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Chapter 1. Introduction

Nowadays, companies focus on a worldwide perspective due to the increasing globalization in recent years. Therefore, a variety of employees is needed to fulfill the global market demands. Additionally, the majority of working methods to solve problems shift towards a more team based approach, in which different skill sets, backgrounds and point of views are required.

Realizing these requirements, the Engineering College of Copenhagen founded the European Project Semester (EPS). The program offers the opportunity to learn to work in teams in an international, multicultural and interdisciplinary atmosphere and thereby providing the students with the proper knowledge of the future work life. This year the EPS at the *Escola Politècnica Superior d'Enginyeria de Vilanova I la Geltrú, Universitat Politècnica de Catalunya* is offered for the fourth time.

The European Project Semester gives students the possibility to work in a team with the same goal. Besides the different backgrounds, the young engineers have to manage the project development by demonstrating the skills gathered during the studies. Therefore, the variety of studies does not create distance during the work process. Moreover, the diversification of ideas leads to discussions and debates which will enrich each member's knowledge. Hence, the project offers the opportunity to improve greatly in all the aspects possible.

The biggest hurdle to overcome is an effective communication, because it is fundamental to establish a good team work. For this reason, not only does everyone have to get a proper usage of the English tongue in order to share their opinions and develop the project, but also each team member needs to be confident to express his or her ideas and criticism. Therefore, a good and friendly relationship as well as respect for one another must be established.

This paper deals with the collaborative project 'Automatic Asset Tracking System', which is performed in cooperation with the AENA (*Aeropuertos Españoles y Navegación Aérea*) Company, in particular with *El Prat de Llobregat - Barcelona Airport*, and the *Escola Politècnica Superior d'Enginyeria de Vilanova I la Geltrú*. The Aena Company offers the opportunity to work on a pioneering project for the biggest airport in Catalonia. In addition to that, we received significant support from our supervisor Vicenç Parisi. The project resembles a great challenge for everyone involved.

1.1. Background

In 2007, the Airport of Barcelona acquired a new Terminal, in order to offer a larger variety of flight opportunities /destinations, as well as the growing number of customers in the Air Travelling Sector. This expansion led to an increase of 6.5% to a total of 29.2 million passengers in 2010 compared to 2009. Today the Barcelona airport is considered the 10th busiest airport in Europe.

As a result of this development, the number of supporting vehicles in the airport has increased dramatically. Today, over 1000 buses, cars, trucks, emergency cars and other vehicles are needed to run an airport safely and smoothly. However, the coordination and traffic control has become harder and harder, due to the lack of an electronic surveillance system.

Until now, the airport is surveying their vehicles with the help of ground personnel communicating the information to the Headquarters. This solution, however, is not very accurate or efficient. For this reason, the AENA Company started to think about a better way of handling this problem. As a result of this, a new project was founded with the title 'Automatic Asset Tracking System'. This project was given to the EPSEVG for the European Project Semester.

Considering the fact that over one thousand vehicles are moving and surveying the Airport of Barcelona, a system that could be implemented must have a high performance rate and reliability. However, no matter how good the system is, it will be difficult to monitor each and every car not only because of interferences or system limitations, but also for the controller to spot that many vehicles at once. Hence, it would be better to decrease this number by any means possible. This leads to the suggestion, that there is no reason to control all the airport vehicles just those that can be involved in an accident or represent a high risk for the safety of the airport. Therefore, the vehicles, which should be monitored, are all the cars that have access to the airstrip like: airplane tugs, fire trucks, maintenance cars, etc.

1.2. Project Specification

The project aims to search for an existing system or develop a new solution, which is able to track all vehicles moving in the airport area. Furthermore, the positions should be available once every second in order to monitor the cars in real time.

Another very important specification is that the displayed position needs to be within 5 meters of the actual location in order to clearly see if a vehicle is on a real street, on the runway or on a field. This information can be used to prevent accidents or collisions inside the surveillance area. Therefore, the accuracy of the entire system has to be ± 5m.

The next requirement is that the area, which needs to be covered, has a maximum range of 10 km. This enables the possibility that the limits of the area are clearly stated and the software and maps can be adjusted to these facts.

Since no employee will have any experience with a newly developed system and in order to make the handling of it as user friendly as possible the software part of the project also has to take some facts into consideration.

Firstly, the interface should be easy to understand and operate in order to enable everyone to use the system without a special training. Secondly, the software should be written in an open-source programming language to easily implement the system without buying any licenses or patents. Moreover, open-source based programs can be improved and evolved more smoothly in comparison to licensed programs or languages due to the larger information freely available on the internet. Finally, the software should run under every operating system, like Linux and Windows. Furthermore, the program needs to be fast and accurate to fully support the hardware features and to be refreshable once every second.

All these demands have to be combined in a system, which is not only highly reliable, efficient and accurate, but also has to be very cost-efficient as well. Hence, a comparison between already existing systems and the system in development has to point out the benefits of creating a new system and spending a lot of money for the research and development. Thus, the system should always try to spend as little as possible on parts or materials, which is why an open-source software is very useful.

1.3. Plan of Development

To guide the reader through the development and research, the report is divided into the following sections.

I. **State of the Art.** In this section an overview of the current state of the art systems for monitoring and tracking vehicles or objects is given.

II. **Hardware Implementation.** Contained in this section is a detailed description of the components used to develop the new system.

III. **Software Development.** This section presents the design and development of the software used to run and operate the system.

IV. **Field Tests.** In this part the results of the tests performed to confirm the functionality of the system are explained in detail.

V. **Economic Evaluation.** A cost analysis in comparison with other systems is presented in this section**.**

VI. **Future Improvements.** This section lays out the future improvements and innovations of the new system.

VII. **Conclusion.** The final section is a summary of the founded results and a critical review of the entire project.

Chapter 2. State of the Art

There are already several existing solutions in other airports around the globe to track vehicles. Also, the biggest users of such systems are companies, who need a fleet tracking system to monitor all their trucks and cars on the road. In the following sections, the state of the art of current systems used to track and control cars or objects, as well as the new technology implemented in the developed system, is described.

2.1. ZigBee/GPS

ZigBee is a wireless mesh networking standard. In combination with a GPS device it could function similarly to our solution. The benefit of a ZigBee network is its low–cost and low-power consumption.

As a result, the low-cost enables a wide spread of this technology in wireless controls and tracking or monitoring solutions. In addition to that the low-power consumption promises a better usage of smaller batteries with a higher charge level. The ZigBee network is also known for its high reliability.

Even though all these attributes would fit perfectly in our concept it has one major flaw. In order to send the data over more than 200 meters a hop is needed. Therefore, we would need a complete mesh-hop network around the airport area, which would lead to bigger cost due to the equipment needed as well as an increased sending time. Consequently, our data would be send every second but arrive with a delay at the receiver. Furthermore, the data volume, which 1000 vehicles would produce would go beyond the recommended and supported bandwidth of ZigBee modules.

2.2. ADS-B

Automatic Dependent Surveillance-Broadcast (ADS-B) is a surveillance technology for tracking aircrafts as part of the Next Generation Air Transportation System (NextGen). In addition to that, some airports also provide their ground vehicles with this system to keep track on all the activity on their landings fields, terminals and the wider airport area. The ADS-B system is used in the airports of Frankfurt, Helsinki and other big airports. This solution uses ADS-B Out Transponders, which will need to be installed in every modern airplane, at least in the US. It can track airplanes or vehicles faster and much better than the radar system and it also functions in any weather condition. It sends data to the ADS-B In Station at the airport towers. This information, which is broadcasted every second or even faster, includes altitude, heading, speed, and distance to other airplanes or vehicles. However, this system is relatively new and the needed technology is not that wide spread. The United States try to have the system completely running by 2020. Nonetheless, this solution would also only have material and installation costs, but no service fees or additional costs. It is definitely a system, which will gain popularity in the future and is as cost efficient as any system can be.

2.3. GPS/GPRS/GSM

The GPS device in combination with the GPRS function is quite similar to our new found solution. The GPRS would take the place of our radio frequency device. The General Packet Radio Service (GPRS) aims to send data packages to GSM and UMTS networks. Nonetheless, it needs a SIM card and therefore a telephone contract to send the position. This leads to fixed cost every month of around 10 Euros per car, which will quickly add up. However, this system is able to track assets with a 1 second/location rate, which would meet our demands. In addition to that, there are a lot of different systems available already. This system would be the easiest, safest and most tested/used solution due to the fact, that it is used by a lot of companies, which have a Fleet Managing and Tracking System. On the other hand it is also the most expensive solution considering the long term costs.

2.4. RFID

Radio-frequency identification (RFID) is a technology that uses communication through the use of radio waves to exchange data between a reader and an electronic tag attached to an object, for the purpose of identification and tracking. This system, however, is not able to track cars in real time. It is normally used in supermarkets or other stores to read barcodes. Also, the manufacturing business uses it to track their materials throughout their entire production area. This means that the system can rather be used to restrict areas or monitor cars going in or out of a certain area, but not tracking the vehicles in real time on the whole airport area. Nonetheless, this system would have no service fees or additional cost than the installation and material costs. In order to be an alternative this system would need to evolve a great deal. However, this system provides the basic level of communication of the new system, by using those radio frequencies to send the data packages.

2.5. RF/GPS Solution

The State of the Art of the newly invented solution combines the positive aspects of the systems mentioned in the Alternatives section of this report. The new tracking system uses a Radio Frequency Device to communicate not only the characteristic of the object, e.g. the size, speed and classification of the car, but also the position gained from the GPS device. Therefore, the result is a more mobile solution that only uses one receiver. In addition to that, it functions similar to the GPS/GPRS/GSM system, but eliminates the need of a mobile contract, because of the RF-communication.

Chapter 3. Automatic Asset Tracking System

Nowadays, many companies around the world offer automatic asset tracking systems which can meet the demands of the project. As it is mentioned in the previous chapters, the system that is going to be designed will track the location of one thousand vehicles around the airstrip and the area of the Barcelona Airport in real time. Therefore, the system needs to be mobile and able to support the bandwidth needed for such an amount of cars. Consequently, the RFID system and the ZigBee solution are not a fitting choice for the task. Furthermore, the new system should be as cost-efficient as possible and not produce any long term costs. Thus, the GPS/GPRS solution cannot be used for our project.

Finally, after researching the market for other available tracking systems, the choice was made to develop a new system with a mix of the aforementioned solutions. Considering the pros and cons, it became clear that a Radio Frequency technology will be the most appropriate communication system. It was chosen not only due to the low costs of the transmission modules, but also because it does not produce any additional monthly expenses. In order to make the system more mobile than the normal RFID solution we added a GPS device to determine the position. Therefore, the data can be sent from the RF device to one central receiver thus avoiding any fixed checkpoints for determining the position.

Our system is basically composed of a mobile device, which is used to keep track of the current position of the vehicles, placed on the roof of each car. In addition to that, a fixed antenna, which will receive the position, is installed in a central and high position. This combination enables the data to be displayed on a monitor in close proximity to the receiving point.

The mobile device is a plastic box containing all the elements that establish a remote connection. Those elements are a positioning system and a power supply, which is supports this device. The box is designed to maintain the internal elements safe from all weather conditions. Additionally, the case has a magnetic surface at the base which is necessary to keep the device in a fixed position on the roofs of the cars, as displayed in figure 1.

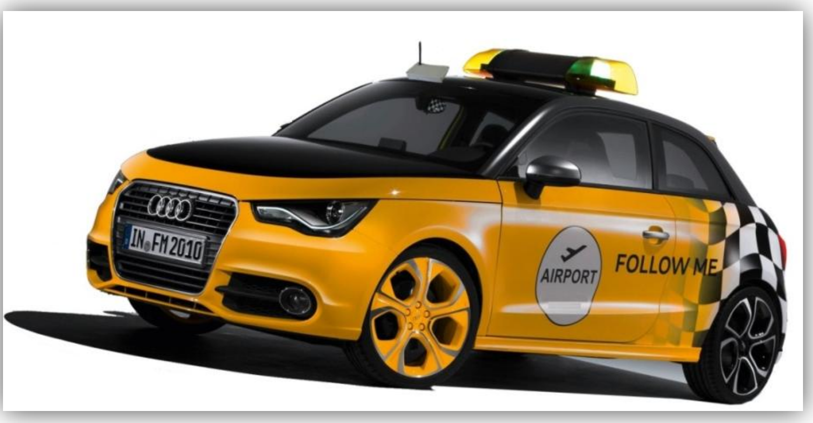


Figure 1. Airport vehicle[1] with the Tracking Device on the roof

[1] The picture shown is not an actual vehicle of the Barcelona Airport.

The antenna will be placed in a strategic point at the area of Terminal 2 of *Aeroport el Prat de Llobregat.* In other words, this element is situated on the roof of the Technical Block Building to eliminate interferences and improve the signal strength. The device is actually a receiver with an external and prolonged antenna attached to it. A long antenna has to be used due to the fact that the fixed module has to be in reach of a Personal Computer (PC), which is located inside of the building.

A transmitter, which sends the information, as well as a receiver are providing the networks communication. Initially, the connection between the two points is made by configuring the two modems properly. Therefore, it is crucial to select the same frequency channel to maintain a virtual connection between the devices. Another very important aspect to take into consideration is the baud rate, because it represents the actual speed in which the data is send. Further details about the hardware are presented in the Hardware chapter, in the Modems section.

Aside of the communication, another important element of the system is the GPS (*Global Positioning System*). The function of the GPS is to determine the mobile device’s actual position, which is composed of the longitude and latitude parameters, at a specific time. Moreover, a significant aspect of the system is that it updates the location every second. In order to transmit all the information collected by the mobile case to the fixed module, the GPS and the transmitter need to be connected to each other. As a result, each second the acquired frames will be sent by the mobile device at a specific frequency channel. This channel should also be used by the configured fixed module.

In figure 2 the Automatic Asset Tracking System is illustrated. On the left side the mobile case, containing the GPS and the transmitter modem, can be seen. On the right side of the picture is an illustration of the receiver connected to the monitor, which will display the location of the trucks at the airport area.

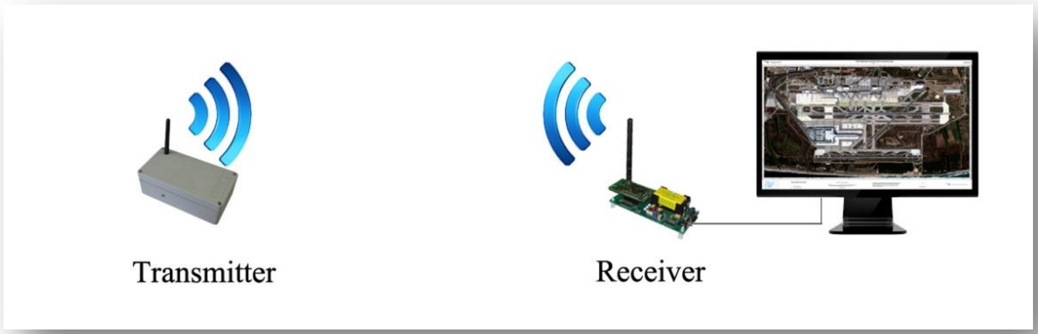


Figure 2. Basic communication network

Taking into account, that the system needs to cover a ten kilometer area, the addition of node router would be recommendable. This new element doubles the possible tracking range making it a very useful accessory. In order to fully reach the best functionality, the router has to be placed in a strategically valuable point. The new structure of the network it is shown in figure 3.

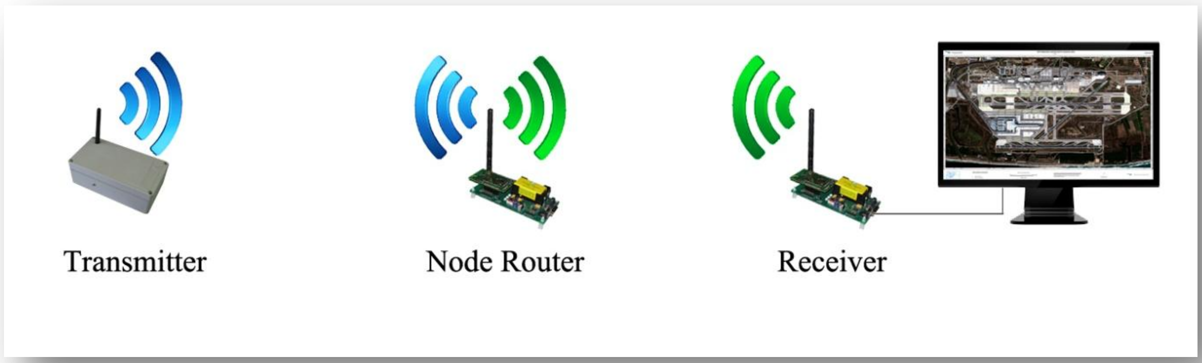


Figure 3. Communication network

No solution that met all the requirements of the project was available at the beginning of the semester. For this reason, a program managing the data had to be created entirely from scratch. In order to present all the information received through the fixed antenna, the modem is connected to the computer’s serial port. Furthermore, the data received is managed by the application that is able to read and analyze the information.

One of the key elements, why this project is made, is that operators should be able to monitor the vehicles from one single screen. Therefore, the application prints a map covering the airfield and additionally, plots all the locations of the vehicles on it, depending on the information received from the devices.

Since the system should be able to handle the locations of at least one hundred vehicles, the program should handle a large amount of data in real-time. Besides the importance of fluency in the program, there are some features that will make the application as user friendly as possible. Therefore, a logging function, recording all the received and interpreted information, has been created. The feature makes it possible for the user to come back and check the log files if something needs to be examined.

Chapter 4. Hardware Implementation

This chapter provides the reader with all the necessary information regarding any technical aspects related to all the hardware components of the system. The materials defined as hardware are all the tangible and physical elements included in the Automatic Asset Tracking System.

The main function of the hardware is to gain the position of a tracked vehicle and to transmit this information to the receiver, where all the information will be interpreted and displayed. Furthermore, due to the requirement to send the data in real-time, it is essential that all the devices are synchronized. Also the system has to be absolutely reliable, because it not only ensures a safer airport environment, but also logs all the files in case of an accident.

