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Design of Motorcycle Positioning System

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Abstract

The problem of motorcycle theft emerges one after another. This paper proposes the design of motorcycle positioning system. Through embedded, wireless communication, satellite positioning, attitude calculation and other technical means, the position of motorcycles can be monitored and the status of motorcycles can be controlled.

Keywords

GPS, Attitude algorithm, GSM.

1. Introduction

Nowadays, quick and easy transport has been an essential part of our daily life. As the dark side of this phenomenon, vehicle theft has become one of the costliest property crimes of modern society[1]. According to statistics, the number of stolen motorcycles is still rising every year. Even with the perfect monitoring system, it is still very difficult to recover the lost motorcycles, and most of the cases of stolen motorcycles are never recovered. Most stolen motorcycles are broken into parts and sold on the black market, which is an important reason why the final detection rate of stolen motorcycles is low. Despite the various technologies that have been introduced in recent years to deter car thefts and tracking it, it was reported that many cars were stolen yearly in the world [2]. Engineers have been performing researches aimed at providing a lasting solution to this endemic act[3].

Although, today's positioning system is more and more mature, more and more widely used. However, there are still some technical bottlenecks in the traditional vehicle positioning technology. In special circumstances, it can not effectively prevent the vehicle from being stolen, nor can it inform the user of the current state of the vehicle, resulting in the owner can not make the corresponding treatment in time.

The vehicle positioning system introduced in this paper realizes triple positioning with GPS, Beidou and base station, which ensures the positioning accuracy to a great extent. The system is equipped with six axis attitude sensor. The quaternion algorithm is used to calculate the motorcycle body posture in real time, and the current state information of motorcycle is packaged into a specific string and sent to the connected server through GSM. Real time vehicular tracking system incorporates a hardware device installed in the vehicle (In-Vehicle Unit) and a remote Tracking server [4].

2. System structure

The hardware structure of the motorcycle positioning system is shown in Fig.1. The system includes high-performance ARM microcontroler, triple positioning system (it is composed of GPS, Beidou navigation and base station), network communication, attitude acquisition and solution, and data storage. The whole system can be embedded in a vehicle or installed anywhere as a stand-alone device.

The triple positioning system and network communication system can inform users of the motorcycle's location and its current status in real time. Users can see the specific location of the motorcycle on the map by opening the mobile APP. The monitoring center can also push information to the system devices. The six-axis attitude sensor continuously collects and calculates the motorcycle

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attitude at a frequency of 10 ms. Combined with the positioning and communication system, when a traffic accident occurs, it can be reported to the monitoring center quickly and timely rescue can be obtained.

