PERSONAL POSITIONING AND NAVIGATION SYSTEM BASED ON GPS

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ABSTRACT

The Global Positioning System (GPS) is a very accurate, all-weather, world wide three dimensional navigation system and it has been used in almost every field related to positioning and navigation. This paper presents a new application of GPS technology—personal positioning and navigation system. It combines VP ONCORE receiver OEM (Original Equipment Manufacture) board and an intelligent system controller, with a keyboard and a programmable LCD as its peripherals. This system can realize rich navigation functions and satisfy the need of personal use.

KEY WORDS

GPS, Navigation, Positioning, I/O Protocol, Range and Heading

1. INTRODUCTION

GPS was designed and implemented for military purpose at first, but it has been adopted for public services worldwide due to its high performance. We now make efforts in the research and development for personal application of the GPS technology.

However, GPS receiver is a positioning equipment and can only give accurate coordination information of the current position. To realize real time navigation, we design an intelligent main controller to control and communicate with the GPS receiver. It uses its internal algorithms and program to analyze and process messages sent by the receiver to guide a moving object. Concerning the feature of personalization and portability, we also consider low cost, multi-function, low power consumption and small dimension in the design.

2. WORK PRINCIPLE OF GPS RECEIVER

Motorola VP ONCORE OEM board is selected as the receive part of this navigation system. ONCORE OEM board is specifically designed for embedded applications, it is a 6-channel receiver capable of tracking six satellites simultaneously. The signals transmitted from GPS satellites are collected by a low-profile microstrip antenna and routed to the RF signal processing section. Here they are downconverted and converted to a digital sequence. This digitized IF signal is passed to the digital signal processor where it is split into six separate channels for code correlation, filtering, carrier tracking and signal detection. The microprocessor section computes the satellite data and pseudorange measurements to extract position, velocity and time and sends these results to its I/O port in a predefined protocol.

Motorola ONCORE receiver provides three different user selectable I/O protocols: Motorola Binary Format; National Marine Electronics Association (NMEA)-0183 Format; LORAN Emulation Format. Motorola binary format provides a most effective and complete I/O instruction set and its transfer rate is as fast as 9600 bit/s, so it is selected as the I/O format in our application system. All Motorola binary format messages are formatted in sentences that begin with ASCII @@ and end with ASCII <CR><LF>. The first two bytes after the @@ are the message ID bytes that identify the particular structure and format of the remaining binary data. The byte before <CR><LF> is a checksum C (the exclusive-or of all message bytes after the @@ and prior to the checksum), used to check the validation of the whole message.

In order to work correctly, the ONCORE receiver must be initialized first. This includes the initialization of I/O protocol mode, operating mode, data transfer rate and GMT time difference. The initialization commands are stored in the EPROM of the system as a constant table. They are sent to the receiver through the I/O port according to the predefined format.

- switch I/O format command

@@CimC<CR><LF>

m -- format 0 -- Motorola Binary Format
1 -- NMEA-0183 Format
2 -- LORAN Emulation Format

- select operating mode

@@CgmC<CR><LF>

m -- mode 0 -- Go to idle mode (i.e. a reduced power mode)
1 -- Go to Position Fix Mode (i.e. the normal operating mode)

- set position/status/data output rate

@@BamC<CR><LF>

m -- mode 0 -- output response message once (polled)

1..255 -- response message output at indicated rate (continuous, once per n second)

- set current GMT time correction

@@AbshmC<CR><LF>

s -- sign 00 -- positive ff -- negative

h -- hours 0 .. 23

m -- minutes 0 .. 59

3. THE NAVIGATION SYSTEM ARCHITECTURE

Based on the GPS ONCORE OEM receiver, a personal positioning and navigation system is designed. A simplified structure block diagram of the system is shown in figure 1.

