GPS for Global Performance System
new aspects of time and space in art

Marcin Wierzbicki
Computer Music Studio
Chopin Academy of Music
Okolnik 2, 00-368 Warsaw
Poland
email: mawi@chopin.edu.pl

Marek Choloniewski
Studio for Electroacoustic Music
Cracow Academy of Music
Tomasza 43, 31-027 Cracow
Poland
email: studiomch@wp.pl

Abstract
The subject of the text is a presentation of computer system dedicated to outdoor interactive activity. GPS receiver, the engine of the system, describes object position and follows its motion in 3D space (with the only limitation to the satellite signal, so practically available on the whole surface of the globe). The use satellite signal opens new applications of the interaction, not available through early methods: video, photocell, infrared, ultrasonic systems[1]. First of all it works for long distances (as well out the visual scope). It is also quite precise working with high resolution (several meters). It is especially useful for large scale outdoor spaces (urban projects), as well as can be used as an extension for the short-distance systems.

Introduction
The first GPS application for interactive artistic purposes was designed during *ArtBoat* environmental project in 2000. The idea was to measure the position of the boat sailing on Vistula River, its speed, distance to the bottom of the river, temperature of water and air, speed of wind, light during night and day (with, or without clouds). All these natural parameters are translated to the sound sequences performed live during whole project in one of the cabin of the boat. In fact, it was designed as a giant sound installation controlled by natural parameters of the boat.

Seeking for the best method of the boat scanning, we've considered GPS device used mainly for navigation purposes. Choosing GPS device as a main sensor for our art projects, we introduced new field of art exploration called *GPS-Art*. We founded also the basic idea of a large scale art exploration. Confirming the official regulations in American law on May 2, 2000 according to the range of the GPS frequency band available for civil purposes (Selective Availability) the range resolution decreased from 100 m to 15 m. Another official regulation stabilizing use of GPS was confirmed on ICMC conference held in Berlin in 2000, partly considering interactive purposes. Most of the projects were dedicated to extended space and higher resolution and precision of interactive systems. There is an obvious contradiction to both theses[2], so most of the projects presented on ICMC in 2000 were kind of compromise between 2 factors.[3]

On the contrary, GPS System can work on largest scales (whole globe) with high resolution (some of the system up to 3 m), which isn't dependent of the size of performance's area.

Basics of Global Positioning System
Basic idea refers to the measurement of the distance between receiver and several satellites chosen from 24 going around Earth 2 times for 24 hours. Particular orbits of satellites, their direction and speed are precisely assigned. There is an exact 24-hours schedule, assigning the time and space position of the satellites stored in ROM memory of each GPS unit. The measurement is a permanent process, comparing incoming signals with the information stored in a memory of GPS unit. Time distance of incoming signal multiplied by the speed of the signal equals distance of GPS receiver from the satellite. Comparing distance from at least 3 satellites, GPS is able to assign its own position. Considering precision of electronic (quartz) clocks used in civil GPS devices and comparing them with the precision of the satellite's (atom) clock, GPS unit has to make a correction using at least one extra satellite.

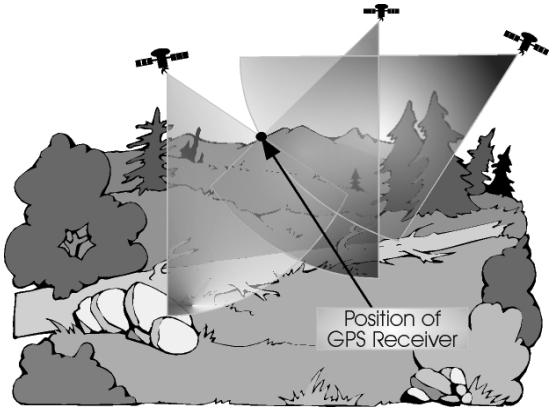

Figure 1. Evaluating position of GPS unit in 3D space as a distance from three satellites.

[1] Compare: [11], p. 129; [13] p. 138; [10], p. 141.

[2] Discussed in [13], p. 138, where "The ability of a work to foster social interaction is an artistic decision that may be limited by a given space, or the capabilities of software and sensors".

[3] See also: [12], p. 277.

