Measuring System for Outline Dimension of Vehicle Based on ARM11

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Abstract
On-vehicle Linux, a kind of embedded system, was transplanted into S3C6410 processor, from which a measuring system for vehicle’s outline dimension was designed to meet the requirement of parking fees system and over-limit measuring system on highway. Position sensor was used in the system to detect vehicle’s coming, from which USB camera began to work to get vehicle’s picture. And then, the picture was transmitted to PC from TCP interface and saved into SD card. On PC, measuring software was designed with VC, in which the vehicle’s outline dimension was calculated by advanced algorithm. All the procession will automatically finished and the working efficiency is developed. Now, the measuring system has been applied in parking fees system and over-limit measuring system.

Key words: Linux; Embedded System; S3C6410; Vehicle Image; SOCKET; TCP/IP

1. INTRODUCTION
With the development of society, more and more intelligence in parking fees system and over-limit measuring system are needed. In parking lot, parking vehicle at different space according to the real dimension can save parking resource. On highway, driving over-height and over-length vehicle can bring a lot of potential safety hazard. So, how to measure vehicle’s outline dimension become more and more important. In traditional way, vehicle’s outline dimension is measured by manual, whose efficiency is low and cost is high (Nakayama, Shiohara, Sasaki, et al., 2014).

Intelligent measurement of vehicle size is a key step in the field of intelligent transportation (Taniguchi and Shimamoto, 2004), but the existing algorithm for vehicle size measurement is not applied to the actual project due to the impact of real-time, accuracy and other elements. Develop and research a vehicle size measurement algorithm by machine vision technology, and work hard to meet the needs of actual project.

In this paper, a kind of image acquisition and measuring system was designed based on S3C6410 processor and embedded operating system Linux, in which USB camera can take photo when the position sensor detects vehicle’s arrival. The Linux operating system has many advantages including high communication speed, high reliability, high stability, and so on. The image is transmitted to computer through TCP/IP network, which is processed and calculated in further by software designed by VC, VB or other program tools. From the above operation, the vehicle’s dimension can be measured automatically, from which the working efficiency in parking lot and highway system is developed.

2. WORKING PRINCIPLE
When the position sensor, set in measuring site, detects vehicle’s arrival, the USB camera is ordered to work to get the image, which will be transmitted to computer through TCP communication interface to process in detail (Felicetti Luca, Femminella Mauro, Realigianluca, et al., 2014).

The position sensor outputs low voltage level when there is no vehicle’s arrival and it will output high voltage level when vehicle arrives. When S3C6410 processor measures such low-high level change, it will control the USB camera to work to get the vehicle’s image. The image will be saved in SD card immediately, from which the image can be checked easily. The measuring system is connected to computer by TCP/IP network line, from which the image can be obtained and then transmitted to computer by SOCKET program. When computer get the image, it will send ACK command to measuring system to be ready to take the next image. The software working in computer will calculate the vehicle’s outline dimension according to the image. The working process is shown by Figure 1.
3. HARDWARE DESIGN

The measuring system is divided into CPU module, getting image module, detecting digital signal module, saving image module, communication module, which is shown as Fig.2.

3.1. CPU Module
As the key module of this system, S3C6410, a kind of ARM11, was used to manage the whole working process, in which the operating system Linux could work well. The ARM11, based on ARM1176JZF-S, has 256M Mobile DDR RAM, 1G extended NAND Flash and TCPIP interface, which can meet the system’s requirement.

3.2. Getting Image Module
This module was composed of USB camera and USB extended circuit. ZC301 USB camera was employed to take vehicle’s image, whose max resolution is 800*600-pixel. There are a lot of advantages, such as low cost, easy operation, and so on. AU9254, a kind of multi-USB chip, was used in the system to extend four USB interfaces to accomplish the whole operation.

3.3. Detecting Digital Signal Module
YJ0411, a kind of position sensor, was used to detect whether vehicle came or not. When vehicle is coming, USB camera will begin to take the image (Fuchiwaki Ohmi and Aoyama Hisayuki, 2011).

