International Journal of Multimedia and Ubiquitous Engineering
Vol.10, No.4 (2015), pp.131-140
http://dx.doi.org/10.14257/ijmue.2015.10.4.14

An Efficient Portable Navigation Device with GPS and BDS Positioning Capabilities

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Abstract

A portable navigation device is a portable electronic product, which has an important function in terms of positioning capability. In order to improve the positioning performance, an efficient portable navigation device is proposed in this paper. The proposed portable navigation device integrates the GPS receiver module and BDS receiver module, and then owns the GPS and BDS positioning capabilities simultaneously. In order to improve the performance of displaying the electronic maps, an efficient strategy based on the levels of detail is designed to display the electronic maps. A series of experiments are conducted and the experimental results show that the proposed portable navigation device can receive and analyze both the BDS and GPS data correctly, as well as the proposed strategy for displaying the electronic maps is better than the traditional strategy that displays all the map files at the same time.

Keywords: *Portable navigation device, GPS, BDS, Levels of detail*

1. Introduction

Because of the positioning and navigation capabilities of the portable navigation devices, the portable navigation devices are widely used in many fields, such as ship navigation, vehicle navigation, and so on [1]. The market demand for portable navigation devices soars and the market size for portable navigation devices will be projected to increase by 99.3% per year in the next five years [2]. Obviously, the market potential for portable navigation devices is very huge and the portable navigation devices show a wide market prospect [3].

Currently, the United States' Global Positioning System (GPS), which consists of up to 32 satellites, is the most used satellite navigation system in the world [4]. Most of the portable navigation devices are equipped with the GPS positioning module and interacts with the GPS to implement the positioning and navigation capabilities. In order to break the monopoly of GPS in our country, the BeiDou Navigation Satellite System (BDS) is built by China [5]. The emerging BDS makes the satellite navigation industry in our country develop quickly and promotes the portable navigation devices to be widely used in national security and daily life. The GPS is a global positioning system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The GPS shows high-accuracy positioning and navigation functions. Moreover, the GPS has been built for a long time and its critical technologies are mature. However, the portable navigation devices with only GPS receiver module cannot receive the GPS data from the GPS and then cannot complete the positioning and navigation functions when they are located in the occlusion area hidden by the high buildings and woods. The BDS is a local positioning system that mainly offers navigation services for customers in China and neighboring regions. Although its positioning accuracy is lower than that of GPS, the

ISSN: 1975-0080 IJMUE

portable navigation devices with only BDS receiver module can receive the BDS data from the BDS and then can complete the positioning and navigation functions when they are located in the occlusion area hidden by the high buildings and woods. Moreover, it also supports the short message service function and users can interact with each other by using the portable navigation devices based on the BDS receiver module. In order to inherit the advantages of GPS and BDS, we design a portable navigation device that integrates the GPS receiver module and BDS receiver module.

The remainder of this paper is organized as follows. Section 2 presents the detailed system design of the proposed portable navigation device. The dual-mode data processing function of the proposed portable navigation device is showed in Section 3. Section 4 describes the map displaying strategy. The experimental results are presented in the Section 5 and Section 6 concludes the work in this paper.

2. System Design

2.1. Functional Requirements

A portable navigation device is a smart embedded device used to assist the users when they are moving. It mainly provides the users with the positioning and navigation functions by using the data received by the GPS receiver module and BDS receiver module. Based on the application requirements, the portable navigation device should complete the following tasks.

(1) Building an embedded system. According to the requirements for miniaturization and low cost, we choose a suitable hardware platform and build an embedded operating system to build the essential environment for the embedded navigation application.

(2) Dual-mode data processing. The portable navigation device receives the data from the GPS and BDS system and analyzes the data by extracting the location and time information from the data.

(3) Displaying the electronic maps. The navigation application running on the portable navigation device reads the electronic map files from the non-volatile memory card and draws various geographical objects in the electronic map files onto the display screen.

(4) Matching the data in the map. Map-matching is a kind of technology that uses related software to determine the location of the portable navigation device in the map. According to the positioning information, it uses the matching algorithms to obtain the location of the portable navigation device in the map and displays itself in that location.

(5) Route planning and navigation. Users choose the place of departure and destination. The navigation software running on the portable navigation device computes and finds out the optimal route in order to provide the navigation information in real time.

