# Management of Mobile Objects in an Airport Environment

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***Abstract*—A new approach is proposed to the surveillance of identified Security and Safety occurrences concerning mobile objects in an airport environment, in particular to monitor aircrafts, vehicles and staff at the manoeuvring area for all weather conditions. A middleware platform merges localization information from the different mobile objects in the airport and fuses that information through intelligent algorithms in the platform middleware. The system outputs are shown in an advanced Graphical-User interface, providing a collaborative environment with the relevant information to the airport stakeholders. The outputs can be used by the stakeholders to take decisions on the best way to improve Security and Safety and also on the optimization of airport operational procedures in compliance with existing business rules.**

***Keywords-Mobility management; Situation awareness; Airport Safety and Security; Location based services.***

## I. INTRODUCTION

In the airport environment, about 90% of the accidents and incidents occur during the ground handling services assisting parked aircrafts at the Stand. According to ICAO [1], there is a potential for aviation mishaps to become catastrophes with high casualty numbers. The need for coordination of multiple activities occurring simultaneously requires therefore a continuum control of all ground movements, in particular during taxi operations. However, the current lack of context awareness and controllability is frequently identified as a causal factor for Safety infringements.

Without a unified control infrastructure capable to provide, in real-time, information related to the surveillance of Safety and Security occurrences, airport stakeholders (e.g., Airport Authority, Ground Handlers, Airlines, etc.) have not an objective and reliable view of the overall situation to take well informed decisions in real-time, as needed in various operational domains.

The SECAIR project [2] brings a new approach to the surveillance of identified Security and Safety occurrences for airports, available at an affordable cost, in particular to monitor the mobility of aircrafts, vehicles and staff at the manoeuvring areas in all weather conditions. The SECAIR project combines different location-based technologies to detect the presence of objects (e.g., persons, vehicles), inside the airport terminal or in the apron, at predefined locations. It intends to improve situation awareness for supporting decision makers and task forces in handling with Safety and Security issues. The project relies therefore on the development of an event observer system, capable to identify automatically predefined events and generate alarms in real-time. This means that for each ground movement (e.g., vehicles or any other cooperative moving object), it takes less than one second for the system to determine the new position of the surveyed objects and validate if any of those objects is causing a Safety/Security infringement. A middleware platform provides advanced fusion techniques to determine the localization of objects based on radio based tracking and video based technology. The middleware is part of a larger platform that, on the whole, will manage the mobility of the objects and will enable the accomplishment of an automatic and reliable prediction of hazardous situations.

To test the capabilities of the system, a set of business scenarios addressing airport operational requirements [3] were defined in close collaboration with ANA-Aeroportos de Portugal - the main Portuguese airport's management company, based on the following needs:

- Traceability of vehicles and Ground Support Equipment (GSE) with automatic detection of unauthorised incursions into restricted access areas;
- Tracking and controlling of Handling operations (objects, staff and passengers);
- Surveillance of aircrafts ground movements within the apron area;
- Provision of context awareness about on-going operations at the apron area, triggering Safety and Security alarms with different levels of severity;
- Support the decision making process of the airport stakeholders by providing a reliable view of the

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overall situation whenever a Safety or Security event is detected;
- Ensure that each airport stakeholder has access only to data according to its operational needs.

The paper is organized as follows: Section II presents the main software components within the multi-tier architecture designed for the SECAIR system. Section III presents the environment where the project will be deployed together with the operational scenarios defined for testing the system. Finally, conclusions are included in Section IV.

## II. SYSTEM ARCHITECTURE

The SECAIR system has a client-server architecture, structured into three tiers, as outlined in Figure 1. At the communication tier, SECAIR will operate with heterogeneous wireless location-based technologies (sensors), each one sending data, in real-time, about the location of the tagged objects. At the application tier, the middleware software component is responsible to collect and process incoming data from the wireless sensors, delivering reliable location data to the Business Logic. This is performed based on a data fusion process that computes positioning data to provide accurate and reliable location data about the surveyed object.

