

The Application of Function Approximation Algorithm in Magnetic Parking Detection

Liye Zhao and Yaojie Sun

*School of Electronics and Information Engineering, Hebei University of Technology,
5340 Xiping Road, Beichen District, Tianjin, China
zhao_1829@163.com, sunyaojie@hebut.edu.cn*

Keywords: Magnetic sensors, parking detection, CORDIC algorithm, digit-by-digit algorithm.

Abstract: In order to improve the accuracy of magnetic parking location detection, the microcontroller needs to use transcendental function to exclude the parking interference of adjacent parking process. Because the microcontroller does not contain hardware multipliers, the function approximation algorithm is introduced. In this paper, the CORDIC algorithm and digit-by-digit algorithm are used to estimate the square root and arccosine function in the process of magnetic data processing. Experiments show that after adding the algorithm, the running time of the microcontroller is much less than the sampling interval of the sensor. The experimental results prove that the algorithm can exclude the interference of adjacent parking process in real time.

1 INTRODUCTION

In recent years, the problem of urban congestion and air pollution is becoming more and more serious with the rapid increase of vehicle volume. The phenomenon of a low parking utilization rate has attracted the attention of scholars. As a part of the intelligent transportation system, the performance of the parking detection system directly affects the traffic congestion near the parking lot.

At present, there are a variety of methods to realize vehicle parking detection. In the field of image processing, the grayscale projection and first derivative method were used to find the height of a vehicle in one image and the status of multiple parking spaces in one image can be judged (Choorat et al 2017). In the ultrasonic detection field, there were two ultrasonic sensors had been installed on the same side of the entrance or the exit, when the vehicle to enter or exit the parking lot then two sensors were blocked at the same time, and the number of idle parking spaces in the parking lot can be obtained (Zadeh et al 2016). A detection system based on RSSI (Received Signal Strength Indication) had been proposed, in which the data receiving node and data sending node were installed on the top and bottom of each parking space respectively, and the occupancy of parking space

was judged according to the received signal strength (Li, 2016). In the field of magnetic detection, the detection system was made up of magnetic sensors, routing nodes and sink nodes. The magnetic sensor realized parking detection, and its result was transmitted from the routing node to the sink node (Zhu, 2016).

By analyzing the environment of indoor and outdoor parking lot, it can be found that using image processing to detect parking space is convenient and feasible. But the accuracy of detection is easily disturbed by light conditions, shielding and other environmental factors, and the cost of equipment is high. The use of ultrasonic detection is low cost, high accuracy and easy installation. However, its detection results are affected by extreme weather and will fluctuate with temperature changes. The RSSI detection system requires the data receiving node and data sending node to be arranged at the upper and lower ends of the parking space, which is not conducive to the application of the outdoor parking lot. The magnetic sensor had the characteristics of small volume, high sensitivity, strong adaptability to bad environment and so on (Qian et al 2009). It is widely used in parking lot detection system.

There were fixed threshold algorithm, adaptive threshold algorithm, state machine algorithm in magnetic parking detection system (Zhang et al

2013). The core of each detection algorithm is to analyze and extract the characteristics of the change of magnetic curve caused by the vehicle. The actual magnetic field of parking detection was the superposition of a variety of magnetic disturbance vectors (Han et al 2009; Wu et al 2014). In this paper, the parking interference of adjacent parking process is analyzed, and the threshold detection algorithm is supplemented.

2 INFORMATION PROCESSING

2.1 Information Acquisition

The information collection system of vehicle parking space is composed of the superior computer and the inferior machine. The inferior machine is responsible for collecting data and transmitting it in a wireless way to the superior computer.