(6) Communications between two portable navigation devices. Using the short message service provide by the BDS, the portable navigation devices can communicate with others.

2.2. System Architecture

A portable navigation device is a typical embedded system. It consists of two components, which are the hardware component and the software component. The hardware component contains an ARM11 development board [6], GPS receiver module, BDS receiver module, display screen, power supply equipment, and so on. The hardware component is responsible for supporting the communication interface and display interface to the software component and completing the collection of the positioning data from the GPS and BDS systems. The software component contains two parts, which are the embedded Linux operating system and the embedded navigation software. The embedded Linux operating system is responsible for the initialization of the underlying hardware and managing the overall scheduling. The embedded navigation software is developed by using the C/C++ programming language, the QT/Embedded graphical interface [7], and the related application programming interface. Figure 1 illustrates the whole system architecture of the proposed portable navigation device.

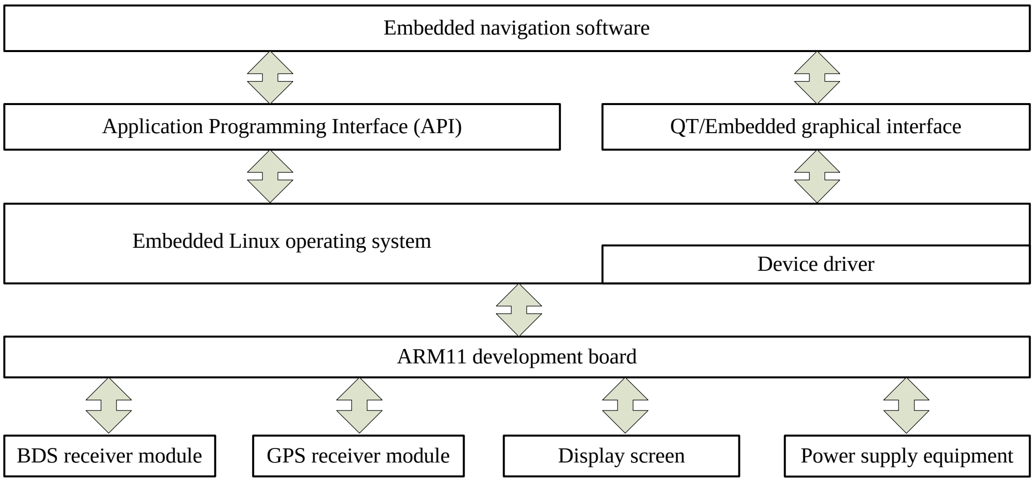

Figure 1. The System Architecture of the Proposed Portable Navigation Device

2.3. Hardware Design

In order to satisfy the functional requirements of the proposed portable navigation device, a UT6410BV04 develop board is used. The develop board is equipped with a S3C6410XH-66 chip as its core microprocessor. It is also equipped with a 128MB DDR SDRAM, a 256MB NAND flash, a 7-inch display screen, and several physical interfaces.

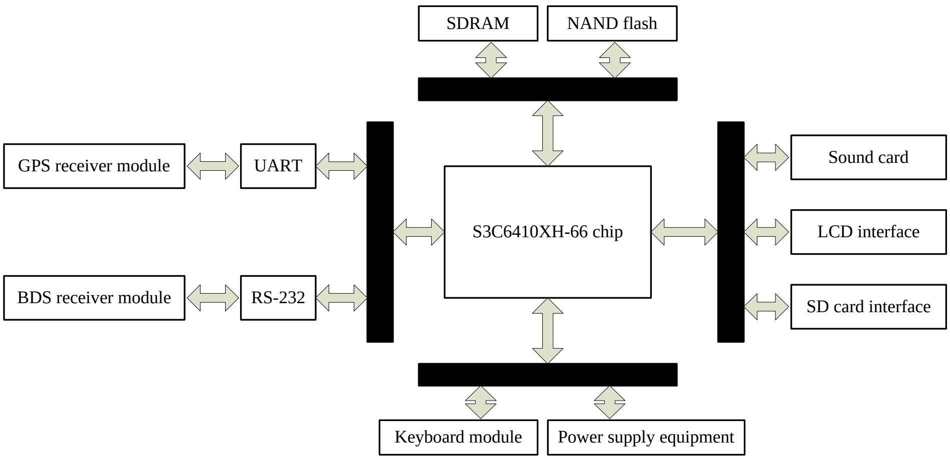

Figure 2. The Hardware Architecture of the Proposed Portable Navigation Device

As illustrated in Figure 2, the GPS receiver module is connected with the develop board through the UART serial port and BDS receiver module is connected with the develop board through the RS-232 serial port.

