Safe management of fleet operations in complex and critical infrastructures

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Abstract

Safety of surface movements and the efficiency of airport operations should be managed as a whole. However, it is not unusual to find scenarios where both services are performed independently. With the advent of mobile computing and with the dissemination of location-based services, improvements to the way airports monitor ground movements are expected. It is also expected a higher level of integration between the airport systems. The integration of airport systems with sensor related networks of mobile devices create in fact a consistent view about airport ongoing operations, enabling airport stakeholders to take better operational decisions based on up to the minute information. Improvements within the wireless sensor network area enable European transport policy and in particular airport stakeholders to benefit from solutions capable to provide reliable situation awareness related to surface movements, complemented with real-time alerts about safety occurrences within the spatio-temporal context they occur. Indeed, airport stakeholders started to request new and more integrated tools to improve the management of surface movements according to A-SMGC requirements while maintaining the required level of safety. This paper presents the AAS platform and how it meets some of the A-SMGCS functional requirements.

Key words: Location-based services, Sensor data fusion, ground traffic management, A-SMGCS

1. Introduction

In an airport a variety of organisations operate in stressing operational environments in order to accomplish tight schedules without causing risk breaches derived from safety or security infringements [1]. In most situations airport stakeholders need to spend a huge effort synchronising airport ground operations. The management is however performed apart from each other, without having a collaborative view of ongoing ground movements at the airport manoeuvring area. This lack of integrated systems, capable to communicate to each other, is at the root difficulty to collaboratively manage airport ground movements. Consequently, it is almost impossible for airport stakeholders to act more proactively. As such, when incidents happen, it is often difficult to identify the airport stakeholder(s) field worker(s) responsible for an incident [2]. Data has to be correlated manually with all the mistakes which happen when people are working under time pressure. Furthermore, valuable information can be lost when shift changes take place. Existing safety management procedures do not enable decision makers to efficiently take the required reactions to business service demands.

At the same time, nowadays the position of each field worker is not known by all stakeholders and most operational vehicles circulate without any electronic detection device, connecting them to an operational control centre and to each other enabling vehicle drives to have an overview about ground movements at the neighbourhood of the vehicle. The lack of electronic monitoring functionalities for decision makers or field worker to be notified about ongoing operations, in particular at rush hours, contributes for high levels of congestion, increasing the likelihood of incident rate to increase, as well as the probability of vehicles or aircraft assisting equipment to be misused.

In a critical infra-structure such as an airport, the usual procedure done by operational decision makers (e.g., fleet managers) is to position vehicles and assisting equipment at predefined areas [3]. In most situations such decisions are taken without having information about current operational needs. When a vehicle or equipment is requested because of unexpected schedule changes (e.g., flight delay), the synchronization between field workers and operational decision makers is performed by radio voice communication. Such approach enables only a reaction to the situation. Indeed, every time a non planed request is triggered or changes to planned tasks are required, decision makers do not have any mechanism to dynamically check which vehicle is best position to respond to task changes.

Actual reports do not efficiently allow a good planning and identification of which vehicle is best positioned to perform an unplanned task, avoiding operational inefficiency and leading to considerable savings in daily operational costs [4]. Such approach would contribute to reduce congestions, enhancing safety in apron areas. This scenario is particularly relevant for the apron area due to the many different companies operating at the same time on a small restricted access area [5]. Situation awareness is therefore a core issue for airport stakeholders such as air traffic controllers, airport coordinators, and handling agent's supervisors to monitor safety breaches derived from congestions, incursions or any other infringement to predefined airport operational rules.

With the advent of mobile computing, the surveillance of aircraft and vehicle movements through location-based services has become a fundamental tool for the development of safety management solutions capable to overcome operational constrains [6]. In most situations these constraints are derived from the lack of coordination between airport systems leading, in crisis situation (e.g., emergency or bad meteorological conditions,) to a malfunction of the airport and eventually compromising the required level of safety.

In this paper we present the Integrated Airport Apron Safety Fleet Management (AAS) project, and in particular how the identified problems are managed. The AAS is an R&D project presently supported by the European Commission under the 7th Framework Program. The AAS system provides an efficient and safe distribution of tasks to field workers, with time fleet management functionalities to support airport stakeholders at their daily activities, avoiding break times, deadlocks and bottlenecks. For this purpose, two communication networks (IEEE 802.11a and GPRS) are used. The IEEE 802.11a is a high bit rate wireless communication technologies like Wi-Fi and the general packet radio service (GPRS) is a packet oriented mobile data service on the 2G and 3G cellular communication systems global system for mobile communications (GSM). Additionally, the AAS system makes use of geo-fencing features to validate if vehicles are causing security infringement or safety incursions into restricted access areas.

The airport layout defines the spatial context environment, represented by the system with a graphical map layout and a set of metadata for validation of business rules infringements. For instance, roadways are represented as a set of polygon feature segments with data about vehicle circulation directions, speed limit and category of vehicles authorized to circulate on each road segment for each airport status conditions. Besides a rigorous map-based accuracy the AAS system also provides visual information about changes to the status of map features over time. Because of data interoperability issues, the map features are formatted in conformity to the ED-119 standard.

The AAS project also applies to airport ground services the "Just-in-Time" principle developed for the industry. This principle is based on the use of available information and different sensor technologies to optimise the usage of airport resources and services to enhance the overall performance of airport operational process.

