TABLE OF CONTENTS

GPS RESEARCH

What is GPS?

GPS is the acronym for Global Positioning System. Mainly, GPS is a network of 24 satellites that continually transmit coded information, which makes it possible to accurately identify locations on earth by measuring the distance from the satellites. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. There are no subscription fees or setup charges to use GPS.

GPS Satellite System

The 24 (at least) satellites that make up the GPS space segment are in a “high orbit” about 12,000 miles above the Earth’s surface. The satellites are traveling at speeds of 7,000 miles an hour. By this way, they circle the Earth twice a day. GPS satellites are powered by solar energy, moreover they have backup batteries. Each satellite is built to last about 10 years.

How it works?

As indicated before, GPS satellites circle the earth twice a day in a very “high orbit” and transmit signals to earth. GPS receivers take these signals and use triangulation to calculate the user's exact location. To do this, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. With some distance measurements from a few more satellites, the receiver can determine the user's position. A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. The receiver can determine the user's 3D position (latitude, longitude and altitude) if four or more satellites are locked. Once the user's position has been determined, the GPS unit can calculate other information, such as speed, track, trip distance, distance to destination, sunrise and sunset time and more.

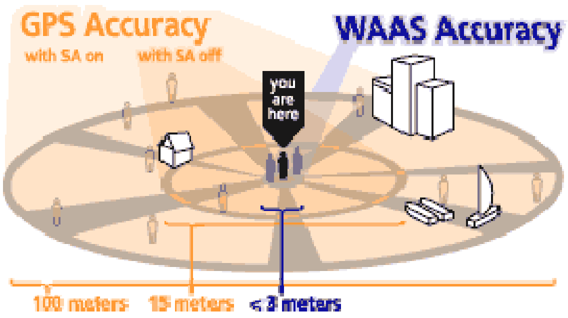
Accuracy of GPS

Today’s GPS receivers are very accurate in fact, by the help of their parallel multi-channel design. Parallel channel receivers (usually between 5 and 12) are quick to lock onto satellites when GPS receiver is first turned on and they maintain strong locks even in dense forests and urban areas with tall buildings. Certain atmospheric factors and other sources of error can affect the accuracy of GPS receivers. Most GPS receivers are accurate to within 15 meters on average.

Other than typical GPS, there are two improvements of GPS also. The first one is Differential GPS (DGPS), which corrects GPS signals to within an average of 3 to 5 meters. This system consists of a network of towers that receive GPS signals and transmit a corrected signal by light transmitters. In order to get the corrected signal, users must have a differential light receiver and light antenna in addition to their GPS.

The second one is Wide Area Augmentation System (WAAS), which can improve accuracy to less than 3 meters on average. Basically, WAAS is a system of satellites and ground stations that provide GPS signal corrections, serving even better position accuracy. WAAS signal reception is ideal for open land and marine applications. Moreover, WAAS does not require additional receiving equipment while DGPS does.

These can be combined in a figure:



<u>100 meters:</u> Accuracy of original GPS in the days of government-imposed Selective Availability (SA) program. (*)

<u>15 meters:</u> GPS accuracy without SA.

<u>3-5 meters:</u> Differential GPS accuracy

<u>< 3 meters:</u> WAAS accuracy.

(*) The U.S. military's intentional degradation of the signal is known as "Selective Availability" and is intended to prevent military adversaries from using the highly accurate GPS signals. SA was turned of May 2, 2000.

GPS Signals

GPS satellites transmit low power radio signals on several frequencies (designated L1, L2, etc.). Civilian GPS uses the L1 frequency of 1575.42 MHz in the UHF band. The signal travels "line of sight", meaning it will pass through clouds, glass and plastic but will not go through most solid objects such as buildings and mountains.

A GPS signal contains three different bits of information: a pseudorandom code, ephemeris data and almanac data. The pseudorandom code is simply an I.D. code that identifies which satellite is transmitting information. Ephemeris data contains important information about the status of the satellite (healthy or unhealthy), current date and time. This part of the signal is essential for determining a position. The almanac data tells the GPS receiver where each GPS satellite should be at any time throughout the day. Each satellite transmits almanac data showing the orbital information for that satellite and for every other satellite in the system.

Sources of GPS Signal Errors

Factors that can degrade the GPS signal and thus affect accuracy include the following:

- <u>Ionosphere and troposphere delays:</u> The satellite signal slows as it passes through the atmosphere. The GPS system uses a built-in model that calculates an average amount of delay to partially correct for this type of error.

