adapter board module for Raspberry Pi</td>
<td>4.18</td>
<td>1</td>
<td>1.98</td>
</tr>
<tr>
<td>LED</td>
<td>green, red,yellow 5mm led light</td>
<td></td>
<td>2.27</td>
<td>3</td>
<td>1.98</td>
</tr>
<tr>
<td></td>
<td>screw &amp; washer</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Hex Nut &amp; Washer</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>breadboard</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

$ 227.59$