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Journal of Air Transport Management 12 (2006) 375–381

Journal of
AIR TRANSPORT
MANAGEMENT

www.elsevier.com/locate/jairtraman

Surface movement ground control by means of a GPS–GIS system

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Abstract

Despite the traffic increases at the World's airports, little works have been done on methodologies to improve vehicles and airplanes ground control. This may be leading to reduced safety. Here an integrated system is developed to help guarantee suitable separations of land vehicles and airplanes moving on the airport ground area It can also addressed issues of the optimal use of taxi and runways. The system is composed of global positioning systems hardware, checks on the position of land vehicles and airplanes on the ground in real time, and special-purpose geographical information systems software for the tracking of land vehicles and airplanes within different planning operations.

Keywords: Airport ground control; GPS; GIS; Airport safety

1. Introduction

Traffic congestion at many major airports is increasing. There are generally more vehicles moving in the airside, including aircraft and land vehicles (buses, service cars, vehicles for handling operations, and tank trucks). While some areas are kept specifically for aircraft (e.g., runways) or land vehicles (e.g., maintenance areas), potential conflicts arise during such operations as passenger transferring to/from the aircraft, and aircraft handling and servicing. Furthermore, on the restricted areas, there is a potential conflict between aircraft and aircraft, or land vehicles and land vehicles. This is a particular challenge during operations such as landing or take-off when the aircraft speeds are high and manoeuvrability is limited.

The US Federal Aviation Administration (FAA) defines a runway incursion as "any occurrence at an airport involving an aircraft, vehicle, person or object on the ground that creates a collision hazard or results in a loss of separation reduction with an aircraft taking-off, intending to take-off, landing or intending to land" (Flight Safety Foundation, 2000). A similar definition has been developed by the European Organization for the Safety of the Air Navigation (within Eurocontrol), that defines the runway incursion as "any unauthorized presence on a runway of an aircraft, vehicle, person that creates a collision hazard or results in a potential loss of separation". Potential conflicts, however, also can occur with circulation in other spaces, such as taxiways and aprons, even if the most critical situations involve runways (Janic, 2000).

To assure safe operations at airport areas surface movement ground control systems (SMGCS) (Pitfield et al., 1998) have been developed. They aim to control ground circulation to meet safety standards and to optimally manage ground movements, e.g., by reducing excessive spacing of aircraft and directing moving vehicles along paths optimal for the system.

Here we combine global positioning system (GPS) advanced technology and user-friendly geographical information systems (GIS) to check in real time the location of land vehicles and aircraft. Data coming from land vehicles and aircraft by GPS providers are processed by a centralized system and the position of each is depicted in a GIS tool.

2. Requirements of an advanced ground control system

An advanced SMGCS (A-SMGCS), as defined by the International Civil Aviation Organization (2004), must

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0969-6997/$ - see front matter
doi:10.1016/j.jairtraman.2006.09.003

have a surveillance function, a routing function, a guidance function, and a control function. The surveillance function, generally based on "see and be seen" criterion, needs to identify and locate aircraft and land vehicles within the airport. The routing function must be directed to plan and assign a path to each moving aircraft and land vehicle to assure a safe, quick, and efficient movement from its existing position to its final position. An advanced routing function must consider the opportunity to change the path at each time, plan all the paths for aircraft and land vehicles for each traffic condition, interact with the tower to minimize all possible conflicts at intersections, and answer quickly to path requests of all users. Currently, routing is provided via radio communications to pilots and to drivers for land vehicles with paths established by the tower operators on the basis of visual observations and knowledge of the airport landside. The guidance function, done by means of visual aids, directs pilots and drivers using suitable, unequivocal and continuous information about the path to be followed and the speed to be maintained. Finally, the control function guarantees against possible collision and runway incursion, and assures safe, quick, and efficient movements. This function is under the responsibility of both pilots and controllers following "see and avoid" rules. An advanced control function must be able to support the ground movements in any traffic condition and the required movements for up to 1 h; it must be able to identify 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 are reduced to a minimum value. Similarly, it must advise in case of runway or other restricted area incursions through a suitable alarm systems; it must coordinate driver and pilot actions; space aircraft to ensure minimum delay and maximum utilization of the airport capacity, and separate movements from obstacles, secure areas, and restricted areas.

Radar-based systems (ground movement radar or surface movement radar) are currently used to locate aircraft. Other systems used to follow aircraft surface movements in high traffic density airport areas involve networks of under-pavement detectors—airport surface monitoring equipment (ASME)—that can distinguish different kinds of traffic components. A further detector network on the outside of the paved areas allows a possible miss-positioned aircraft to be quickly located and assisted. Under-pavement detectors are, though, intrusive, require an interruption of the airport operations during their installation and cannot be easily removed if some changes in the runways/taxiways system are needed.

3. The GPS approach

The Navigation Satellite Timing And Ranging Global Positioning System (NavSTAR GPS) is based on 24 satellites orbiting around the earth and receivers located at points to be surveyed. The receivers involve with antennas to communicate with the satellites as well as hardware and software to compute the coordinates of specific points. The coordinates are then communicated to the external storage and/or monitoring devices by several possible technologies according to the exigencies (cables, Irda Infrared Data Association, Bluetooth, radio, GSM, MMS, etc.—see, Schwartz, 2004; Umar, 2004). The communication of the coordinates is mainly based on the NMEA transmission protocol (Meng et al., 2004).

The working principle of a GPS is based on the computation of the distances between the receiver and satellites, whose positions are known, by using topographical triangulation methods (Hoffman-Wellenhof et al., 1997). Unfortunately, GPS may involve several sources of error such as irregular disposition of the satellites on the sky at the moment of the survey and slackening of speed due to the ionosphere that can generate a location error even of 60 m. The use of more satellites other than the three ones theoretically needed for triangulation procedures can help to overcome these problems, as well as the development of different operational survey modalities.

Static modalities are characterized by longer observation time for each receiving station; intervals of 2–60 min are needed if a sub-centimetre precision is required. Dynamic modalities are characterized by the use of a fixed station and one or more mobile receivers providing detailed information about a prefixed tracing. The Real Time Kinematic (RTK) dynamic modality, with On The Fly (OTF) initialization, can be used to compute the coordinates directly at the moment when the survey of the mobile receiver occurs, without additional off-time data processing. Furthermore, the compulsory synchronization between the two receivers does not require the system reset after a possible loss of the satellite link. However, the time required by RTK and OTF to provide coordinates after satellite link restoration is large compared to the time the aircraft takes to move on the runway. Other problems include potential interferences to the mean frequency radio communication between two stations and the absence of government concessions for the unlimited use of large distances operational frequencies.

For these reasons, the pseudo-range survey modality using only one receiver with European Geographic Navigation Overlay System (EGNOS) correction, managed by the European Space Agency, is used. EGNOS uses three geostationary satellites and a terrestrial stations network to process the signal delay emitted by the GPS satellites due to the ionosphere ionization. Its working principle is the same as for standard GPS, but the terrestrial stations located over Europe compare their positions with those computed at a given time by the pseudo-range GPS detectors located in the station. After the comparison, errors due to signal propagation in the atmosphere can be identified. Then, the detected data together with the errors are sent to a central station that generates a thick network of correction factors. These are sent to the EGNOS satellites, from where they are sent on to the ground station by using the GPS