The hardware block diagram of the collection system is shown in Figure 1. The white one-way arrow shows the direction of electric energy transmission. The grey bidirectional arrow indicates the direction of data transmission. STM8L151K4T6 is chosen as a microcontroller, because it has five low power modes and a short start time as well as a variety of available wake-up sources. The chip is internally integrated with 16MHz and 38KHz two kinds of clocks. Under working mode, the appropriate working clock can be selected for CPU and peripherals by programming the preset frequency register, and the power consumption is

reduced while ensuring the execution efficiency. The point-to-point communication module SKB360 is chosen as the wireless module. It is a Bluetooth transmission module for the Nordic scheme based on nRF51822 and supports Bluetooth 4.0 BLE and BR/EDR stack. The magnetic sensor uses Freescale's MAG3110. It has a two working modes of the low power consumption and three sampling axes, the data rate and sampling ratio of the control register can be configured to determine the data output rate. TPS62110 is chosen as the power supply chip, which is to realize stabilizing voltage by using a PWM wave and its switching frequency of 1MHz, compared to linear regulator chip which has higher conversion efficiency. Its input voltage range of 3.1V to 17V, and the output voltage range of 1.2V to 16V. Its maximum output current of 1.5A, and the typical quiescent current value 20uA.

2.2 Information processing

The magnetic sensor has three vertical sampling axes, and the data on each axis are the components of the magnetic disturbance vector. Compared with the case of the adjacent vehicle and passing vehicles, in which the parking detector are not covered by vehicles, the angle of the covered parking detector between the magnetic disturbance vector and the vertical sampling axis of the sensor is larger(Chen et al 2015). This feature can be used as the basis to exclude the parking interference of adjacent parking spaces. At present, the vehicle position detection algorithm is based on the threshold detection.

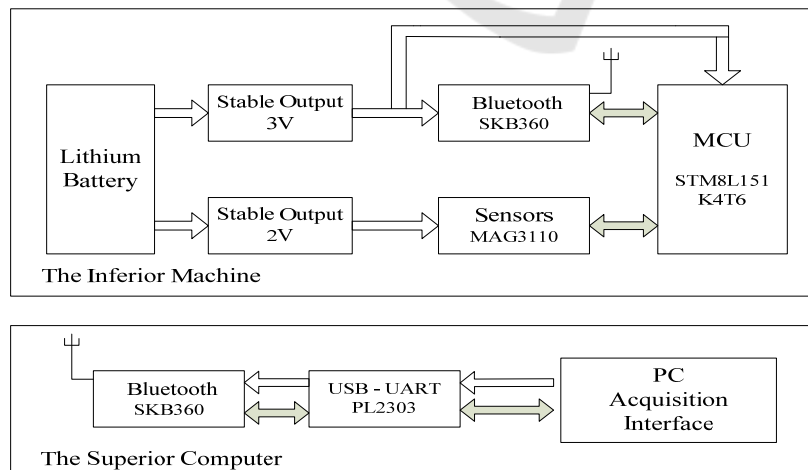


Figure 1: The hardware block diagram of acquisition system.

In order to improve the accuracy of parking detection, the angle calculation between the magnetic disturbance vector and the vertical sampling axis is added in threshold detection. However, the microcontroller does not have the hardware multiplier to calculate the floating-point number and the transcendental function, then the function approximation algorithm is introduced in this paper.

Because of the high frequency interference in the original data of the magnetic sensor, a sliding filter is needed to eliminate the high frequency interference first. The principle of sliding filtering is shown as formula (1). The $s(k)$ is the original magnetic data, the $r(k)$ is the filtered data, and the N is the length of the sliding filtering interval. The intensity of the magnetic disturbance vector and the angle between the magnetic disturbance vector and the vertical sampling axis are shown by the formula (2) and formula (3). In formula (2), r_i ($i = x, y, z$) is the component of the magnetic vector on each axis, and $|\Delta r|$ is the strength of the magnetic vector. In the formula (3), the calculation of the division and the inverse cosine function is included in the process of solving the angle.

