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DEVELOPMENT OF A TRAINING PROGRAM FOR ENHANCING THE USE OF ICT TOOLS IN THE IMPLEMENTATION OF PRECISION AGRICULTURE

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Training package 2

GPS Configuration.

Tutor instructions

Authors: UPC

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Note to the teacher: This document contains an extended introduction for the tutor, the exercises of the 'Student guidelines' and the answers in blue color.

1 Introduction

1.1 NMEA

The National Marine Electronics Association (NMEA)[1] has developed a specification that defines the interface between various pieces of marine electronic equipment. The standard permits marine electronics to send information to computers and to other marine equipment. A full copy of this standard is available for purchase at their web site. None of the information on this site comes from this standard and I do not have a copy. Anyone attempting to design anything to this standard should obtain an official copy.

GPS receiver communication is defined within this specification. Most computer programs that provide real time position information understand and expect data to be in NMEA format. This data includes the complete PVT (position, velocity, time) solution computed by the GPS receiver. The idea of NMEA is to send a line of data called a sentence that is totally self contained and independent from other sentences. There are standard sentences for each device category and there is also the ability to define proprietary sentences for use by the individual company. All of the standard sentences have a two letter prefix that defines the device that uses that sentence type. (For gps receivers the prefix is GP.) which is followed by a three letter sequence that defines the sentence contents. In addition NMEA permits hardware manufactures to define their own proprietary sentences for whatever purpose they see fit. All proprietary sentences begin with the letter P and are followed with 3 letters that identifies the manufacturer controlling that sentence. For example a Garmin sentence would start with PGRM and Magellan would begin with PMGN.

Each sentence begins with a '$' and ends with a carriage return/line feed sequence and can be no longer than 80 characters of visible text (plus the line terminators). The data is contained within this single line with data items separated by commas. The data itself is just ascii text and may extend over multiple sentences in certain specialized instances but is normally fully contained in one variable length sentence.

[1] https://www.gpsinformation.org/dale/nmea.htm#GGA

The data may vary in the amount of precision contained in the message. For example time might be indicated to decimal parts of a second or location may be show with 3 or even 4 digits after the decimal point. Programs that read the data should only use the commas to determine the field boundaries and not depend on column positions. There is a provision for a checksum at the end of each sentence which may or may not be checked by the unit that reads the data. The checksum field consists of a '*' and two hex digits representing an 8 bit exclusive OR of all characters between, but not including, the '$' and '*'. A checksum is required on some sentences.

NMEA consists of sentences, the first word of which, called a data type, defines the interpretation of the rest of the sentence. Each Data type would have its own unique interpretation and is defined in the NMEA standard. The GGA sentence (shown below) shows an example that provides essential fix data. Other sentences may repeat some of the same information but will also supply new data. Whatever device or program that reads the data can watch for the data sentence that it is interested in and simply ignore other sentences that is doesn't care about. In the NMEA standard there are no commands to indicate that the gps should do something different. Instead each receiver just sends all of the data and expects much of it to be ignored. Some receivers have commands inside the unit that can select a subset of all the sentences or, in some cases, even the individual sentences to send. There is no way to indicate anything back to the unit as to whether the sentence is being read correctly or to request a re-send of some data you didn't get. Instead the receiving unit just checks the checksum and ignores the data if the checksum is bad figuring the data will be sent again sometime later.

There are many sentences in the NMEA standard for all kinds of devices that may be used in a Marine environment. Some of the ones that have applicability to gps receivers are listed below: (all message start with GP.) (the bold sentences are the most used)

AAM - Waypoint Arrival Alarm
ALM - Almanac data
APA - Auto Pilot A sentence
APB - Auto Pilot B sentence
BOD - Bearing Origin to Destination
BWC - Bearing using Great Circle route
DTM - Datum being used.
GGA - Fix information
GLL - Lat/Lon data
GRS - GPS Range Residuals
GSA - Overall Satellite data

GST - GPS Pseudorange Noise Statistics
GSV - Detailed Satellite data
MSK - send control for a beacon receiver
MSS - Beacon receiver status information.
RMA - recommended Loran data
RMB - recommended navigation data for gps
RMC - recommended minimum data for gps
RTE - route message
TRF - Transit Fix Data
STN - Multiple Data ID
VBW - dual Ground / Water Spped
VTG - Vector track an Speed over the Ground
WCV - Waypoint closure velocity (Velocity Made Good)
WPL - Waypoint Location information
XTC - cross track error
XTE - measured cross track error
ZTG - Zulu (UTC) time and time to go (to destination)
ZDA - Date and Time

In the link above the explanation of each sentence component can be found in this format:

GGA - essential fix data which provide 3D location and accuracy data.

eg. : $GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,,*47

Where:

GGA	Global Positioning System Fix Data
123519	Fix taken at 12:35:19 UTC
4807.038,N	Latitude 48 deg 07.038' N
01131.000,E	Longitude 11 deg 31.000' E
1	Fix quality: 0 = invalid 1 = GPS fix (SPS) 2 = DGPS fix 3 = PPS fix 4 = Real Time Kinematic 5 = Float RTK 6 = estimated (dead reckoning) (2.3 feature) 7 = Manual input mode