In order to determine the position of a vehicle it is crucial to implement a highly accurate GPS (*Global Positioning System*) device. In addition to that, a communication network needs to be established. The network is composed of a receiver, a transmitter and a Personal Computer (PC). The transmitter is integrated within the same box as the GPS to send the acquired position, coordinates and other irrelevant parameters, to the receiver. Nonetheless, the only function of the receiver is to process the information to a Personal Computer, which analyses and processes all the information. Additionally, the communication network operates through different frequency channels, which means that the acquired information has to be sent through an addressed secured mode.

Considering that the aim of the project is to survey the entire airport area, the receiver has to be positioned in a strategic place, preferably as high and free as possible. The same goal applies to the transmitter, which is why it should be placed on the roof of the airport vehicles.

In summary, the system is basically composed of:

- A GPS (*Global Positioning System*)
- A Transmitter
- A Receiver
- A node Router
- A Personal Computer
- Connection cables/ devices

In the following subsection, a description of every device and connection used in order to develop the first prototype will be given as well as an explanation of their essential contribution to our system.

4.1. Global Positioning Systems

The GPS (*Global Positioning System*) is a worldwide navigation system that provides reliable location and time information. Originally it was developed, installed and operated by the Defense Department of the United States of America. This system works in a network of twenty-four synchronized Navstar (Navigation System and Ranging) satellites to cover the entire surface of the Earth. These satellites constantly send their orbital position, the exact time when they are emitting the signal and the positions of the other GPS satellites.

In order to ensure the transmission of an accurate position, four main signals are needed. Those are the communication signals between at least three satellites and another signal form the receiver, which is the GPS chipset placed on the mobile case with the transmitter.

To track a position, the receiver sends an identification signal and a time signature. Using these signals, the satellites synchronize the time signature and calculate the time it took to receive them. Due to the cooperation between these satellites, the proper coordinates are sent back to the GPS device. The data is transmitted as electromagnetic waves with a microwave frequency between 1.2 and 1.645 MHz. This would not be possible without the cooperation of five monitoring stations spread all over the Earth, which control and verify the state of each of the satellites in real time.

Knowing the position of the satellites, the propagation speed of signals and the time the signal needs to reach the receiver, the receiver's position on Earth can be calculated by trilateration. In figure 4 a theoretical view of the trilateration concept is shown. Also, it is a common mistake to confuse triangulation with trilateration. Triangulation, in geometrics, is a process to determine a position by measuring the angle between known and fixed points. On the contrary, trilateration is used to determine absolute or relative locations of points by measurement of distances, using the geometry of spheres or triangles.

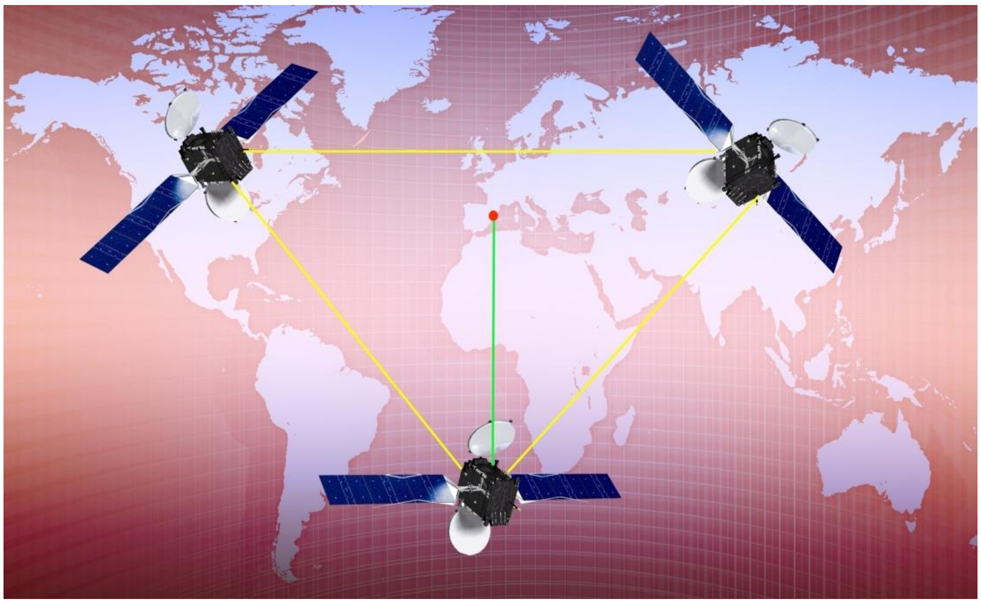


Figure 4. Concept of trilateration

4.1.1. General features

The GPS chosen is a GT-320R, manufactured by RF Solutions. This device meets all the demands of our project. The GPS module is continuously tracking all the satellites to provide accurate positioning data. Furthermore, this device is suitable for our system because of the good performance ability, the low purchase costs and its maximum flexibility.

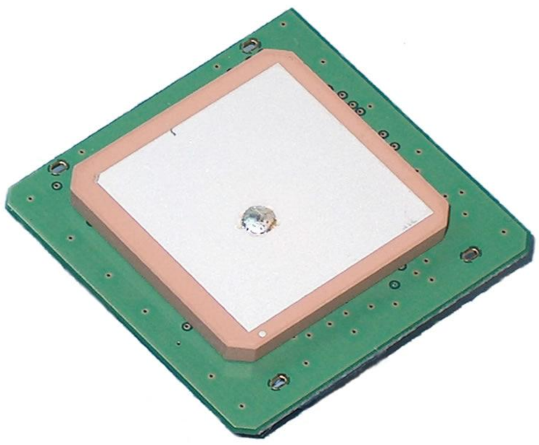


Figure 5. GPS chipset from RF Solutions GT-320R

Features such as 16 parallel channel or 4100 simultaneous search bins provide fast satellite signal acquisition and guarantee a short startup time. Furthermore, -140dB acquisition and -155dB tracking sensibility offer a good navigation performance. Other important aspects to choose this device were the availability of an interface, a LVTTL-level and RS-232 serial connectors. Additionally, the power supply offers a high flexibility, 3.8V to 8V is supported.

Once the device is connected, the GPS sends the received coordinates through both output interfaces. The information is sent each second by the previously configured protocol. In addition to that, another useful feature of this device is that it has different types of output protocols, which are NMEA-0183, GPGGA, GPGLL, GPGSV, GPVTG and GPZDA. The serial port interface protocol is based on the National Marine Electronics Association’s NMEA 0183 ASCII interface specification. This standard is fully defined in “NMEA 0183, Version 3.01”. The default speed to transmit the data is 4800 baud.

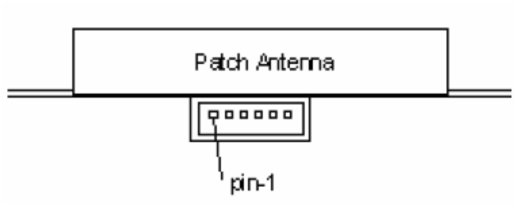


Figure 6. GPS pin connectors

In order to establish a connection it is crucial to take the pins mentioned below into consideration. Otherwise the GPS will experiment a malfunction or it might even damage the chipset. In the table below different inputs and outputs of the GPS chipset are shown.

Table 1. Pinout description

Pin Number	Signal	Description
6	**Serial Data Out 1**	Asynchronous serial output at LVTTL level, to output NMEA message
5	**Serial Data In 1**	Asynchronous serial input at LVTTL level, to input command message
4	**Serial Data Out 2**	Asynchronous serial output at RS-232 level, to output NMEA message
3	**Serial Data In 1**	Asynchronous serial input at RS-232 level, to input command message
2	**Power**	3.8V to 8.0V input
1	**Ground**	Ground signal

4.1.2. NMEA 0183 Protocols

In the past there were as many GPS protocols as there were GPS manufacturers. However, the NMEA (*National Marine Electronics Association*) 0183 protocol has evolved to become the protocol of choice for most software applications. The NMEA 0183 defines an electrical interface and data protocol for communication between marine instrumentation. Furthermore, is can also be applied to other fields. [2]

Table 2. NMEA 0183 Protocols

Acronym	Name	Description
GGA	**Global Positioning System and Fixed Data**	Time, position and fix type data.
GLL	**Geographic Position Latitude/Longitude**	Latitude, longitude, UTC time of position fix and status.
GSA	**Global Active Satellites**	GPS receiver operation mode, satellites used in the position solution and DOP values.
GSV	**Global Satellites in View**	The number of GPS satellites in view satellite ID numbers, elevation, azimuth, and SNR values.
RMS	**Recommended Minimum Specific GNSS Data**	Time, date, position, course and speed data.

As seen in table 2, NMEA has different types of configuration and, depending on the protocol used, the data transmitted includes a variety of parameters. Taking the parameters which represent the position on a map into consideration, the most relevant information is the longitude and the latitude. Thus, the main protocols that comply with the requests are GLL and RMS.

[2] Specific Information from: www.kronosrobotics.com

Having in mind that in order to send the data, it must be modified and processed. Therefore, the proper protocol should just contain the useful information and the minimum size.

To test the prototype, the GPS device was connected to a Personal Computer. Once the correct settings were made, a real location could be printed on a map. The messages name, which is also referred to as the option, is composed of the characters following the $GP. Each data element is separated by a comma and is terminated by the * character. After that the checksum is stated.

Table 3. GPGLL (*Graphic Position Latitude and Longitude*)

Name	Example	Description
Message ID	*$GPGLL*	GLL protocol header
Latitude	*2328.2329*	ddmm.mmmm (Degrees and minutes)
N/S Indicator	*N*	North/South
Longitude	*12056.9328*	ddmm.mmmm (Degrees and minutes)
E/W Indicator	*E*	East/West
UTC Time	*161229.487*	hhmmss.sss (Degrees,minutes and seconds)
Status	*A*	A=valid position/ V=warning
Mode indicator	*A*	N=Data invalid / A=Autonomous D=Differential / E=Estimated
Checksum	**25*	Security number to verify the data.

Table 4. GPRMC (*Recommended Minimum Specific Data*)

Name	Example	Description
Message ID	*$GPRMC*	RMC protocol header
UTC Time	*161229.487*	hhmmss.sss (Degrees,minutes and seconds)
Status	*A*	A=data valid / V=data not valid
Latitude	*2328.2329*	ddmm.mmmm (Degrees and minutes)
N/S Indicator	*N*	North/South
Longitude	*12056.9328*	ddmm.mmmm (Degrees and minutes)
E/W Indicator	*E*	East/West
Speed over ground	*0.13(knots)*	Speed of traveling
Course over ground	*309.32º*	Degrees of inclination
Checksum	**25*	Security number to verify the data.

With regard to the previous tables an appropriate operating protocol had to be chosen. Even though both protocols, RMC and GLL, can be used, the RMC protocol is the better choice, because of the more complete and useful information, which can, for example, be used in case of an accident at the airport. Once the PC receives the RMC message, the program will automatically log all the parameters into an external file, which can be checked at any time. Even though, the software will only display the latitude, longitude and time, it is very useful to save and have further information as well. Therefore, we opted to use the RMC protocol.

4.1.3. Connecting the GPS

In order to monitor and verify the correct performance of the GPS chipset, it has to be supplied with a power between 3.8V and 8V .Moreover, the output pins have to be properly connected. Therefore, the output pins have been manufactured with a special output plug. RF Solutions offers the possibility to buy the right connector to make the connection between the GPS and the interface easier. The picture number 7 shows a CBA-LS-40M cable.

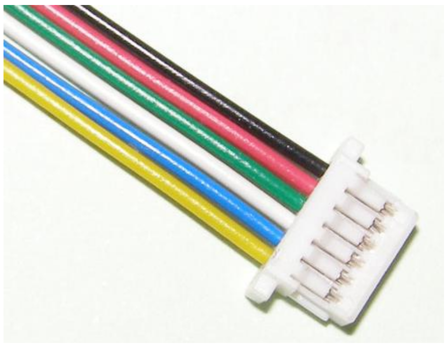


Figure 7. Cable assembly for connection with GPS-320R modules[3]

Once the cable was plugged into the GPS dowel, a RS-2323 connector was used to make the connection with the interface possible. Most importantly, the *Rx* (Receiver pin), *Tx* (Transmitter pin) and *GND* (Ground pin) have to be attached to the GPS chipset. After following all these steps, it was possible to verify a behavior structure of the GPS chipset connected to the RS-2323, which is plugged together with the RS-2323 to USB(*Universal Serial Port*) converter. The USB converter is very useful because most of the current computers have a USB In/Output.

After gaining all the aforementioned information, the GPS was ready to be tested. However, to ensure the best possible connection, a specific driver for the USB input/output had to be installed in order to recognize the USB converter. Otherwise, it would not have been possible to monitor the GPS. These drivers[4] are free and available for all types of Personal Computers courtesy of Future Technology Devices International Ldt. Company, who offer their products to every interested user. This tool is called *Virtual COM Port* (VCP) and it causes the USB device to appear as an additional COM port available to the PC.

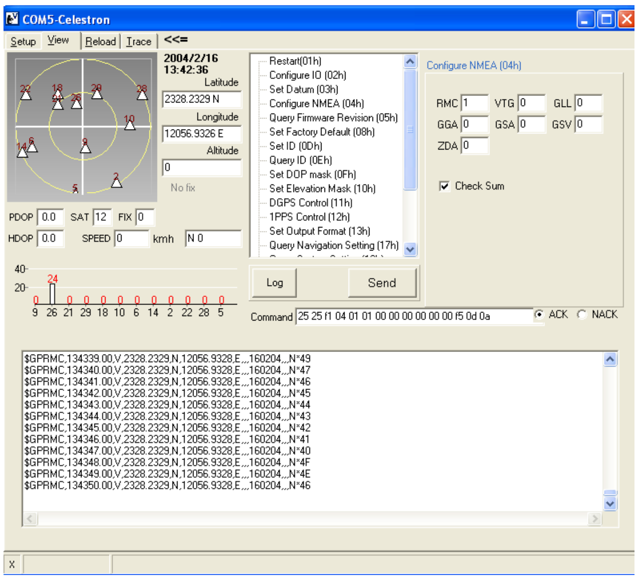
The market offers a lot of free software tools to check the coordinates on the PC. The program used during this project is called Celestron®.

4.1.3.1. GPS Software: Celestron®

Celestron is a free program, which is not only used for monitoring, but also offers the users the function to select and configure almost all of the parameters. Especially that different type of frames can be requested from the GPS. Another feature of this program is that it can be used to configure the time clock of the GT-320R receiver.

[3] Picture from RF Solutions: http://www.rfsolutions.co.uk
[4] Drivers available at this web: http://www.ftdichip.com/Drivers/VCP.htm

Since the default time is set in a UTC (*Coordinated Universal Time*) format, the time had to be set forward by two hours to synchronize with Spanish real time. The user friendly interface makes it very easy to fully understand and uses all features of this software.



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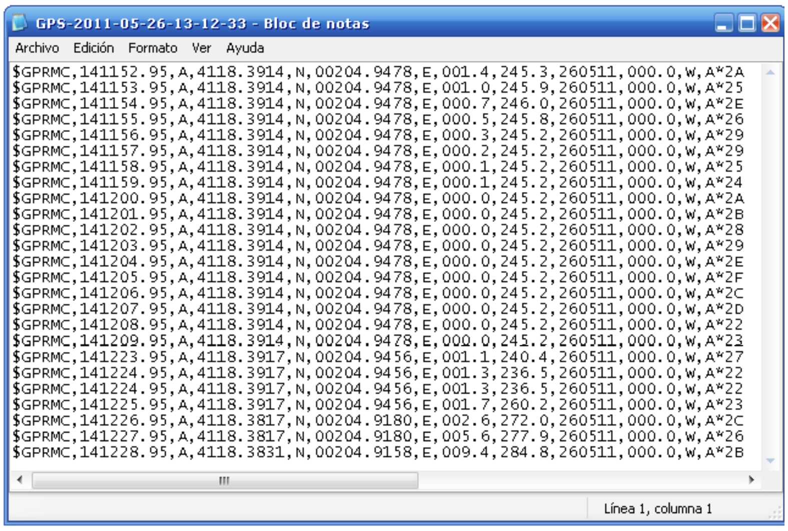
$GPRMC,134339.00,V,2328.2329,N,12056.9328,E,,,160204,,,N*49
$GPRMC,134340.00,V,2328.2329,N,12056.9328,E,,,160204,,,N*47
$GPRMC,134341.00,V,2328.2329,N,12056.9328,E,,,160204,,,N*46
$GPRMC,134342.00,V,2328.2329,N,12056.9328,E,,,160204,,,N*45
$GPRMC,134343.00,V,2328.2329,N,12056.9328,E,,,160204,,,N*44
$GPRMC,134344.00,V,2328.2329,N,12056.9328,E,,,160204,,,N*43
$GPRMC,134345.00,V,2328.2329,N,12056.9328,E,,,160204,,,N*42
$GPRMC,134346.00,V,2328.2329,N,12056.9328,E,,,160204,,,N*41
$GPRMC,134347.00,V,2328.2329,N,12056.9328,E,,,160204,,,N*40
$GPRMC,134348.00,V,2328.2329,N,12056.9328,E,,,160204,,,N*4F
$GPRMC,134349.00,V,2328.2329,N,12056.9328,E,,,160204,,,N*4E
$GPRMC,134350.00,V,2328.2329,N,12056.9328,E,,,160204,,,N*46
```

Figure 8. Celestron interface

Figure 8 presents a screenshot of the GPS software. In top left corner the available satellites are shown. In the middle all the options, which can be modified, are displayed. As a last part, at the bottom of the picture the GPS output is exposed.

4.1.4. GPS Output

The information provided by the GPS receiver, as mentioned in previous paragraphs, can be different depending of the protocol used. For this reason and after considering all the protocols that can fulfill the project requirements, the Recommended Minimum Specific Protocol was chosen due to the facts mentioned in section 5.1.2.