Since the SECAIR system will operate with heterogeneous sensors, prior to the data fusion process, it receives multiple positioning data originated in the mobile objects from the communication tier. In fact, we can have a set of data for one object. But after the data fusion process, we obtain one computed position per object that is reliable. Based on such issues, the SECAIR system will provide a set of innovative capabilities for positioning accuracy and reliability, which is required more and more by value-added location-based services such as Safety and Security applications for airports [4].

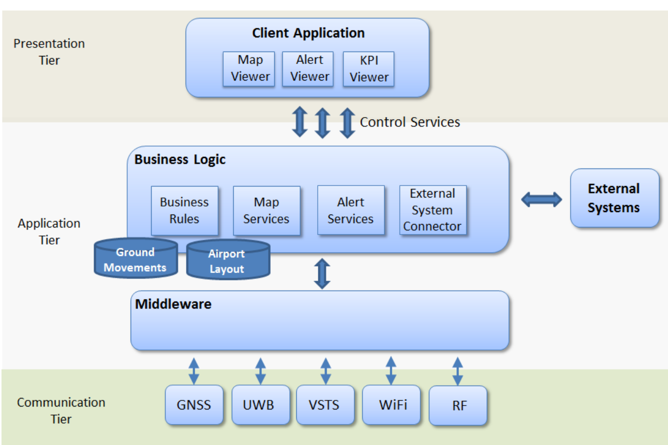


Figure 1. Architectural structure of the SECAIR system.

The Communication tier will operate with the following localisation technologies:

- The Stand-alone Global Navigation Satellite System (GNSS), will be used together with a WiFi communication device to collect and transmit, in each second, the coordinates of the vehicle position;
- The Ultra Wide Band (UWB) system provides immunity to multipath propagation and precision range measurement capability. The IEEE 802.15.4a UWB standard implements precision location measurement. when tracking items close to large metallic objects such as Aircraft, Vehicles, Cargo containers etc.;
- The Video Surveillance and Tracking System (VSTS) consists of multiple video cameras installed at predefined locations so that they fully cover the monitored area with overlapping field of view. The video data collected from the cameras will be processed by the VSTS to detect, track and classify the foreground objects within the monitored environment;
- The Radio Frequency (RF) locating system consists of mobile devices (tags), antenna units (anchors) equipped with smart-antennas and mounted in the area of interest. It measures the position of a mobile device attached to the person or the object to be tracked in the area of interest (see Figure 2).

The Middleware is responsible to continuously provide the calculated position of a specific observed object to the Business Logic. A major concern regarding the project real-time effectiveness and positioning accuracy is reflected on the analysis of the fusion algorithm which follows a multi-particles approach. The particle filter is a technique that implements a recursive Bayesian filtering using the sequential Monte Carlo method, currently one of the most advanced techniques for data fusion. Three concepts for the data fusion process are considered by the Middleware component:

- Quality of positioning-based selection;
- Sequential Kalman Filtering [5] for simple data fusion without map filtering for simple localisation error distributions;
- Sequential Bayesian Filtering (Particles filters) [5] suitable also for the map filtering.

There is no single technology which can provide satisfactory performance in all environments and scenarios; therefore, various localisation technologies have to collaborate in order to deliver a flexible locating system, instead. Sensor data fusion will combine sensory data from different localisation technologies to outperform any individual systems working alone. These are lessons learned from the LocON project [6] in relation to techniques for multi-target, multi-sensor tracking.

At the Application tier, the Business Logic aggregates a set of core software components. For each ground movement, the Application tier takes descriptive data (metadata) to correlate existing business rules with the spatial-context of the airport and if applicable trigger the right event. The integration of all these data enables the system to perform a set of validations based, for instance, on the type of object, its location within the airport, the operational status of the areas where the object is located.

 

Depending on the business rule being infringed a specific event (i.e., alert message) is triggered to the end-users at the Presentation tier. This is done by creating a subscription offered as a public endpoint by the system.

At the SECAIR system every location based services run in parallel, and is accessed via Network Load Balancing, a clustering technology that enhances the scalability and availability of mission-critical, TCP/IP-based services. Since every service runs in parallel, the number of instances on different machines is unlimited.