Operational trials are carried out at two airports, in Portugal at Porto (OPO) and in Germany at BerlinTegel (TXL). Both airports have only one Ground handler to perform the majority of airside ground handling tasks: ANA / Portway and GlobeGround Berlin, respectively. Both are partners in the AAS project.

Within the scope of this paper and we will only refer to the pilot being deployed at Porto airport.

However, in both cases, the airport layouts, their spatial context and operational rules were identified and related to different aspects of airport safety and security constrains. The goal was to gather enough business information to trigger situation awareness events whenever a safety or security breach is detected. The continuity in positioning is accomplished by monitoring surface movements of cooperative vehicles equipped with a GPS/EGNOS receiver and by correlating driver's identification and vehicles location with assigned tasks, flight information and business data.

The rest of the paper is structured as follows. Section 2 provides a high level view of the A-SMGCS strategy with a description of the corresponding functional layers. Section 3 provides a short introduction to apron safety risks. Section 4 describes the AAS architecture together with the presentation of the communication network and the main functionalities of a client application to interact with the AAS system. In section 5, the scenarios for situational awareness of the location and identification for cooperative vehicles operating at the airside area is presented. Preliminary results are outlined in section 6. Main conclusions are discussed in Section 7.

2. A-SMGCS Requirements to Monitor Airport Surface Movements

During periods of low visibility, the surveillance of surface movement performed by airport stakeholders can be enhanced though location-based services. For instance, surveillance and alerts functionalities can help stakeholders, at a control centre, to monitor ongoing surface movements without having to exclusively rely on the pilot's and field worker's radio reports to identify conflicts. Without the localization and situation awareness events provided by location-based technologies together with the identified events being displayed over a map-based layout, airport stakeholders, in particularly pilots and vehicle drivers, find that their ability to operate in the "see and be seen" mode is severely impaired.

The current situation of aircraft and vehicle surface movements in European airports raises a number of issues that have led EUROCONTROL to define a strategy for the implementation of a system for airport traffic management [7]. The main goal of this strategy, known as advanced surface movement guidance and control system (A-SMGCS), is to provide a roadmap for an integrated solution capable to ensure the safety and efficiency of airport operations in relation to specific weather conditions, traffic density and airport layout. Due to the availability of new location-based technologies, including automation, it is possible to increase airport capacity at complex and high-density airports, even in low visibility conditions.

Currently, most airports still rely on the former concept of SMGCS as defined by the International Civil Aviation Organization (ICAO). The SMGCS procedures are mainly based on the "see and be seen" principle. These procedures apply for control, guidance and low visibility conditions. It is foreseen that the A-SMGCS will be implemented progressively in a phased approach consisting in a package of services addressing Surveillance, Control, Route Planning and Guidance. Surveillance provides airport stakeholders with the situational awareness in the airside area. The control functionality allows preventing conflicts and collisions by providing alerts for incursions in restricted areas such as runways. These functionalities generically characterize the two first levels of the A-SMGCS strategy. Through the routing functionality a more efficient route, either manually or automatically, is designated for each aircraft or vehicle. Guidance gives indications to pilots and vehicle drivers to enable them to follow an assigned route. These functionalities define the two higher levels of the A-SMGCS strategy.

Each package of services is structured according to four different implementation levels [8]. The main concerns of levels I and II rely on the improvements of safety, whereas the ground movement's efficiency is dealt with in levels III and IV [9]. The first criteria for implementing A-SMGCS relates therefore to operational needs. The services that address urgent operational needs should be implemented first. This means that services like surveillance and control have priority on route planning, which serves the efficiency of surface movements. Figure 1presents a diagram of the A-SMGCS layers strategy where the surveillance service is represented as a pre-requisite for implementing all the other A-SMGCS services.

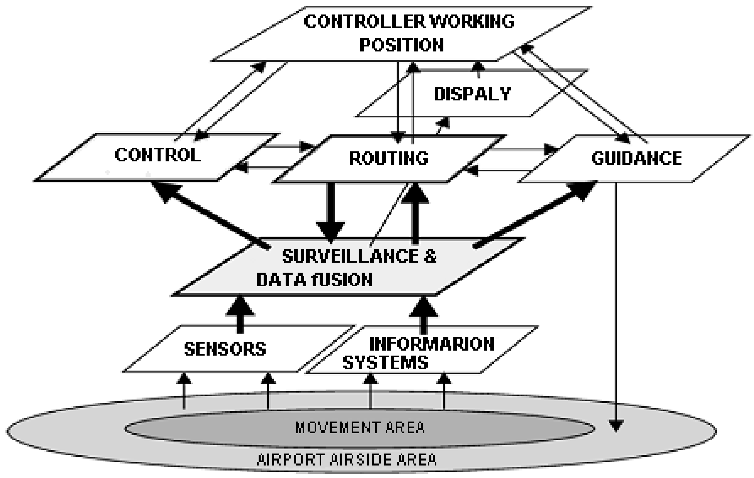

Figure 1: A-SMGCS functional layers [10].