```
$GPRMC,141152.95,A,4118.3914,N,00204.9478,E,001.4,245.3,260511,000.0,W,A*2A
$GPRMC,141153.95,A,4118.3914,N,00204.9478,E,001.0,245.9,260511,000.0,W,A*25
$GPRMC,141154.95,A,4118.3914,N,00204.9478,E,000.7,246.0,260511,000.0,W,A*2E
$GPRMC,141155.95,A,4118.3914,N,00204.9478,E,000.5,245.8,260511,000.0,W,A*26
$GPRMC,141156.95,A,4118.3914,N,00204.9478,E,000.3,245.2,260511,000.0,W,A*29
$GPRMC,141157.95,A,4118.3914,N,00204.9478,E,000.2,245.2,260511,000.0,W,A*29
$GPRMC,141158.95,A,4118.3914,N,00204.9478,E,000.1,245.2,260511,000.0,W,A*25
$GPRMC,141159.95,A,4118.3914,N,00204.9478,E,000.1,245.2,260511,000.0,W,A*24
$GPRMC,141200.95,A,4118.3914,N,00204.9478,E,000.0,245.2,260511,000.0,W,A*2A
$GPRMC,141201.95,A,4118.3914,N,00204.9478,E,000.0,245.2,260511,000.0,W,A*2B
$GPRMC,141202.95,A,4118.3914,N,00204.9478,E,000.0,245.2,260511,000.0,W,A*28
$GPRMC,141203.95,A,4118.3914,N,00204.9478,E,000.0,245.2,260511,000.0,W,A*29
$GPRMC,141204.95,A,4118.3914,N,00204.9478,E,000.0,245.2,260511,000.0,W,A*2E
$GPRMC,141205.95,A,4118.3914,N,00204.9478,E,000.0,245.2,260511,000.0,W,A*2F
$GPRMC,141206.95,A,4118.3914,N,00204.9478,E,000.0,245.2,260511,000.0,W,A*2C
$GPRMC,141207.95,A,4118.3914,N,00204.9478,E,000.0,245.2,260511,000.0,W,A*2D
$GPRMC,141208.95,A,4118.3914,N,00204.9478,E,000.0,245.2,260511,000.0,W,A*22
$GPRMC,141209.95,A,4118.3914,N,00204.9478,E,000.0,245.2,260511,000.0,W,A*23
$GPRMC,141223.95,A,4118.3917,N,00204.9456,E,001.1,240.4,260511,000.0,W,A*27
$GPRMC,141224.95,A,4118.3917,N,00204.9456,E,001.3,236.5,260511,000.0,W,A*22
$GPRMC,141224.95,A,4118.3917,N,00204.9456,E,001.3,236.5,260511,000.0,W,A*22
$GPRMC,141225.95,A,4118.3917,N,00204.9456,E,001.7,260.2,260511,000.0,W,A*23
$GPRMC,141226.95,A,4118.3817,N,00204.9180,E,002.6,272.0,260511,000.0,W,A*2C
$GPRMC,141227.95,A,4118.3817,N,00204.9180,E,005.6,277.9,260511,000.0,W,A*26
$GPRMC,141228.95,A,4118.3831,N,00204.9158,E,009.4,284.8,260511,000.0,W,A*2B
```

Figure 9. GPS Output format

As presented in the previous section, the latitude and longitude are received in a specific format. Therefore, the received data should be converted to the standard format in order to make it easier for the software to process and display the information. To convert the received data, the format has to be transformed from fractions of minutes to decimal degrees. In addition, there is no need to transform the first figures because they represent the degrees and consequently are the same for both formats. The last required change is to move the comma two digits to the left.

```
$GPRMC,141140.95,A,4118.4041,N,00204.9820,E,009.7,211.6,260511,000.0,W,A*29

Time: 14:11:39 Latitude: 41.3067666667 Longitude: 2.08306666667
```

GPS degrees and fraction of minutes format:

$$4118.4041 \rightarrow 41.184041 \rightarrow 41°\,18.4041' \quad [1]$$

Decimal degrees format:

$$Decimal\ degrees = \frac{18.4041'}{60} = 0.3067666667° \quad [2]$$

$$Degrees\ format = 41.3067666667\,°$$

Degrees, minutes and seconds format:

$$41.184041 \quad Degrees = 41°$$

$$Minutes = 18'$$

$$Seconds = \frac{0.4041'}{60} = 24.246''$$

$$Degrees, minutes\ and\ seconds\ format = 41°\,18'\,24.246''$$

4.2. Communications

One of the most important parts of this project is the communications between the devices. Because of high reliability that this system should present, the communication has a significant role. For this reason all the cables should be placed in the proper way. The main signals that the system has to manage are basically the transmitter bit (*Tx*), receiver bit (*Rx*) and common ground (*GND*). A very important fact that has to be taken into account is, that the transceiver and the receiver have *Tx* and *Rx* pins twisted to make the communication protocol possible.

For instance, to establish the connection between the GPS and the PC we use the RS-232 interface with the purpose of making the proper settings. The transmitter modules use the same kind of interface as well. Afterwards, the GPS and the modules are configured with the correct parameters; the communication between these devices is made via LVTTL (Low Voltage Transistor-Transistor Logic).

4.2.1. RS-232

This serial port is an interface for communication with the use of digital data which is sent bit by bit. To make the link between the device and the computer a physical port is needed. It is also referred to as COM.

Currently, this type of communication is not used much and has been replaced by the USB interface, which is much faster. However, the serial port can still be found in industrial automation systems since its use is simpler and cheaper, and also allows data exchange between different types of devices.

RS-232 (*Recommended Standard 232*) is the interface to make the communication with the devices possible. The next figure shows the physical connector RS-232. In addition to that, the table number 5 presents the pins and corresponding signals.

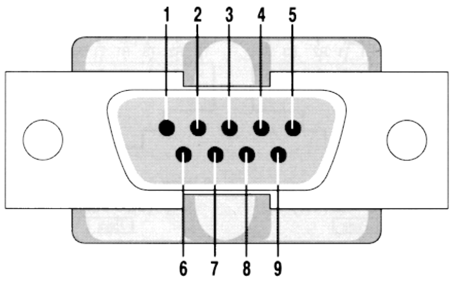


Figure 10. DB9 Connector[5]

The RS-232 interface is designed for short distances (up to 15 meters) as the standard for communication speed is low (no more than 20 kilobits per second). It can work in synchronous or asynchronous communication, and in the following channel types: simplex, half duplex or full duplex. In a simplex channel, data is always transmitted in one direction.

[5] Picture from: http://www.hflink.com

In the half duplex channel, data can travel in both directions (switching necessary, to change the direction of transmission). In a full duplex channel, data can be transmitted in both directions simultaneously.

Table 5. Relation between Pins and Signal

Pin	Signal
1	Data Carrier Detect
2	Received Data
3	Transmitted Data
4	Data Terminal Ready
5	Common Ground
6	Data Set Ready
7	Request to send
8	Clear to send
9	Ring Indicator

The serial port transmits and receives data through a UART (*Universal Asynchronous Receiver / Transmitter*).

4.2.2. LVTTL

TTL (*Low Voltage Transistor-Transistor Logic*) is a simple, universal and well understood data interface. This interface became important because it was the first time that low-cost integrated circuits made digital techniques economically practical for tasks previously done using analog methods. The fundamental switching action of a TTL gate is based on a multiple-emitter input transistor.

The active operation of this input transistor removes stored charge from the output stage transistors more rapidly than a comparable DTL gate, making TTL much faster in switching. A small amount of current must be drawn from a TTL input to ensure proper logic levels. The total current drawn must be within the capacities of the preceding stage, which limits the number of nodes that can be connected (the fan out).

All standardized common TTL circuits operate when the voltage supply is 5V. If the supply (*VCC*) is lower, TTL levels are no longer viable. A TTL signal is defined as "low" or L when the voltage is between 0V and 0.8V with respect to the ground terminal, and "high" or H when between 2V and 5V. For instance, LVTTL uses as a standard supply 3.3V. In this project the connection between the mobile modem and GPS is made using LVTTL – LVTTL cable.[6]

[6] http://www.rapidbridge.com/productbriefs/liqio_lvttl_pb.pdf

4.3. Radio modules

The purpose of the project is to locate vehicles within a small space (less than 10km^2) and to then represent their positions on a screen thus improving overall security. To realize this and to see the coordinates on an interface, a way to transmit this information from the spot where it is placed or runs the track must be picked. This information is sent to a PC with the intention of monitoring the safe landing of airplanes on the runway. To implement this system radio modules were chosen because the other alternatives which are GPS/GPRS/GSM (Global Positioning System, General Packet Radio Service, Global System for Mobile communications), ADS-B (Automatic Dependent Surveillance-Broadcast) and RFID (Radio-frequency identification) are too expensive. A decision has been made to work with radio modules TinyOne Pro M868 provided by Telit RF Solution for the reason that they have the essential characteristics required by the system: they are cheap, they use a free license frequency band, the distance range in which they are sensitive to transmit and receive data is significant, they are accurate and also possess some additional functions that improve the tracking process. The information travels from the sender to the receiver through a specific channel, thus avoiding collisions and making the communication more confident and safe.

Radio modems transmit data wirelessly, transform an analog signal to encode digital information and also demodulate such signal to decode the transmitted information. The aim is to create a signal that can be easily transmitted and decoded in order to reproduce the initial digital data.

Radio modems are used to create a Private Radio Network (PRN) for the Aena Company. These are generally used in industrial applications, when real-time data communication is needed and it is preferred to be independent from telecommunication or satellite network operators.

4.3.1. Hardware components

All the hardware components used to develop this tracking system for one airport vehicle are the following: transmitter/receiver modems, one GPS module, connection cables and additional PCB (printed circuit board) realized to connect the GPS to the modem. Additionally one or more node routers can be placed at the airport to improve the covered distance range.

The classification of the chosen modems:

- one fixed node: radio modem Tiny Pro M868 with IP67 (Fig.11.a) connected to a PC
- one node router: radio modem Tiny Pro B-868 (Fig.11.b) with a serial port RS232 (an interface board + a radio module on its DIP support + an antenna)
- one mobile node : radio modem Tiny Pro B-868 connected to the GPS – GT 320 RW

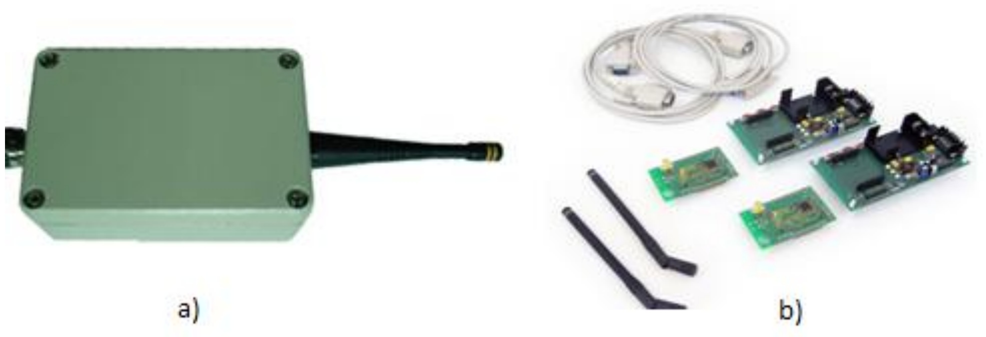


Figure 11. **Modems Tiny Pro : a) M868, IP67 and b) B868**

The fixed modem is connected to the PC through a RS-232 cable to the serial port, as shown in figure 12. Additionally, the modem receives data from the mobile device connected to the additional PCB board with the GPS module. If it is necessary, because of distance range coverage, it can get data from the router as well. The received data will be displayed on a graphical interface, which allows locating the GPS module.

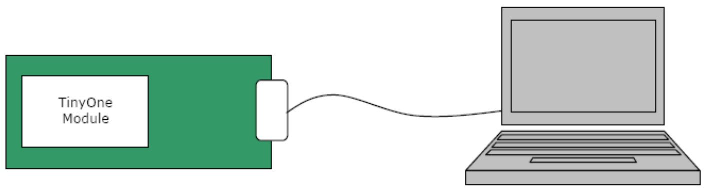


Figure 12. Connection between TinyOne Module and Computer

As mentioned before, the fixed modem is placed in the Technical Block Building at the T2 terminal and the antenna is located on the rooftop of the building to improve the receiving quality and to allow the transmission and receiving of data to be done directly.

The node router is used for instance when the distance between receiver and transmitter is too big. In this case, the role of the router, located in a midpoint of the surveyed area, is to receive the signal from the mobile device and to transmit it further through a specified channel to a fixed modem.

Before proceeding to more detailed explanation of the role of each device in the system, it is very important to know the characteristics of these modems.

4.3.2. Characteristics

Two different types of modems are used to create a more complex system in addition to cover all the set requirements. The characteristics offered by this device fulfill all the requested needs like data transition range, frequency band, sensitivity and communication protocol. The common features will be presented in this part of the report.

Both of the modems are powered with a power supply block of +7.5V or with a +9V battery.

The distance, in an optimal environment, in which the radio modems are sensitive to receive and transmit data is ranged between 3000 and 4000 meters. However, in zones with many infrastructural barriers, the achieved distance is only between 200 and 300 meters which is not enough. Therefore, all requirements for locating the modems must be strictly respected. All these limitations to the range of the rules lead to the necessity of using an additional router or two.

The TinyOne Pro M868 radio modem with an IP67 case is a complete radio frequency solution for tough environments and weather conditions. In the Technical Block Building, where the work conditions are not the best the electronic parts need to be especially protected. This modem includes a 500 mW radio module with an advanced embedded firmware, as well as a reinforced hard metal casing and a quarter wave antenna. The modem communicates with the host through a RS232- USB cable connected to terminal blocks on the mother board.

B868 TinyOne Pro is chosen as the transmitter because this model allows having direct access to the LV TTL and RS232 communication interface. The B868-TinyPro module, illustrated in figure 13, consists of digital and RF parts. The tasks of these components are data coding and frequency synthesis respectively.

Beside the interface board, there is a DIP support with an antenna available. The developing board includes an RS-232 connector, a battery slot, a TTL level and an on-off switch. Furthermore, to indicate the transmission of the data, the board has three LED diodes.

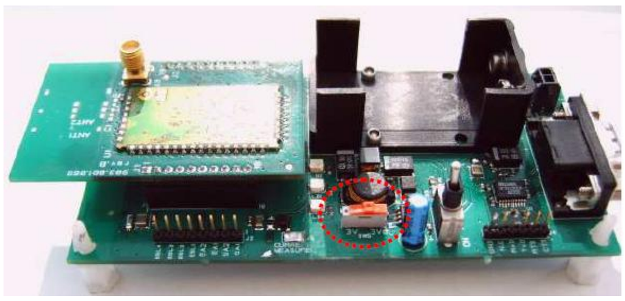


Figure 13. B868-TinyOne Pro

The Tiny radio module can be placed on the host boards by pick-and-place mechanism like any integrated circuit with the following recommended parameters.

4.3.3. Functional characteristics

All the TinyPro terminals allow two types of functioning: single channel mode, which means that only channel number one is selected, or multi channel mode, which means that at least two channels are selected. In single channel mode the operating frequency is 869.525MHz, with an output power of 500mW. In multi channel mode the frequency is 869.4125MHz with an output power of 100mW. This module works in temperatures between +85ºC and -40 ºC. The relative humidity for a proper functioning of the modem varies from 20% to 75%. The sensitivity range of around 100 dB for both functioning modes indicates a high quality. In the following table the main features are presented which are the same for both types of modems.

Table 6. Functional characteristics of TinyPro terminal

Frequency band:	.400 - 869.650 MHz	
Temperature range:	-40 ºC to +85 ºC	
Relative humidity:	20% to 75%	
Transmission	**Single channel**	**Multi channel**
Chanel number:	1 (869.525MHz)	10 (869.4125MHz)
Channel spacing :	wideband (ERC-Rec 70-03)	25 kHz (ERC-Rec 70-03)
Radio bit rate :	up to 38.4 kbps	4.8 kbps
Output Power :	500mW (27dBm ± 1dB)	100mW (20dBm ± 2dB)
Reception consumption	6V-30mA, 12V - 25mA, 40 V- 20mA	
Reception Sensitivity	-100dBm ± 2db	105dBm±2dB
Range: ▪ In difficult environment:	200m	300m
▪ In optimal environmental :	3000m	4000m

4.3.4. Transmission process

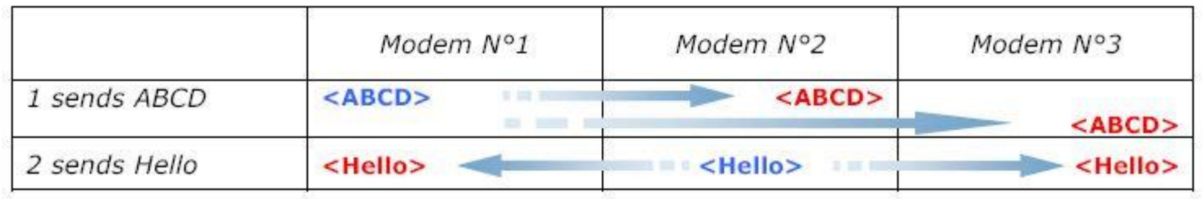
The tracking process starts when the transmitter captures data from the GPS, which is set to send a specific message (to detect just specified parameters). The frames are addressed, checked through a CRC, acknowledged and sent further to the receiver. Information is taken from the receiver and processed in the developed software, where the selection of the data needed is done. After this the coordinates are interpreted, decoded and shown on the map of the Aena airport. Therefore, all the modems are configured.

The modules can operate under four different modes:

- Transparent mode:
  - the default communication protocol of the module
  - data transmitting is made transparently, without encapsulation or addressing
- Addressed Secured mode:
  - it is used in multipoint network protocol
  - each module can communicate with every other module in the same network
  - the frames are addressed, checked through a CRC and acknowledged

- Downloader over the air:
  - allows re-flashing of remote module
- Auto-repeat mode:
  - the module sends back the frames it has received (radio or serial) without echoing
  - used for testing the module remotely

In the beginning the modems were programmed to work in transparent mode to see if they work properly, because in this mode all the frames are transmitted transparently. This mode reproduces the half duplex function of a RS232 serial link which means that only one device can send or receive at a time. It allows Point to Point or Point to Multi-point transmission of data with all the modems receiving the messages sent by any modem, as shown in figure 14.



	Modem N°1	Modem N°2	Modem N°3
1 sends ABCD	<ABCD>	<ABCD>	<ABCD>
2 sends Hello	<Hello>	<Hello>	<Hello>

Figure 14. Transparent mode

Every unit configured in transparent mode will receive every radio data flowing on the same communication channel in the same frequency. In this communication mode, radio modems automatically transmit every serial data received on their radio link, or radio data received on the serial link.

The time between switching from reception mode to transmission mode is reduced as far as possible. The latency time includes: the time for one character received by the modem, the carrier duration, the time for the transmitted radio data consisting of one byte and the time to transmit one character from the modem.

In spite of these values, no data control, neither on the serial link, nor on the radio link, is performed by these radio modems in transparent mode. Therefore, the data control must be passed on to the software application and, in this case, the users must adequately verify that all frames are transmitted properly, taking into account that an interrupted transmission may lead to characters or buffer losses.

After the quality had been proven a decision was made to work in a different mode which can assure data control. Because of this, the addressed secured mode was chosen to allow a good communication between the modules as well. The addressed secured mode offers an optimal radio link quality given by the multipoint access of the transparent mode in combination with the security of the secured transparent mode. Furthermore, all modems can communicate with each other, addressing each frame to one of them. This mode can handle 255 up to 65535 clients.

Compared to the transparent mode, which addresses each data frame to a specific modem, the addressed secured mode includes some additional features, such as:

- Fully verified data transmissions
- The modem works similar to the transparent mode, but differs by adding frame encapsulation
- Identifying clients with a specific number added to each data frame
- The receiver recognizes the transmitting modem by the first number of the data frame
- The possibility to add one frame ending character is given. The addition of Carrier Return <CR>, after each received frame is distinguishing.
- Data frames can easily be transmitted simultaneously from one modem to any other modem in the same network.

The secured algorithm of address secured mode is: if nothing is received after a delay equivalent to 3 serial time-outs after the flow control signal activation, the following frame will be considered as going to a new modem. If something is received during this delay, it will be considered as going to the same unit. This way, a long frame can be sent and will be split by the flow control.

Each of the radio modems are set to operate in addressed secured mode, because all the frames are addressed, checked and acknowledged through a CRC (cyclic redundancy check). In this operation mode the TinyOne Pro modules can communicate only if they are all part of the same 'network'. This means, it is necessary to set the same network ID. However, it is essential to set different client numbers as transmission addresses in order to indicate the default address to which every radio frame will be sent. This is described in figure 5.

For both communication protocols, Transparent and Addressed Secured Mode, the LBT (Listen Before Talk) function is available. If this function is activated, before sending data the transmitting modem will scan the radio link and verify that it is available (no radio activity). This is done to avoid collision.

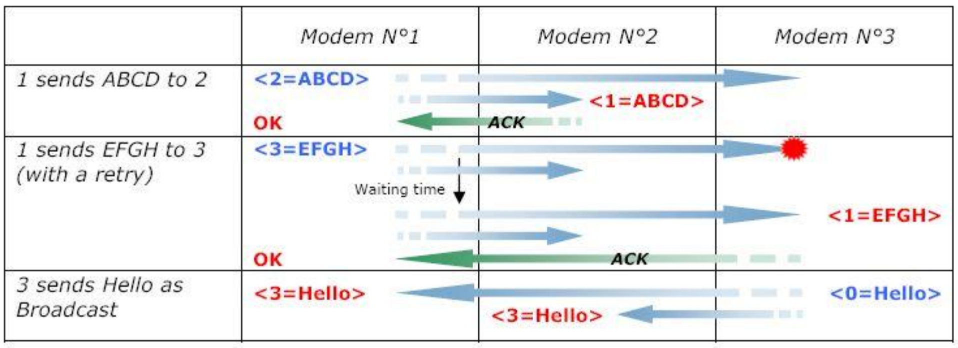
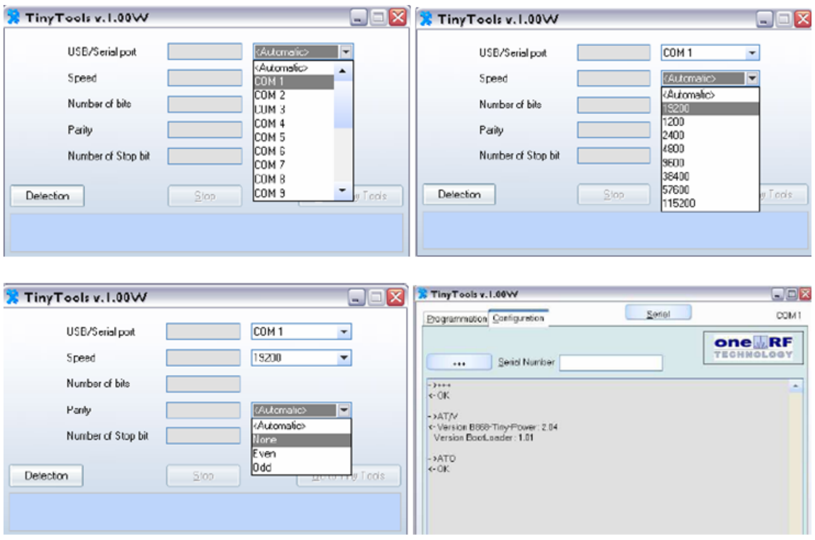


Figure 15. Adressed Secured Mode

These modems are operating in the 869.4 – 869.65 ISM (International Science and Medical) frequency band, with some limitations. Most of these restrictions are integrated in the conception of the module, except for the duty cycle. The 869.400 to 869.650 MHz band is limited to a 10% duty cycle. This means that each module is limited to a total transmission time of 6 minutes per hour.

4.3.5. Tiny Tools

For each modem used in the system certain changes to the parameters and registers were made. These changes are made by the Tiny Tools software and are depending on the function of each radio module in the tracking process. The Tiny Tools software, provided by One RF Technology, allows programming of Tiny PRO Modules by a PC. In figure 16, the Tiny Tools software interface is presented.[7]