The position sensor, set in earth’s surface, was connected to IO port of CPU. When there was no vehicle, it gave low voltage level. When vehicle came, it gave high voltage level. Therefore, CPU could know whether vehicle came or not based on voltage level change. When the level changed from low voltage level to high voltage level, USB camera was controlled to take image.

3.4. Communication Module
TCPIP network of communication has many advantages, such as high speed, long distance, good anti-jamming ability and so on. So, such communication type can meet our requirement. TCPIP interface of S3C6410 was used to exchange data between computer and the measuring system.

Communication module was composed of Ethernet controller DM9000A and crystal HR91105A. SD0-15 of DM9000A was connected to IO ports of CPU. X1 and X2 of DM9000A was connected to quartz crystal of 25M, which was the system’s clock. DM9000_TD+, DM9000_TD-, DM9000_RX+ and DM9000_RX- were the connect pins between DM9000A and HR91105A. LEDG and LEDY was indicator lamp of connection and communication respectively. The communication module was shown as the Figure 3.
3.5. Saving Image Module

SD card was inserted into slot of SD card connected to CPU, from which the vehicle image of JPG type could saved safely. The image can be read and written easily.

TCP/IP network of communication has many advantages, such as high speed, long distance, good anti-jamming ability and so on. So, such communication type can meet our requirement. TCP/IP interface of S3C6410 was used to exchange data between computer and the measuring system.

4. SOFTWARE DESIGN

Linux operating system was used to develop software part, having a lot of advantages, such as multi-plat, multi-tasking, open source, network communication, and so on (SimpsonAndrew, 2002). In the design, the above characteristics worked well.

4.1. Construct Development Environment of Linux

Constructing the development environment includes making Boot-loader, burning Linux kernel, constructing file system and developing application program. U-boot was selected to make Boot-loader. Linux kernel source code and file-system were constructed, modified, cut out and added according to requirement of system. After the Linux operating system was constructed, the application program could be downloaded into it to finish the software design.

4.2. Design of Device Drivers

The device drivers of Linux include character device, block device and network device. The former one was designed according to the requirement, taking IO character device driver for example. The latter two were added into kernel already, which were embedded and called by application program.

4.3. Design of Application Program

When position sensor detected vehicle’s arrival, CPU controlled USB camera to take image, which was saved into SD card and transmitted to computer through TCP/IP network interface. After computer received the image, it sent ACK back to system to finish transmitting process. And then, the image was analyzed and calculated by software of computer, from which the outline dimension of vehicle was got. The software design is shown by Fig. 5.
V4L2 standard was employed to take image of YUYV-format through USB camera. Such kind of image, requiring large storage space, can’t be displayed by computer easily. Therefore, compressed algorithm was used to convert the YUYV-format into JPG-format, whose storage space is one-fifth as the size of original one. So the storage space of SD card could be saved and the transmitting speed could be developed. The taking image process of USB camera is shown as the Fig. 6.

Vehicle’s image was transmitted into computer through TCPIP network in socket program type, in which computer was server and the measuring system was client. Server listened the connection from client and received image, between which three times of shake-hand communication were accomplished.
5. MEASURE VEHICLE’S OUTLINE DIMENSION

Background difference method was used to calculate vehicle’s outline dimension in computer software (Wang, 2011). First, foreground inclusive of vehicle and background exclusive of vehicle were given respectively as the Fig. 7.

![Figure 7. Original image](image)

During the process of segmenting vehicle’s image, low-threshold method and high-threshold method were applied, having different effect. High-threshold method can filter tiny noise, yet it can cut off detailed information of image. On the other hand, low-threshold method can hold the detailed information, yet it is easy to be interfered by tiny noise. Therefore, difference and fusion of double-channel with both low-threshold method and high-threshold were used to get fairly complete difference image. And then, the minimum external rectangle method was used to calculate vehicle’s outline dimension. The flowchart of algorithm is shown as the Fig. 8.