The Business Logic sends the requested data, either as a stream of updates (event-based queries) or as a chunk of current state data (instant-queries). The first are triggered on a certain event, e.g., an object moving into an area. The Business Logic can create an event subscription (“tell me about objects moving into a specific area”) to be notified on that event (“an object moves into an area”) and perform specified actions accordingly (“alert: object moved into restricted area”). This kind of subscription may be triggered very often, or never, depending on how often the event occurs. Contrarily, the result of an instant query is always returned immediately and is not dependent on any event. This kind of query is useful to retrieve the current state of an object. For instance, “give me a list of all objects which are currently in a certain area” or “tell me the current battery status of an object”.

For simplicity, the core data handled by the Business Rules software component are represented in Figure 1 by two distinct databases. These data are managed by the Business Logic using the Microsoft SQL Server 2008, a database management system capable to deal with business data and map features, describing the airport cartographic layout, within the same database.

In the SECAIR system, all thematic layers use the World Geodetic System 1984 (WGS84) as the spatial reference system to fulfil the requirements defined in the A-SMGCS manual [2] and to comply to the ED-119 standard [7]. Therefore, horizontal locations are provided as latitude/longitude coordinates. Each layer can be managed as an information set independent of other layers. Since each layer is spatially referenced, they overlay one another and can be combined in a common map display. The user can then interact with the features of each layer by selecting, for instance, a specific stand and manually change its status, or to get information about flights, resources and assigned tasks. It is also possible to verify which road segment is operational and check for traffic circulation rules that apply to a selected road segment (e.g., speed limit and directions of traffic flow). In this case, authorized users can even specify speed limits for each road segment for different visibility condition.

The resulting geo-database consists of vector and attributes features. The vector features represent geometric feature instances that are classified as points, lines, or polygons. Examples include runway thresholds, holding lines, and aircraft stand locations. The vector features can also represent obstacle data elements, which may be represented by points, lines, or polygons.

The ED-119 standard defines the physical dataset requirements that have been followed to develop the airport mapping. These include: geometry and quality, feature rules and descriptive attributes.

The Business Logic also holds a software component that is responsible to handle the interoperability with external systems, for instance, to collect data related with flight schedules, resources and assigned tasks. With such approach, location based data for each observed object can be coherently correlated with metadata from external sources, enabling the surveillance and track of events according to business logic/rules [8]. The Application tier, being responsible to implement airport business logic, seeks grounds for the coexistence and balance between the dual trends of the airport industry: increased demand for air travel and strengthened aviation Safety and Security [9].

For each predefined event (e.g., Safety or Security) detected by the system, a semantic meaningful alert message will be triggered, with the corresponding relevance and severity risk. These functionalities is provided by a geographic information system (GIS) specifically designed to handle with the business logic taking into account the airport spatial context provided by the Map Services. Depending on the nature of the detected event, the Alert Services will interact with the GIS to generate an alarm to be broadcasted to each connected client application. A log record of all events is stored for historical data analysis purpose.

At the Presentation tier, the surveillance capability of the SECAIR system is presented to end-users in three different ways. The Map Viewer represents moving objects as colour coded point features with a timestamp and a set of descriptive data about the resources causing, for instance, a Safety event; this may include data about the aircraft (A/C), vehicle, driver, flight data, airport layout of the area where the event occurred. The Alert Viewer shows the corresponding textual description of the alert messages in terms understandable by the end-user (e.g., for each moving object causing an event, the Alert Viewer at each Client Application will present the alert messages contextualized with business semantic and ordered by severity level). All alert messages have a start and end time, plus a set of additional descriptive data related to each event. The KPI Viewer presents in a spatial dashboard, the values of key performance indicators (KPI) describing how the business is performing.

The correlations between KPI are mapped in a dendrogram structure. Each individual KPI are arranged along the bottom of the dendrogram and referred to as leaf nodes. KPI clusters are formed by joining individual KPI or existing KPI clusters with the join point referred to as a node, forming a node-link tree diagram. Each node of the tree carries some information needed for efficient plotting or cutting as attributes, of which only members, height and leaf for leaves are compulsory:

- Members, total number of leaves in the branch;
- Height, numeric non-negative height at which the node is plotted.