```
->+++
<-OK

->AT/V
<-Version B868-Tiny-Power : 2.04
  Version BootLoader : 1.01

->ATO
<-OK
```

Figure 16. Tiny Tools v.1.00W Software

When Tiny Tools software is launched, a window appears which allows the configuration of the serial port. It is a straightforward process and the user can rapidly choose which Com-port, Speed, Parity and Number of Stop bits to use.

After the configuration part is finished, the detection of the modem will be started. If the link between the modem and the software program is made and the module characteristics are shown at the bottom of the software page, then the “Go to Tiny Tools” button can be selected and further configuration of the modem are allowed.

4.3.6. Settings

To receive GPRMC (Recommended Minimum Specific Data) frames properly from the GPS 320RW, the radio modems and their registers were configured in order to enable communication between them.

To configure the Tiny Pro modules, the registers were set with the Tiny Tools program. This configuration allows access to the register by AT or Hayes commands to modify each register. A data frame always begins with the two ASCII ‘AT’ characters, standing for ‘Attention’. For example, to change the value of a register the following command is used: ATSn = m, where n is the registration number in the value that is given. Once the register is changed by running the command AT / S, status of all relevant registers, the new values of all registers can be seen.

[7] 2010. Manual TinyTools_v1.1.

In the configuration module, a click on '+++' establishes the communication with the device. If this link is set up, the radio module will answer 'OK'; otherwise the communication has failed and an error message will be received. When the configuration is finished, the command 'ATO' will reset the radio module into functional mode. The 'ATO' command also gives an instant access to the modems operating mode, configured in the S220 register.

In the following table, a short description of the most important registers used to make the ideal communication between radio modems, is presented.

Table 7. Register description

Register	Description
S200	Sets the radio channel or frequency used for communication
S201	Selects the transmission speed or baud rate
S202	Allows choosing the maximum output power or consumption of the module
S204	Sets the duration (in milliseconds) of the radio carrier sent before the data
S206	Chooses the mode of operation, single channel or multichannel
S210	Selects speed connection through the serial port
S212	Sets the format and parity of characters sent by the serial port
S213	Defines number of stop bits: 1 bit or 2 bits
S214	Timeout transmission of serial data. This indicator decides when the data frame is finished. If nothing is received for a time equal to this timeout, the frame is finished
S216	This register works with the buffer size register S218, which sets the limit to activate the flow Control
S220	This is the most significant register. It selects the operation mode of radio modems
S223	It represents the number of times a message will be repeated in case of non acknowledgement, or the number of times the modem will try to send the message in case that the radio link is not free
S226	Allows you to enable and configure the functionality of LBT . The LBT sensitivity refers to the detection on the RF level over which the RF link is considered as occupied
S227	Activates a random waiting time before each radio transmission
S240	Activation of the stand-by mode designed for low power consumption of the radio modem
S250	Resembles ID of the network. There can be up to 65535 networks defined, but only one can work in a given area in each radio channel.
S252	The user can configure a custom number between 1 and 65535. Client numbers must all be different within the same network
S256	If this register is different from zero, the frames received by the serial connection will be sent to this address without any header detection done

All the devices, modems as well as routers, are configured with the same appropriate values. After both of the communication protocols were tested, the configurations for the application remained as followed:

- A single channel mode at a frequency of 869.525MHz, which means that the first mentioned register is automatically set to ‘10’
- The radio baud rate is 38.4 kbps for all the modems; because it works in single channel mode and allows a low power consumption value of 500mW.
- To obtain broadcasting time and smaller power consumption the duration of a radio carrier given has a value of 5ms.

For all the modems the speed rate was set to be the same as the GPS, 4800 bps.. The format has been set without parity, which equals a value of ‘1’. The serial timeout value is 3 ms, which is according to the serial baud rate. A choice to not have a flow control on the serial link was made in order to prevent the buffer from overflowing. Furthermore, the host must manage its outgoing data frames and activate the LBT function in case of high sensitivity.

The number of repetition has to be kept as low as possible to ensure that the system works in real time. In this case the value has been set to two, which is the number of times the message will be repeated in case of non acknowledgement. Two is also the number of times the modem will try to send the message in case of an unavailable radio link (when LBT functionality is activated).

M868/ B868-TinyPRO modems can communicate in addressed secured mode only if they are a part of the same network. Therefore, the ID network, given by 252 register, is set to be the same for all devices. Although there can be up to 65535 defined networks only one can work in a certain area of each radio channel. Even though the client numbers can vary between 1 and 65535, it has to be unique for the receiver and transmitter. The number for the system’s mobile modem was set to 10 and for the fixed one to 20.

For displaying the sender address, the register S255 is set to the default parameters, which in conclusion means that each of the bits has the appropriate value. The S256 register sets the address where the frames are being sent. Table 8 represents the values of the registers used to configure the radio modems.

Table 8. Configuration of the radio modems

Registers	Fixed Modem	Node Router	Mobile Modem
S200	10	10	**10**
S201	3	3	**3**
S202	2	2	**2**
S204	8	8	**8**
S206	0	0	**0**
S209	0	0	**0**
S210	3	3	**3**
S212	1	1	**1**
S213	1	1	**1**
S214	5	5	**5**
S215	0	0	**0**
S216	2	2	**2**
S220	9	9	**9**
S223	2	2	**2**
S226	1	1	**1**
S227	1	1	**1**
S240	0	0	0
S250	0	0	0
S252	20	X	10
S255	80	80	80
S256	10	X	20

As it can be seen in the table above, the last three registers are configured with different values. This is done because one modem is transmitting and one is receiving. The S252 register shows the assigned client number and the register S256 indicates which modem is sending the frames. The router can receive data from different modems as well as transmit it further to several other devices. Therefore, the router settings are based on how many clients are used in the network.

During the field tests the hardware was configured like:

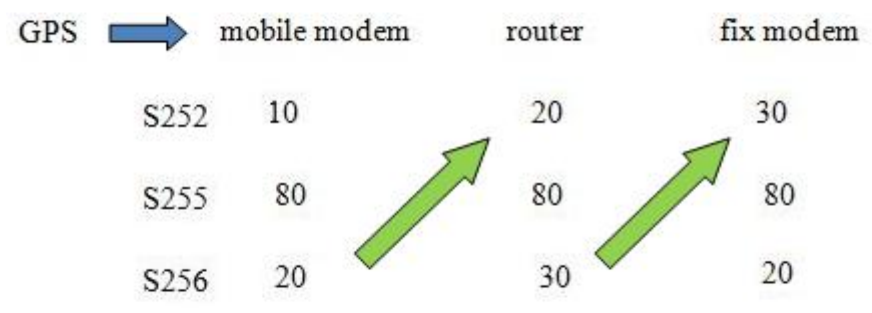


Figure 17. Register configuration

This figure shows how the GPS is transmitting the coordinates of the vehicle to the mobile node, which has the client number 10. It is set to transmit this information further to the address 20, representing the client number of the system's router. The router sends the data to the fixed modem, which has been assigned the address 30. Furthermore, the fixed modem sends the data through a RS232-USB convertor cable to the software application. This is processing all the data and displaying it on the user interface.

4.4. Mounting

The quality and range of our system will increase if the device is mounted high, and free of and reflective materials. Therefore, it would be best to install the system on the roof of the monitored vehicles. In order to do this, we need a solution that can withstand the forces attacking a driving car in addition to emerging forces of gravity. This means the mounting device must hold at least 5 kilograms.

With the purpose of achieving this goal and also providing a smooth mounting and demounting method, several ways were taken into consideration. However, most of them would be permanently on the car such as tape, screws or glue. In the end a decision had to be made between two solutions.

4.4.1. Suction Cup

The first solution is a suction cup. This device can easily be removed from the car once applied as well as mounted on any other car just as soon. Furthermore, the M6 thread provides a solid way to combine the device with the suction cup. The downside of this solution is that the surface has to be clean and even when mounting the device. Also the suction could decrease over a longer time period, which could lead into a loss of the box.

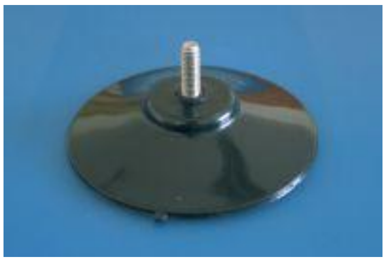


Figure 18. Suction cup[8]

4.4.2. Magnetic System

The second and most promising solution is a magnetic system. The magnet it equipped with a safety rubber around it to ensure no scratching on the vehicles surface. In addition to that, it also contains a M6 thread to provide a solid connection to the box. Even though this solution is slightly more expensive than the suction cup it provides a safer and cleaner way of mounting and demounting the device.

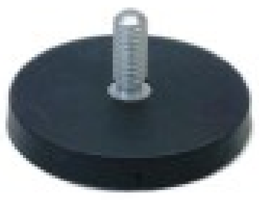


Figure 19. Magnetic system[9]

[8] www.saugnaepfe-online.de
[9] www.magnet-shop.net

Chapter 5. Software Development

Although, there was a rather strict division of tasks within the team, since different people were responsible for the implementation of software while others were mainly focusing on the hardware development, the final success could only be achieved by cooperation of these subgroups. Therefore, it is not possible to say that any of these parts were more important than another one. Moreover, both of them were crucial elements of the project and depend on each other. In the following chapter the explanation of the software part will be done.

The main task of the software used in the project is to gather all the information received by the devices. The data is to be presented in an application that allows the user to interact with the program. In addition to that, the software will log every event in order to offer help in case of an emergency situation at the airport. That means that the information in the log files has to be in a readable form in order offer the user the function to check for possible errors made by the system.

Since there is a lot of information being managed at the same time, the program needs to be as fast as possible with the purpose of avoiding unnecessary delays that could cause the program to be misinterpreted by the user. Additionally, the application itself needs to be somewhat user friendly making it easy to configure and utilize it even while being run.

Bearing the requirements of the software in mind, a decision was made to split it into two independent programs which work simultaneously and interact with one another. The first program handles the receiving of the data and takes care of creating the additional files needed, such as the logs. Meanwhile the other program takes care of the interaction with the user and makes sure that all the data is displayed properly. Since all the conversions are mainly being done by the first mentioned program, the workload of the program that handles the displaying of the data will be significantly less.

A decision was made to use only open-source solutions in order to lower the costs as much as possible. The fact that open-source software is being used will make the future modifications a lot more trouble-free and provides the possibility to use the software in any way needed. Apart from that, there are already numerous examples available to use freely for programming.

The final crucial thing to mention is that the operating system under which the new programs have to run has to be one of the Linux distributions. The reason for that is the speed and versatility of the system. When run under Windows, some image flickering is clearly visible when the application is refreshing the map. This issue does not occur under Linux. The distribution that was chosen is the latest version of Ubuntu – 11.04. This system is very user friendly and fully fits the needs of the project.

5.1. Programming environment

With the intention of realizing the project in a modern way, research was carried out in order to choose a proper programming environment. Choosing between different languages relevant for the system, a decision was finally made to use the Python language. This is mainly due to its open source structure that will contribute to lower the total costs of the project, but also because of its flexibility that will make the program run smoother

5.1.1. Python

Python is an open source programming language that was developed in the end of the 1980's. Since its release, the language has developed into a powerful, and at the same time easy to use, language that supports several programming styles: structured, object oriented and functional programming. Therefore, the user is not restricted to just one style and can feel more independent while creating a program. A distinctive characteristic of the programming language is its clean coding structure, as it uses indentations instead of braces to divide the code into sections. Furthermore, it does not use semi-colons to state the end of each line. Additionally, Python is a version-dependent programming language and at the moment there are two versions that are being used: 2.x and 3.x. These versions are not fully compatible with each other. Nonetheless, new packages are being developed for Python constantly. By installing one of these modules the language's potential and capabilities in the form of new classes and functions will be extended. In the end version 2.7 was chosen because, compared to the 3.x versions, it has got greater compatibility with additional components.

5.1.2. wxPython

The most vital extension module that is being used is wxPython. It is a wrapper, which allows the user to create a graphical user interface (GUI) more effortlessly compared to using the native Python interface called Tkinter. The task of wxPython is to import wxWidgets (a library written in C++) into the programming language making additional components, for creating GUIs, available for the programmer. With similarity to Python, wxPython is also an open source module and made in a similar sense of simplicity.

This extension module is being used in order to create a window, which will be used to show the map with the vehicles depicted within it. Therefore, it plays a huge role in the interpretation of the application. Besides that, this extension is being used to offer the user the possibility to interact with the application more naturally.

5.1.3. pySerial

Another important Python extension used in the development of the software is pySerial. It is a library which provides support for serial connections over a wide range of different devices: Bluetooth dongles, infra-red ports, universal serial ports and RS-232 ports.

It is mainly used for accessing the serial port and allows the data to be read directly in Python. The RF-receiver is connected to the computer via an RS-232-to-USB adapter serial port and the received coordinates can easily be gathered and operated on by using pySerial.

5.2. Receiving data

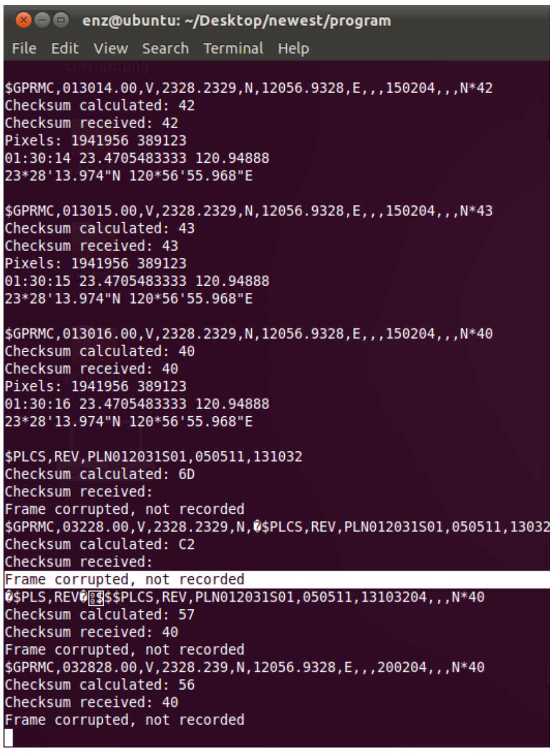
The data received through the universal serial port is in a rather complex form before being dealt with by the software. It contains not only the GPS coordinates, which is the most important part of the data, but also some other information. This information needs to be filtered by selecting only the parts of information that store information needed to display the data properly. Once a connection between the RF-sender and the receiver has been established, the system is capable of receiving the information. The recognition of what parts are needed is being done in a fully automatically way.

The part of the software that handles the reception of the data will utilize two text files to store the needed data. One of those is meant to be read by the users and the other is including the data needed in the printing process.

5.2.1. The receiving process

When the data created by the GPS is sent through the radio frequency devices, some unwanted data will also occur. This unwanted information appears as a result of the protocols used when sending the data. Unwanted parts are being discarded by using a function that recognizes what valuable lines of information look alike. Afterwards, each piece of information has to be taken care of separately in order to define all the different values, e.g. speed, course and checksum. The whole process has to be done with assurance that no important part of the information is going to be lost.

Furthermore, it is very crucial for the accuracy of the vehicles positioning that the software can check if the frame received is corrupted or not. Each frame is followed by a checksum in hexadecimal form. It is calculated as an *exclusive-OR* function of all elements within the particular frame. To be able to check its correctness, a function that is reviewing all the checksums of the received frames, has been created. This function calculates the checksum of the specified frame on its own and compares it with the received one (computed and sent by the GPS). If the outcome of the comparison between the two checksums is different, the software will make a notification in the log file to inform the user about the corrupted data.


enz@ubuntu: ~/Desktop/newest/program
File Edit View Search Terminal Help