2.4. Software Design

The software component contains the embedded Linux operating system and the embedded navigation software.

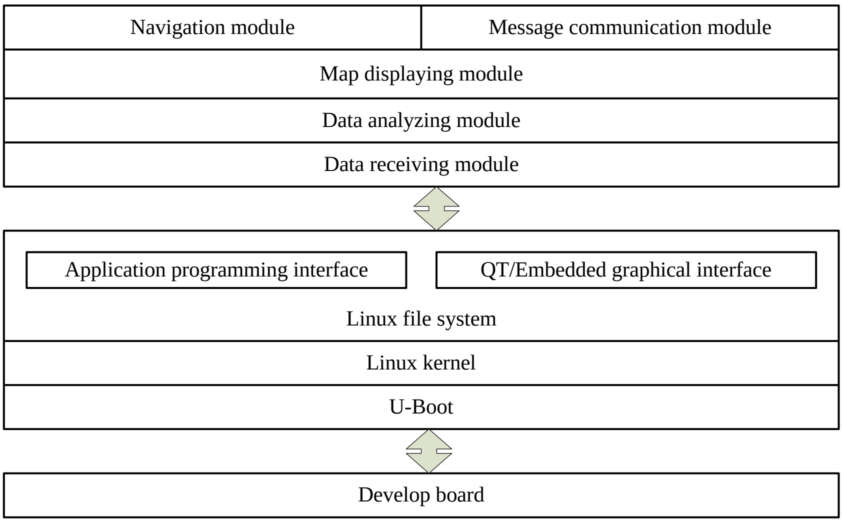

Figure 3. The Software Architecture of the Proposed Portable Navigation Device

As illustrated in Figure 3, the embedded Linux operating system includes two parts, which are the Linux kernel and the Linux file system. Qt/Embedded graphical interface is used to build the graphical user interface of the software component. The embedded navigation software contains four modules, which are the data receiving module, data analyzing module, map displaying module, navigation module, and message communication module.

3. Dual-mode Data Processing

3.1. Linux Serial Port Communication Programming

In the embedded Linux operating system, all the hardware devices are considered as files to be managed and operated by the embedded Linux operating system. Each hardware device has a corresponding device file in the embedded Linux operating system. The embedded Linux operating system operates the device files and completes the open, close, read, and write operations of the device files by using a set of system calls. In the embedded Linux operating system, the serial ports are considered as the device files that are located in the /dev directory. For example, the UART serial port used by the GPS receiver module corresponds to the device file /dev/ttyS0, and the RS-232 serial port used by the BDS receiver module corresponds to the device file /dev/ttyS2.

(1) Serial Port Settings

Serial ports in the Linux operating system are system resources, so programmers cannot set and operate serial ports directly. The Linux operating system provides a terminal control interface termios to set the parameters of serial ports and control serial ports. The parameters are defined in a system head file termios.h, which contains a data structure termios and a group of terminal control functions. The data structure termios is defined as follows:

```
Struct termios
{
        tcflag_tc_iflag; //the parameter for input mode;
        tcflag_tc_oflag; //the parameter for output mode;
        tcflag_tc_cflag; //the parameter for control mode;
        tcflag_tc_lflag; //the parameter for local mode;
```

```
        cc_tc_cc[NCCS]; //the control character;
};
```

In the data structure termios, tc_flag_tc_iflag is a parameter for the input mode of the serial port and is responsible for managing all the processing options of the inputs of the serial port. tc_flag_tc_oflag is a parameter for the output mode and is responsible for managing all the processing options of the outputs. tcflag_tc_cflag is a parameter for the control mode and is responsible for managing the basic settings of the connection characteristics of the hardware. tcflag_tc_lflag is a parameter for the local mode and manages the return signals due to the user interactions. The array cc_tc_cc[NCCS] contains the control character parameters and defines a series of control characters and their characteristics, it also sets the mode that the data are sent to the calling programs.

