POSITIONING AND NAVIGATION SYSTEM USING GPS

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ABSTRACT:

In this paper, some of the ideas of positioning and navigation using GPS (Global Positioning System) where explored, GPS is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. This paper provides the use of a handheld GPS receiver in the areas of precise positioning, mapping locations, navigating across the mapped locations very easily. The purpose of this paper is to showcase the experiences that incurred in designing a positioning and navigation system (with the aid of a 12 parallel channel handheld GPS), which can be used as a moving compass, steering to any mapped destination, providing the information about near by places, tourist attractions, petrol bunks etc. The Magellan 310 handheld GPS which is being used for developing the proposed system allows users to connect to a personal computer through RS-232 Serial Interface and the protocol used by the device for communication is NMEA 0183, (National Marine Electronics Association). It is an American national regulatory body, which, among other things, sets standards pertaining to the interfacing of marine electronic devices. This NMEA 0183 Protocol transmits data to the connected PC every 1 second, this data has to be interpreted and filtered accordingly to get the needed information from the GPS device. This paper provides a case study in the process of designing such a system and its limitations in the era   where through distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map. It also portrays the implementation details and their results obtained and along their pros and cons when compared with the other existing positioning and navigation system designed for basic handheld GPS (without having advance features like provision for electronic map etc. in the device), It also addresses some of the enhancements that can be accomplished in the designed system. This paper is organized by providing a brief introduction to GPS technology and then dealing with hardware description & NMEA Messages along with a case study implementation detail of the system, its features and possible enhancements in the system.

1. INTRODUCTION

In this section of the paper, a brief overview of GPS Technology is provided. The Global Positioning System (GPS) [1] is a constellation of satellites that orbit the earth twice a day, transmitting precise time and position (latitude, longitude and altitude) information. With a GPS Receiver, users can determine their location anywhere on the Earth. The complete system consists of 24 satellites orbiting about 12,000 miles above the Earth, and five ground stations to monitor and manage the satellite constellation. These satellites provide 24-hour-a-day coverage for both two-and three-dimensional positioning anywhere on Earth.

A GPS satellite navigation system was begun in the 1970s by the US Department of Defense, which continues to manage the system, to provide continuous, worldwide positioning and navigation data to US military forces around the globe. GPS basically offers two levels of service namely SPS (Standard Positioning Service) for civilian access and PPS (Precise Positioning Service) for exclusive military use with higher level of encryption.

As already stated above, the basis of GPS Technology revolves around precise time and position information, which is being accomplished through atomic clocks and location data. Basically the satellites broadcast the time and their position. A GPS receiver receives these signals, listening to three or more satellites at once (it's also called tracking), to determine the users position on earth.

A GPS working principle is that, it measures the time interval between the transmission and the reception of a satellite signal, and then it calculates the distance between the user and each satellite. Through the distance measurements of at least three satellites in an algorithm computation, the GPS receiver arrives at an accurate position fix. To obtain a 2-D fix (latitude and longitude), information must be received from three satellites and for a 3-D fix (latitude, longitude and altitude), four satellites are required.

2. HARDWARE DESCRIPTION & NMEA MESSAGES

2.1 Hardware – Magellan GPS 310 Description

Figure 1. Magellan GPS 310

In this section of the paper, the hardware details used for building the proposed system is being dealt.

Magellan GPS 310 Model with a parallel multi-channel design to increase the accuracy of the receiver is used, these Magellan's 12 parallel channel receivers are relatively quick to lock into satellites when first turned on initially and they maintain strong locks, even in dense foliage or urban settings with tall buildings. They are accurate to within 15 meters on average and it offers the users with a low cost GPS Solution with NMEA data output and PC interface capabilities.

The advantages and features of using the Magellan 310 GPS hardware are stated as below.

Advantages

1. Powerful 12-parallel channel receiver and super sensitive quadrifilar antenna for fast satellite signal locking and accurate tracking.
2. Incredible easy to use with EZstart, dedicated operation keys, and three user-friendly navigation screens, and saves 100 waypoints and 1 route with up to 10 reversible legs.
3. Features a brilliant backlit display or nighttime use, and its small, portable, lightweight housing is not only rugged – it floats.

Important Features

1. NMEA data output for PC interface
2. DGPS ready
3. Powerful 12-parallel channel receiver
4. Displays distance, bearing, heading, direction, steering, speed, time to go, elevation, time and satellite directions.

2.2 NMEA Messages

The NMEA (National Marine Electronics Association) is dedicated to the education and advancement of the marine electronics industry and the market, which it serves. It's a non-profit association composed of manufacturers, distributors, dealers, educational institutions, and others interested in peripheral marine electronics occupations.