The primary aim of a surveillance service is to have situational awareness of the position and identification of all moving vehicles and aircraft in real time, with assured reliability and integrity. In general, the surveillance service provides identification and accurate positional information on aircrafts, vehicles and obstacles within the required area. In order to feasible implement a Control service it is most important to reduce false alarms in relation to hazardous situation. Consequently, a control service should first detect the most critical operational situations and progressively monitor for other less severe situations. For instance, such a service may be first developed to detect basic runway incursions and later on to deal with more complex situations or less critical hazardous situations, e.g., detection of a non-authorized vehicle in a stand area or of vehicles exceeding speed limit. Alerts should be generated when appropriate.

The routing service addresses the planning and assignment of a route to individual aircraft and vehicles to provide safe, expeditious and efficient movement from its current position to its intended position. Finally, the guidance service assigns continuous, unambiguous and reliable information to pilots of aircrafts and drivers of vehicles to keep their aircrafts or vehicles on assigned routes intended for their use.

As outlined in Figure 1, the display layer integrates the inputs provided by the other A-SMGCS layers, providing a continuous display of the vehicles position in real-time at the airport stakeholder's monitors [10]. The primary objective is to implement the functionalities defined for the implementation levels I and II of A-SMGCS. The display layer is responsible to implement functionalities to continuously and accurately update the location of the mobiles position, representing them as point features over the airport layout. In this way, we are convinced it is possible to provide a collaborative decision making (CDM) environment with GIS functionalities to enable airport stakeholders to take more informed decisions.

3. Safety Risks at the Airport Apron Area

The variety of people and organizations operating at the apron area or connected with airside tasks is increasing in number and density. Consequently, a variety of public and private organizations are actors in the airside area. These actors are currently managed independently from each other. As a result, ground damages occur that costs to airlines, according to the International Air Transport Association (IATA), approximately US$ 4 billion per year [11]. The financial burden is worsened by the indirect costs of ground accidents, namely the ones coming from lost revenue, from ticket sales, flight cancellations, repositioning and replacement of aircrafts. Indirect costs are at least three times higher than the direct costs. Safety risks at the apron area can be classified into three categories:

- **Category one** – damages done directly from a person outside the vehicle, e.g., smashing something into a window. Monitoring such damages usually requires a closed-circuit television (CCTV).

- **Category two** – damages related to incidents inside a vehicle. The way to avoid such incidents is through an Access Control System (ACS) for vehicle where only authorized staff is allowed to drive a vehicle. The combined approach of having a driver access validation process with a resource management system (RMS) will enable the check not only of the driver's access authorizations, but also if there is an assigned task for the vehicle and the logged driver. This approach enables inside vehicle damages to be related to a specific person. The same ACS in the vehicle can also be used to collect vehicle performance metrics and transmit those data to the RMS at a control centre. The RMS would be able to use this information to optimise the next tasks for the vehicles by calculating actual movement times between positions for the vehicles, to the next task.
- **Category three** – Damages of the third category are the ones of most interest for the AAS. These damages are caused by GSE-vehicles, e.g. a tractor collision with an aircraft engine, and leaving without reporting the damage. Last year an overall damage of 2 billion Euros occurred at the airport aprons, worldwide. By using the telemetric unit in combination with a GPS-module the positions of the vehicles can be stored in a database. If damage is detected, a data request is triggered at the database storing the position of the vehicle or aircraft with a timestamp of the reported occurrence.

The AAS database will list all relevant vehicles which were close to a collision position at a requested time, enabling airport stakeholders, namely the Safety Manager and the Ground Handler Manager, to search for who is responsible for the reported damages. After finding the right vehicle it is easy to identify the apron operator and the related driver, because all relevant data are stored. These objectives of the AAS project are fitting into a broad range of European Union (EU) overall goals for the European transport policy and in particular for the airport of the future [12].

4. The AAS System

The implementation of a good A-SMGCS strategy should imply advanced localization techniques, state-of-the-art wireless communication networks with performing embedded systems for vehicles and the use of advanced geographical information systems (GIS) for airport cartography. With such approach, the concept of an A-SMGCS can effectively enhance airport stakeholder's operational activities in terms of fleet management. The AAS project follows an A-SMGCS approach by making use of a set of wireless technologies and procedures to support accurate and continuous localization of moving objects for ground handling operational scenarios.

It is expected that the results of the AAS will reinforce competitiveness of the European industry in two dimensions. At a first instance it will directly affect the transportation industry. By getting access to the unique highest competency advice on safety issues, companies can optimise their actions, by taking advantage of doing it within the context of the system as a whole. Secondly, avoiding duplication and unnecessary overlap of system functionalities, AAS will make running the transportation services in the apron area more attractive economically, without necessity of compromising safety standards.

The AAS platform is suitable only for cooperative moving objects, meaning any object equipped with a localization device, ranging from a very simple RFID tag to a complete embedded system with GPS/EGNOS receivers for installation in vehicles. In its current version, the communication with aircrafts is not tested, therefore in this paper interactions with pilots are not considered. Instead the emphasis is on the compliance of an integrated solution that leads to a reduced workload for airport controllers and vehicle drivers.

4.1. AAS Architecture

The AAS architecture implements a client-server model with two major components. One, that acts as a control centre with functionalities for the management of ongoing ground operations, adequate for airport controllers, and another with functionalities for cooperative vehicles adequate for field workers like vehicle drivers operating at the airside area. In this way, besides providing A-SMGCS functions to support airport stakeholders in their daily management activities, the AAS system can adjust its surveillance, tracking and monitoring functionalities according to changes derived from the external system, namely alterations derived from the airport flight information system for instance to deal with flight schedule changes or alterations derived from the rostering system reporting last minute changes to staff task plan because of flight delays. Figure 2 shows the architecture of the deployed system and its main components.