According to the communication parameters defined in the GPS and BDS data transfer protocols, the serial ports of the GPS and BDS receiver modules are set as follows.

①Baud rate settings

The embedded Linux operating system offers two functions that can be used to set the baud rates of the serial ports. The function cfsetospeed() is used to set the output baud rate of the serial port and the function cfsetispeed() is used to set the input baud rate of the serial port. The baud rate of the serial port in the BDS receiver module is 115200bps, while the baud rate of the serial port in the GPS receiver module is 4800bps.

②Character settings

The character settings of the serial port contains three parts, which are the data bit setting, the stop bit setting, and the parity bit setting. They are implemented by using mask. Because the communication parameters of the serial ports are 8 data bits, 1 stop bit, and no parity bit, the character settings of the serial ports are as follows.

```
_termios_fd.c_cflag&=~CSIZE; //shielding the character size;
_termios_fd.c_cflag&=~CSTOPB; //set 1 stop bit;
_termios_fd.c_cflag&=~PARENB; //no parity bit;
_termios_fd.c_cflag|=CS8; //set 8 data bits;
```

(2)Accessing the serial port

In the embedded Linux operating system, accessing the serial port can be implemented by opening its corresponding device file. Performing the read and write operations to this device file can complete the receiving and sending processes of the data. The embedded Linux operating system offers five system calls, which are the open(), close(), read(), write(), and ioctl(), to implement the read and write operations. The open() and close() are used to open and close the serial ports, respectively. The read() and write() are used to receive and send the data in the serial ports. The ioctl() is used to control the serial ports.

3.2. Receiving Process of the Dual-mode Data

The proposed portable navigation device needs to read the positioning data from two serial ports, so the multi-serial port access technology is used to complete the receiving of the dual-mode data from the GPS and BDS receiver modules through two different serial ports. The multi-serial port access technology is a serial port programming method that is suitable for controlling and accessing multi serial ports.

In this paper, the I/O multiplexing [8] is introduced to control and access multi serial ports.

The basic idea of the I/O multiplexing technology is described as follows:

①A table containing all the serial port device file descriptions is constructed;

②A system call is called to block I/O until some serial device corresponding to one of the serial port device file descriptions in the table is ready. The system call returns when a serial device is ready and reports the corresponding device file description to the upper applications. Finally, the applications in the user space can access the serial port.

In the embedded Linux operating system, the system call select() is used to implement the I/O multiplexing and it also provides the applications with the function that checks the inputs, outputs and abnormal states of one or several device file descriptions. The file descriptions often point to the regular file, pipe, socket, and device file. The I/O multiplexing technology in the embedded Linux operating system is implemented as follows:

The user applications call the function select() to monitor the active states of the serial ports corresponding to the device file descriptions in the table [9]. If all the monitored serial ports have no data to be transmitted, the thread enters into the waiting state. The function select() returns the number of the ready file descriptions and their active states when there are serial ports ready to transmit data. Finally, the user thread calls the function read() to read the data from above serial ports. Accessing multi serial ports can be implemented by repeating above steps.

Therefore, the data receiving flow can be shown in the Figure 4.