The whole data processing is summarized as four steps: sliding filtering, square root, division and arccosine. In the next section, the function approximation algorithm of microcontrollers to process data can be introduced.

$$r(k) = \begin{cases} \frac{s(1) + s(2) + \dots + s(k)}{k}, & k < N \\ \frac{s(k-N+1) + s(k-N+2) + \dots + s(k)}{N}, & k \geq N \end{cases} \quad (1)$$

$$|\Delta r| = \sqrt{r_x^2 + r_y^2 + r_z^2} \quad (2)$$

$$\theta = \arccos\left(\frac{r_z}{|\Delta r|}\right) \quad (3)$$

3 APPROXIMATION

3.1 CORDIC Algorithm

The CORDIC (COordinate Rotation Digital Computer) algorithm, also known as Volder's algorithm, is an effective algorithm for calculating hyperbolic functions and trigonometric functions. As

the only operations it requires are addition, subtraction, bit-shift and table lookup, the algorithm has a strong portability and high execution efficiency. The estimation method of trigonometric functions is described in this paper. The process to estimate an inverse cosine function of a known value is equivalent to estimate an angle between the vector and the abscissa axis's positive direction in the unit circle, and the known value is abscissa of the vector.

The iterative schematic diagram of the CORDIC algorithm is shown in Figure 2. The v_0 is the initial vector, and the coordinate rotation formula is shown in formula (4). The v_i can be get after rotating v_{i-1} into γ_i . In order to simplify the computational complexity, γ_i need to satisfy the formula (5). In this way, the multiplication of the coordinate rotation formula can be replaced by bit-shift. The coefficients K_i in the coordinate rotation formula are shown in formula (6), γ_i and K_i can be recorded in the table.

$$v_i = \frac{1}{\sqrt{1 + \tan^2(\gamma_i)}} \begin{bmatrix} 1 & -\tan(\gamma_i) \\ \tan(\gamma_i) & 1 \end{bmatrix} v_{i-1} \quad (4)$$

$$\tan(\gamma_i) = \pm 2^{-i} \quad (5)$$

$$K_i = \frac{1}{\sqrt{1 + \tan^2(\gamma_i)}} = \frac{1}{\sqrt{1 + 2^{-2i}}} \quad (6)$$

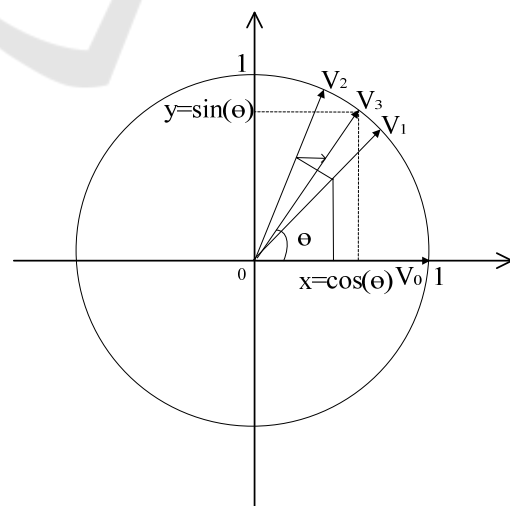


Figure 2: CORDIC algorithm iteration diagram.

3.2 Digit-by-digit Calculation

Digit-by-digit calculation is an efficient algorithm for calculating square root. Compared with other algorithms, the algorithm is applicable to any system.

Taking the decimal system as an example, the detailed calculation steps of the algorithm are summarized as follows:

(1) The square number be converted to decimal form, and separate the digits into pairs, starting from the decimal point and going both left and right. Beginning with the left-most pair of digits d_i , and calculate the current value c_i based on the remainder of the previous pair r_{i-1} , in which $c_i = r_{i-1} \times 100 + d_i$, and the initial remainder $r_0 = 0$.

(2) Finding the largest integer x_i that satisfies the inequality $x_i(20p_i + x_i) \leq c_i$, and to figure out $y_i = x_i(20p_i + x_i)$, the initial $p_1 = 0$. The x_i as a digit of the root has been placed above the two digits of the square d_i . Then update the value of p_i , $p_{i+1} = p_i \times 10 + x_i$.