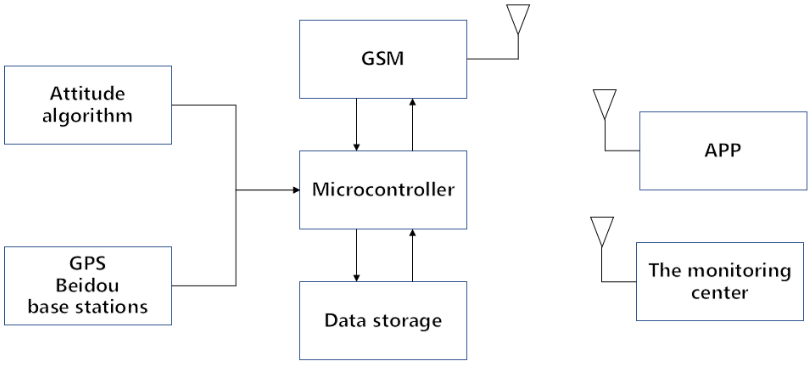

Fig.1 Structure drawing of vehicle positioning system

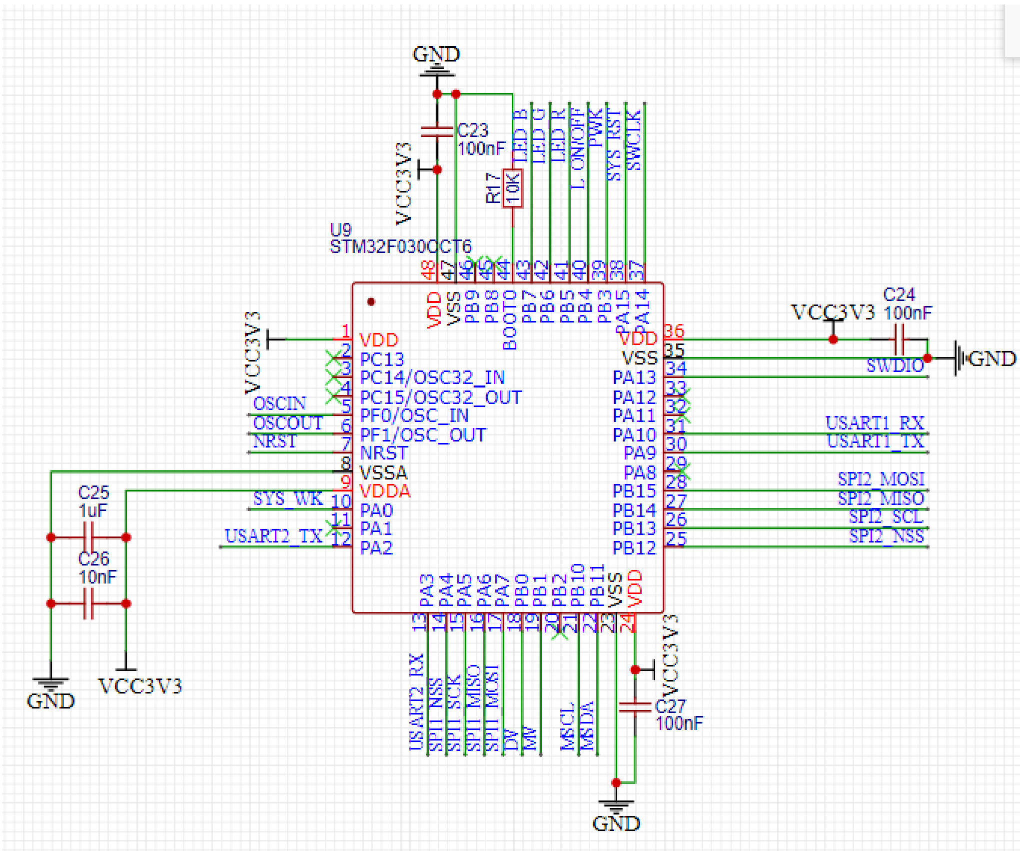

Fig.2 Pins used for microcontrollers

3. Positioning and communication

Global System for Mobile Communication (GSM) was first introduced in 1982 to develop a common European mobile communication[5]. GSM-900 and GSM-1800 are used in most regions of the world: Europe, the Middle East, Africa, Oceania, and most of Asia.

The GPRS is the abbreviation of general packet radio service and has a wide range of coverage[6]. GPRS is a wireless packet switching technology based on GSM system that provides end-to-end, wide-area wireless IP connectivity. Compared with the original GSM dial-up mode of circuit switching data transmission, GPRS is packet switching technology, with the advantages of real-time online, fast login, high-speed transmission and free switching.

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The positioning and communication set functions on one module, reducing the size of the circuit board. MC20 is a multi-functional wireless module that integrates a high-performance GNSS engine with a quad-band GSM/GPRS engine. The GSM part of MC20 supports the following working bands: GSM850, EGSM900, DCS1800 and PCS1900.The module supports GPRS multi-slot classes 1~12 and GPRS coding formats CS-1, CS-2, CS-3 and CS-4.The GNSS receiver of this module integrates BeiDou and GPS system, which can support multiple positioning and navigation systems such as GPS, BeiDou, SBAS (including WAAS, EGNOS, MSAS and GAGAN) and QZSS. It can achieve industrial-grade receiving sensitivity, high accuracy and fast initial positioning at minimum power consumption.

To provide location and time information anywhere on Earth, the Global Positioning System (GPS) is commonly used as a space-based global navigation satellite system[7].

The RMC is the sentence that is been used in this work for location. The RMC analysis is shown below:

$--RMC,161229.487,A,3723.2475,N, 12158.3416,W,0.13,309.62,120598, A*10

Table 1 shows an explanation of RMC.

Table 1. RMC explanation

$--RMC	Message ID
161229.487	UTC time
A	Data is valid
3723.2475,N	North latitude 37 degrees 23.2475 min
12158.3416,W	West longitude 121 degrees 58.3416 min
0.13	Ground speed 0.13 knots
309.62	Azimuth 309.62 degrees
120598	May 12th, 1998
*10	the checksum

4. Attitude algorithm

The six-axis attitude sensor consists of a three-axis accelerometer and a three-axis gyroscope. Accelerometer is inertial navigation and inertial guidance system is one of the basic measuring element, namely the accelerometer is a oscillation system, installed in the interior of the motion vector, the acceleration of the used to measure the carrier, and gyroscope angular velocity sensor, is different from that of the accelerometer, it is physical quantity measured deflection, tilted rotation angular velocity.