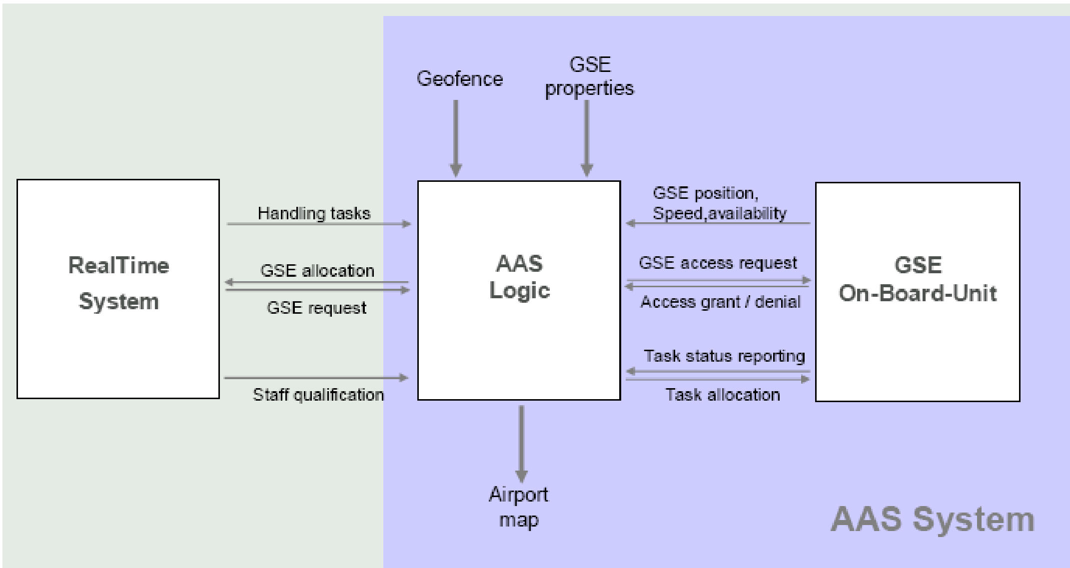

Figure 2: A high level view of the AAS architecture

The AAS Logic component is responsible to validate in a continuous way if field workers, in particular vehicle drivers are performing according to what is expected. To accomplish such goals the component needs to characterize the airport layout as a set of thematic map features (i.e., Geofences), each one with a predefined business semantic and a set of metadata. The information received from one or more positioning source is fused with the environmental descriptions inserted in the AAS Logic.

The airport layout together with the description of mobile devices, the description of the people working at the airside area, the description of task allocations and business rules aggregate the major requirements for the AAS logic to validate, for each movement, if a mobile device is causing a safety incursion or security infringement. The external airport operational data tasks, staff qualifications and mobile devices are provided to the AAS logic by the existing airport systems. Based on those data, for each cooperative vehicle three verifications start to be performed:

1. Store the position of the mobile object, its status and additional descriptive attributes such as temperature and vehicle speed;
2. Validate if the moving object requires a logged user. If so, upload to the vehicle embedded system all the tasks allocated to the logged user. If no logged user is registered then an alert message is triggered to the AAS Logic at the control centre;
3. Cooperative vehicles equipped with a touch screen display enable logged drivers to report the status of the tasks. This is particularly relevant for the AAS logic to monitor intruders, meaning vehicles moving at the apron area without an assigned task;
4. All location-based data processed by the AAS Logic are sent to the application clients as point features, with the positioning parameters in WGS84 coordinate system.

Interface between location-based services and AAS system is developed based on the AAS protocol specification aligned to mobile devices localization standards and context aware information. The minimum location hardware requirements for AAS compliance are:

- TCP/IP communication;

- AAS protocol messages interpretation;
- AAS protocol messages building/decomposing;
- Swift response to messages;
- Clock speed, memory and computing power.

The present level of technological development in the information and communication technologies allows the definition of a low cost platform aligned with the A-SMGCS strategy. The AAS platform relies on a set of interconnected components, on the deployment of IP-based wireless communication networks and on end user applications. Geographical information (GIS) functionalities for representation and interaction with the environment spatial context constitute another feature performed by the AAS system at the back end. Topological functionalities such as point into polygon, and point near point are used to validate spatial context awareness rules at the airport environment. The cartographic context includes features such as runway protection areas, roads, stands, gates, terminal and cargo buildings, power infrastructures.

Every time a position from a vehicle is received, the AAS at the backend will generate an OTI Position Report and will send it to the Resource Management System. The Open Telematics Interface (OTI) interface is a project consortium interface protocol that enables a seamless integration of the AAS system with third party enterprise applications. Enterprise Resource Planning (ERP) systems, as for example SAP ERP, are able to extend the enterprise information system to the vehicle fleets for effective and efficient business process planning and controlling. The use of OTI fosters a high degree of business process automation, to improve transport and service quality. An important goal is the intent to save costs.