![Figure 8. Flowchart of algorithm](image)

5.1. Detect Vehicle’s Outline

Segmentation of method high-threshold method and low-threshold were used to detect vehicle’s outline (Wang P, Li X, Lv Z, 2015). The former one could filter tiny noise and reserve vehicle’s main frame and the latter one could reserve vehicle’s detailed information. \( T_{HL} \) and \( T_{LG} \) is the set high-threshold and low-threshold respectively. Figure 9(a) and Figure 9(b) is the segmentation result of high-threshold method based on low-resolution difference image and low-threshold method based on high-resolution difference image respectively. For Figure 9(a), 2*65-rectangle was used to expand downward to get filter model as Figure 9(c), from which the vehicle’s range of coordinate was decided. Figure 9(b) and Figure 9(c) were calculated by fusion to get intersection to cut most of noise of environment, whose result is shown as Figure 9(d). For Figure 9(d), tiny circle-structure element was expanded and its connected area was filled, from which the ideal outline of vehicle, calculated by software on computer as Figure 9(e), appeared. The above process of detecting vehicle’s outline is obviously shown as Figure 9.

5.2. Get High-threshold Value and Low-threshold Value Automatically

Because different environments have different light conditions, threshold value should be set automatically to make the system run effectively. In order to get threshold value automatically, the image should be analyzed
in three channels of R, G, and B. Each channel has two-pair threshold values. There were high-threshold values \((T_H G, T_L G)\) and low-threshold values \((T_H G, T_L G)\), taking channel G for example. Figure 10 is difference histogram \(H_{L,G}\) of channel G, in which:

\[
\Delta G(x, y) = G_i(x, y) - G_B(x, y) \quad (1)
\]

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\]

\[
H_{L,G} = \frac{1}{5} \sum_{k=-2}^{2} H_{L,G}[j + k], \quad j=-254 \ldots 254 \quad (2)
\]

The inflection point was calculated as Formula 3:

\[
H_{L,G}[k-1] \geq H_{L,G}[k] \leq H_{L,G}[k+1], \quad F \delta(3)
\]

The threshold value of channel R and B can be got with the same method.

**Figure 9.** Process of detecting vehicle’s outline

Abundant experiment has proved that the histogram distribution is similar to Gaussian distribution. Therefore, inflection point near to the average is the positive and negative low-threshold value. In order to reduce influence of noise, smooth operation on the histogram was completed first.

**Figure 10.** Histogram of channel

\[ H_{L,G}[j] = \frac{1}{5} \sum_{k=-2}^{2} H_{L,G}[j + k], \quad j=-254 \ldots 254 \quad (2) \]

\[ H_{L,G}[k-1] \geq H_{L,G}[k] \leq H_{L,G}[k+1], \quad F \delta(3) \]
5.3. Measure Length and Width Dimensions of Vehicle

The ideal vehicle outline is shown in the Figure 9 (e), we can also see that vehicle body and the vehicle type parts have multiple connected domains. Therefore, the minimum external rectangle method can’t be used to realize the vehicle’s enclosure. In this paper, we try to connect all the spatial geometric objects into one connected domain, and then obtain the minimum enclosing rectangle. The specific steps of the algorithm are given as the following:

1) Calibrate all the connected domain of the ideal vehicle outline image and calculate each barycenter of the domain, thus, obtain the coordinate set of barycenter \( P\{ (x_1, y_1), (x_2, y_2), ..., (x_n, y_n) \} \). Next step is to take each of barycentre as vertex and connect \( P_1, P_2, ..., P_n, P_1 \) in sequence. Eventually, we will get the connected polygon shape.

2) Fill in the polygon with pixels of 255-gray value, and then implement the combination of all connected domains. Processing the image 9(e), we will get the new connected domain, which is shown in the Fig. 11.