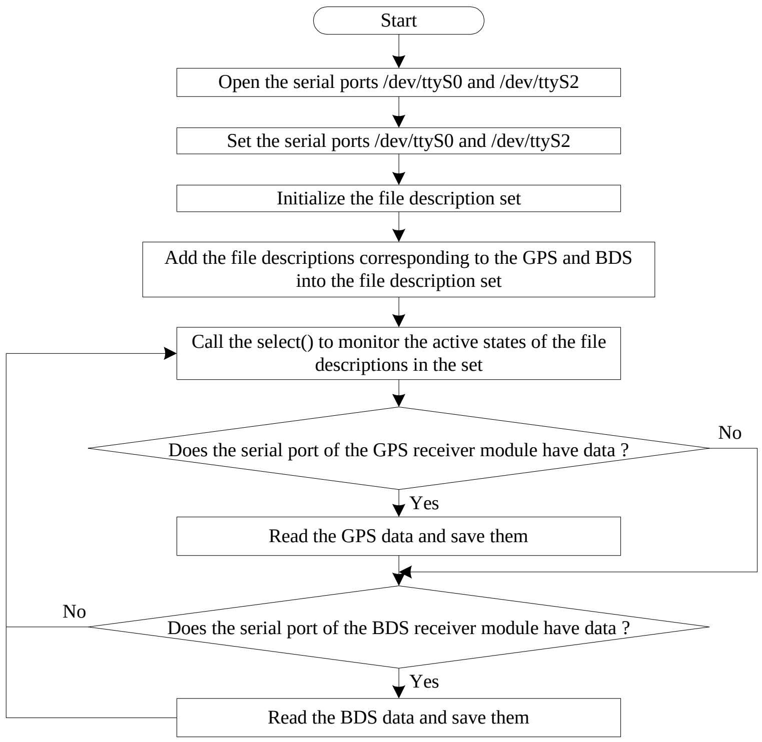

Figure 4. The Receiving Process of the Dual-mode Data

3.3. Analyzing process of the Positioning Data

After receiving the positioning data from the GPS and BDS receiver modules through the corresponding serial ports, the navigation software extracts the positioning sentences from the whole positioning data. Then, the navigation software extracts the positioning parameters from the corresponding fields in the positioning sentences according to the sentence formats. Finally, the extracted positioning parameters are stored into the corresponding data structures.

Figure 5 shows the analyzing process of the positioning data.

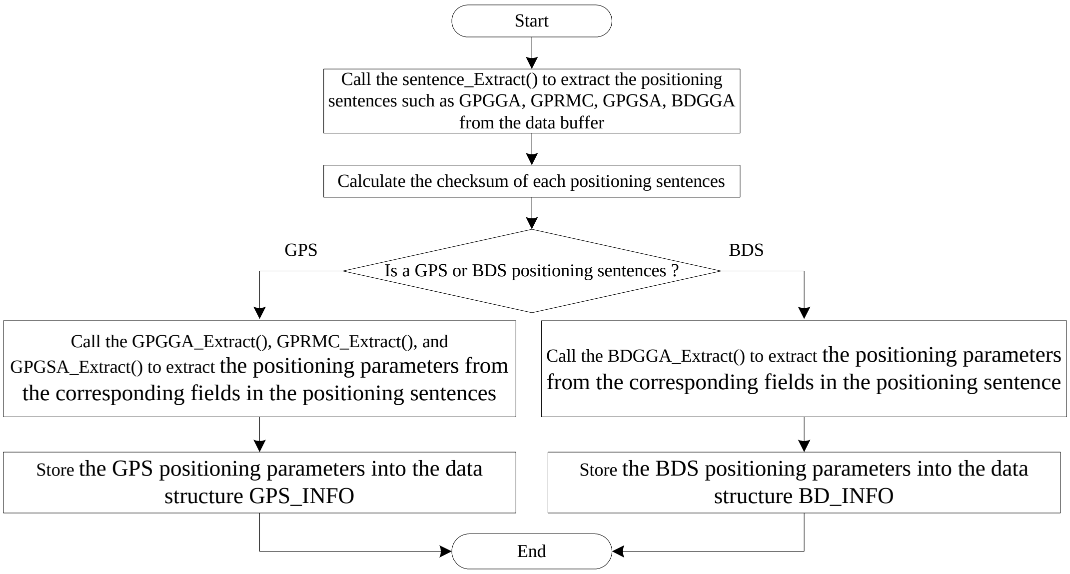

Figure 5. The Analyzing Process of the Positioning Data

4. Map Displaying Strategy

In order to reduce the user waiting time of displaying the electronic maps, a layering displaying strategy is proposed to display the electronic maps. The proposed layering displaying strategy introduces the idea of LOD (Levels of Detail) [10]. LOD is a technology that is used to decrease the complexity of a 3D object representation.