FIG. 3 shows the use of Euler angles to describe a plane coordinate rotation:

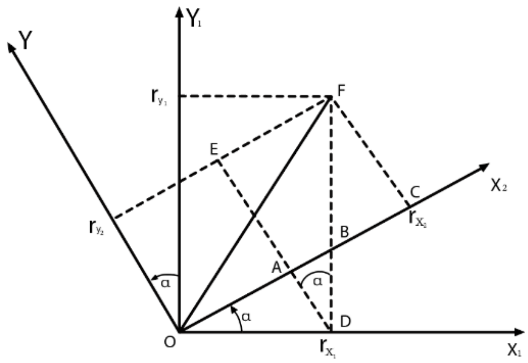

Fig. 3 Schematic Diagram of plane rotation

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Assuming that the XOY plane rotates counterclockwise around the Z-axis, it can be obtained as follows:

$$r_{x2} = OA + AB + BC = ODcos\alpha + BDsin\alpha + BFsin\alpha = r_{x1}cos\alpha + r_{y1}sin\alpha$$

$$r_{y2} = DE - AD = DFcos\alpha - ODsin\alpha = r_{y1}cos\alpha - r_{x1}sin\alpha$$

$$r_{z2} = r_{z1}$$

The transformation matrix is expressed as:

$$\begin{bmatrix} r_{x2} \\ r_{y2} \\ r_{z2} \end{bmatrix} = \begin{bmatrix} cos\alpha & sin\alpha & 0 \\ -sin\alpha & cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_{x1} \\ r_{y1} \\ r_{z1} \end{bmatrix}$$

Further arrangement:

$$r^1 = \begin{bmatrix} r_{x1} \\ r_{y1} \\ r_{z1} \end{bmatrix} \quad r^1 = \begin{bmatrix} r_{x2} \\ r_{y2} \\ r_{z2} \end{bmatrix}$$

$$C_1^2 = \begin{bmatrix} cos\alpha & sin\alpha & 0 \\ -sin\alpha & cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The above rotation is only about a single axis, and the euler angle in three-dimensional space needs to be rotated three times, thus:

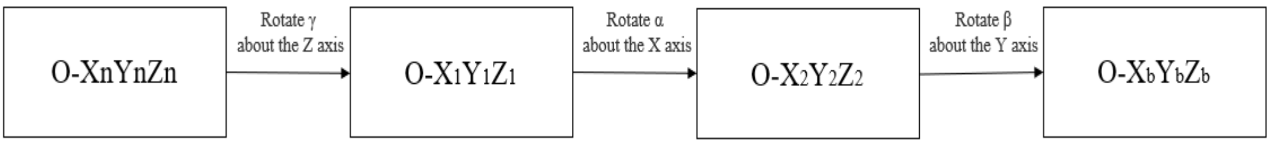

Fig.4. Space coordinate axis rotation process

$$C_n^b = C_2^b C_1^2 C_n^1 = \begin{bmatrix} cos\beta & 0 & -sin\beta \\ 0 & 1 & 0 \\ sin\beta & 0 & cos\beta \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\alpha & sin\alpha \\ 0 & -sin\alpha & cos\alpha \end{bmatrix} \begin{bmatrix} cos\gamma & -sin\gamma & 0 \\ sin\gamma & cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} cos\beta cos\gamma + sin\beta sin\gamma sin\alpha & -cos\beta sin\gamma + sin\beta cos\gamma sin\alpha & -sin\beta cos\alpha \\ sin\gamma cos\alpha & cos\gamma cos\alpha & sin\alpha \\ sin\beta cos\gamma - cos\beta sin\gamma sin\alpha & -sin\beta sin\gamma - cos\beta cos\gamma sin\alpha & cos\beta cos\alpha \end{bmatrix}$$

So that's how we describe the rotation of space coordinates in terms of Euler angles. In fact, euler Angle is rarely used to represent rotation, because euler Angle differential equation contains a large number of trigonometric operations, which brings certain difficulty to real-time solution. At the same time, when the pitch Angle reaches 90 degrees, the phenomenon of "Gimbal Lock" will occur. Therefore, euler Angle method is only applicable to the situation of little change in attitude.

Quaternion method is a practical engineering method, which can only solve linear differential equations with four unknowns. A rotation on a plane (x,y) can be expressed as a complex number, just as a three-dimensional rotation can be expressed as a unit quaternion. The direction cosine matrix represented by Euler Angle is changed to quaternion description as follows:

$$C_n^b = \begin{bmatrix} q_1^2 + q_0^2 - q_3^2 - q_2^2 & 2(q_1q_2 - q_0q_3) & 2(q_1q_3 + q_0q_2) \\ 2(q_1q_2 + q_0q_3) & q_3^2 - q_2^2 - q_1^2 + q_0^2 & 2(q_2q_3 - q_0q_1) \\ 2(q_1q_3 - q_0q_2) & 2(q_2q_3 + q_0q_1) & q_3^2 - q_2^2 - q_1^2 + q_0^2 \end{bmatrix}$$

Axyz is the gravity vector measured by the accelerometer, that is, the actual gravity vector measured, and Vxyz is the gravity vector calculated by the attitude of the gyroscope integral. They are all the gravity vectors in the coordinate reference system of the motorcycle. The error vector between them, which is the error between the attitude after gyroscope integration and the attitude measured by the

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counting, can be expressed by vector cross product.The vector cross product is proportional to the gyro integral error and can be used to correct the error of gyroscope.