Measurement from 3 satellites (called 2-Dimension Navigation) gives a horizontal resolution of 10-20 meters and vertical resolution of 20-80 meters. Measuring signal from 4 satellites we are obtaining 3-D resolution with horizontal resolution under 9 meters and vertical up to 25. More satellites for simultaneous measurement increase the resolution of the system. Testing GPS unit model *Garmin GPS 12* we were checking 9 satellites (quite typical for Europe), and were obtaining EPE (Estimated Precision Error) of 3 m resolution and making long-term measurements with resolution of 10 m.

Currently available resolution of GPS is too small to obtain measurements of a small motion of different parts of the body (gesture control), but can be used successively in a range of several meters on stage. However the main application of GPS lies in bigger scales of kilometers and it is the only device working in such a circumstances, measuring the movement of car, boat or airplane. And working in such large scale fields the resolution of 3 m is relatively very small.

There is a chance to decrease the error of measurement below 2 m using DGPS (differential GPS). It is a circuit of 2 receivers. One of them is fastened to precisely assigned (and known) position. The second GPS is moving, receiving signal from satellites and from the first receiver. Additional signal from preciously assigned place lowers the resolution of EPE to 2.1 m. DGPS system will be replaced between 2003 and 2013 by a new III GPS systems, using new frequency bands (besides current – L1, L2 till 2005, and L5 till 2012) and new transmission codes (M code). Another solution is a new concept of WAAS (in Europe known as EGNOS) using series of extra stable transmitters (kind of stationary DGPS units with large access). The system will be ready in 2008. Use of III GPS will be visible in form of 1 m resolution and translation of each movement of the performer on stage.

NMEA – how to get connected with computer

In 1980 National Marine Electronics Association assigned first standard of data transfer between electronic devices. Nobody considered the connection between GPS and computer; the NMEA 0180 protocol was used to combine loran (device informing about deviation of the main course) with autopilot. So both, NMEA 0180 and 0182 was used only for the deviation from the main course of data transmission. In 1983 NMEA 0183 (currently used version 2.0) extended several instructions describing course parameters (point position, latitude, speed etc) and the information about weather parameters: wind, temperature, and air pressure.

Electrically interface NMEA is quite close to RS-232 – serial port still often used in computer world. But it works with different protocol – EIA422, what is the main obstacle. However certainly GPS unit should work properly with PC COM port, we can not easily connect it to the serial port of Macintosh computer. Mostly GPS wouldn't to work connected to the printer port. Also plugging it in to the modem port not ever could work properly. With extraction of pin 8 in the serial cable it is possible (all details you can find at [5]). GPS working under NMEA 0183 2.0, with 4800 baud speed, 8-bit data, 1 bit stop with parity, will transmit NMEA messages in form of ASCII codes, where each data enters by $, 2-letter symbol assigning type of device: (for example GP – GPS, LC – Loran-C), 3-letter mnemonics (i.e. RMC – Recommended Minimum GPS, GSV – Satellites in View), and series data fields interconnected by commas. Standard uses data with variable length and makes gaps of unnecessary data, so the length of particular message (and fields of data inside) is not constant. It means that the only correct form of NMEA message interpretation is commas counting (not characters). In case of lack of the symbol empty space is calculated by commas. Each message looks as follows <CR><LF> anticipated (optionally) by symbol * and 2-bytes (in hexadecimal form) checksum of message (XOR).

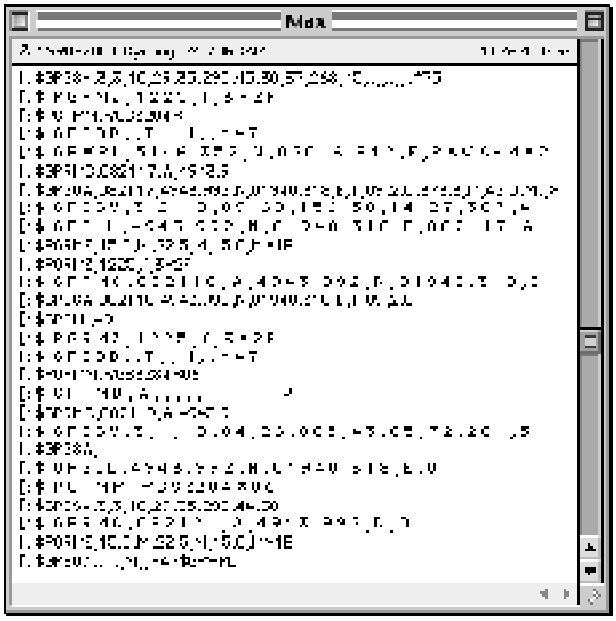

Figure 2. List of NMEA Messages outputted *by Garmin GPS 12* receiver into Max Window.

