



## Study and implementation: GIS-GPS Integrated for Air Traffic Ground Control Issues

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### ABSTRACT

*The high congestion at the airports, due both to the increase of air traffic demand and the lack of significant intervention on the infrastructures, and the need to guarantee a high safety level in the airport areas ask for more intensive studies concerning the problem of the ground circulation in an airport area. Particularly, high traffic airport areas must be continuously monitored in order to know at each time the position of all the moving objects, land vehicles and aircrafts, on the ground (aprons, taxiways, runways). Recent solutions used to resolve the problem of object positioning move towards the use of GPS apparatus. In this work, a system that integrates GPS and Geographical Information System is proposed for monitoring the airport areas, following the new requirements of Intelligent Transport System (ITS) applications and with an innovative communication network among GISs.*

### Introduction

The ground movement control system plays an important role for the estimation of the airport capacity; in fact, it establishes the time and/or space minimum separations that has to be guaranteed between two aircrafts during the landing/take of operations. In order to guarantee safety conditions to the ground vehicle movements (not only aircrafts, but also land vehicles as bus for passenger transfers, luggage and refuelling vehicles, and so on) suitable separations has to be ensured among them as during the flight. The risk linked to interferences among aircrafts and/or vehicles during ground movements is still high with respect to the suitable standards for the system.

The safety problem of the ground operations has been also studied by a simulation approach [5], in order to verify the incidence of the airport configuration on the ground movement operations. At present, the so-called Surface Movement Ground Control Systems (SMGCSs) can be used to control the ground circulation in order to guarantee suitable safety standards and manage in an optimal way the ground movement. Actually, the SMGCSs are mainly based on radar systems and/or underground detectors.

Limits of radar systems are linked to the wave propagation system and to the reflections generated by adverse meteorological conditions, that reduce their efficacy; as regards the detector systems, they can detect the movement of the vehicles (both aircrafts and land vehicles) only at specific points, because they are located in prefixed points on the ground. Moreover, in spite of technological progresses, the actual system can neither locate and identify the moving vehicles with the needed accuracy nor convert the signals acquired by detectors in analogical data to be used in an automatic computing system. It is due by using of only one kind of technology, and it is confirmed by continuous occurring of accidents due to insufficiency of the technological systems and wrong communications between pilots and tower operators. For this reason different systems have been studied in order to integrate the radar control with other apparatus, also by using completely different technologies to guarantee both the ground movement safety and the airport capacity increase. In this paper, an integrated approach GPS-GIS will be described; its goal is to provide a surveillance and guidance system for the airport ground movement; the GPS component is used to establish the aircrafts position in real time while the GIS component is used to manage and depict the geographical information of the aircrafts position.

### 1. Requirements of a Ground Air Traffic Control System

An Advanced SMGCS (A-SMGCS), as defined by ICAO [3], must answers to these requirements: surveillance function; routing function; guidance function; control function. The surveillance procedures must be directed to the identification and location of aircrafts and land vehicles within the airport area. Because they are based in most cases on the criterion "see and be seen", they should be unsafe when the external conditions do not permit a good visibility (e.g., in presence of fog) or the traffic density is quite high.

The routing function must be directed to plan and assign a path to each moving aircraft and land vehicles in the airport area in order to assure a safe, quick and efficient movement from its current position (origin) to its final position (destination). At this time, the routing is provided via radio communications to pilots (or to drivers for the land vehicles); paths are established by the tower operators, on the basis of the visual observations from the tower and the knowledge of the airport landside. An advanced function of routing must consider the opportunity to change the path at each time, plan all the paths for aircrafts and land vehicles for each traffic condition, interact with the tower to minimize all possible conflicts at the intersections, answer quickly to path requests of all users. The guidance function must be directed to provide pilots (and drivers) with suitable, unequivocal and continuous information about the path to be followed and the speed to be maintained to continue safely; at this time, the control function is realized by means of visual aids. Finally, the control function must guarantee from each possible collision and runway incursion, and assure safe, quick and efficient movements in the airport surface area.

At this time, the control function is under the responsibility of both pilots and controllers, following the rule "see and avoid". An advanced control function must be able to support the ground movements in any traffic condition and the required movements for up to one hour; it must be able to find conflicts and to provide fast solutions to avoid them; it must be able to verify that the required safety distances are kept and advise if they reduce by a minimum value. Similarly, it must advise in case of runway or other restricted area incursions by means of suitable alarm systems; it must coordinate driver and pilot actions; spacing aircrafts to ensure minimum delay and maximum utilization of the airport capacity; finally, it must separate movements from obstacles, secure areas and restricted areas.