```
$GPRMC,013014.00,V,2328.2329,N,12056.9328,E,,,150204,,,N*42
Checksum calculated: 42
Checksum received: 42
Pixels: 1941956 389123
01:30:14 23.4705483333 120.94888
23*28'13.974"N 120*56'55.968"E

$GPRMC,013015.00,V,2328.2329,N,12056.9328,E,,,150204,,,N*43
Checksum calculated: 43
Checksum received: 43
Pixels: 1941956 389123
01:30:15 23.4705483333 120.94888
23*28'13.974"N 120*56'55.968"E

$GPRMC,013016.00,V,2328.2329,N,12056.9328,E,,,150204,,,N*40
Checksum calculated: 40
Checksum received: 40
Pixels: 1941956 389123
01:30:16 23.4705483333 120.94888
23*28'13.974"N 120*56'55.968"E

$PLCS,REV,PLN012031S01,050511,131032
Checksum calculated: 6D
Checksum received:
Frame corrupted, not recorded
$GPRMC,03228.00,V,2328.2329,N,�$PLCS,REV,PLN012031S01,050511,13032
Checksum calculated: C2
Checksum received:
Frame corrupted, not recorded
�$PLS,REV��$$PLCS,REV,PLN012031S01,050511,13103204,,,N*40
Checksum calculated: 57
Checksum received: 40
Frame corrupted, not recorded
$GPRMC,032828.00,V,2328.239,N,12056.9328,E,,,200204,,,N*40
Checksum calculated: 56
Checksum received: 40
Frame corrupted, not recorded
```

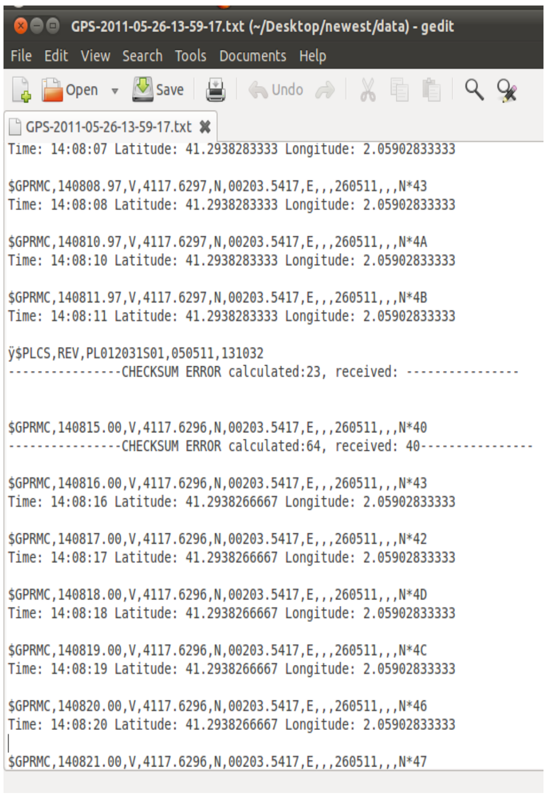
Figure 20. The console showing a corrupted frame

Neither the data that fails the checksum test nor the one that is inappropriate for the program is being recorded in the log files and only data that fulfills all the criteria will be passed on for further functions. This is a measure taken to facilitate the workload of the program, even though the original data is always logged in its raw form for administration purposes.

5.2.2. Creation of log files and data files

Once the discarding of all the unnecessary data and the identification process are done, the vital data is saved in a log file with the purpose of making it easier for the user to check for possible faults done by the program. The user can, for example, check all the positioning data, timestamps and checksums if he or she suspects that there has been an error in the displaying process. For this reason, all the data is presented in such form that it will be easy to read and identify what the different numbers represent. It will also be easy to localize corrupt data since the program will make a notification in the log file.

Additionally to the log files, the software simultaneously creates a separate data file including only the pixel coordinates created from the longitude and latitude information of each frame received, as well. This is simply done with the intention of separating files meant to be read by the users by the files that have an actual purpose for the program. A separate data file is created for each vehicle and new coordinates are recorded into the file as soon as new positioning information is being received. The form of the data stored in the files is width and height in pixels. The reason of this format is to make the process faster when it is time to print the position of the vehicles. Because of that, a function transforming the longitude to width in pixels and latitude to height in pixels is being activated as soon as it is time for the program to make a new entry in the data file.


GPS-2011-05-26-13-59-17.txt (~/Desktop/newest/data) - gedit
File Edit View Search Tools Documents Help
Open
Save
Undo
GPS-2011-05-26-13-59-17.txt

```
Time: 14:08:07 Latitude: 41.2938283333 Longitude: 2.05902833333

$GPRMC,140808.97,V,4117.6297,N,00203.5417,E,,,260511,,,N*43
Time: 14:08:08 Latitude: 41.2938283333 Longitude: 2.05902833333

$GPRMC,140810.97,V,4117.6297,N,00203.5417,E,,,260511,,,N*4A
Time: 14:08:10 Latitude: 41.2938283333 Longitude: 2.05902833333

$GPRMC,140811.97,V,4117.6297,N,00203.5417,E,,,260511,,,N*4B
Time: 14:08:11 Latitude: 41.2938283333 Longitude: 2.05902833333

ÿ$PLCS,REV,PL012031S01,050511,131032
---------------CHECKSUM ERROR calculated:23, received: ---------------


$GPRMC,140815.00,V,4117.6296,N,00203.5417,E,,,260511,,,N*40
---------------CHECKSUM ERROR calculated:64, received: 40---------------

$GPRMC,140816.00,V,4117.6296,N,00203.5417,E,,,260511,,,N*43
Time: 14:08:16 Latitude: 41.2938266667 Longitude: 2.05902833333

$GPRMC,140817.00,V,4117.6296,N,00203.5417,E,,,260511,,,N*42
Time: 14:08:17 Latitude: 41.2938266667 Longitude: 2.05902833333

$GPRMC,140818.00,V,4117.6296,N,00203.5417,E,,,260511,,,N*4D
Time: 14:08:18 Latitude: 41.2938266667 Longitude: 2.05902833333

$GPRMC,140819.00,V,4117.6296,N,00203.5417,E,,,260511,,,N*4C
Time: 14:08:19 Latitude: 41.2938266667 Longitude: 2.05902833333

$GPRMC,140820.00,V,4117.6296,N,00203.5417,E,,,260511,,,N*46
Time: 14:08:20 Latitude: 41.2938266667 Longitude: 2.05902833333