Max Implementation

With exact description of NMEA protocol we are able to realize an application, which can read GPS data on serial port, make interpretation and processing.

Our main project is a musical one, so we decide to use Max program to operate GPS. Entirely we created a simple interface, receiving message $GPRMC (Recommended minimum specific GPS/Transmit data) from *Garmin GPS 12*. This message is sent every 1 sec. It includes basic geographic parameters of the object, speed, course, current date and time and warning, if receiver is out of the satellite access. Reading and interpreting all those parameters was the entire position for our project GPS-Trans 2. The basic idea was to follow a car moving through the Krakow city, receiving its position and generating musical phrases. In this very moment we encountered another problem of wireless communication.

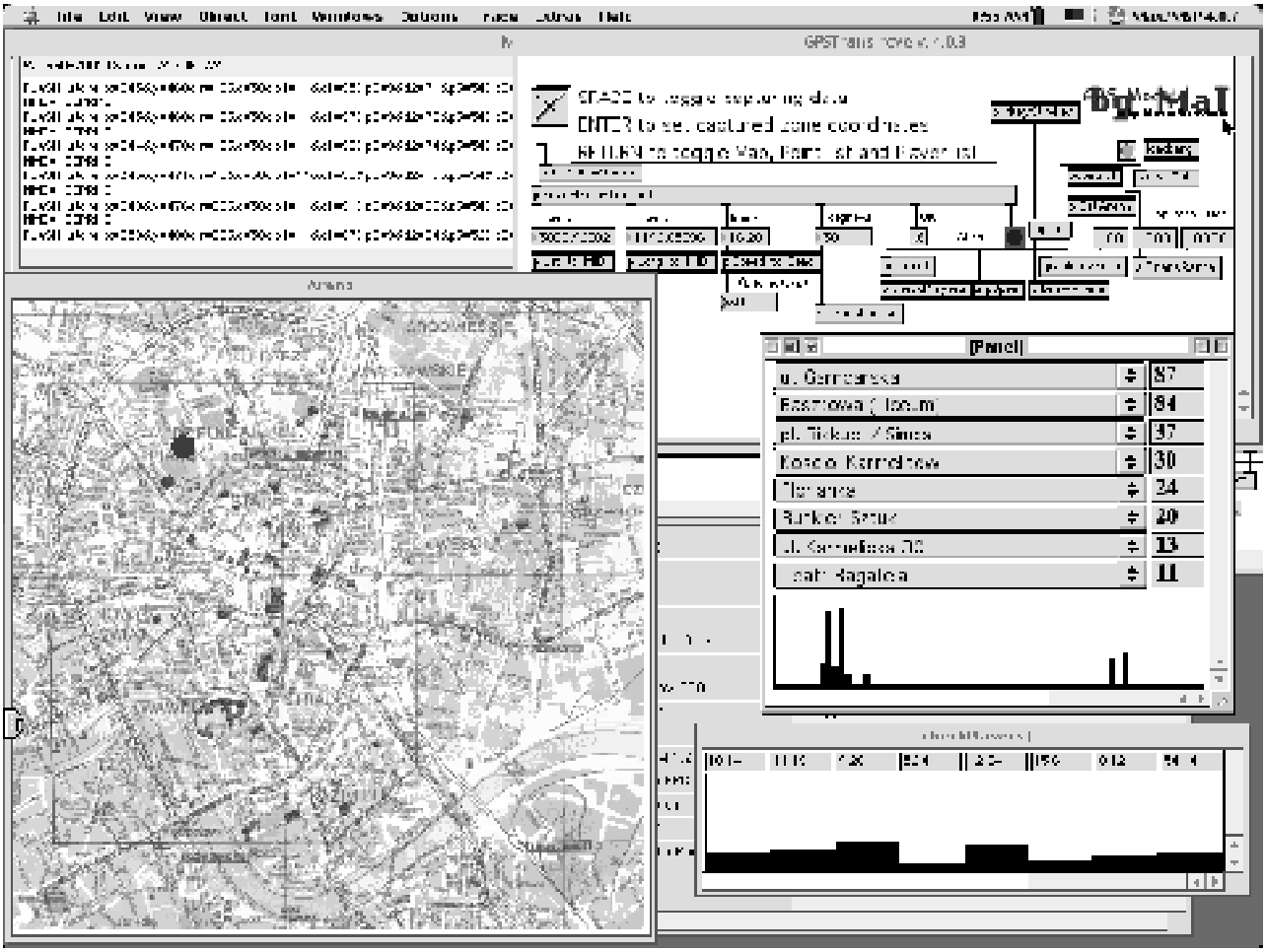

Figure 3. NMEA Receiver Module written in Max 4.0, which has been used during *GPS Trans 2 & 3*.
Screenshot presents Map Window (purple dot shows current position of car), window with list of Nearest Points, and Players Window, which displays volume of currently played back samples.