AAS comes with a so called “Service Bus” to exchange data between AAS components in XML format. This is a current technological standard and it makes it easy for other systems to use AAS data. This XML message was chosen because it’s quite simple/small and should be enough for what its intended. Therefore the AAS can offer a data interface that has a state of the art format.

Example of an unsuccessful LOGIN XML exchanged messaged between a Pushback_01 vehicle and the AAS Logic:


```
<?xml version="1.0" encoding="iso-8859-1" ?>
<!DOCTYPE MOMessage SYSTEM "reply.dtd">
<!-- @version: -->

<MOMessage
MessageId = "10012563" –> will be a sequential number starting from 1.
EquipmentId = "Pushback_01"
Date = "24.01.2009 18:21:36"
DateObu = "24.01.2009 18:21:19"
DateGPS = "24.01.2009 18:21:10"
Latitude = " 48.401451"
Longitude = " 9.945045"
Description1 = ""
Description2 = ""
PassoStatus = "0"
PassoMacro = "112" -> Logon
Text = ""
Pin = "2222" -> PIN
Km = "" -> will always be empty since it is not needed for the login procedure.
Item1 = ""
Item2 = ""
Item3 = ""
Item4 = ""
Item5 = "5"
Item6 = "Wrong login or password">
</MOMessage>
```

The item5 and item6 are used to represent predefined coded messes, for instance:

1: "Driver license expired""
2: "Driver license not authorized to drive the vehicle category"
3: "Vehicle inspection date expired"
4: "Vehicle insurance date expired"
5: "Wrong login or password"

AAS comes with a so called "Service Bus" to exchange data between AAS components in XML format. This is a current technological standard and it makes it easy for other systems to use AAS data. AAS also provides WebServices, Socket based communication and exchange of files as alternative interfaces for application integrations.

4.2. Communication Network

Mobile objects communicate with AAS platform through a TCP/IP communication infrastructure - wired and wireless. To guarantee the project success, Porto Airport installed of an IEEE 802.11a Wi-Fi network to the baggage terminals, apron and movement areas. The Operational Wi-Fi network as defined for Porto Airport will guarantee a mobile communication platform for operational environment and therefore for operational mobile applications. Also a GPRS mobile network is available, which can be used alternatively for the communications.

Under the AAS project scope for the first scenario and to be used as an A-SMGCS mobile communication network, low roaming times and centralized management of Access Points (AP) on a controller were fundamental requirements. To guarantee that no mobile device chooses the AP to which it will roam, only a MAC address will be seen by the device as if only one AP exists on the Wi-Fi network - this is called a virtual cell concept. Therefore problems of disassociation, re-login and re-authentication on a new AP are avoided.

4.3. Layout of the A-Guidance Client Application

The design objective of the client application developed to communicate with the AAS Logic was to provide surveillance and control services for all cooperative vehicles in one single screen with a map-based layout at least 2/3 of the screen display, with basic GIS functionalities (e.g., pan, zoom, feature selection, feature identify, feature labelling) as the main way for end-users to interact with the system. As presented in Figure 3, the client application, named Airport Guidance (A-Guidance), enables end users to benefit from a state of the art graphical user interface functionalities to interact with the airport layout. Location-based data are presented as point features over the graphical map-based.

The A-Guidance main advantage is its simplicity; just by using mouse clicks, end-users can perform diverse interactions with the MapControl, namely by selecting a stand feature it is possible to get the next four flights scheduled to the selected stand. The end-user can also use the mouse right button and the mouse wheel to visualize the airport layout in a different perspective and rotate the map to visualize specific details from different angles.