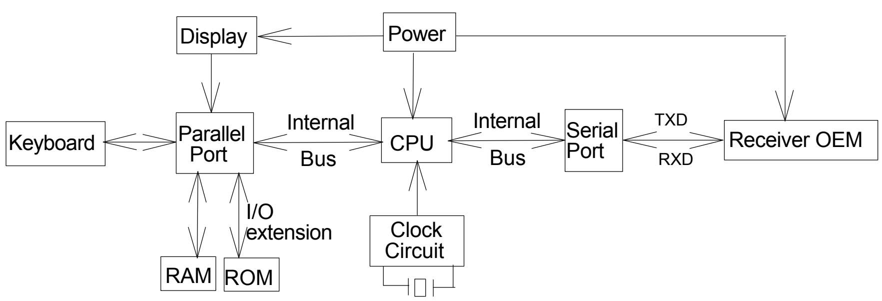

Figure1. The Navigation System Architecture

An intelligent process&control unit is designed as the main system with a microprocessor as its CPU. It combines with the ONCORE OEM board and communicates with it through its serial port. The main system sends specific I/O commands to the OEM board according to the selected I/O format to initialize the OEM receiver. It receives data and response messages by serial interruption mode or polling mode in light of actual situations. Then it uses the algorithms stored in the nonvolatile memory to obtain route, heading and other navigation information. The main system uses a keyboard and a programmable LCD as its peripherals to interface with the user. The user can input the initial position data into the receiver and select display menu with the keyboard. The system displays the desired positioning and navigation information on the LCD.

4. NAVIGATION ALGORITHM ANALYSIS

As a positioning equipment, GPS receiver can only give the absolute positioning information – latitude, longitude, height, velocity, direction, date and time of current moving object. To realize real navigation, special algorithm must be designed to calculate the range and heading of a route. Fig. 2 illustrates how to calculate the range.

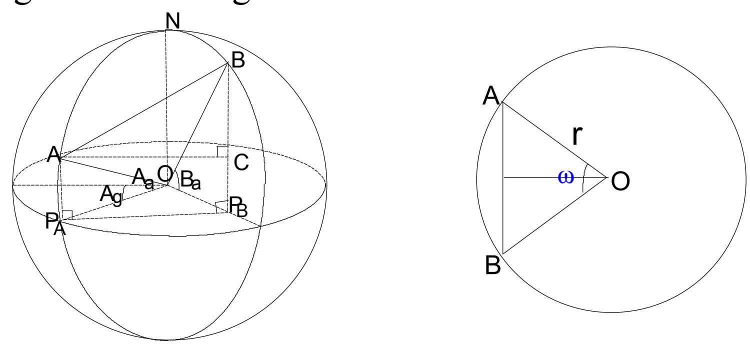

Figure 2. The diagram of route AB

Suppose A is the start point and B is the destination. The latitude and longitude of A and B have been known as (Aa,Ag),(Ba,Bg). AP_A and BP_B are two lines vertical to the equational plane.

$$\theta_1 = B_g - A_g$$

$$\begin{aligned} P_AP_B^2 &= OP_A^2 + OP_B^2 - 2 \times OP_A \times OP_B \times \cos\theta_1 \\ &= (r\cos A_a)^2 + (r\cos B_a)^2 - 2r^2\cos A_a \cos B_a \cos\theta_1 \end{aligned}$$

$$\begin{aligned} AB^2 &= P_AP_B^2 + BC^2 \\ &= (r\cos A_a)^2 + (r\cos B_a)^2 - 2r^2\cos A_a \cos B_a \cos\theta_1 + (r\sin B_a - r\sin A_a)^2 \end{aligned} \qquad (1\text{-}1)$$

Where r = the radius of the earth

θ_1 = the included angle of OP_A and OP_B

The actual route is the arc from A to B.

$$\omega = 2\arcsin(AB/2r)$$

$$\overset{\frown}{AB} = r \times \omega = 2r\arcsin(AB/2r) \qquad (1\text{-}2)$$

The next step is to get the heading from A to B. For better understanding, the left part of Fig. 3 should be compared with the right part, which is the tangent plane diagram of the heading.

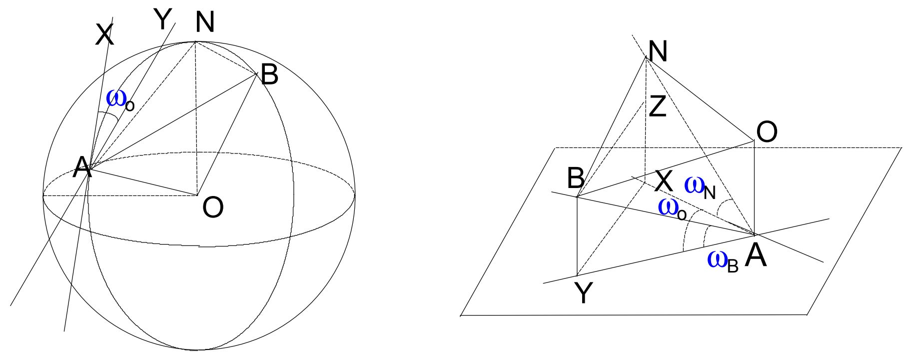

Figure 3. The spherical and plane diagram of the heading

Line AX is the tangent line of the circle determined by A, N and O. Line AY is the tangent line of the circle determined by B, A and O.