The proposed Positioning and Navigation System is developed in accordance with NMEA-0183 Standard. An NMEA standard defines and electrical interface and data protocol for communications between marine instrumentation. The electrical specifications actually recommend a newer standard called RS-422 Standard which slightly varies from RS-232 Standard, in the sense that, RS-422 standard adapts to two wires each for transmitting and receiving for a total of four signal wires.

The general sentence formats of NMEA message from GPS are discussed as follows. Under the NMEA-0183 standard, all characters used are printable ASCII test (plus carriage return and line feed). NMEA-0183, data is sent at 4800 baud. The data is transmitted in the form of "sentences". Each sentence starts with a "$", a two letter "talker ID", a three letter "sentence ID", followed by a number of data fields separated by commas, and terminated by an optional checksum, and a carriage return/line feed. A sentence may contain up to 82 characters including the '$" and CR/LF. If the data for a field is not available or field is variable width, the field is simply omitted, but the commas that would delimit it are still sent, with no space between them. The optional checksum field

consists of a "*" and two hex digits representing the exclusive OR of all characters between, but not including the "$" and "*". A checksum is required in some sentences.

The standard allows individual manufacturers to define proprietary sentence formats. These sentences start with "$P", then a 3 letter manufacturer ID, followed by whatever data the manufacturer wishes, following the general format of the standard sentences.

Some common talker IDs are:

1. GP Global Positioning System Receiver
2. LC Loran-C Receiver
3. OM Omega Navigation Receiver
4. II Integrated Instrumentation (e.g.AutoHelm Seatalk system)

Magellan GPS 310 receiver supports the standard sentences like APB, GGA, GLL, RMB, RMC, and GSV. In the above standard sentences, let us see an example illustration for a most used sentence called GLL (Geographic Position Latitude and Longitude). The sentence format is as shown below.

GLL, 4916.45, N, 12311.12, W, 225444, A

4916.45, N	Latitude 49 degree 16.45 minute North
12311.12, W	Longitude 123 degree 11.12 minute West
225444	Fix taken at 22:54:44 UTC
A	Data valid

When the receiver is interfaced with a PC, these NMEA Messages have to be gathered through serial communication and the necessary information like user's Longitude, Latitude, Speed over ground etc. are to be filtered and they can be used in subsequent phases in developing the proposed system.

3. CASE STUDY IMPLEMENTATION OF A GPS SYSTEM

In this section of the paper, the phases involved in designing a GPS system are discussed and elaborated with the needed information.

The phases involved in developing a case study implementation are:

1. Initialization of the GPS Receiver
2. Serial Interfacing of GPS with PC and Mapping of various important locations
3. File Management & filtering of GPS data
4. Designing a Location Master to accommodate the mapped data
5. Moving Compass and precise positioning

The case study implementation of the GPS system is done for a city named Salem present in South India. The developed system acts as a basic positioning and navigation interface for traveling across the city providing the users the requisite information. The mapped data's that will be presented in the coming sections are all pertaining to the positional coordinates of the various locations present in the Salem city. The implementation to be portrayed below is easily extensible for any other corner of the globe since the positional coordinates needed for a particular location is going to vary and it only involves two primary changes namely

1. Re-Initializing of the GPS Receiver using EZ-Start
2. Mapping and storing the locations of the new destination

3.1 Initialization of the GPS Receiver

In this section the steps involved in initializing the GPS receiver are discussed, these steps are solely for the Magellan GPS receiver 310; however steps in initializing the other receivers will be more or less the same as described below. Initialization step in GPS is required while taking it more than 10,000 kms for fastest tracking and also it is always preferable to initialize the receiver for that region.

Before using GPS 310 for the first time, the receiver needs to know its approximate location. Using Magellan's EZStart procedure, the GPS 310 will prompt us for the information it requires when we turn it on for the first time. There is no need to initialize receiver each time we use it. For the first time when using GPS 310, the following steps needs to be done for initialization.

1. Press **PWR** to turn the GPS 310 on
2. SELECT REGION. Use the ARROW pad to change the flashing text to select the appropriate region for your present location, Press **ENTER**
3. SELECT COUNTRY or STATE. Use the ARROW pad to change the flashing text to select the country or state for your present location. Press **ENTER**
4. ENTER ELEVATION. Use the ARROW pad to enter the approximate elevation for your position. If unknown leave the elevation at 0. Press **ENTER**
5. ENTER TIME. Use the ARROW pad to enter your present time. Press **ENTER**
6. ENTER DATE. Use the ARROW pad to enter the date. Press **ENTER**

When the above initialization steps are performed, the GPS 310 displays the **POSITION screen** and automatically searching for satellites that it knows are in this area for the date and time that the user entered. The reinitializing process mentioned above is similar to the initialization except for the reason that new datum has to entered in doing so. Example: In the proposed GPS system, the following values are selected when performing initialization, REGION: West Asia COUNTRY: India and other standard entries like DATE & TIME.