## 2. Global Positioning System (GPS)

The NavSTAR GPS (Navigation Satellite Timing And Ranging Global Positioning System) system was originally borne in USA for military purposes; it allows the three-dimensional positioning of objects (also moving) to be identified by means of information coming from a geostationary satellite system by using distance-measuring spatial intersections (ground receiver - orbit satellite). Mainly two kinds of GPS measures can be used [2]: the pseudo-range and phase measures. The first ones are used above all for navigation assistance, while the second ones are used in all applications for which a greater accuracy is required, as the land deformation control. The relative (RTK) positioning are particularly useful to continuously control in real time the moving means of transport; in this case, the measure (Cartesian coordinates of the baseline vector between the known master station and the rover station referred to the vehicle to be positioned) must be initialized and the satellite visibility must be guaranteed during all the time of the positioning measure. In detail, RTK measure requires two receivers, which simultaneously register observations; it is possible that rover receiver calculates its position in motion. The RTK technique uses double-frequency GPS surveys (L1/L2) and it is tolerated the signal loss from the satellite. Focusing our attention on receivers, one is placed in a known place, and the other is placed on a moving object/platform. If the survey is led in real time, a link to transfer data and a microprocessor are requested.

Communication link is used to transfer raw data from the reference station to rover one. RTK relief are precise inner the 10 centimeters when rover-master distance is not greater than 20 kilometers. However, since GPS system can be affected by observation errors (i. e. variation of position of antenna phase center), the acquisition system must be equipped with a firmware for the on-the-fly (OTF) initialization with a moving rover in case of temporary loss of the signal and suitable links among the acquisition stations (master and rover) to obtain in real time the correct transmission of the data, following given protocols.

## 3. A GPS-GIS Approach for the Air Traffic Ground Control Problem

In this section an integrated GPS-GIS system is proposed for monitoring the airport areas, following the new requirements of Intelligent Transport System (ITS) applications. ITS applications use telematics technologies and data processing methods to obtain an "intelligent" management of the transport system in terms of efficiency, safety and environmental aspects. GISs are an essential support to plan, manage and depict all useful information related to the examined system, and particularly many applications have been made (and some other can be thought) also in the transport field [1]. The system here proposed involves both the GPS and GIS systems in order to obtain an efficient, safe and quick management of the vehicle movements at an airport area (both aircrafts and land vehicles). In fact, thanks to GPS systems, the actual trace of the aircraft (or land vehicles) can be followed (by means of transmission and updating of the navigation data in real time), while the GIS system allows the geographic information and the position to be managed and visualised (by means of the implementation of suitable software functions to resolve the problems of perception and management of the information and to update in real time the acquired data). Particularly, the proposed system (Fig. 1) considers:

location and position of aircrafts and other moving vehicles in aprons by GPS and transfer of data referred to its position (other data measured by different sensors can also be considered);

- management and data processing operating in a GIS system;
- re-transmission of information to the aircrafts/vehicles by a communication system based on IEEE 802.11b protocol.

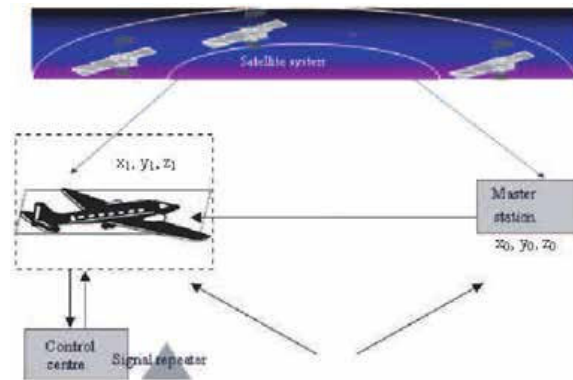


Figure 1: The GPS system to detect the moving vehicles on the ground

### 3.1 Components of Our System

The main components of the system are:

- a Master Station (MS) of known coordinates, which can communicate to each rover by means of a 440 MHz radiomodem and can or cannot coincide with the control centre;
- a RTK-OTF device, located on each moving vehicle (rover); it has to detect real time position and must be able to communicate with the MS in real time; it is equipped with a display, connected to a network of data transmission, where on a cartographic support is showed the path to be followed;
- a control centre equipped with a data reception system, a GIS system for visualising and processing the data and with a data transmission system that returns the information to the aircraft (Fig. 1).
- a communication system based on IEEE 802.11b protocol, used to transfer GIS informations from MS to rovers and vice versa.

### 3.2 The GPS Module

Each GPS device, autonomous and supplied by suitable batteries, is characterized by a system able to receive and apply a real-time correction in terms of code range and/or phase, initialize the measure (OTF firmware to initialize quickly or during the movement), compute the object position in real time, memorize and store the coordinates and transmit the memorized data to the control centre according to international protocol (NMEA). Concerning the OTF firmware in order to solve the phase ambiguity resolution on-the-fly, RTK-OTF technology allows remote receiver initializes and solves integer ambiguity on baseline calculus without a period of static initialization. With RTK-OTF, if cycle-slips occur, the initialization can happen in motion. Integers can be solved by rover in 3-10 seconds: all depends by distance from reference station. RTK-OTF uses L2 frequency, transmitted through GPS satellites in ambiguity resolution. After integers are solved, only L1 and C/A frequencies are used to compute position.