	8 = Simulation mode
08	Number of satellites being tracked
0.9	Horizontal dilution of position
545.4,M	Altitude, Meters, above mean sea level
46.9,M	Height of geoid (mean sea level) above WGS84 ellipsoid
(empty field)	Time in seconds since last DGPS update
(empty field)	DGPS station ID number
***47**	The checksum data, always begins with *

1.2 SNR

https://sciencing.com/convert-decibel-increase-percent-8208377.html :

The SNR units are Decibels, which determine the relationship in signal strength between two sources. When the power of the first signal outweighs that of the second, a loss occurs; this can be desirable, as with the use of carpets to quiet a library, or it can be detrimental, as when a bad cable weakens electrical signals from an antenna on their way to your TV.

Eg of dB use:

« Measure the attenuated signal with the same meter; this is the signal for which you expect a reduction in power. For example, an antenna picks up a radio signal; right at the antenna, the meter measures 20 miliwatts, but the long cable connected to the antenna reduces the power to 5 miliwatts. In this instance, you measure the attenuated signal at the output end of the long cable. Write down the results, labeling them "attenuated."

Solution: Divide the first signal's power by the second signal's power to find the ratio of the two signals. For instance, if signal A has a power of 20 mW and signal B has a power of 5 mW: 20/5 = 4. Take the log of the the ratio of the signals by pressing the log button on the scientific calculator. For instance: log 4 = 0.602. Multiply this answer by 10 to find the decibels. For the example: 0.602 x 10 = 6 decibels (dB). »

Signal-to-noise ratio numbers are all about the strength of the desired signal compared to the unwanted noise. The larger the number, the more the desired signal "stands out" in comparison to the noise, which means a clearer transmission of better technical quality. A negative number means the noise is stronger than the desired signal, which may spell trouble, such as a cell phone conversation that's too garbled to understand. For a fair-quality voice transmission such as a cellular signal, the SNR averages around 30 dB, or a signal that's 1,000 times stronger than the noise. Some audio equipment has an SNR of 90 dB or better; in that case, the signal is 1 billion times stronger than the noise.

If your signal and noise measurements are already in dB form, simply subtract the noise figure from the main signal: S - N. Because when you subtract logarithms, it is the same as dividing normal numbers. The difference of the numbers is the SNR. F*or example: you measure a radio signal with a strength of -5 dB and a noise signal of -40 dB. Then the SNR = -5 - (-40) = 35 dB.*

Thus we have two formulas to use:

SNR1 = Signal (W) / Noise(W)

SNR (dB) = 10 * log (SNR1) = Signal (dB) - Noise(dB)

1.3 GNSS RECEIVER

There are many GNSS devices that you can use to record track logs. This includes dedicated GPS loggers, to smartphones with built in GNSS (many phones simply call this "GPS"), and everything in between. As you might expect, the quality and feature set of the GNSS receiver you use can greatly effect the accuracy of your recorded track logs. The following areas are of particular importance.

https://wiki.openstreetmap.org/wiki/Accuracy_of_GPS_data

1. GNSS systems the device can receive

Many modern devices are capable of receiving numerous GNSS systems at the same time. GPS receivers were the first systems capable to do that, but today, many systems are. This includes that they can receive signals from GPS, Galileo, QZSS, Beidou, and so on. The more systems a device is capable of receiving, the more resilient it will be when recording position and traces.

2. GNSS frequency bands the device can receive

Historically, consumer GNSS devices were only able to receive in what is known as the Upper L-Band, in the 1500 MHz range. In the Upper-L Band, GPS has the L1 signal, Galileo has E1, and GLONASS has G1. Most GNSS receivers that can receive only Upper-L Band will generally discuss maximum accuracy of about 3 meters. However, some new to market GNSS devices can leverage the newest Lower-L Band GNSS signals, represented by L5 in GPS, G3 in GLONASS, and E5a and E5b in Galileo. These newer signals are broadcast in the 1100-1200 MHz range; they penetrate structures more easily, and are less prone to reflections; plus, an additional band allows for correcting for atmospheric effects. Being able to receive both bands in a GNSS device is a huge advantage, and devices that do so advertise accuracies as high as 30 centimeters (rather than the legacy 3 meters). GNSS devices that do this are almost always referred to as "Dual band GPS" or "Dual band GNSS". If you plan to use a device to do GNSS/GPS traces, buying a dual band device if possible will provide significant opportunity for higher accuracy.

3. Antenna

Most obviously, a good antenna (also known as aerial) is required in order to detect the message signals coming from GNSS satellites. The strength of a GNSS signal is often expressed in decibels referenced to one milliwatt (dBm). By the time a GNSS signal has covered the distance from a satellite in space to Earth's surface, the signal is typically as weak as -125dBm to -130dBm, even in clear open sky. In built up urban environments or under tree cover the signal can drop to as low as -150dBm (the larger the negative value, the weaker the signal). At this level some GNSS devices will struggle to make an initial signal acquisition/fix (but may be able to continue tracking if a signal was first acquired in the open air). A good high sensitivity GNSS receiver can acquire signals down to −155 dBm and tracking can be continued down to levels approaching −165 dBm.