The electronic maps used in the proposed navigation device are based on the MIF/MID format. This kind of electronic maps use the map layer as the basic unit to manage the map data files. Each map layer contains several geographical objects. Because of the data organization method in the form of map layers, each map layer is assigned with a displaying parameter that shows the importance of geographical objects in the map layer. The map layer with a high displaying parameter should be displayed in prior to the map layer with a low displaying parameter. The navigation software only reads the map layers with high display parameters from the storage medium when the electronic map is loaded by the navigation software. As the electronic map is scaled up, the navigation software continues to read the map layers with low display parameters and displays them to draw the electronic map more accurately. This map displaying strategy can read the map data files on demand to improve the user waiting time and the displaying performance of the electronic maps.

5. Experimental Results

5.1. Results for Dual-mode Data Processing

In order to evaluate the effectiveness of the dual-mode data processing module in the proposed portable navigation software, a serial port tool is used to display the positioning parameters from the GPS and BDS system on the display screen. Figure 6 and Figure 7 show the processing results of the GPS data and BDS data, respectively.

2014-04-10 09:15
Positioning pattern: A
Positioning type: 3
GPS state: 1
PDOP: 1.5
HDOP: 1.0
VDOP: 1.1
The number of visible satellites: 4
UTC date and time: 2014.4.10.9.15.22.000
Longitude: 29.565931N
Latitude: 106.465758E
Elevation: 523.0
Velocity: 0

Figure 6. The Positioning Parameters from the GPS System

2014-04-10 09:15
Beidou positioning state: 1
Longitude: 29.565889N
Latitude: 106.465723E
UCT date and time: 2014.4.10.9.15.52.000
Elevation: 604.00
Velocity: 0

Figure 7. The Positioning Parameters from the BDS System

The results show that the proposed portable navigation device can receive and analyze the GPS positioning data and BDS positioning data effectively.

5.2. Map Displaying Strategy

In order to improve the displaying performance of the proposed portable navigation device, a layering displaying strategy is proposed to display the map layers on demand. In order to evaluate the effectiveness of the proposed layering displaying strategy, the displaying performance is tested and analyzed in terms of the user waiting time.

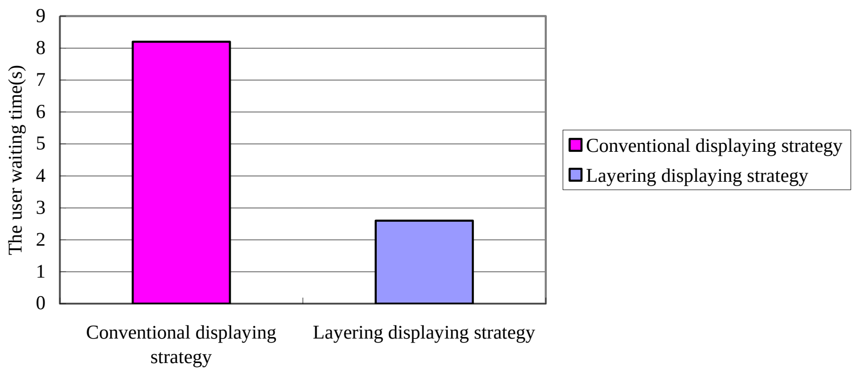

Figure 8. The User Waiting Times for Two Displaying Strategies

First, an electronic map with the MIF/MID format is divided into four layers with four different displaying parameters. Second, the user waiting time is recorded when the layering displaying strategy is used in the navigation software. Finally, the layering displaying strategy is removed from the navigation software and then the navigation software reads all the map files each time. In this case, the user waiting time is also recorded.

As shown in Figure 8, the user waiting time of the layering displaying strategy is less than that of the strategy that reads all the map files each time. Therefore, the layering displaying strategy shows a higher displaying performance than the conventional displaying strategy that reads all the map files each time.

6. Conclusions

This paper presents the detailed design of a portable navigation device that integrates the GPS and BDS receiver modules. According to design requirements of a portable navigation device, the system architecture of the proposed portable navigation device is designed. The dual-mode data processing function and the map displaying strategy are also proposed. The experimental results show that the proposed portable navigation device can receive and analyze the GPS and BDS positioning data effectively, as well as the proposed layering displaying strategy shows higher displaying performance than the conventional displaying strategy that reads all the map files and displays all the geographical objects at one time.

Acknowledgments

The authors are grateful to the editor and anonymous reviewers for their valuable comments on this paper.

The work of this paper is supported by the National Natural Science Foundation of China under grant No.61370078 and No.61402109.

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