### 3.3 The Control Center and the GIS Module

The control centre, whose aim is the real-time view of the movements of the vehicles/aircrafts on ground, is characterized by a GIS modulus realized to manage the monitored information; it works on a cartographic map that reproduces the airport ground area and is equipped in order to acquire, re-process, return and re-transmit positioning information on a digital base.

GIS of control tower's station, other than monitoring operations, includes other advanced functions to manage the traffic on airport runway; these allow to do:

- "pre-routing" operations: the control system aids the personnel to path definition which will be followed by vehicles, in order to optimize the runway occupation, minimizing usage times and at the same time guaranteeing a high

safety degree; moreover, into the “pre-routing” operations, GIS considers geographical position of airport, time period to plan, meteorological forecast, in order to predict availability and reliability of GPS measures (number of satellites, DOP, etc.), so that to trace for each target paths adequate to fixed security range;

- real time operations of path modification: in an automatic or semi-automatic way, GIS can modify paths fixed on “pre-routing”, and can signal these corrections to pilots/drivers of various vehicles, so that they converge in a “maximum safety position” if there is a fault of any part of GPS-GIS system, i. e. the sudden non-availability of GPS measures;
- the storage, with date and time, of each path (or its correction) linked to whatever vehicle; so that, it is available a real GIS “space-time”, which is able to make an of-line analysis of historic trends in order to better sharpen the parameters which will be used during “pre-routing” phase; in other words, system for path identification learns from events occurred in past e managed by the same GIS. Moreover, crossing over the vehicle movements “in a visual way”, it would be simple to find possible responsibilities in case of accident.

**3.4 The Data Transmission**

Since that we described above, it is clear that it has to exist a GIS Slave over each aeroportual vehicle more than a GIS on control station (GIS Master); the aim is to view, on a graphic console (Fig. 2), the path of the same vehicle and the positions of possible neighbouring vehicles. The GIS Slave does not make any path elaboration, but it draws paths executing GIS Master’s instructions (see section 3.3).

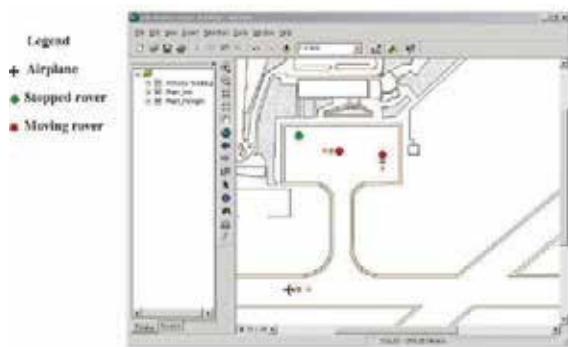


Figure 2: Graphic visualization on ArcView software

Communication architecture between the GISs must be linked to a hardware/software structure, which has to be reliable, un-failing, and above all available in whatever point on runway is the mobile vehicle. IEEE 802.11b is the best and cheapest communication protocol for these requirements. Generally, it is used to build WLAN linking computers located on a maximum distance of 100 meters each other; but it could be

cover adequate distances for our application using opportune power levels, special transmission channels, and high-gain directive antennas. On detail, communication among various GIS Slaves and the GIS Master can count on a system (Fig. 3) composed by:

1. omnidirectional wireless antennas 802.11b, placed on each mobile target;
2. directional wireless antennas 802.11b, located on opportune points of runway, in order to cover the area of interest, even in a redundant way;
3. coaxial cables which link the directional antennas to GIS Master;
4. some hardware gateways, to which are directly linked the directive antennas and which manage the communication between link Wireless and coaxial cable.

Naturally this system allows GPSs located on each vehicles to transmit the NMEA codes to GIS Master, which uses them with other informations in order to calculate and transmit paths to GIS Slave. Therefore, according to our standards, no vehicles can directly access to GPS data in order to know its position. This kind of control centralization allows to manage optimally even the more critical situations: in fact, only the GIS Master, being able to cross various kind of data, can notice an even if improbable anomaly in coordinates returned by a GPS, and order to corresponding GIS Slave the visualization of deviation towards an alternative “maximum safety position”.

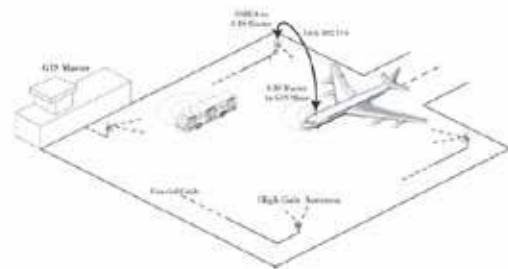


Figure 3: Schema of data transmission

**Conclusion**

The system described before has been tested on a small private aeroplane, during the taking-of operations. Even if it is still under test, because more moving vehicles, higher taking-of speeds and diferent solutions to communicate data between the diferent apparatus are now testing, however the results are very encouraging. Some problems could verify during the landing operations, given the possible GPS signal latency due to the high involved speeds and then the impossibility to visualize the aircraft in real time. In any case, more tests and more work need in this field due to the importance of the topic involving the human safety.

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