(3) Updating the remainder r , $r_i = c_i - y_i$.

(4) To determine whether r_i and d_{i+1} are 0, if both of them are 0, the iteration be stopped, otherwise it returns to the first step.

4 EXPERIMENT

In this paper, the vector components of the magnetic disturbance produced during the vehicle parking

process are collected by a large number of experiments. The calculation of the sliding filter, vector strength and vector angle of the magnetic data is completed in the superior computer. By comparing the magnitude of the angle between the magnetic disturbance vector and the vertical sampling axis generated during the neighboring parking process and the parking process of covering the sensor, we can determine the valid bits of the threshold to exclude the interference brought by the neighboring parking, and improve the accuracy of threshold detection algorithm.

In the experimental process, the sampling rate of the magnetic sensor MAG3110 is set to 80Hz. The microcontroller approximate the computation result of the superior computer by digit-by-digit algorithm and CORDIC algorithm. The iteration ends when the valid digits of the microcontroller's output is equal to the valid digits of the threshold. The operation time of the algorithm in the microcontroller is recorded to ensure that the microcontroller can handle the data in real time. In the experiment, the magnetic data acquisition interface of the superior computer is shown in Figure 3. Figure 3 shows the magnetic component curve processed by sliding filter of the vehicle in and out of a parking space. The collection personnel can set the range of the filter interval through the interface, and observe the magnetic component on each axis of the sensor in real time, and intuitively analyze the magnetic curve and save the effective magnetic experimental data.



Figure3: The acquisition interface of superior computer.

The experimental process of data acquisition is shown in Figure 4. The experiment is to collect the parking process of the covering sensor and the adjacent vehicles respectively. After a lot of experiments, it is concluded that the angle between the magnetic vector and the vertical axis of the sensor should be retained at least four valid digits to identify whether it is the interference from adjacent parking process. Microcontroller after receiving the magnetic data through sliding average, square root, division and arccosine several steps to obtain the final angle, the whole process needs to consider the accuracy and running time of the calculation. There are three methods of calculation in the experiment, and the retained valid digits in different stages is different, as shown in Table 1. Microcontroller system clock select 16 MHz, and the Method1's running time is the fastest and far less than the sampling interval of 12500us (80Hz). The experimental results show that the magnetic data can be processed in real time after adding the angle calculation based on the existing threshold detection algorithm.

5 CONCLUTIONS

Since the microcontroller does not have hardware multipliers, in this paper, the digit-by-digit algorithm and the CORDIC algorithm are used to complete the estimation of the square root and the arccosine function. The retained valid digits of the angle threshold is determined by experiment. Experiments show that after adding digit-by-digit algorithm and CORDIC algorithm, the running time of microcontroller is much shorter than the sampling interval of sensors, it ensure that magnetic data are processed in real time, and the accuracy of parking detection can be improved.

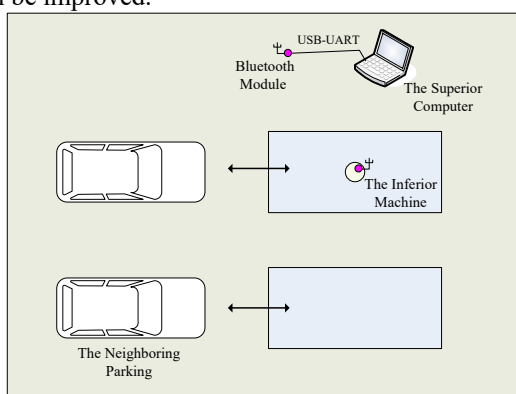


Figure4: The experimental process.

Table 1: The valid digits and time of different methods.

Stages	Method1	Method2	Method3
Sliding filtering	4	3	2
Square root	1	2	3
Division	3	3	3
Arccosine	3	3	3
Running time	41.125us	44.812us	46.437us

ACKNOWLEDGEMENTS

This work is supported partly by Tianjin science and technology special project under Grant No. 16JCTPJC50600.

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