So the included angle of AX and AY, that is ω_0, is the current heading from A to B.

$$w_N = 90^0 - \angle NAO = 90^0 - \frac{180^0 - \angle NOA}{2} = 45^0 - \frac{A_a}{2}$$

$$w_B = 90^0 - \angle BAO = 90^0 - \frac{180^0 - \angle AOB}{2} = \frac{w}{2}$$

Where ω_N = the included angle of NA and AX

ω_B = the included angle of BA and AY

Suppose N is the North Pole Point, the length of NA, AB and NB are known using the above algorithm.

$$\cos w_0 = \frac{AX^2 + AY^2 - XY^2}{2 \times AX \times AY}$$

$$= \frac{NA^2 \cos^2(45^0 - A_a/2) + AB^2 \cos^2(w/2) - [BN^2 - (AN \sin w_N - AB \sin w_B)^2]}{2 \times NA \times AB \cos(45^0 - A_a/2)\cos(w/2)} \qquad (1\text{-}3)$$

Generally the truth north is defined as 0^o in navigation. The course range is from 0^o to 359^o if rotate clockwise. The ω_0 in the above equation is an acute angle. The actual heading should be selected from ω_0, $180^o \pm \omega_0$ or $360^o \pm \omega_0$ according to the relative position of B to A. As the object moves from A to B, the range and heading change from time to time. Since the current position of the object can be obtained from the receiver, using the above algorithm, we can get the range and heading of any point in the route.

5. NAVIGATION FUNCTIONS REALIZATION

Based on the design of hardware and the above algorithms to get the heading and range, rich navigation functions are realized in this personal navigation system by programming elaborately.

(1) Display satellite status
This function gives a summary of satellite visibility status by showing the number of visible satellites and tracked satellites, DOP (Dilution of Precision), the ID, elevation, Azimuth and signal strength information for each visible satellite.

(2) Display current position
It presents the latitude, longitude and height of current position according to the selected World Geodetic System. The height can have either of two references: GPS Ellipsoid Height or MSL.

(3) Define route point
Route points are some important points used to mark a route. Defined route points are useful in navigation. For example, we can make up a route with a series of route points, go to some route point directly and complete the whole travel plan.
There are two ways to define a route point. The first is to define its name, longitude, latitude and setting time. The second is giving its relative distance and direction from current position. The system can convert between these two definition mode using the algorithm described in part 4.

(4) Navigate to a route point
GOTO function can show user a through route from his current position to a selected route point by displaying the range, heading and estimated navigation time.

(5) Route and travel plan
The system provides automatic navigation function. When user passes a route point, it selects the next route point as the destination automatically. If the travel plan changes for a short time, the user can also select his required route point as the destination. In addition, the route can be executed directly or reversely (to realize return navigation).

(6) Automatic save
After getting coordinates of the current position, this function saves it as a route point automatically. By this way the user can make up a route he has traveled. Suppose you go fishing on the sea and want to return before dark. Using this function to record the route to the fishing ground. When you come back, the system can execute the route reversibly to lead you back safely along the same route.

(7) Date and time
The function gives the current date in day, month & year and current time in hour, minute & second. The time can be GMT or local time.

(8) Timing
GPS receiver measures precious time and provides a 1PPS (pulse per second) output signal. Using this function we provide timing and alarm clock services.

(9) Set alarm
An alarm circle can be defined around a route point such as shoals, submerged rocks or other dangerous locations (by setting an alarm radius). When you enter the alarm circle, the system will warn you by tone and message. This guarantees safe traveling.

(10) Unit conversion
In navigation, commonly used units include metric system, British system and nautical system. To meet the need of various users, we define conversion between these systems. You can select your favorite unit combination to present the position and velocity.

6. CONCLUSION

This paper described the theory and method used in developing the personal navigation system. Its model has been completed in the lab. All this shows the system is practical and very useful. Next we will introduce GIS (Geography Information System) into it to make it more visual and more convenient to use. We forecast a wide market for it.

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