$GPRMC,140821.00,V,4117.6296,N,00203.5417,E,,,260511,,,N*47
```

Figure 21. Log file in which checksum errors have occurred

Now, since the data is already received in an easy to manage form and ready to be displayed, the second part of the software has to take care of it. This must happen in real time, i.e. as soon as new data is written to the file, it is being interpreted and printed. In fact, it is a separate program which presents the data for the user in such a form that it is as easily understandable as possible. This is achieved by using the already divided files for each asset (one file per vehicle). Each second the program is being updated, checking all the data files for new information. If a new position is located the program is refreshed using the new data.

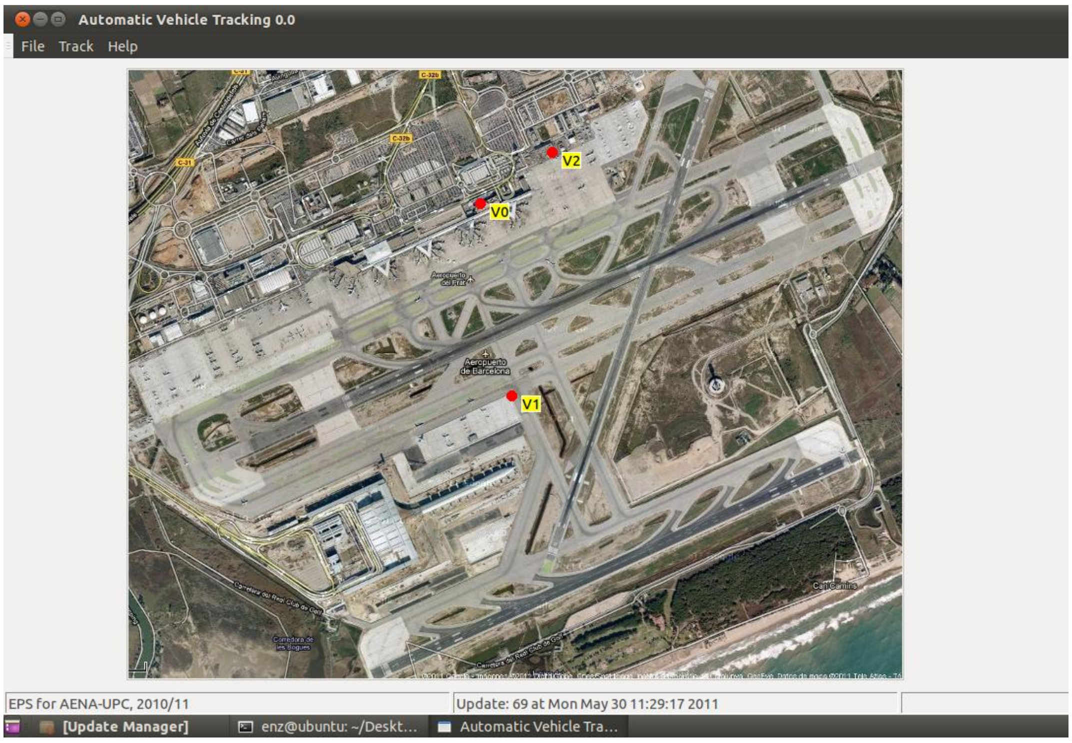
5.2.3. Reading files

Files, which are required for the printing process to work, are the data files (the ones with just the pixel coordinates). A method, which searches the specified directory to find all the .txt files and writes their paths into a list is not only being executed with the start of the program, but also with every iteration of the program, so that if new file (new vehicle) appears while the program is already running; it is immediately taken into account and becomes visible on the map. When found, each file is assigned a number, which later allows the recognition of the vehicles' representations on the map. This feature will be described in more detail in the following section. After that, the initial coordinates of each objects (1,1) are put into another list. With every iteration of the program (i.e. every second), the newest coordinates (in the form of a line) from each file are being read and compared to those read in the previous step. If they are the same, nothing happens, but if they differ, they are replaced by the newly read ones. The total number of refreshing cycles is being counted and displayed within the toolbar at the bottom of the screen. As a result it is easy to check how much time has passed since the program had been launched and what the exact amount of updates is.

For safety reasons and to guarantee longer faultless uptime, the part responsible for reading the files is handled by a separate thread. Threading is particularly useful in applications with their own graphical user interfaces to take care of long-lasting processes running in the background. This approach ensures that the action taking place in the background is not interrupted by user interactions.

5.2.4. The printing process

The next step is to use the coordinates in order to create a list of Icon class objects. This class gathers all the basic properties of the icons (representing the vehicles) to be drawn within the window: the current scale, recent position on the map and the number assigned after the corresponding file has been found. Whenever a vehicle changes its position, the coordinates of the corresponding icon are being superseded. The final part of each iteration of the printing process is to redraw the map of the airport and the vehicles representations on top of it. Additionally, each of the objects marked on top of the map has its own label in the form of the letter V followed by an appropriate number which allows the vehicle to be identified at once. The update event of the window takes place once per second. This frequency has been chosen based on the knowledge that new GPS data will be received with a regularity of one second. The map, with a few vehicles marked, can be seen on figure 22.



EPS for AENA-UPC, 2010/11

Update: 69 at Mon May 30 11:29:17 2011

Figure 22. The program displaying the positions of the vehicles

5.3. Graphical user interface

Since the basic aim of the project is to develop a system which is able to monitor and, what is most vital, display the movements of vehicles in the airport area, a very important aspect of the application is to make it as user-friendly as possible, while maintaining full functionality. Therefore, adjusting the interface to the users' needs was a big challenge. The appearance of the application is not entirely ready yet. Nevertheless, the following chapter is meant to describe its current functionality.

When the program is launched, the initial window looks as depicted in figure 22. The most crucial and largest part of the window is a map of the airport located in the central part. To help understand what is going on, a status bar is situated in the bottom part of the application. A menu bar can be found at the top of the interface.

5.3.1. Status bar

Located at the bottom of the window, the status bar is divided into three sections horizontally, as it can be seen in figure 22. The one found to the left is mainly responsible for display additional informative statements to the user. When the program is launched, the initial text represents a concise message from the authors. Additionally, when any of the menu options is hovered over, a short message is shown, explaining briefly what the highlighted option does. The middle section is assigned for more important messages, like displaying the number and time of the latest update, and the information about which menu option has been selected. Finally, the last segment of the status bar is meant for displaying additional urgent messages.

5.3.2. Menu bar

Situated at the top part of the window, the menu bar is split into three separate menus, named *File*, *Track* and *Help*. The *File* menu consists of two options: *Choose what files to read* and *Quit*. At this moment, the first option is not implemented yet. Its task is to make it possible for the user to choose some already recorded data files to display the vehicles' route. This should be done faster than the real time displaying (one update per second). The quit option causes an additional window to appear which gives the user the possibility to confirm whether to close the application or not.

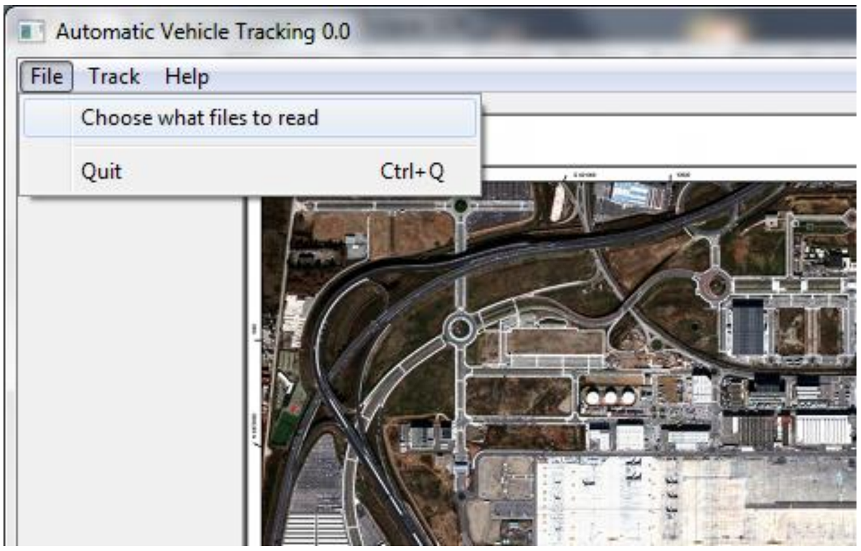


Figure 23. The File menu

The *Track* menu is composed of three options, as seen in figure 23. These options are: *Draw a simulated track*, *Display live tracks* and *Stop displaying live tracks.* The first option was created with the purpose of testing the program. It was mainly used at the time when the part responsible for reading the data from the port had not been ready. After selecting this option, as the name clearly states, the user is given the opportunity to draw an artificial route of an imaginary vehicle. The path is being sketched with a red color while keeping the left mouse button pressed. The program records the trail in the same form as if it was received via the universal serial port, i.e. using pixel coordinates. When the route is ready, the user has to double click the left mouse button within the area of the map and a new window will appear. Then the possibility to type in the filename and save the route as a file with .txt extension is given. After saving the file, it will be recognized as a file created in the ordinary manner. The user can afterwards use this file to check whether the movement is displayed properly by using the following menu option. The second option is in fact used to start the primary feature of the application. After choosing this option the program starts to present the current positions of the vehicles. As the structure of both, the artificially made files and the files created by the received data, are similar, the program will print all routes simultaneously. Details of how it is done are explained more deeply in the section 5.2.4. (Printing process). The final option allows the user to stop displaying the tracks without closing the application itself. Therefore, after pausing the application, when the *Display live tracks* button is pressed again, the program will continue instantly from the point it was interrupted in.

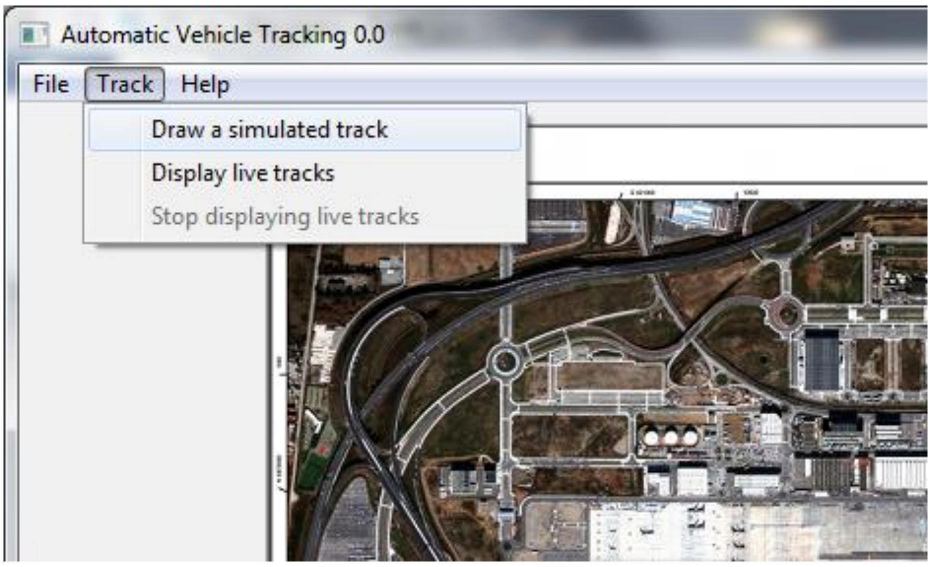


Figure 24. The Track menu

The third menu section, *Help*, is created to offer the user different kinds of assistance. The menu options are *Show user manual* and *About.* If the first menu option is selected a user guide is opened. This guide should cover all the basic functions of the program and instructions on how to use them. If one has any doubts of how to do a specific task, the answer will be found in the guide. Finally, the *About* option was created in order to present the software’s developers and contact information of the people responsible for the development.

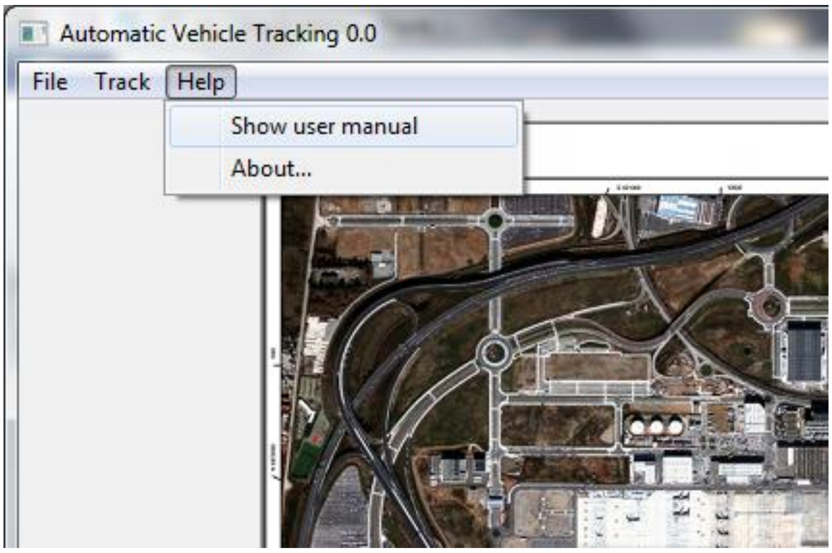


Figure 25. The Help menu

5.3.3. Zoom function

The program has an integrated zoom function so that each user has the opportunity to show the map in a bigger scale. Not only will this make small details clearer, but also minor movements of the vehicles will be easier to notice. The function works even when the application is running. By clicking the right mouse button anywhere inside the map, the area will enlarge. After the zooming, depending on where the button is pressed, that place will be the new center to make it as instinctive as possible. There are two magnifying steps: the map size can be twice and three times as big as the initial size. The feature is realized by replacing the original map with a larger one as soon as the button is clicked. Since the resized maps do not fit inside the main window entirely, scrollbars appear in order to be able to view the whole area.

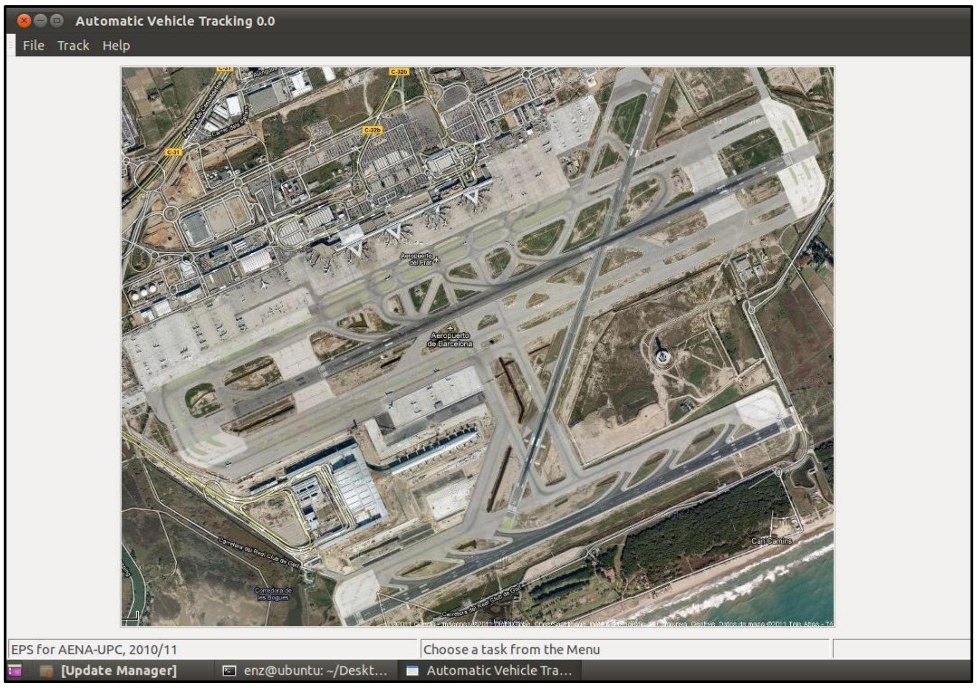

Automatic Vehicle Tracking 0.0
File
Track
Help
EPS for AENA-UPC, 2010/11
Choose a task from the Menu
[Update Manager]
enz@ubuntu: ~/Deskt...
Automatic Vehicle Tra...

Figure 26. Initiating the program

Chapter 6. Economic Evaluation

This chapter will show in detail what costs are involved in order to develop and install such a system in an airport. This will involve the costs of the engineers and software designers as well as the cost for assembling such a device. Furthermore, the prices of every material used in the device will be stated and added up to show the cost of one unit. In the end, our system will be compared to a valid existing solution.

6.1. Development

In order to develop an Automatic Asset Tracking System, a lot of different specialists/engineers and coordinators are needed. This means, that we need at least 2 technical engineers, 2 software designers, 1 person from the marketing and research department and a supervisor to coordinate everything. Therefore, the chart below shows the hours one engineer or software designer would need to develop such a system .The price per hour is not the actual hourly earnings of an engineer, but how much his work is worth if he would do something else.

Table 9. Costs for human resources[10]

Field/Department	Working Hours	Cost per Hour	Overall Costs
Technical Engineer	400	55 €	22.000 €
Software Designer	400	55 €	22.000 €
Research/Marketing	200	55 €	11.000 €
Supervisor/Management	50	75 €	3.750 €

6.2. Implementation

The actual implementation consists of assembling the devices and then installing them on each car and the receiver in a tower or any other location where it could operate most efficiently. This work can be done by normal technical assistants, which do not cost as much as specialist in their fields. However, the costs and time involved has to be taken into consideration. Therefore, the next chart shows the time and cost to assemble the devices and, on the other hand, the installment costs to provide 1000 vehicles with this system.

[10] The cost per hour are taken from *Xarxa inalámbrica a la Banda ISM per a la monitorització d'un dispositiu GPS*, 2009- Bachelor Project

Table 10. Costs for assembling and installation

Field/Department	Working Hours	Cost per Hour	Overall Costs
Technical Assistant/Assembling	1000	40 €	40.000 €
Technical Assistant/Installation	500	40 €	20.000 €

The Assembling of the device is predicted to take 1 hour in total, which will make a total of 1000 working hours. The installation of the devices onto the cars, however, should be done in approximately a half hour summing up to 500 working hours.

6.3. Materials

The following table lists all materials involved in a whole prototype system. In addition to that, it also presents the cost for each of those materials and the number of those needed. In the end, the prices are being cumulated to determine the overall price per Unit.

Table 11. Material costs

Material	Price in €	Units	Overall Price in €
GPS 320R	45,00	1,00	48,95
M868-tiny-plus with IP67 case	239,70	1,00	239,70
Tiny One Pro Demo Kit B868 with two modules	437,00	1,00	437,00
USB to RS232 Adapter	24,95	1,00	24,95
RS232- DB9	2,00	3,00	6,00
Printed Circuit Board for the GPS	15,00	1,00	15,00
Supply Block	23,00	3,00	69,00
Magnet	7,80	1,00	7,80
Li-Ion Battery Varta	23,00	1,00	23,00
9 V Battery Duracell	5,00	1,00	5,00
Box	22,90	3,00	68,70
Cumulated Price			**945,10**

The cumulated price represents the cost for one prototype package including a receiver, a transceiver and a node router. However, to give a better understanding for the calculations below the prices for each devise are as followed:

The transmitting device is composed of the GPS, the M868-tiny-plus with a IP67 case, a RS232-DB9 plug, the printed circuit Board for the GPS, a supply block, a magnet, a LI-Ion Battery, a 9v Battery and a box, which have a combined price of 387,35€.

The receiver, on the other hand, is composed of a Tiny One Pro Demo Kit B868 with two modules, a USB to RS232 Adapter, a RS232-DB9 plug, a supply block and a box, which has a value of 509,85€.

The node router consists of one of the two modules from the receiver (no additional costs), a supply block a RS232-DB9 plug and a box, summing up to a price of 47,90€.

Taking into consideration that we only need one receiver and one node router, the major cost factor, as seen in table 12, will be the transmitter, because the network consists of 1000 vehicles which have to be tracked.

Table 12. Material costs for the entire airport

Device	Price	Units	Overall Price
Receiver	509,85 €	1	509,85 €
Transmitter	387,35 €	1000	387.350 €
Node Router	47,90 €	1	47,90 €

6.4. Cost-effectiveness

As a result of all the factors mentioned above, the development, implementation and the materials will cost a lot of money in the beginning. However, from a long term point of view, this will be a profitable investment as the comparison with a GPS/GPRS solution shows.

Overall Costs for the new system:

Development Costs:	58.750€	
Implementation Costs:	60.000€	
Material Costs:	387.907,75€	
Receiver:		509,85€
Transmitter:		387.350€
Node Router:		47,90€
Overall Costs:	**447.966,50€**	

Overall Costs for a GPS/GPRS system:

Development Costs:	0€
Implementation Costs:	20.000€
Material Cost:	100.000€
Monthly Fee:	10.000€
Overall Costs:	**120.000€ + 10.000€ per month**

As one can see, the GPS solution is much cheaper in a short- term point of view due to the fact that the system already exists, thus having no development costs, as well as the fact that a wide range of products is available, which reduces the price immensely. However, in a long-term analysis the GPS system will cost 10.000€ per month for as long as it exists. Therefore, the new system will become profitable after 3 Years.

This development is shown in the table and graph displayed below:

Table 13. Cumulated costs

Tabla 1Year	Cumulated Price New System	Cumulated Price GPS/GPRS System
1	447.966,50 €	120.000 €
2	447.966,50 €	240.000 €
3	447.966,50 €	360.000 €
4	447.966,50 €	480.000 €
5	447.966,50 €	600.000 €
6	447.966,50 €	720.000 €

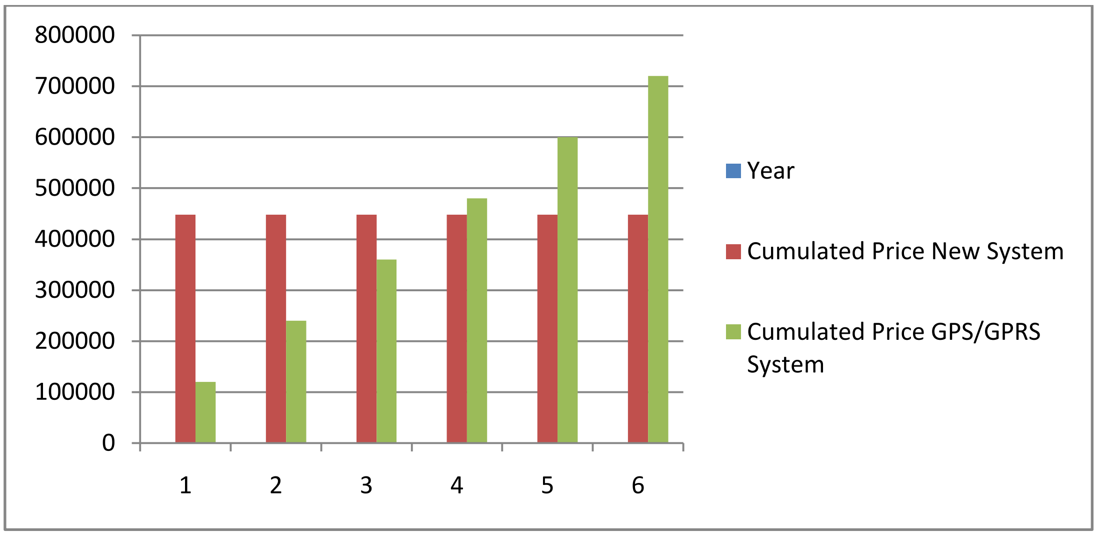


Figure 27. Comparison of long term costs of the two systems

Chapter 7. Field Tests

This chapter will guide through every gained experience with the new system, while testing it. In the beginning of the project every hardware or software solution was only made on a theoretical basis. However, to present the system to the airport officials a practical test was absolutely necessary. However, one test was not enough which lead to many more experiments in the laboratory of the university at first. Nonetheless, during the later stages of the development, the tests had to take place in the actual working environment to gain valid information from the results and learn about problems that could only occur in this particular area.

Each time a newer version of system was available, tests were performed to try the new features that had been implemented. If any mistakes or defects were discover they were dealt with at once to improve the overall experience. After that, the tests were repeated to check if any new problems arose. During the entire development process the whole improving-testing procedure was absolutely crucial in order to pinpoint where the weaknesses of the system were. One of the main issues discovered during the lab tests was that it appeared that the GPS unit needs some time to warm up. As a result, after turning on the GPS, during first few minutes it is constantly receiving the same data even though the unit is moving. It occurs due to the fact that the GPS unit needs some time to establish the connection with the satellites.

After three months of working in the laboratory, the team was given the opportunity to go to Barcelona Airport itself to perform some actual field tests. During the first introductory meeting it was decided that a provisional antenna needed to be installed somewhere within the area of the airport in order to try the system in its full potential. The decision was made to place it on the roof of the Technical Block located near the Terminal 2. Due to that reason, a testing area was dedicated to the project team inside the Technical Block building, to be able to use the received signal with ease. The group visited the airport on three different occasions.

During the first visit the main focus was placed on getting the software to work under the required conditions. As soon as the system was assembled, the group suffered a minor setback in the form of compatibility issue, concerning the operating systems on the personal computers. It appeared that the application did not work under Linux distribution Ubuntu 11.04 as it was supposed to. However, the problem was narrowed down moderately fast to be caused by not being able to access the universal serial port in the same manner as it was under Windows. The solution was merely a matter of knowledge and consequently solved after doing some research. That is, after realizing that the *COM* ports are not named the same way under Linux as they are under Microsoft’s operating system. Therefore, only some parameters had to be changed. The second problem that emerged was caused by passing wrong arguments to one of the functions responsible for translating latitude and longitude into pixel coordinates. The outcome was that the coordinates did not appear in the proper position. It was resolved relatively quickly as well after doing some debugging. To sum up the first day, the system was adapted to the circumstances of the airport and ready to be used in conditions similar to the real ones.

On the second day of field tests the time had come to test the GPS device more intensively. This was achieved by walking around the airport area and thereby gathering data and checking for possible errors. During these tests it was noticed that a huge amount of disturbances was present in the area, which is supposed to be covered by the system. After some consulting with the airport personnel it became clear that it was in fact a commonly occurring problem in the airport's communication. Another problem regarding the quality of the received signal was that there is a huge amount of metal elements present throughout the airport area. These disturbances caused a decreased signal strength and in some cases even a complete loss of the signal. One of the possible solutions for this problem is to install an additional router, which will collect the signal from the GPS and resend it to the fixed antenna. Implementing this device makes it possible to double the distance range. Nevertheless, the tests were reasonably profitable for the development of the system.

The third and last day of field tests continued in the same manner as the previous one. That day the project team was also given access to a car, which allowed a wider test radius and also the possibility to test the device's signal strength within the zone where airplanes are present. Two members of the team were situated in the car, together with a set composed of a GPS unit and a transmitter. The rest of the team was monitoring the receiver on a PC and ensuring the proper performance of the system. The communication between these two parts of the team was established by walkie-talkies. The car was driven to areas on the airport further away and closer to the location of the antenna. The strength of the signal differed from place to place. The inspected range of reception is marked on figure 28.

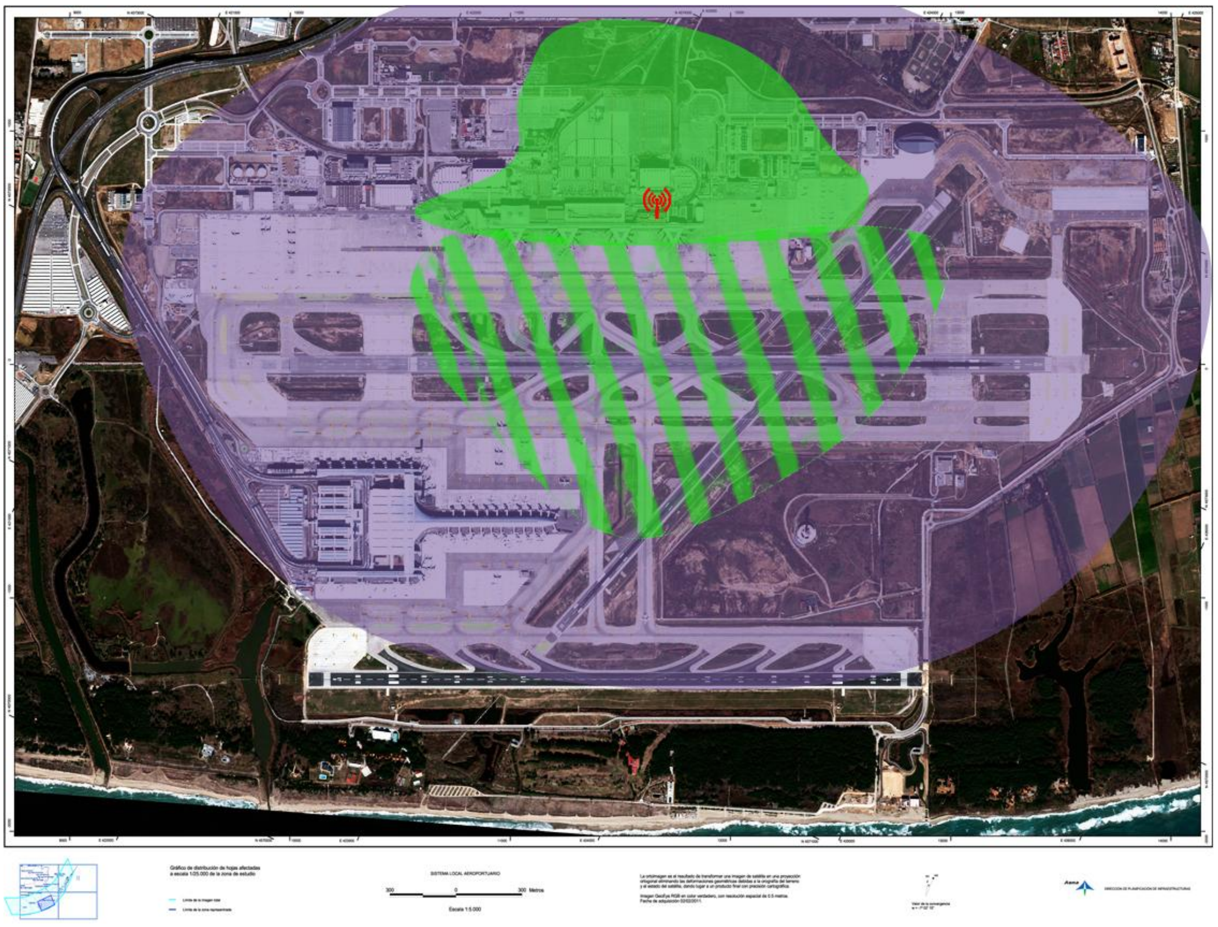


Figure 28. Coverage area at the Airport of Barcelona

The covered area, as displayed in the picture above, is not homogeneous. This is due to the fact that in numerous locations within the area of the airport the signal encountered some interference with other communication systems already present in the facilities of the airfield. Another reason that could affect the reception of the signal is that the location of the antenna was not yet the appropriate one. In case of the actual system implementation, the aerial would be installed in a more suitable and higher spot. Finally, there was a huge amount of buildings and metal constructions in the region where the tests were performed which also caused the signal to weaken. Making a reference to figure 28, the green area represents the zone where the strength of the signal is guaranteed, could be received and read without any problems. This range was approximately one kilometer and two hundred meters. Based on the results of the field tests', the green striped area represents the zone where the system is supposed to operate without any significant interference. However, this has not been tested due to a lack of permission to enter the area surrounding the landing strip. The purple color corresponds to the region where the system ought to work properly, but could be affected by some external factors. That area has been tested, but the results were not satisfying because some major signal interruptions were detected.

The results obtained during the different field tests confirmed much of our earlier calculations and concerns. Even though some parts of the system did not perform as well as predicted, the results gave directions to new ideas and knowledge. The guaranteed operating distance had been discovered and the positioning error is estimated to be not more than 5 meters. This distance was measured without any major obstacles weakening the signal strength.

In the last two tests besides the transmitter, which includes a GPS 320R, another GPS, GARMIN 60Cx, was used to ensure that our device send the data correctly as well as to observe the appeared errors in the transmitting process and to check if the system is accurate enough.

This Garmin GPS uses the same protocol messages**,** NMEA 0183, as the new system. This GPS has the update rate of 1/second and the accuracy of the position of the vehicle is less than 10 meters. These two devices have been used to confirm the accuracy of one another during the testing between terminal T1 and terminal T2. The outcome was very satisfying. For example, the coordinates shown below were received by the Garmin GPS while testing the accuracy.

N (north)	41º 18.238
E (east)	2º 04.923

For the GPS 320 we received almost the same coordinates, only with a difference in the last number of the frame which means that the accuracy is within 10 meters for both devices. Therefore, the accuracy for our GPS alone is ± 5 meters of the actual position.

Chapter 8. Future Improvements

This chapter explains what kind of improvements could still be done in order to enhance the performance of the system. There are several aspects and features which could be added not only in the hardware part, but also in the software development. In addition to that, a SWOT analysis had been made.

8.1. Software

Even though the software has been designed and tested, it cannot be said that it is completely finalized. The greatest importance was attached to creating a whole functionality of the most crucial parts of the software. Therefore, the graphical user interface is not yet entirely finished. Nevertheless, in the shape as it is in now, it can safely be implemented in the new system and the airport network. In this section some improvements and changes, which could significantly enhance the user-application interaction, are being proposed. Examples of what could still be done are as followed:

- Implement a terminal within the main window of the application to be able to keep an eye on all the events in just one window.
- Display a list of all the observed devices with the possibility to choose which ones to show.
- Add additional data to be viewed, e.g. the current speed of the vehicle and its direction.
- Include warning sounds when corrupted data is received.
- Replace the currently used map with one of higher resolution to be able to zoom in more.
- Implement the possibility to grab the map and move it in the desired direction for more intuitiveness than using scrollbars
- Make the menu options, which are not implemented yet, available, i.e. *Choose what files to read* and *Show user manual*, as described in the section 5.3.2.

Until this point, the focus has been put in getting only one device to work properly. Since the main task of the system is to monitor several vehicles at once, the implementation of the identification utility still has to be done. In order to do that, not only have some additional functions to be created, but also some changes have to be done on the hardware side. When it comes to the hardware part, additional frames containing the identification number of the device have to be included in the messages sent. After this is done, the next step is to implement functions to recognize the identification numbers and based on what the outcome is, a different file will be appended. Since the software already detects all the activity on the serial port, it will be a rather straightforward process.

8.2. Hardware

It can be said that the hardware part is already finished, but some improvements can still be added. Until now, as it was already mentioned, just one prototype has been implemented. For this reason, the network has not yet been tested with more than one connected transmitter.

Taking that into account, some futures improvements which can be made are:

- The receiver's antenna can be placed in the control tower of the airport instead of the Technical Block Building. This way the antenna is located as high as possible, which leads to an avoidance of interference and an enlargement of the overall coverage.
- Other tests are necessary to see which communication mode is the most proper one for the entire network.
- The functionality of the router must be tested at the airport field.
- To improve the detection coverage of the signal between Terminal 1 and Terminal 2, it is advisable to use more than one router.
- To increase the accuracy of the vehicles' position, the actual GPS320R can be switched to a superior one.
- The power supply of the mobile case can be done by a car charger instead of batteries.

8.3. SWOT Analysis

In order to make our system a valid alternative, in comparison to other solutions, some actions have to be done and some points taken in to consideration. If the suggestions stated in the table below are followed, the new system has the potential to be a competitive system in the Automatic Asset Tracking Systems market.

Table 14. SWOT Analysis

SWOT Analysis	**Strength**	**Weakness**
Opportunity	Reduction of development costs and increased range can make one of the best system on the market	Eliminate any outside interference to make it a solid and consistent system
Threat	Improve the user interface and fluent system flow with the improvement of the software	Implementation of node router and more accurate GPS can eliminate any threat of low accuracy or range

Chapter 9. Conclusion

Even though the current market offers numerous Asset Tracking solutions, the new and innovative system, described in this paper, has the potential to become a major competitor in this particular field. This system is the most cost-efficient solution available at the moment as well as it works with an open-source based software. These facts are just two of the major achievements of this project. In addition to that, the new system tries to transfer the best functions and abilities of other solutions to combine them in a system that not only does a very proper and effective job, but also aims to be the most complete system overall.

Another benefit of this system is that, once all the testing is done, the system could actually be offered to airports or companies in need of such a system. This will cover the development costs of the project and after some time it might even start to raise a profit which would lead into making the new system cheaper for the users and in a long term even profitable.

Although the project has ended successfully, the developed system is far from being done. The most essential future improvement is to execute a major testing phase where one hundred up to one thousand vehicles are being monitored. This test could work out perfectly, while at the same time, any kind of problems could occur. Such problems could be interference, the loss of a signal or the bandwidth not being able to support the necessary amount of data coming from that many devices.

In order to conclude this paper and this project, it has to be stated that a good basic level has been created to base a successful Automatic Asset Tracking system solution on it. This system reveals a lot of potential if configured, tested and implemented correctly. Finally, the system can serve not only as an airport surveillance system, but also in a harbor, in a production area, a major construction side or a mid-range cab tracking system. The varieties will grow as soon as the range can be improved even more. Taking everything into account, the system can become one of the next major systems in the field of real-time vehicle surveillance.

Chapter 10. Acknowledgment

The EPS group would like to thank all colleagues and students who contributed to making this project possible. We are grateful to our supervisor, Vicenç Parisi, for giving assistance and guidance through the whole project, and to all the professors that contributed with their knowledge during the development of the system. The EPS group is very grateful for the cooperation and interest of the employees at Aeropuertos Españoles y Navegación Aérea, Barcelona Airport. This project would not have been possible without their interest in developing this system. Last but not least we would like to thank the Escola Politècnica Superior d'Enginyeria de Vilanova i la Geltrú, Universitat Politècnica de Catalunya and the International Coordinator of the EPS program, Patricia Benson, for giving us the opportunity to participate in the European Project Semester.

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Chapter 12. Appendices

12.1. Responsibility matrix

Responsibility Matrix	Philipp	Leonard	Oana	Jakub	Linus
Research for Alternatives	R	S	S	S	S
Selection of a GPS device		R	S		
Comparison of RF-Modules		S	R		
Comparison of Protocols		S	R		
Assemble all necessary components		R	S		
Carrying out Lab Tests	S	S	R	R	S
Implementing Hardware in Network		R	S		
Creating Data Files and Logs				R	S
Research for Programming Language				S	R
Selction of Proper Files to read				S	R
Interpretation of Data				R	S
Implementing Software in Network				S	R
Cost- Evalutation	R				
Layout of User Interface				R	S
Carrying out Field Tests	R	R	R	R	R
Overall Documentation	R	R	R	R	R
Create Midterm Report and Presentation	R	S	S	S	S
Structure and Writing of the Article	S	S	R	R	S
Wrinting and Review of the Final Report	R	R	S	S	S
Layout and Creation of the Poster	S	R	S	S	R

R: Responsible S: Support

12.2. Software source code

12.2.1. Main program