4. Number of simultaneous GNSS receive channels

As described in the GPS lecture, 3 visible GPS satellites, in theory provide all the data you need to calculate a reasonably accurate location. In practice, however, signals must be received from a minimum of four GPS satellites in order to correct for errors: the more the better. Modern GNSS receivers have enough "tracking channels" to follow many satellites at once, and can typically do so across multiple GNSS providers. More simultaneous receive channels are useful for overall accuracy, to reduce the time it takes to get an initial fix (cold start) and to reduce power consumption.

5. Position algorithms

To calculate the distance the GPS receiver is from each satellite, the receiver first calculates the time that this signal has taken to arrive. It does this by taking the difference between the time at which the signal was transmitted (this time is included in the signal message) and the time the signal was received (by using an internal clock). As the signals travel at the speed of light, even a 0.001 second error equates to a 300km inaccuracy of the calculated distance! To reduce this error level to the order of meters would require an atomic clock. However, not only is this impracticable for consumer GNSS devices, the GPS satellites themselves, in particular, are only accurate to about 10 nano seconds (in which time a signal would travel 3m). It is for precisely this reason why a minimum of four satellites is required. The extra satellite(s) is used to help correct for the error. Although rarely discussed at the consumer level, it is therefore important that your GNSS receiver includes good error correction algorithms.

1.3.1 POSITION OF SATELLITES

As noted above, generally the more satellites used in calculating your position the greater the level of accuracy. As GNSS system satellites orbit around Earth, the number of satellites in view (under optimal conditions) naturally fluctuates. Obviously the position of the satellites is completely out of our hands, however it is worth recognizing this as a factor influencing accuracy.

Some GNSS receivers can display the number of satellites currently in view, the GNSS system a given satellite is a part of, and satellites' positions on a radar type diagram. On some receivers this can be prominently found in the within the standard menus, however on others it may be within a "hidden" or "debug" menu. Unfortunately with hundreds of GNSS receivers available, it is impossible to provide documentation for all devices - please refer to the manual that came with your device or try searching online. Smartphone apps with this "satellite view" feature are commented in the practice section.

2 Practice

There is another concept to understand before the practice. The "visibility" of a satellite, or when we can "see" a satellite. By this terminology, we do not mean that we can, with the unaided eye, see the satellite (although it is sometimes possible to do so, especially when the Sun glints off it). We use the term "visibility" and "seeing" to mean "to have an unobstructed view of." Since the GPS satellites orbit the Earth in a non-geostationary orbit, they will rise and set. After they have set, for example, they are below the horizon and therefore "not visible." We cannot "see" satellites below the horizon. After they rise, satellites are above the horizon and thus potentially "visible."

Sometimes, even after satellites rise, their view is obstructed. Sometimes a building or tree will get in the way. That is usually not a good situation. When you perform the experiment, try to stay away from such obstructions like buildings or trees. You want to maintain good sky visibility so that you can see as many satellites as possible.

2.1 GPS test app

Download the smartphone app "GPS test" and answer the following questions:

- Which satellites net do you see? You can scroll the screen to see the satellites signal section and see all of them. In Europe should be GPS, GLONASS and maybe an SBAS.

- Which satellite net is giving better signal? Notice the shape that represents each net (circle/triangle...), Disable and enable satellites net to check the accuracy between them. Should be GPS.

- How many satellites did you see in the constellation map? How many is the app using to determine your position? Will depend on each mobile antenna.

- There is any difference between your classmates display? Why is this difference? Due to the phone antenna and its specifications.

- Cover the phone with somthing metalic (aluminim paper should be brought), which accuracy do you have now? There is any difference from before? Should be, the GPS waves are very weak, be care to cover you antennas!.

- If we get a SNR of 55dB* for a certain satellite how much Noise do we have if we know that the Signal power on the earth surface for this satellite is about 1*10-12 W.

The decibel (symbol: dB) is a unit of measurement used to express the ratio of one value of a power(in this case the signal power) or field quantity to another (in this case the noise power)

Solution => 55dB = 10 log [(1*10-12 W) / NoisePower]→
NoisePower = (1*10^ (-12)) / 10 ^ (55/10) = 3,16*10^(-18)

2.2 GPS NMEA app

Download the smartphone app “GPS NMEA” and answer the following questions:

1. Click on «Sat. Positions»; Compare and confirm that the satellite seen by this application are the same as the other app and click the back button.
2. Click on NMEA Raw Data, Save some data on a *.txt file
3. Go too your Android file browser and try to find GPSNMEA folder.
4. Transfer it to your computer (i.e.: by WhatApp or mail) in *.txt format
5. Open the file with excel
6. Then extract the position, UTC time and all the observable information from the GGA sentences.