3.2 Serial interfacing of GPS with PC & Mapping of various important locations

In this section of the paper, we will discuss
1. The standard RS-232 interfacing of GPS with PC
2. Data acquisition of GPS data on to file through serial communication.

In general, the GPS 310 is designed to interface to a PC or other devices using a data cable. It continuously outputs NMEA messages through the data port at a rate of every one second. The GSV message is output all the time including when the receiver is not computing fixes. After the first fix is computed, GSA, GLL, GGA and RMC messages are also output.

These messages contain position, time, date, satellite position as well as other status information. The above said messages that are available for the personal computer are used in the case study implemented GPS system. Incase of the receiver computing fixes and has a route set the RMB and APB messages containing useful information like steering, distance to destination etc needed to navigate to the route destination are also output.

The standard settings needed to receive the NMEA messages outputted from GPS are furnished as follows.
BAUDRATE=4800
PARITY= NONE
STOPBIT=1
DATABITS=8
PORT ID=1

To acquire the NMEA Messages on to the PC connected with GPS, we have to open the serial port with the above settings by disabling all the system interrupts. The sample NMEA messages acquired when GPS compute fixes will be of the below format.

$GPGGA,054544.59,1140.7023,N,07807.4575,E,1,04,2.3,00316,M,,,,,*21
$GPGLL, 4916.45, N, 12311.12, W, 225444, A
$GPRMC, 054544.59, 1140.7023, N, 07807.4575
$GPGSV, 3, 3, 08,,,,,,,,,,,,,,,,,,,*71

These continuously NMEA messages obtained through serial communication interface of GPS with PC have to handled, processed, filtered to formulate the necessary information so as to enable the users to track down their positions and give them inputs about other nearby important places, along with distance, directions for steering to destination of their interest, for providing the user with such information requires positional coordinates of various locations in hand before developing the GPS system. This task is accomplished through mapping of the important places manually. Let us discuss the process of mapping positional coordinates of a location.

The GPS 310 will begin to acquire information from the satellites and use this information to compute your current position (called a position fix). Before doing so, initialization of the GPS receiver has to be done, the screen of the GPS 310 displays the number of satellites are being tracked. After the GPS receiver has received positioning data from at least three satellites (it takes approximately 2-3 minutes), it will begin computing a position fix based upon the information it is receiving. As soon as a position fix is computed, the receiver switches to the navigation screen displaying the moving compass. The word "TRACKING" is displayed in the lower right corner indicating that the receiver is computing position fixes. The obtained position fixes can be saved in memory for use later when you want to return to that position, saved position fixes are referred to as landmarks or LMK (can be saved through pressing **MARK** in GPS Receiver). Using the above procedure for mapping and computing position fixes in GPS Receiver, the following precise positioning of some of the locations in and around Salem is taken and they are stored in the backend for further computing.

Example:

Certain samples of mapped locations using GPS in Salem stored in the backend are as follows:

Latitude	Longitude	Location
1139.2345, N	07809.3000, E	Collectorate, Salem
1139.1789, N	07809.2000, E	Gandhi Stadium, Salem
1139.0023, N	07808.0123, E	4 Roads, Salem
1141.0023, N	07806.3653, E	Burn & Co., Salem

Table 1. Sample Mapped Data

3.3 File Management & Filtering of GPS data

The file management and filtering of GPS data is done in real time while the GPS system acquires the NMEA data from the GPS through serial interface every one second. The GPS system is developed in such a way to handle large amount of NMEA data, by constantly flushing the buffer and then refreshing it to accommodate new sets of NMEA data.

As explained above in the previous section, mapping is equivalent to acquiring computing fixes of various positional coordinate locations and then storing them in the backend for further computing. The continuous NMEA messages outputted every one second from GPS is stored in the temporary file buffer for some period of time, where in the mean time exact filtering of different formats of messages like GLL, RMB, RMC, GGA, and APB are done and stored in different files for extracting different kinds of information like Latitude, Longitude, distance, direction, speed etc.

Example of continuous NMEA data outputted by GPS stored in the Main file.