![Figure 11. New connected domain](image)

3) Calculate the minimum external rectangle of the new connected region and then get the length and width of the rectangle which are the length and height of the vehicle. In this paper, we adopt the principal axis method to obtain the minimum bounding rectangle of the new connected region [6]. The realization process is given as the following:

   a) From the start coordinates \((x_{i1}, y_{i1})\) and the end coordinates \((x_{i2}, y_{i2})\) of each column by scanning the image, we can get barycentre coordinates of each column:

   \[
   x_i = \frac{x_{i1} + x_{i2}}{2}, \quad y_i = \frac{y_{i1} + y_{i2}}{2} \tag{4}
   \]

   b) Implement the fitting of the barycentre coordinates of each column through the least square method to get the linear equation of initial position of horizontal spindle. Linear equation is expressed as the Formula 5.

   \[
   y = k_i x + b_i \tag{5}
   \]

   c) In the same way, we can get the linear equation of initial position of vertical spindle, which can be expressed as the Formula 6.

   \[
   x = k_y y + b \tag{6}
   \]

   d) Moving the horizontal spindle, along the direction of the vertical spindle, finds the top and bottom tangent lines of horizontal axis and the new connected domain. At the same time, we defined these two tangents as the two sides of the outer rectangle. Similarly, we can get another two sides, left and right of the outer rectangle. The test result is shown in the Figure 12.

![Figure 12. Test result of minimum enclosing rectangle](image)

e) In the previous step, we calculate the minimum enclosing rectangle. The next step is to calculate the multiplication of the rectangular length/width and the calibrated pixel size ratio.
In order to calculate and measure the practicality and validity of the algorithm, we have tested different vehicles, the test results of which are shown in the Fig. 13, and Table 1. Table 1 gives the data of different vehicles’ real length and measured length.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Real length (mm)</th>
<th>Measured length (mm)</th>
<th>Length error (mm)</th>
<th>Real height (mm)</th>
<th>Measured height (mm)</th>
<th>Height error (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAVAL (H6)</td>
<td>4649</td>
<td>4773</td>
<td>124</td>
<td>1700</td>
<td>1907</td>
<td>207</td>
</tr>
<tr>
<td>CHANGAN (mini-vans)</td>
<td>3690</td>
<td>3735</td>
<td>45</td>
<td>1870</td>
<td>1845</td>
<td>25</td>
</tr>
<tr>
<td>CITROEN (C4L)</td>
<td>4620</td>
<td>4692</td>
<td>74</td>
<td>1498</td>
<td>1421</td>
<td>77</td>
</tr>
</tbody>
</table>

Since we use the area-array cameras, there is a slight distortion of the image. Seen from the table, we find that test data is often slightly larger than the actual length and the error range is in 150 mm, so vehicle size detection system meets the needs of project.

Also, the data of Table 1 show that the measurement height error of H6 is larger than others. Later Analysis indicates that black color vehicles have approximate gray value with the vehicle shadow. And in the process of segmentation it will take parts of vehicle shadow as the vehicle part, so the measurement error will be much larger than usual conditions. The problem of shadow removal of black color vehicle is the next research direction of the subject. At present, the project used the fluorescent lamp light to reduce the interference of vehicle shadow. And one day in the future, we hope to solve the shadow problem and raise the measurement accuracy of vehicle size.

6. CONCLUSIONS

In this paper, from transplanting Linux to S3C6410 and programming char device driver, a set of embedded measuring system on vehicle’s dimension has been developed, which has been used in the real project. Position sensor, USB camera and other sensors are applied in the system. When position sensor detects vehicle’s arrival, USB camera begins to take its image, which is transmitted to computer through TCPIP network. The software in computer is responsible for calculating vehicle’s dimension, in which high-threshold value method and low-threshold value work well, from which we can extract vehicle’s outline. From marking all the connectivity area, their barycentres can be found. A polygon has been drawn clearly from connecting all the barycentres in sequence, which is filled with black-color to complete inter-connection between all the connectivity areas. Minimum external rectangle of the new connected region has been used to calculate the length and height of the vehicle. Experiment results show that the measured error is less than 150mm, meeting the system’s requirement, which has been used in parking fees system and over-limit measuring system on highway.

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