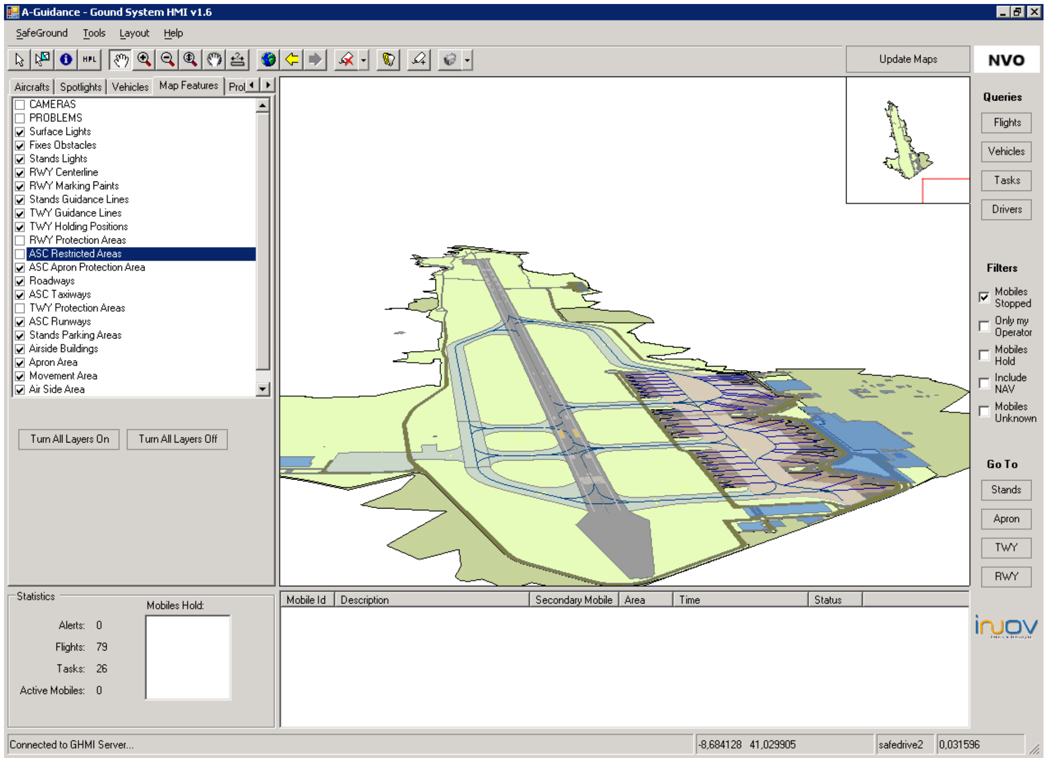

Figure 3: A-Guidance Application.

The A-Guidance is the link between the AAS system and the end-users. It provides a view of what is contributing or influencing the safety performance, alerting for underperforming situations together with information about the appropriate actions to improve performance. Hence, it is most important to display location-based information in a continuous and accurate way. The main objective is to cope with the requirements of A-SMGCS for surveillance, control, guidance, corresponding to the level I and level II presented in section 2.

Alert messages are presented at the Alert Viewer (bottom window in Figure 3) according to their severity level, type, and user profile. Alert messages are ordered by date; end-users can use graphical scrolls to search the list to see the history of alerts. An end-of-alert timestamp is automatically added whenever the vehicle stops being in an infringement or incursion situation, removing the alert form the Alert Viewer. A double click in one of the alert messages canters the display at the current location of the vehicle that is causing the selected alert.

As presented in Figure 4, end-users can activate the drawing of vehicle's movement path as line features, useful when there is a need to analyze the vehicles movement patterns. These patterns can be filtered by date/time, type of task(s) or by airport operator for a better understanding of driving habits, bottlenecks caused by traffic congestions, identification of operational inefficiencies or strange vehicles movements.

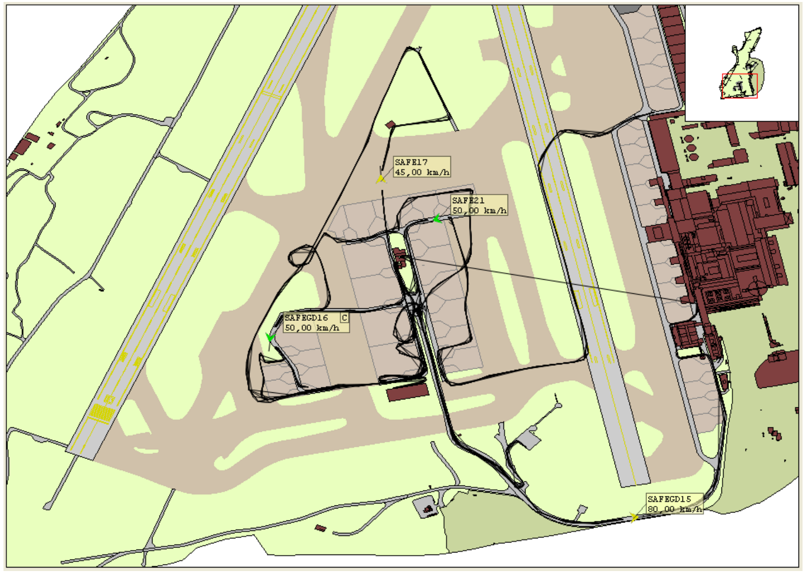

Figure 4: Vehicle movement patterns.

From an operational point of view the proposed platform also supports airports stakeholders in performing their airport operational activities management, namely basic functionalities of routing and guidance services. This is particularly true for ground handlers to monitor their fleet performance behaviour and to monitor how well driver's behaviour comply with the airport safety rules and business requirements.

The screen refreshing time cycle occurs every second. This means that location-based information about the vehicles is updated every second. It is therefore possible to continuously monitor the vehicle position.

5. Location-based Services

As described before, the primary goal of the AAS platform is to have situational awareness of the location and identification for all cooperative vehicles operating at the airside area, with a particular focus at the apron area. Another goal of the AAS systems aims at providing a reliability and cost efficient solution for a standard approach for location-based data integrity in critical and highly congested environments.

In this context, the wireless technology together with geofencing context awareness performs a key role to accomplish some of the A-SMGCS requirements [12]. Indeed, both issues can affect the system final performance as well as its accuracy degree at peak hours, when an increase in the amount of cooperative vehicles that simultaneously operate at the apron area requires more aware surveillance capabilities. Geofencing alerts were adjusted to fit the ASTERIX data structure format, as defined by EUROCONTROL.

By handling the encoding/decoding of the ASTERIX format into the data format used by the AAS system at the backend it is also possible to support ob-board systems from heterogeneous technologies and manufactures. Taking the ASTERIX data format as our base communication benchmark, the data flow between the onboard systems and the ground system is performed as follow. The onboard unit (OBU) uses a GPS/EGNOS receiver to obtain its position and communicate the vehicle position to the AAS Logic at the ground system. This information is received by the AAS Logic at the application server. The AAS Logic validates and transforms the data to a format understood by the AAS components and to display the vehicle position at the A-Guidance applications presented in Figure 3.