The hierarchical structure of the dendrogram is represented by the KPI Viewer using the Squarified Treemap algorithm [10]. The Treemap technique provides an area-based visualization where the size of each rectangle represents the relevance of the KPI and the color indicates how the value of the metric is evolving. The Treemap technique is indeed very effective in showing the attributes of the dendrogram nodes using size and colour coding.

The Squarified Treemap algorithm avoids the generation of thin rectangles, improving the representation of the dendrogram structure in a space-constrained layout. It also enables end-users to compare nodes and sub-trees even at varying depth in the dendrogram, and help them spot patterns and exceptions.

## III. CASE STUDY

In order to validate the SECAIR system, a system prototype for a pilot test will be installed at Airport of Faro (AFR), Portugal. AFR is one of the Portuguese transport infrastructures included in the Priority Project 8 - Multimodal axis Portugal/Spain-rest of Europe, 2009-PT-08006-E. Acting mainly as a gateway for tourists who predominantly visit the Algarve region and the Spanish region of Huelva, AFR operates mostly with low cost carriers in a seasonal basis with its peak at Christmas and Summer time.

The implementation comprises the system deployment, the interfaces to heterogeneous localization technologies and a set of client applications with a geographical interface for airport stakeholders to benefit from the control services provided by the system. For field tests, ANA-Aeroportos will provide airport vehicles together with a wireless network covering all airport operational areas. The manoeuvring area of AFR is already equipped with an infrastructure of Wi-Fi Access Points (AP) forming the wireless network that will support the data communication.

Figure 2 outlines the areas selected for the specified scenarios and to be used for the site test, namely indoor environment, adjacent indoor-outdoor transition area (to demonstrate ability to track targets moving from indoor to outdoor and back) and the apron area adjacent to stands 14 and 16. Indoor environment scenarios (Boarding Gates 01 and 02), include: zone intrusion detection, target tracking and left behind luggage. The outdoor environment (130x130m of apron comprising aircraft stands 14 and 16), include additionally the following situations: Aircraft Stand Area Vehicle Surveillance (vehicle tracking, obstacle detection), Incursion/Collision Avoidance and Aircraft Ground Movement Tracking.

As presented in Table 1, indoor scenarios reflect operational procedures related to:

- Traceability of a person at the boarding gate area;
- Localization capability of the SECAIR system in the transition area from passenger terminal into restricted access areas (outdoor);
- Localization obtained by fusion of data obtained from the following technologies: VSTS and RF.

The outdoor scenarios reflect operational procedures related to:

- Traceability of vehicle and driver at the Apron area;
- Automatic detection of drivers without driving permission / not logged (RFID Reader)
- Localization obtained by fusion of data obtained from the following technologies: VSTS, GNSS and UWB;

The airport layout is represented (at the Map Viewer) as a collection of overlapped themes, each one representing a specific operational area within the airport environment. These themes form the background context over which the observed objects are represented as point features. All thematic layers are provided by the airport authority in a standard format as shape files.

Whenever an object causes a hazardous event, the Business Logic uses the metadata provided by each theme for location-awareness purposes and generation of the proper alert message to be sent to the Presentation tier.

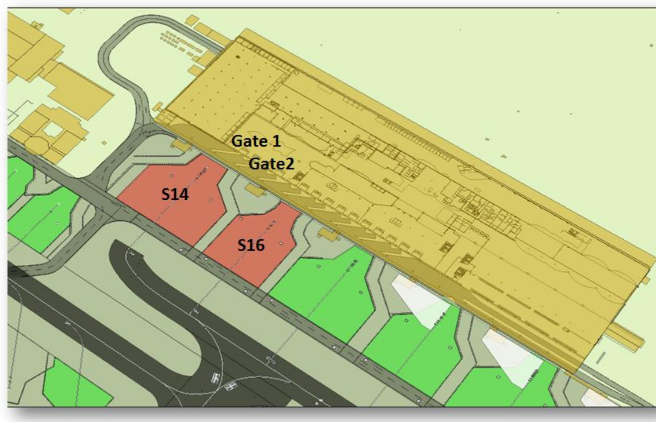


Figure 2. Airport layout of the manoeuvring areas selected for the specified scenarios.