Quaternion differential equation, where T is the measurement period, gx, gy, gz is the angular velocity of the gyroscope.Here, first-order Runge-Kutta is used to solve the quaternion differential equation:

$$q_0 = q_0 + \left(-q_1 g_x - q_2 g_y - q_3 g_z\right) \times \text{halfT}$$
$$q_1 = q_1 + \left(q_0 g_x + q_2 g_z - q_3 g_y\right) \times \text{halfT}$$
$$q_2 = q_2 + \left(q_0 g_y - q_1 g_z + q_3 g_x\right) \times \text{halfT}$$
$$q_3 = q_3 + \left(q_0 g_z + q_1 g_y - q_2 g_x\right) \times \text{halfT}$$

Finally, according to the conversion relationship between the cosine matrix of the quaternion direction and Euler Angle, the quaternion is converted into Euler Angle, and the following equation can be obtained:

$$roll = \text{atan2}(2 \times q_2 q_3 + 2 \times q_0 q_1, -2 \times q_1 q_1 - 2 \times q_2 q_2 + 1) \times 57.3$$
$$yaw = \text{atan2}(2 \times q_1 q_2 + 2 \times q_0 q_3, q_0 q_0 + q_1 q_1 - q_2 q_2 - q_3 q_3) \times 57.3$$
$$pitch = \text{asin}(-2 \times q_1 q_3 + 2 \times q_0 q_2) \times 57.3$$

5. Experiment

In order to test the practical application of the motorcycle positioning system, it was installed on the motorcycle and tested for normal driving. The effect is shown in Fig.5:

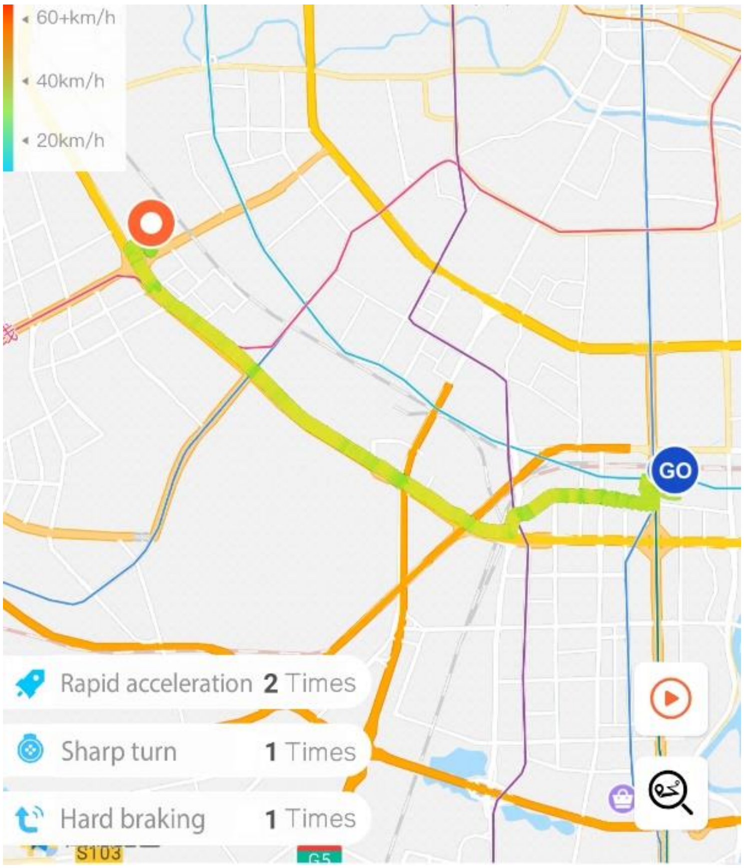

Fig.5. Test results

The results of many tests are stable, the real-time positioning system describes the motorcycle's location well, and the real-time registration point reported also meets the requirements.Some special events during the ride were also reported successfully.

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6. Conclusion

The motorcycle positioning system has been successfully designed and implemented, and the positioning system, communication system, attitude calculation, data storage and other parts of the operation are relatively stable.Each module is carefully selected to achieve the best overall performance at the lowest possible cost.The realization of the onboard positioning system helps to reduce the theft rate of small vehicles such as motorcycles and increase the probability of recovering stolen vehicles.

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