The platform is divided into functional blocks, of which all play a specific role in the processing of the data coming from cooperative vehicles. This data is used based on predefined rules and split up in location data and other data which can be used later to improve efficiency or system auditing purposes. The GPS/EGNOS location is used by the GIS engine to accurately position the location of an object at the right place. The innovative approach relates to the way fleet managers are kept informed about changes to scheduled tasks, enabling them to manage field resources more efficiently, reducing costs and the risk of safety branches by diminishing the number of vehicles operating simultaneously at restricted areas.

The AAS system establishes an integrated Airport User Platform by providing a collaborative decision making solution for airport operation officers, air traffic controllers, ground handling managers, to discuss and define cost-efficient and advanced fleet management solution. Authorized airport stakeholders can dynamically introduce changes to the airport layout without having to worry if all other airport stakeholders are informed about those changes. For instance, when the Airport Maintenance Officer at the A-Guidance selects a specific stand features from the apron area and changes its state to deactivated, the algorithms at the AAS system responsible for safety and security hazards detection automatically stop triggering safety incursion for vehicles positioned at that stand area. The CDM nature of the AAS system also enables all airport stakeholders to simultaneously perceive changes to the airport operations as i it the case when the airport changes its operating mode form Normal Visibility Operation (NVO) to Low Visibility Operation (LVO).

The CDM nature of the AAS system also enables airport authorities such as the Safety Manager to be informed in real time about ongoing occurrences with the huge advantage that at the same time all intervenients have the same context aware perception. This means that the vehicle driver is informed by the onboard unit that he is causing a safety incursion or a security infringements, the resource manager at the control centre is also informed that one of his flied workers is causing a safety hazard and finally both know that the Safety Manager is monitoring for which corrective action are being taken to solve the occurrence being reported by the AAS System.

The use of heterogeneous wireless network technologies (e.g., IEEE 802.11a and GPRS) enables cooperative vehicles to act as a set of wireless network sensors that continuously provide location-based data to the AAS central system. The AAS system then detects, by using navigation and surveillance algorithms, as well as a digital airport maps (geo-referencing via GPS and prepared for future GALILEO), if they are operating in conformity to what is expected.

The described geo-fencing approach allows to identify both, which vehicles are to be used for which tasks, and under which status vehicles are currently operating (e.g., availability, down time). At the same time, the on-board-units connected to the resource management system of the AAS Logic, continuously receive actualisations to the timetables and positions of the aircrafts and apron units. Due to these efforts, the experiences for ground handling and its safety relations are deepened and widened because of the build-up of linkages to A-SMGCS as part of a CDM approach.

The control procedures at the ground system intend mainly to prevent collisions, runway incursions and to ensure safe, expeditious and efficient movement. Hence, the main goal is to provide guidance information, and to enable airport stakeholders (at the ground system) to monitor the vehicles movements in order to maintain movement rates under all local weather conditions within the Airport Visibility Operational Level (AVOL) whilst maintaining the required level of safety.

A common database interchange standard for Aerodrome Mapping Databases (AMDBs) is also a key success factor for the implementation of digital functions in the aviation domain. It enables a common interchange between data originators, data integrators, and system designers. An AMDB that characterizes the airport map layout, consists of thematic vector features structured into thematic layers and characterized as points, lines, or polygons. Examples include runway thresholds, hold lines, and aircraft stand locations. All features are described with their own set of attributes (metadata) describing the properties of the features.

The EUROCAE document ED-119 sets guidelines and requirements to develop an AMDB data interchange format for AMDB [12]. The interchange standard was generated on the basis of the ISO 19100 (geographic information) series of standards as applied to terrain, obstacle, and airport mapping databases that are to be used in aviation. The ED-119 specifications consist of scope, identification, metadata, content information, reference system, data quality information, data capture information, and maintenance information requirements. The ED-119 requirements also include: geometry and quality, feature extraction rules, the set of features, and the set of attributes for each feature. Location data are presented in conformity to the ED-119 requirements for georeferencing spatial features, e.g. latitude/longitude positions, using the

GCS_WGS_1984 (ETRS89) coordinate system. The precise values of the coordinate system parameters are:

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree (0,017453292519943295)
Prime Meridian: Greenwich (0,000000000000000000)
Datum: D_WGS_1984
Spheroid: WGS_1984
Semimajor Axis: 6378137,000000000000000000
Semiminor Axis: 6356752,314245179300000000
Inverse Flattening: 298,257223563000030000

Airport critical geofencings like protection areas are represented as polygon features with a precise definition of the protection boundaries for each airport operational status. Within the AAS System, the identified protection areas are:

- The runways protection areas for NVO and LVO;
- The taxiways protection areas;
- Aircraft circulation paths at the Apron area;
- Critical equipment protection areas (e.g., GP and ILS).

6. Performance Indicators

All traffic data related to cooperative vehicles are provided, with an adequate accuracy (error rate less than 98%) and with a real-time update rate (i.e., every second) in order to support airport stakeholder's operational decision-making process. Moreover, the surveillance functionalities and procedures at the AAS system are structured according to the surveillance requirements for the A-SMGCS. These surveillance functionalities deal with data fusion and interoperability issues between the traffic information provided by the cooperative vehicles and the data collected from the airport existing systems for efficiency of real-time operational management requirements.