The GIS engine will have to deal with real-time (i.e., each second) requirements for surveillance of all moving objects, computing simultaneously dynamic changes to the spatial context derived from daily airport business activities. Additional metadata (e.g., speed, logged driver, vehicle category, task, etc.) about each surveyed object, presented as labels, provide airport stakeholders with all the required information to analyse a specific event or to remotely monitor/coordinate on-going operations. Moreover, the ability of the GIS to graphically present information from heterogeneous mobile sources enables the system to be operated even by non-skilled experts. This is particularly relevant to monitor the stands' supporting areas where vehicles and GSE are allowed to park in specific technical supporting areas, before an A/C entering the assigned stand are also included.

Some preliminary tests were performed to collect field data to be used for testing during the development phase. The tests included the collection of a huge amount of data for both Indoor and Outdoor environments, involving personnel

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and some vehicles and a parked A/C at stand 14, for embarking and disembarking procedures. Within the scope of the SECAIR project, the scenarios presented in Table 1 address Safety/Security issues.

TABLE 1. LIST OF OPERATIONAL SCENARIOS FOR THE SECAIR PROJECT.

| Num. | Scenario Name |
|---|---|
| ***Outdoor Safety (OSA)*** | |
| OSA.01 | Surveillance of vehicle movements within a stand area |
| OSA.02 | Collision avoidance support service |
| OSA.03 | Aircraft ground movement tracking |
| OSA.04 | Obstruction of an operational stand area |
| ***Outdoor Security (OSE)*** | |
| OSE.01 | Detection of zone intrusion by unauthorized vehicle |
| OSE.02 | Personnel tracking at the apron area |
| ***Indoor Safety (ISA)*** | |
| ISA.01 | Working zone intrusion by unauthorized person |
| ***Indoor Security (ISE)*** | |
| ISE.01 | Left luggage detection |
| ISE.02 | Indoor-outdoor personnel tracking |

The description of each operational scenario follows a template emphasizing relevant issues from airport stakeholders' point of view. Besides a unique identifier with a semantic meaning for each scenario the template also covers the following items:

- Name of the scenario, pointing out concerns from the perspective of airport stakeholders;
- Classification of the scenario addressing environmental influences (indoor/outdoor) and type of events (Safety/Security);
- Technical constraints and a list of key indicators captured by the scenario to measure its impact or relevance;
- List of actions to be performed by each intervenient actor to test the specified scenario;
- Identification of the scenario expected results. This will define the behaviour of the SECAIR system.

Some vehicles will be equipped with an onboard unit, a touch screen display and a radiofrequency reader. A radiofrequency card, with data about the driver involved on the site tests, will be available to automatically identify the driver at the login procedure. At least two client applications (i.e., situation rooms) are deployed, one situation room corresponding to the Control Centre for the airport operator and a second situation room for another airport stakeholder (e.g., Ground Handler).

## IV. CONCLUSIONS AND FUTURE WORKS

Within the SECAIR project, one of the technical requirements is that all location–based technologies are coherently integrated using advanced data-fusion techniques in order to reduce installation costs and to address multipath effects reduction. The main objective is to develop new context aware services based on an innovative solution integrating high-performance RF tracking combined with optical recognition technologies and mobility management in a middleware platform.

SECAIR is being designed as a heterogeneous sensor fusion system architecture, covering the surveillance of non-cooperative resources and functionalities for continuous control of all ground movements within the apron area. A special attention is being given to the environment of the system, in particular to information flowing from and to the system. The properties of the system components, as well as the relationships between them, are core elements for the analysis and design of the SECAIR architecture. The project takes lessons learned from previous projects in relation to techniques for multi target, multi sensor tracking, responding to very important Security and Safety issues in airport environments

The software components of the SECAIR system are being tested and the results analysed to confirm the ability to improve positioning accuracy and reliability, reduce the likelihood of false alarms and get feedback from airport stakeholders for improving the system-of-interest and to study its feasibility with real data, as required by value-added location-based services.

A field test is planned to take place at Faro airport during the last quarter of 2013, with a full evaluation of the results to be done at the beginning of 2014. The research work in the project addresses data integration from the video system with data from the radio based systems. Improvements to accuracy and scalability of the location based services, provided by the system, will continue until middle of 2013 and from then on the necessary implementations will be completed for the field test.

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