- <u>Signal multi-path:</u> This occurs when the GPS signal is reflected off objects such as tall buildings or large rock surfaces before it reaches the receiver. This increases the travel time of the signal, thereby causing errors.

- Receiver clock errors: A receiver's built-in clock is not as accurate as the atomic clocks on the GPS satellites. Therefore, it may have very slight timing errors.

- Orbital errors: Also known as “ephemeris errors”, these are inaccuracies of the satellite's reported location.

- Number of satellites visible: The more satellites a GPS receiver can "see", the better the accuracy. Buildings, terrain, electronic interference, or sometimes even dense foliage can block signal reception, causing position errors or possibly no position reading at all. GPS units typically will not work indoors, underwater or underground.

- Satellite geometry/shading: This refers to the relative position of the satellites at any given time. Ideal satellite geometry exists when the satellites are located at wide angles relative to each other. Poor geometry occurs when the satellites are located in a line or in a tight grouping.

GPS Data Protocols

GPS receivers use a variety of languages/protocols, such as NMEA, SiRF, Garmin, Delorme, etc. However, the focus should be on the two main languages used in Pocket PC GPS receivers: NMEA and SiRF. These two terms describe two different languages/protocols output by GPS receivers. While all GPS receivers output the NMEA, only receivers built on the SiRF chipset can output to SiRF. Since it is clear that NMEA is more popular than SiRF, one more elimination occurs. In our design, we will focus on NMEA standard because it is now in use by a vast majority of GPS devices.

NMEA 0183 Protocol

NMEA stands for National Marine Electronics Association. They have written some standards. One is NMEA 0183 which “defines electrical signal requirements, data transmission protocol and time, and specific sentence formats for a 4800-baud serial data bus.” One of the groups that have adopted the NMEA standard is the GPS community.

NMEA data is sent in 8-bit ASCII where the MSB is set to zero. The specification also has a set of reserved characters. These characters assist in the formatting of the NMEA data string. The specification also states valid characters and gives a table of these characters ranging from HEX 20 to HEX 7E.

As stated in the NMEA 0183 specification version 3.01, the maximum number of characters shall be 82, consisting of a maximum of 79 characters between start of message “$” or “!” and terminating delimiter <CR><LF> (HEX 0D and 0A). The minimum number of fields is one.

Basic sentence format:

$aaccc,c--c*hh<CR><LF>

- $ Start of sentence
- aaccc Address field/Command
- “,” Field delimiter (Hex 2C)
- c--c Data sentence block

- * Checksum delimiter (HEX 2A)
- hh Checksum field (the hexadecimal value represented in ASCII)
- <CR><LF> End of sentence (HEX 0D 0A)

NMEA data is sent as comma-delimited “sentences” which contain information based on the first word of the sentence. The NMEA 0183 standard defines dozens of sentences, but only a fraction apply directly to GPS devices. The most useful sentences include:

- $GPAAM - Waypoint Arrival Alarm
- $GPBOD - Bearing, Origin to Destination
- $GPBWW - Bearing, Waypoint to Waypoint
- $GPGGA - Global Positioning System Fix Data
- $GPGLL - Geographic Position, Latitude/Longitude
- $GPGSA - GPS DOP and Active Satellites
- $GPGST - GPS Pseudorange Noise Statistics
- $GPGSV - GPS Satellites in View
- $GPHDG - Heading, Deviation & Variation
- $GPHDT - Heading, True
- $GPRMB - Recommended Minimum Navigation Information
- $GPRMC - Recommended Minimum Specific GPS/TRANSIT Data
- $GPRTE - Routes
- $GPVTG - Track Made Good and Ground Speed
- $GPWCV - Waypoint Closure Velocity
- $GPWNC - Distance, Waypoint to Waypoint
- $GPWPL - Waypoint Location
- $GPXTE - Cross-Track Error, Measured
- $GPXTR - Cross-Track Error, Dead Reckoning
- $GPZDA - UTC Date/Time and Local Time Zone Offset
- $GPZFO - UTC and Time from Origin Waypoint
- $GPZTG - UTC and Time to Destination Waypoint

The most common NMEA 0183 Sentence - $GPRMC

The most common NMEA sentence of all is the “Recommended Minimum” sentence, which begins with “$GPRMC”. Here is an example:

```
$GPRMC,040302.663,A,3939.7,N,10506.6,W,0.27,358.86,200804,,*1A
```