```
import wxversion
wxversion.select("2.8")
import wx
import time
import glob
import os
import threading

myEVT_CollectLocations = wx.NewEventType() #threading events
EVT_CollectLocations = wx.PyEventBinder(myEVT_CollectLocations, 1)

class MainFrame(wx.Frame): #Automatic Vehicle Tracking Frame
  def __init__(self, parent, id):
    wx.Frame.__init__(self, parent, id, pos=wx.Point(0,0),
    size=wx.Size(1280,800),
    style = wx.DEFAULT_FRAME_STYLE ,
    title='Automatic Vehicle Tracking 0.0')

    # Main parameters, objects, variables ..
    self.mapFolder = ''
    self.panel = wx.Panel(self)
    self.imageFile= 'google_map7.JPG'
    self.W = (wx.Image(self.mapFolder+self.imageFile)).GetWidth()
    self.H = (wx.Image(self.mapFolder+self.imageFile)).GetHeight()
    self.avtDisplay = MainDisplay(self.panel,-1, self.mapFolder, self.imageFile, self.W, self.H)
    self.avtStatus = AVTStatusBar(self)
    self.SetStatusBar(self.avtStatus)
    self.updateNumber = 0
    self.threadAlive = False
    self.displayTracks = False
    self.drawSimulatedTrack = False
    self.avtStatus.SetStatusText('Choose a task from the Menu', 1)

    # A button
    self.button=wx.Button(self, label="Save", pos=(0, 0))
    self.Bind(wx.EVT_BUTTON, self.OnClick,self.button)

    # Bindings
    self.Bind(wx.EVT_CLOSE, self.Onquit)
    self.Bind(EVT_CollectLocations, self.OnCollectLocations)

    #Menus
    self.SetUpMenus()
    self.stopLiveTrack.Enable(False)

#READING
```

```
  def OnCollectLocations(self, evt): #functions used to collect locations
    self.updateNumber = self.updateNumber +1
    files = self.FileIterator()
    for path in files:
      self.avtDisplay.coords[files.index(path)] = self.Reader(path, self.updateNumber)
#        print path
#        print self.avtDisplay.coords[files.index(path)]
    num = 0
    for coordinate in self.avtDisplay.coords:

self.avtDisplay.icons[self.avtDisplay.coords.index(coordinate)]=(Icon(int(coordinate[0]),int(coordinate[1]),self.a
vtDisplay.scale, num))
      num = num +1
    self.avtStatus.SetStatusText('Update: '+str(self.updateNumber)+ ' at ' +time.asctime(), 1)
    self.Refresh()
    self.Update()

  def Reader(self, filename,n): #function reading the coordinates
    with open(filename) as f:
      lines = f.readlines()
      if len(lines)<n:
        n = len(lines)
      line = lines[n-1].strip().split(" ")
      return line

  def Reader_2(self, filename,n): #alternative function to read the coordinates
    with open(filename) as f:
      first = f.readline()
      if (f.readline() == ''):          #checks if files consists of more than one line
        return first.strip().split(" ")
      else:
        offset=-4
        while True:                     #if more than one line than gets the last line immediately
          f.seek(offset, 2)
          lines = f.readlines()
          if len(lines)>1:
            last = lines[-1].strip().split(" ")
            break
          offset *= 2
        return last

  def FileIterator(self): #function finding all the .txt files
    fileList = []
    for infile in glob.glob(os.path.join(os.getcwd(), '*.txt')):
      fileList.append(infile)
    return fileList

  def SetUpMenus(self): #function creating the menus

    # Menubar Begins ####################################################################
```

```
self.menubar = wx.MenuBar(wx.MB_DOCKABLE)

# Menu File ##########################################################################
self.file = wx.Menu()

self.chooseFiles= wx.MenuItem(self.file, -1, u"Choose what files to read")
self.chooseFiles.SetHelp(u"Choose the files")
self.file.AppendItem(self.chooseFiles)
self.Bind(wx.EVT_MENU, self.OnchooseFiles, id=self.chooseFiles.GetId())

self.file.AppendSeparator()

self.quit = wx.MenuItem(self.file, -1, '&Quit\tCtrl+Q')
self.quit.SetHelp("Exit the program")
self.file.AppendItem(self.quit)
self.Bind(wx.EVT_MENU, self.Onquit, id=self.quit.GetId())

self.menubar.Append(self.file, '&File')

# Track Menu ##########################################################################
self.track = wx.Menu()

self.simulateTrack= wx.MenuItem(self.track, -1, "Draw a simulated track")
self.simulateTrack.SetHelp('Simulate the track with the mouse')
self.track.AppendItem(self.simulateTrack)
self.Bind(wx.EVT_MENU, self.OnsimulateTrack, id=self.simulateTrack.GetId())

self.liveTrack= wx.MenuItem(self.track, -1, "Display live tracks")
self.liveTrack.SetHelp('Display real time collected track')
self.track.AppendItem(self.liveTrack)
self.Bind(wx.EVT_MENU, self.OnliveTrack, id=self.liveTrack.GetId())

self.stopLiveTrack= wx.MenuItem(self.track, -1, "Stop the display of live tracks")
self.stopLiveTrack.SetHelp('Stop displaying real time collected track')
self.track.AppendItem(self.stopLiveTrack)
self.Bind(wx.EVT_MENU, self.OnstopLiveTrack, id=self.stopLiveTrack.GetId())

self.menubar.Append(self.track, '&Track')

# Menu Help ############################################################
self.help = wx.Menu()

self.manual = wx.MenuItem(self.help, -1, "Show user manual")
self.manual.SetHelp("Show user manual")
self.help.AppendItem(self.manual)
self.Bind(wx.EVT_MENU, self.Onmanual, id=self.manual.GetId())

self.about = wx.MenuItem(self.help, -1, 'About...')
self.about.SetHelp("Information about this project")
self.help.AppendItem(self.about)
```