The AAS project is envisioned to improve the safety of operating a fleet of vehicles and Ground Service Equipment (GSE) on the apron by reducing related safety events on the apron and increasing the perceived level of situational awareness among the Ground Handling staff. Using AAS system, personnel, fuel, operation, maintenance and damage and repair costs must be reduced. For AAS project, being efficient is one of the most important goals, so delays related to the operations undertaken by a fleet of GSE on the apron must improve service punctuality and reduce delays due to late personnel and equipment [12][13]. To achieve these objectives, AAS system will increase control over the GSE fleet operating under a single Ground Handler on the apron by optimizing the number of GSE, reducing the number and frequency of misplaced equipment and reducing vehicle idle times. If all this is carried out, then AAS will also reduce delivery time for luggage and should offer a return of investment in up to 3 years for the customer.

It is essential to make sure that safety will never be reduced when improving on other factors and that capacity will never be reduced while reducing cost. Further, AAS is expected to improve system reaction time resulting in added flexibility of the system via better control and fewer delays.

In the AAS project there are three main key performance indicators: Safety, Cost Effectiveness and Efficiency including Punctuality. Safety is one of the most important aims in this project trying to prevent incidents/accidents and to help resolve them. Efficiency will be another factor: it is the goal to reduce the number of Ground Service Equipment needed, or improve their performance. The reason to include cost effectiveness is the possibility to reduce operating cost for ground handlers by optimizing resources and time.

Table 1: AAS validation objectives regarding benefit expectations.

Key Performance Areas and Validation Objectives
Safety
Safety is never reduced when improving on other factors (e.g., efficiency, cost effectiveness)
Improve the safety of operating a fleet of GSE on the Apron by: a. Reducing GSE-related safety events on the Apron; b. Increasing the perceived (i.e., qualitative) level of situational awareness among GH staff.
Cost Effectiveness
Reduce costs of operating a fleet of GSE on the Apron by: a. Reducing personnel costs; b. Reducing fuel costs; c. Reducing operational costs; d. Reducing maintenance costs; e. Reducing damage and repair costs;
Offer a Return of Investment in up to 3 years for the customer
While reducing costs, capacity must be reduced
Efficiency including Punctuality
Increase control over the GSE fleet operating under a single GH on the apron by: a. Optimizing the number of GSE (by detecting whether there is a surplus of equipment); b. Reducing GSE engine idle running times; c. Reducing the number and frequency of incorrectly perceived lack of GSE;
Reduce delays related to the operations undertaken by a fleet GSE n the apron by: Improving service punctuality rate; Reducing delays due to late personnel and equipment.
Reduce delivery time for luggage
Areas of Interest and Validation Objectives
Environmental Sustainability
Reducing emissions by reducing fuel consumption
Predictability
Improve predictability with respect to GSE “in use” or “out of service” times
Reduce deviations in turnaround time resulting from GSE-related delays
Flexibility
Improve system reaction time by better control and fewer delays in GH operations
Reduce congestion by optimizing infrastructure allocation

From the 300 users interviewed in both airports (ASC and TXL), it was possible to collect the following comments on the list of KPAs:

- Safety is a KPA that it is an imperative constraint for all innovation at an airport not to compromise operational safety. Though users would like to see safety improvements on the apron, improving safety will not be the main driving factor for investing in AAS.
- Ground handlers consider safety to be more closely linked to quality of personnel and training, while IT-systems are thought to have only indirect effects.
- As to measurability it is pointed out by users that it will be difficult to attribute a change in a safety indicator to AAS, in particular if - with the economic downturn - there will be a significant reduction in traffic.

Cost effectiveness is considered to be the most important for Ground Handlers in this project. It is connected to efficiency and capacity since improvements in one of these areas will eventually help to improve in the others (all other influencing factors considered equal).

7. Conclusions

Location based services are positioned with a focused objective "To assist with the exact information, at right place, in real time with personalized setup and location sensitiveness". These services integrate location awareness and the location context dynamically to deliver information interactively with geographical and logical views.

The capacity of location awareness to support the management activities of airport stakeholders and their capability to understand complex phenomena through the use of geographic relationships inherent in all information has derived our research interest to the implementation of the AAS platform. By combining map-based and location-related data with other business data, organizations and in particular airport stakeholders can gain critical insights and take better informed decisions . Safety and security applications can also take advantage of this process. This was illustrated in the paper by showing how the AAS project can be used to improve the safety and security of an airport.

We outlined the fact that location awareness is directed by domain knowledge, formal frameworks, with a focus on decision support. Hence, one of the AAS target goals is to implement a model-based location intelligence to capture business-domain knowledge and incorporate business logic. Based on positioning algorithms that compute spatial metrics such as distance, density, direction and proximity, the platform will enhance the implemented location based control services by using geographic and temporal parameters.

Another important feature relates to simultaneous localization and mapping, i.e., acquiring a map of an unknown environment with a moving object (localization device), while simultaneously localizing the object relative to its current position within the airport area. Such location intelligence for business process improvement can significantly assist meeting the goal of timely responses in the provision of both day-to-day and emergency services. Because complex data is often poorly represented, when only expressed in charts or tables, map-based displays and floor plans can reveal hidden insights that would be otherwise extremely difficult to perceive by business users.

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