$GPGGA,054544.59,1140.7023,N,07807.4575,E,1,04,2.3,00316,M,,,,,*21
$GPGLL, 4916.45, N, 12311.12, W, 225444, A
$GPRMC, 054544.59, 1140.7023, N, 07807.4575
$GPGSV, 3, 3, 08,,,,,,,,,,,,,,,,,,*71
$GPGGA,054544.59,1140.7023,N,07807.4575,E,1,04,2.3,00316,M,,,,,*21

From the sets of NMEA data, the GPS system filters for GLL, RMC, RMB, GGA message formats and then store them in different files for further processing. Example of a GLL (Geographic Latitude Longitude) file (filtered from the Main file).

$GPGLL, 4916.45, N, 12311.12, W, 225444, A
$GPGLL, 4916.47, N, 12311.17, W, 225444, A
$GPGLL, 4916.49, N, 12312.01, W, 225444, A

3.4 Designing a Location Master to accommodate the mapped data

The GPS system uses a location master backend file for processing and comparing of the real time data outputted by GPS with that of the static mapped positional coordinates present in it. It is designed in such a way for easily adding, updating, marking, viewing of the mapped coordinates present in the location master.

For instance if say a user finds an important place in the city Salem which is not being present in the location master file, then the user has got an option to view the current location master file and then add a new entry on to it. Location master maintains the mapped positional coordinates in the following format with the location code acting as a primary key to use other additional files as shown below.

ID	Latitude	Longitude	Area	City	Country
1	1139.2345, N	07809.3000E	4roads	Salem	India
2	1139.1789, N	07809.2000, E	Shop	Salem	India
3	1141.0023, N	07806.3653,E	GH	Salem	India
4	1123.4533, N	07807.2322,E	5roads	Salem	India

Table 2. Location Master Data

Id	Latitude	Longitude
1	1139.2345,N	07809.3000,E
1	1139.1789,N	07809.2000,E
2	1141.0023,N	07806.3653,E
2	1139.2315,N	07803.1200,E
3	1123.2322,N	07923.5454,E
3	1125.5454,N	07803.2332,E

Table 3. Example Mapped Coordinates

Location master file allows the GPS system users to perform ADD, DELETE, VIEW and UPDATE on it.

3.5 Moving Compass and precise positioning

This section of the paper portrays the task done in moving compass module of the GPS system as it holds the key for precise positioning and navigation across the city with relative ease. It basically is used for precise positioning by comparing the mapped positional coordinates present in the location master with that of the newly acquired positional fix of the current location of the user while traveling across the city.

With respect to the difference it finds with the existing mapped positional coordinates in the location master, their current locations is found when it is approximately zero and then for difference exceeding but relatively of certain small margin are its nearby places. This information computed after acquiring continuous NMEA messages every one second and then comparison done with that of the mapped positional coordinates present in the location master yields the user about all necessary information that is required. But the accuracy of the computed fix about the current location and nearby places, distance for steering to destination, direction and speed etc. are entirely dependent on the mapped positional coordinates present in the location master and other modules.

This module is dependent on other modules mentioned above like Initialization, Mapping, Location Master, File management and Filtering of GPS data for precise positioning across the city that is shown below in the figure.
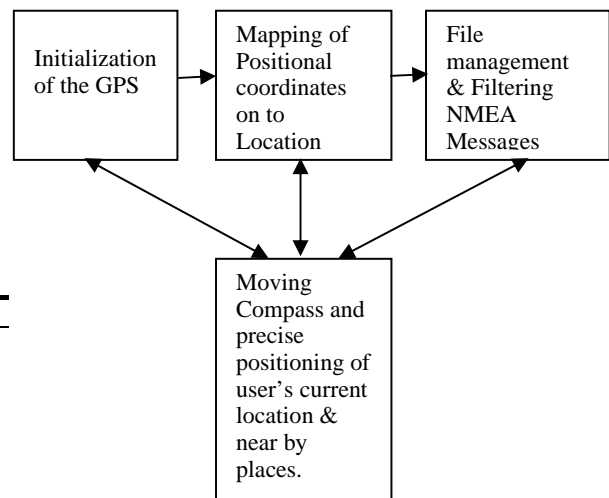

Figure 2. Implemented GPS System

4. APPLICATIONS OF THE GPS SYSTEM

The applications of the designed GPS System are illustrated as below as follows.

1. Identifying user position precisely
2. Navigating from point to point
3. Moving compass
4. Steering to destination
5. To act as a city guide software
6. To identify nearby important places, tourist attractions by computing user's current location

5. CONCLUSION

This system developed is a miniature of what can be done with the usage of GPS technology, since cost being a constraint for further advancement, it provides the users a wide variety of applications by using a basic GPS receiver which is costing less. Thus the implemented system can pave way for developing other systems using high end GPS receivers with lot of new features and advancements, so that applications such as vehicle tracking, tourist guide software etc. can be developed for the users.

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