```
        self.Bind(wx.EVT_MENU, self.Onabout, id=self.about.GetId())

        self.menubar.Append(self.help, '&Help')

        # Menubar Ends ###############################################################
        self.SetMenuBar(self.menubar)



    def OnchooseFiles(self,event): #function enabling viewing the files, not implemented yet
        self.avtStatus.SetStatusText('Not implemented yet', 2)
        time.sleep(1.0)
        self.avtStatus.SetStatusText('', 2)

    def Onquit(self, event): #function showing additional window after pressing the Quit option
        ret  = wx.MessageBox('Are you sure to quit?', '...last question', wx.YES_NO | wx.NO_DEFAULT, self)
        if ret == wx.YES:
            if self.threadAlive:
                self.collectThread.stop()
                self.threadAlive = False
                #self.Close()
            self.Destroy()

    def OnsimulateTrack(self,event): #function activated after pressing Draw te simulated track
        if self.threadAlive:
            self.collectThread.stop()
            self.threadAlive = False
        self.displayTracks = False
        self.avtStatus.SetStatusText('Draw a simulated track', 1)
        self.simulateTrack.Enable(False)
        self.liveTrack.Enable(False)
        self.stopLiveTrack.Enable(False)
        self.Refresh()
        self.drawSimulatedTrack = True



    def OnliveTrack(self,event): #function displaying the vehicles in real time
        self.files = self.FileIterator()
        del self.avtDisplay.coords[:]
        del self.avtDisplay.icons[:]
        for path in self.files:
            self.avtDisplay.coords.append((1,1))
        num = 1
        for coordinate in self.avtDisplay.coords:
            self.avtDisplay.icons.append(Icon(int(coordinate[0]),int(coordinate[1]),1, num))
            num = num+1

        self.displayTracks = True
        self.collectThread=CollectThread(self)
        self.collectThread.start()
        self.threadAlive = True
```

```
      self.simulateTrack.Enable(False)
      self.stopLiveTrack.Enable(True)
      self.liveTrack.Enable(False)


   def OnstopLiveTrack(self,event): #function to stop the real time displaying
      if self.threadAlive:
         self.displayTracks = False
         self.avtStatus.SetStatusText('Live tracks disabled', 1)
         self.collectThread.stop()
         self.threadAlive = False
         self.liveTrack.Enable(True)
         self.stopLiveTrack.Enable(False)
         self.simulateTrack.Enable(True)
         self.Refresh()

   def Onmanual(self,event): #function showing the manual, not yet implemented
      self.avtStatus.SetStatusText('Not implemented yet', 2)
      time.sleep(1.0)
      self.avtStatus.SetStatusText('', 2)

   def Onabout(self, event): #function displaying the About window
      description = u"""This asset tracking system is a joint project between AENA and Universitat Politècnica de
Catalunya"""
      licence = """ Contact: Vicenc.Parisi@upc.edu and jcoronel@aena.es"""
      info = wx.AboutDialogInfo()
      info.SetIcon(wx.Icon('screenruler.png', wx.BITMAP_TYPE_PNG))
      info.SetName('Automatic Vehicle tracking')
      info.SetVersion('0.0')
      info.SetDescription(description)
      info.SetCopyright('(C) 2011 AENA-UPC')
      info.SetDevelopers(['Jakub Wychowaniec','Leonard Filip','Philipp Rühle','Oana Beatu','Linus Storhannus'])
      info.SetLicence(licence)
      wx.AboutBox(info)

class MainDisplay(wx.ScrolledWindow): #class containing the map
   def __init__(self,parent, ID, mapFolder, imageFile, W, H):
      wx.ScrolledWindow.__init__(self, parent,
ID,(125,10),(W,H),wx.HSCROLL|wx.VSCROLL|wx.SUNKEN_BORDER)

      self.parent = parent
      self.mapFolder= mapFolder
      self.imatge = wx.Image(mapFolder+imageFile)
      self.iH = self.H = H
      self.iW = self.W = W
      self.SetSize((self.W,self.H))
      self.cz = self.GetClientSize()
      self.scale = 1

      self.shapes = []
```

```
        self.icons = []
        self.vehicles = []
        self.coords = []
        self.simulatedTracks = []

        self.files = self.parent.GetParent().FileIterator() #finding the .txt files
        for path in self.files:
            self.coords.append((1,1)) #applying initial coordinates
        num = 1
        for coordinate in self.coords:
            self.icons.append(Icon(int(coordinate[0]),int(coordinate[1]),self.scale, num))
            num = num+1

        self.shapes.append(DragShape(self.imatge, self.scale))

        #bindings
        self.Bind(wx.EVT_ERASE_BACKGROUND, self.OnEraseBackground)
        self.Bind(wx.EVT_PAINT, self.OnPaint)
        self.Bind(wx.EVT_RIGHT_DOWN,self.OnRightDown)
        self.Bind(wx.EVT_MOTION, self.OnMotion)
        self.Bind(wx.EVT_LEFT_DCLICK ,self.OnLeftDoubleClick)

        self.Refresh()
        self.Update()



    def OnLeftDoubleClick(self,evt): #function allowing to save the simulated track after double left click
        if self.parent.GetParent().drawSimulatedTrack:
            dlg = wx.FileDialog(self,"Where do you want to save the simulated track?",self.mapFolder,'',"Files TXT
(*.txt)|*.txt", wx.SAVE | wx.FD_OVERWRITE_PROMPT | wx.FD_CHANGE_DIR )
            if dlg.ShowModal() == wx.ID_OK:
                self.trackFile = dlg.GetPath()
                self.trackFilename = dlg.GetFilename()
                if self.trackFile[-4:] != '.txt':
                    self.trackFile= self.trackFile+ '.txt'
                    self.trackFilename = self.trackFilename + '.txt'
                with open(self.trackFile,'w') as simulatedTrackFile:
                    for pt in self.simulatedTracks:
                        simulatedTrackFile.write(str(pt[0])+' '+str(pt[1]))
                        simulatedTrackFile.write('\n')
                simulatedTrackFile.close()
            dlg.Destroy()

            del self.simulatedTracks[:]
            self.parent.GetParent().drawSimulatedTrack = False
            self.parent.GetParent().liveTrack.Enable(True)
            self.parent.GetParent().simulateTrack.Enable(True)
            self.parent.GetParent().avtStatus.SetStatusText('Simulated Track', 1)
            self.parent.GetParent().avtStatus.SetStatusText('Saved in: '+ self.trackFilename, 2)
```

```
  def OnMotion(self, evt): #function allowing to draw  simulated track on mouse movement
    pt = evt.GetPosition()

    if (pt[0] < self.cz[0]) and (pt[1]<self.cz[1]) and (pt[0] > 1) and (pt[1] > 1) and evt.LeftIsDown() and
self.parent.GetParent().drawSimulatedTrack :
      self.parent.GetParent().avtStatus.SetStatusText('Mouse at: '+str(pt), 2)
      self.simulatedTracks.append(pt)
      dc = wx.ClientDC(self)
      dc.Clear()
      self.DrawShapes(dc)
      dc.SetPen(wx.Pen(wx.RED,2))
      dc.DrawLines(self.simulatedTracks)

  def OnLeftUp(self, evt):
    print 'LeftUp'

  def OnRightDown(self, evt):  #zooming dunction
    if self.parent.GetParent().drawSimulatedTrack == False:
      pos = evt.GetPosition()
      view = self.GetViewStart()
      if self.scale < 3.0:
        self.scale = self.scale + 1.0
        self.maxColumn = int(self.scale * self.W)
        self.maxRow = int(self.scale * self.H)
        self.SetScrollbars(1, 1, self.maxColumn, self.maxRow, 0, 0)
        self.Scroll(view[0] + pos[0], view[1] + pos[1])
      else:
        self.scale = 1.0
        self.SetScrollbars(1, 1, 1, 1, 0, 0)
      for shape in self.shapes:
        shape.ChangeScale(self.scale)
      for icon in self.icons:
        icon.ChangeScale(self.scale)
      self.Refresh()
      self.Update()

  def OnPaint(self, evt): #function drawing the map and vehicles
    dc = wx.PaintDC(self)
    dc.Clear()
    self.PrepareDC(dc)
    self.DrawShapes(dc)
    if self.parent.GetParent().displayTracks:
      self.DrawIcons(dc)

  def DrawShapes(self, dc): #drawing the map
    for shape in self.shapes:
      if shape.shown:
        shape.Draw(dc)
  def DrawIcons(self, dc): #drawing the icons
    for icon in self.icons:
      if icon.shown:
        icon.Draw(dc)

  def OnEraseBackground(self, evt):
    self.ClearBackground()

class DragShape: #class containing all the parameters of the map
  def __init__(self, imatge, scalei):

    self.imatge = imatge
    self.origWidth = self.imatge.GetWidth()
    self.origHeight= self.imatge.GetHeight()
    self.origScale = scalei
    self.upos = (0,0)
    if scalei != 1 :
      self.imatge.Rescale(int(self.origWidth*scalei),int(self.origHeight*scalei),wx.IMAGE_QUALITY_HIGH)
    self.width = self.imatge.GetWidth()
    self.height= self.imatge.GetHeight()
    self.bmp = wx.BitmapFromImage(self.imatge)
    self.shown = True
    self.scale = 1

  def ChangeScale(self,scale): #function to change the scale of the map after zooming
    self.scale = scale
    if self.scale == 1.0:
      imageFile = 'google_map7.JPG'
    if self.scale == 2.0:
      imageFile = 'google_map14.JPG'
    if self.scale == 3.0:
      imageFile = 'google_map21.JPG'

    self.imatge = wx.Image(imageFile)
    self.bmp = wx.BitmapFromImage(self.imatge)
    self.width = self.imatge.GetWidth()
    self.height= self.imatge.GetHeight()

  def Draw(self, dc): #drawing the map
    memDC = wx.MemoryDC()
    memDC.SelectObject(self.bmp)
    dc.Blit(0, 0, self.width, self.height, memDC, 0, 0)

class Icon: #class containing all the parameters of the icons
  def __init__(self, posX, posY, scale, num):

    self.scale = 1.0
    self.posX = posX
    self.posY = posY
    self.radi = 5;
```

```
        self.shadowColor = 'Red'
        self.shown = True
        self.num = num
        self.font = wx.Font(16, wx.SWISS, wx.NORMAL, wx.BOLD)
        if scale>1.0:
            self.ChangeScale(scale)

    def ChangeScale(self,scale): #changing the scale of the icons
        self.scaleOld = self.scale
        self.scale = scale
        self.posX = int(self.posX * self.scale / self.scaleOld)
        self.posY = int(self.posY * self.scale / self.scaleOld)

    def Draw(self, dc): #drawing the icons
        dc.SetPen(wx.Pen(self.shadowColor,1))
        dc.SetBrush(wx.Brush(self.shadowColor,style=wx.SOLID))
        dc.DrawCircle(self.posX,self.posY,self.radi)
        #dc.SetTextForeground(self.shadowColor)
        label = str(self.num)
        (w,h)=dc.GetTextExtent('V'+label)
        dc.SetPen(wx.Pen(wx.WHITE,1))
        dc.SetBrush(wx.Brush('Yellow',style=wx.SOLID))
        dc.DrawRectangle(self.posX+2*self.radi,self.posY,w+2,h) #4
        dc.DrawText('V'+label,self.posX+2*self.radi+1,self.posY)

class AVTStatusBar(wx.StatusBar): #class containing the parameters of the status bar
    def __init__(self, parent):
        wx.StatusBar.__init__(self, parent, -1)

        self.SetFieldsCount(3)
        self.SetStatusWidths([-1, -1, -1])
        self.sizeChanged = False

        # Field 0
        self.SetStatusText("EPS for AENA-UPC, 2010/11", 0)



class CollectEvent(wx.PyCommandEvent): #event used to collect the coordinates using threading
    def __init__(self, etype, eid):
        wx.PyCommandEvent.__init__(self, etype, eid)

class CollectThread(threading.Thread): #class containing parameters of threading
    def __init__(self,parent):
        threading.Thread.__init__(self)
        self.finish = threading.Event()
        self.finish.clear()
        self.parent=parent
        self.interval = 0.3

    def stop(self): #function used to stop the threading
```

```
      self.finish.set()

   def run(self): #function used to start the threading
      while 1:
         self.finish.wait(self.interval)
         if self.finish.isSet():
            break
         #if self._finished.isSet(): return
         event = CollectEvent(myEVT_CollectLocations, -1)
         wx.PostEvent(self.parent, event)



if __name__ == '__main__': #initializing the window
   app = wx.PySimpleApp()
   avtFrame = MainFrame(parent=None, id=-1)
   avtFrame.Show()
   app.MainLoop()
```

12.2.2. Reading serial port

```
import serial
import time
import math

def read_pixelz(lati, longi):  #function used to translate longitude and latitude into pixels
   #print str(lati) + ' ' + str(longi)
   lati_diff = 41.31029951631133 - lati
   longi_diff = longi - 2.05843448638916

   pix_row = round(lati_diff / 0.000045846)
   pix_col = round(longi_diff / 0.000061222)

   return(str(int(pix_col)), str(int(pix_row)))

def pixelate(line): # function used to select which lines to translate
   latitude = 0.0
   longitude = 0.0
   split_line = line.strip().split(' ')
   if split_line[0] == 'Time:':
      latitude = split_line[3]
      #print latitude
      longitude = split_line[5]
      #print longitude
   return(read_pixelz(float(latitude), float(longitude)))

def check_checksum(row): #function calculating and comparing the checksums

   item = row[1:]
   checksum_received = ''
```

```
    s = 0
    result = True

    for i in range(len(item) ):
        if item[i] == '*':
            checksum_received = item[i+1:i+3]
            break
        s = s ^ ord(item[i])

    checksum_calc = ""
    #convert to hex
    s = "%02X" % s
    checksum_calc += s
    print "Checksum calculated: %s" % checksum_calc
    print "Checksum received: %s" % checksum_received
    if checksum_received != checksum_calc:
        result = False
    else:
        pass
    return (result, checksum_calc, checksum_received)

def read_coords(row): #function reading and splitting the received frames
    latitude = ''
    longitude = ''
    t_seconds = ''



    roow=row.strip().split(',')
    if roow[0] != '$GPRMC':
        pass
    else:
        t_seconds = str(roow[1][0:2]) +':'+ str(roow[1][2:4]) +':'+ str(roow[1][4:6])
        latitude = str(float(roow[3][0:2]) + float(roow[3][2:])/60.0)
        latitude_degrees = str(int(roow[3][0:2]))
        latitude_minutes = str(int(roow[3][2:4]))
        latitude_seconds = str(float(roow[3][4:])*60.0)
        longitude = str(float(roow[5][0:3]) + float(roow[5][3:])/60.0)
        longitude_degrees = str(int(roow[5][0:3]))
        longitude_minutes = str(int(roow[5][3:5]))
        longitude_seconds = str(float(roow[5][5:])*60.0)
    return(t_seconds,    latitude,latitude_degrees,    latitude_minutes,    latitude_seconds,    longitude,
longitude_degrees, longitude_minutes, longitude_seconds)

ser=serial.Serial('/dev/ttyUSB0',4800) #opening the port

path = "../data/GPS-%4d-%02d-%02d-%02d-%02d-%02d.txt"

filename = path % time.localtime()[0:6]
with open(filename,'w') as f: #a instead of w?
    with open('coordinatez.txt', 'a') as f2:
        while True: #loop finding and analyzing first proper line
            line_begin=ser.readline().split(',')
            first_line = ''
            first_line_to_print = ''

            if line_begin[0] != '$GPRMC':
                pass
            else:
                for element in line_begin:
                    if line_begin.index(element) == 12:
                        f.write(element)              #printing the line into the log file
                        first_line_to_print += element
                        first_line += element
                        break
                    f.write(element+',')
                    first_line_to_print+= element+','
                    first_line += element + ','
                break
        print first_line_to_print,

        (outcome, calc, rec) = check_checksum(first_line)
        if not outcome:                                   #calculating pixels and checksums and printing on the screen and
into the files
            print "Frame corrupted, not recorded"
            f.write ('----------------CHECKSUM ERROR calculated:' + calc + ', received: ' + rec + '----------------\n\n')
        else:
            (time, lati, lati_d, lati_m, lati_s, longi, longi_d, longi_m, longi_s) = read_coords(first_line)
            (pixel_column, pixel_row) = pixelate('Time: ' + time + ' Latitude: ' + lati + ' Longitude: ' + longi)
            f2.write (pixel_column + ' ' + pixel_row + '\n')
            print 'Pixels: ' + pixel_column + ' ' + pixel_row
            f.write ('Time: ' + time + ' Latitude: ' + lati + ' Longitude: ' + longi + '\n')
            print time + ' ' + lati + ' '+ longi + '      ' +lati_d + '*' + lati_m + "'" + lati_s + '"N' + ' '+ longi_d + '*'+ longi_m
+ "'" + longi_s + '"E' + '\n'
            f.write('\n')

while True:                       #loop dealing with the rest of the received frames
    with open(filename,'a') as f:
        with open('coordinatez.txt', 'a') as f2:
            line = ser.readline()
            f.write(line)         #printing into the log file
            print line,
            (outcome, calc, rec) = check_checksum(line)
            if not outcome:       #calculating pixels, checksums and printing on the screen and into the files
                print "Frame corrupted, not recorded"
                f.write ('----------------CHECKSUM ERROR calculated:' + calc + ', received: ' + rec + '----------------\n\n')
            else:
                (time, lati, lati_d, lati_m, lati_s, longi, longi_d, longi_m, longi_s) = read_coords(line)
                (pixel_column, pixel_row) = pixelate('Time: ' + time + ' Latitude: ' + lati + ' Longitude: ' + longi)
                print 'Pixels: ' + pixel_column + ' ' + pixel_row
                f2.write (pixel_column + ' ' + pixel_row + '\n')
                f.write ('Time: ' + time + ' Latitude: ' + lati + ' Longitude: ' + longi + '\n')
                print time + ' ' + lati + ' '+ longi + '\n' +lati_d + '*' + lati_m + "'" + lati_s + '"N' + ' '+ longi_d + '*'+ longi_m
+ "'" + longi_s + '"E' + '\n'
                f.write('\n')
```