This one sentence contains nearly everything a GPS application needs: latitude, longitude, speed, bearing, satellite-derived time, fix status and magnetic variation. The format of the sentence is:

$GPRMC,aaaaaa,b,cccc.cc,d,eeeee.ee,f,ggg.g,hhh.h,jjjjjj,kkk.k,l*mm

Where:

- **aaaaaa** is the time of the fix UTC in hhmmss format
- **b** is the validity of the fix ("A" = valid, "V" = invalid)
- **cccc.cc** is the current latitude in ddmm.mm format

- **d** is the latitude hemisphere ("N" = northern, "S" = southern)
- **eeeee.ee** is the current longitude in dddmm.mm format
- **f** is the longitude hemisphere ("E" = eastern, "W" = western)
- **ggg.g** is the speed in knots
- **hhh.h** is the true course in degrees
- **jjjjjj** is the date in DDMMYY format
- **kkk.k** is the magnetic variation in degrees
- **l** is the direction of magnetic variation ("E" = east, "W" = west)
- **mm** is the checksum

Parsing the “Recommended Minimum” Sentence

The first thing to do is separating each NMEA 0183 sentence (by applying split() function with “,” character) into its individual words and examining the first word to figure out what information is available to extract. Assume that, we have split the words and filled them into a String array named Words[].

If Words[0] == “$GPRMC” then a “recommended minimum” sentence is found.

The next step is to perform actual extraction of information, starting with latitude and longitude. Latitude and longitude are stored in the form “DDD°MM’SS.S”, where D represents hours (also called “degrees”), M represents minutes, and S represents seconds. The fourth word in the sentence, “3939.7”, shows the current latitude as hours and minutes (39°39.7’), except the numbers are squished together. The first two characters (39) represent hours and the remainder of the word (39.7) represents minutes. Longitude is structured the same way, except that the first three characters represent hours (105°06.6’). Words five and seven indicate the “hemisphere”, where “N” means “North”, “W” means “West” etc. The hemisphere is appended to the end of the numeric portion to make a complete measurement. In a clear form, these can be shown as following:

> Words[3] = Latitude
> Words[4] = Hemisphere for the latitude (North or South)
> Words[5] = Longitude
> Words[6] = Hemisphere for the longitude (West or East)

Time is one of the most important properties of GPS technology because distances are measured at the speed of light. Each GPS satellite contains four atomic clocks which it uses to time its radio transmissions within a few nanoseconds. These atomic clocks can be used to synchronize a computer’s clock with millisecond accuracy. The second word of the $GPRMC sentence, “040302.663”, contains satellite-derived time in a compressed format. The first two characters represent hours, the next two represent minutes, the next two represent seconds, and everything after the decimal place is milliseconds. So, the time is 4:03:02.663 AM. However, satellites report time in universal time (GMT+0), so the time must be adjusted to the local time zone.

The $GPRMC sentence includes a value which indicates whether or not a “fix” has been obtained. A fix is possible when the signal strength of at least three satellites is strong enough to be involved in calculating your location. If at least four satellites are involved, altitude also becomes known. The third word (Words[3]) of the $GPRMC sentence is one of the two letters: “A” for “active”, where a fix is obtained, or “V” for “invalid” where no fix is present.

GPS devices analyze receiver's position over time to calculate speed and bearing. The $GPRMC sentence also includes these readings. Speed is always reported in knots, and bearing is reported as an "azimuth", a measurement around the horizon measured clockwise from 0° to 360° where 0° represents north, 90° means east, and etc. Knots can be easily converted into kilometer/hour or mile/hour. (A knot is a nautical mile per hour, and a nautical mile is 1.852 km. There are 60 nautical miles (nm) in 1 degree of latitude.)

A checksum is calculated as the XOR of bytes between (but not including) the dollar sign '$' and asterisk '*'. This checksum is then compared with the checksum from the sentence, which is the last 2 characters of the sentence. If the checksums do not match, the sentence is typically discarded. This is okay to do because the GPS devices tend to repeat the same information every few seconds.

As a result, parsing the NMEA 0183 sentences is very trivial, once we understand the standards and their contents. PDA will have no difficulty in parsing these sentences because it does not require complex calculations, etc.

Connecting GPS Receiver with PDA

In our case, the connection between PDA and GPS receiver will be done via Bluetooth. This connection will be a serial connection. COM port selection and baud-rate setting will be done in PDA side with appropriate values for GPS receiver. Then, once the connection is established, our application will read from the COM port and parse the NMEA 0183 strings.

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