Receiving NMEA Stream Wireless

The portable musical system consisting laptop computer connected with GPS-unit was not hardly installed in a car. But to invite audience in the same vehicle was another challenge, even with the idea of a bus rent. So the only solution was to use a wireless system of communication able to send signal from a moving car to the auditorium. With the use of mobile, wireless cell phone we were not able to send an audio signal. Transmission speed of 9600 baud was too low, but was fast enough to send NMEA data. Finally we created a GPS-Phone hybrid system combining *Garmin GPS 12* unit, PowerBookG3 laptop computer and Ericsson mobile phone. The additional advantage was the fact that the laptop computer was filtering, interpreting and transmitting only those data from GPS, what we planned use. Transmission to the specific IP address was realized using UDP (TCP/IP) format supported by external objects of Max written by Matt Wright (CNMAT, Berkeley) found at [1].

Max objects were designed to be quite stable. Mobile phone was connected to the computer through serial cable (even IR transmission was considered, tested with quite good results). In the same moment all data were receiving by computer system in a Studio of the Krakow Academy of Music. In this form the car was the performer of the audiovisual piece, and GPS receiver appeared to be kind of interface controlling position of its movement.

Past Projects: *GPS Trans 2 & 3* – an artistic idea

Interactive city map appearing in front of the audience was the main principle of GPS-Trans. Center of Krakow was divided for 41 zones. Each zone was connected with selection of pictures. 68 special points-centers were connected with series of prerecorded audio samples representing different regions of the city. Exploration of the car was interactively synchronized with different regions of the city, triggering and controlling series of images and samples. Player module was designed in a way that the car was playing up to 4 (in *GPS-Trans 3* up to eight) sounds/samples with the volume level reflecting the distance to certain point. The result was the illusion that the audience gathered in the listening hall are all coming closer or getting out of certain regions of the city. In Trans 3 we add the speed of the car controlling transposition of the samples and the frequency of the images rotating on the screen. As a result we were getting illusion of the real speed of the car.

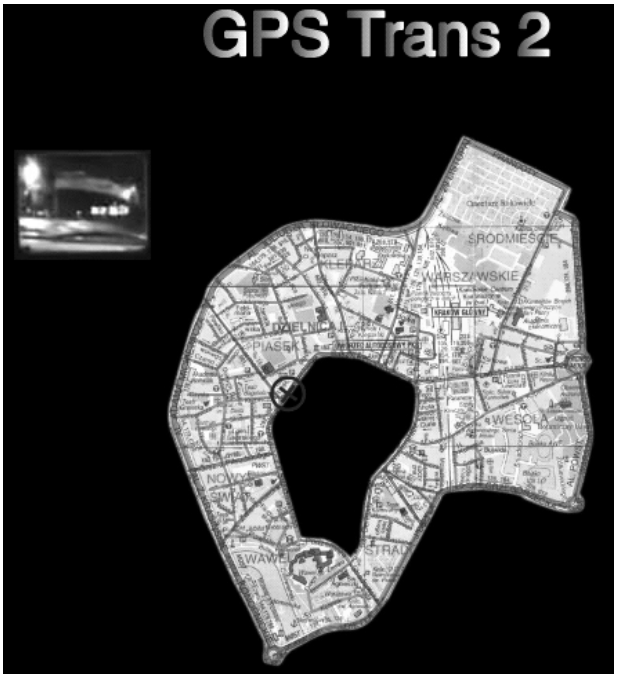

Figure 4. Part of the *GPS Trans 2* screen.
Everyone who visit www.gps.art.pl during the performance has been able to see cutout of map of Krakow with the running "cross-point" (symbolizing car), to observe slide show (left-upper side of the screen) and to listen sounds generated interactively according to the car movement.

Another principle was to create wide access to the audio-visual map of Krakow. Internet was just the right choice. Our decision was to make audiostreaming from Max program to RealPlayer and from Max to Flash (for slide-show). Both transmissions were essential for all web observers/receivers. *GPS-Trans 2* had quite limited response. *GPS Trans 3* was an international project and was a part of Internet project *Cathedral* composed and coordinated by William Duckworth, and during this project was available everywhere on the globe through 2 hours ongoing Internet transmission at www.gps.art.pl. In this way Krakow city was explored and presented everywhere, using such a very sophisticated and original method of art creation.

Future Projects. *ArtBoat* and other

Every year we are trying to realize *ArtBoat* project fixing step by step different problems. Currently designed NMEA Interface written in Max is an universal tool receiving position of the object, distance to the target, latitude, position of satellites and other data as a complete set of messages of *Garmin GPS 12*. The Interface has an open structure, which means that we can add interpretation of new messages, for example MTW (water temperature), VHW (speed of the water), VWR (speed of the wind), DBT (distance to the bottom of the river). All those parameters can be measured and interpreted to

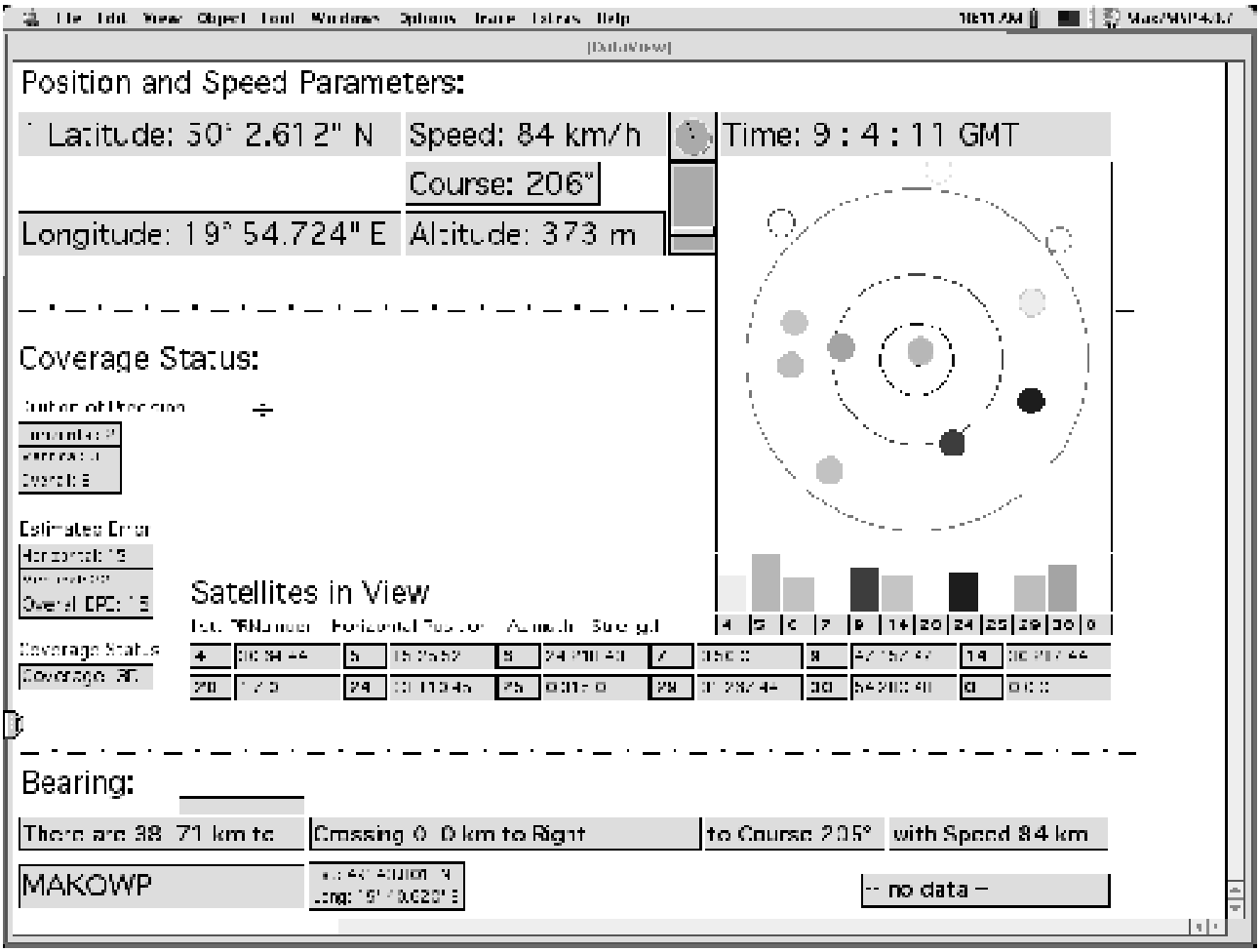

Figure 5. The Complete NMEA Interface done in Max. On the screen appears all data send by *Garmin GPS 12* unit.

Quite interesting artistic results we can obtain adapting opposite methods of use the GPS unit. Instead of measurement of object position, we can check position of satellites. Their trajectories are constant in global meaning, but for the random access can get interesting effects. In case of long-term, continues sound structures, long-time projects, the position of satellites can be an advantage and can be used with a big success. Another factor is connected with the power of the signal from satellites, limited and filtered by clouds, buildings, tries be found on the way of the moving object, which are covering part of the beams of the signal from satellites.

Additional idea is connected with the feedback response from the listener(s)/observer(s) on Internet. We were considering one-way transmission of data from the car to the server. We can also send data to the car, so the response from any computer connected with the web is possible. In fact we can send the message to the driver with certain idea to speed up, or slow down driving, or to change direction, by request of the majority of audience. In this case we are quite close to the *Reality Game* idea with the full form of interaction[4]

Another idea of *GPS GlobalMix* is a kind of performance for many participants using independent GPS devices. It seems to be quite complicated from technical point of view but the current dynamic development of many devices make this opportunity quite possible. We have already access to the PCMCIA GPS cards, GPS modules to the palmtops, as well as mobile phones with build-in GPS's. Simplicity of the NMEA protocol gives also opportunity to realize GPS projects with jMax, PureData, PDA's applications and many other systems.

Troubleshooting

We solved most of the problems with receiving, transmission, interpretation of GPS signal, as well as the right music translation. All new concepts are not easy, but open structure of the system seems to be unlimited. System works fine in all open spaces, even quite limited (for example by car's chassis). One of the biggest problems of GPS is indoor space, where signal of satellites is completely muted. Another one is the resolution of the system, which (as we explained above) will be consequently improved. So in a near future we will be able to realize most advanced interactive project[5] with the use of GPS. Even today there is unlimited access to the GPS devices. There are mounted in cars, mobile phones, boats, airplanes, they are smaller and cheaper, so commonly available.

Conclusions

The civil use of GPS system is improving quite quickly. In a near future it will be available for general interactive projects any kind. Present version of NMEA interface implemented in a lot of navigation devices offers measurement of wide range of the environmental stimuli.

[4] Some aspects of reality show was discussed in [9].

[5] Without limitations of the interface described a/o in [10], [11] and [12].

List of some interesting NMEA 0183 Messages	
ALM	GPS Almanac Data
APB	Autopilot sentence "B"
BOD	Bearing - Waypoint to Waypoint
BWC	Bearing & distance to Waypoint - Great Circle
BWR	Bearing & distance to Waypoint - Rhumb Line
DBK	Depth Below Keel
DBS	Depth Below Surface
DBT	Depth below transducer
DPT	Heading - Deviation & Variation
GGA	Global Positioning System Fix Data Time, Position and fix related data fora GPS receiver
GLL	Geographic Position - Latitude and Longitude
GRS	GPS Range Residuals
GSA	GPS DOP and Active Satellites
GST	GPS Pseudorange Noise Statistics
GSV	GNSS Satellites in View
GTD	Geographic Location in Time Differences
HDG	Heading - Deviation & Variation
HDM	Magnetic Compass Heading
HDT	True Compass Heading
MTW	Water Temperature (°C)
MWD	Wind Direction & Speed
MWV	Wind Speed and Angle
R00	Waypoints in active route
RMB	Recommended Minimum Navigation Information
RMC	Recommended Minimum Specific GPS data
ROT	Rate Of Turn
RSA	Rudder Sensor Angle
RSD	RADAR System Data
TXT	Text Trasmision
VBW	Dual Ground/Water Speed
VDR	Set and Drift
VHW	Water Speed (knots) Magnetic and True Compass Heading
VLW	Distance Traveled through Water
VPW	Speed - Measured Parallel to Wind
VTG	Track Made Good and Ground Speed
VWR	Apparent Wind Speed (knots) and Direction
WPL	Waypoint Location

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