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A METHODOLOGY FOR MULTIPLE OBJECT TRAJECTORY PREDICTION IN AIRPORT ENVIRONMENT

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ABSTRACT

In Airport environment no single sensor system is capable to fulfil the requirement of tracking and identifying all types of moving objects. Recent years have witnessed the deployments of Wireless Sensor Networks (WSNs) for many critical applications such as security surveillance and target tracking. This technology can help to meet the airport surveillance requirements at a lower cost, being especially interesting for small airports, and to fill radar coverage gaps at larger ones. This paper proposes a global and integrated solution using acoustic sensors to predict target trajectories and prevent collisions critical areas of the airport environment. The proposed system represents a low-cost effective surveillance technology for locating and tracking moving objects, by using a more up-to-date wireless sensor network and tracking algorithms. The preferred system could eventually be an alternative to surface movement primary radar (SMR) which is the most widely used in the world to track airport ground movements. The proposed tracking system uses a special form of PHD filter and particle filter to accurately track multiple targets.

Keywords: *WSN, Particle filter, GM-PHD filter, Tracking, A-SMGCS, Airport;*

1. INTRODUCTION

The complete automation of airport operations remains a highly debated issue. Therefore, trends towards higher levels of automation to reduce direct human involvement promise higher level of security, efficiency and regularity.

According to the latest International Civil Aviation Organization (ICAO) regarding long-term traffic forecasts that were published in September 2016, global passenger traffic will almost double by 2032, reaching over 6 billion passengers annually. This becomes more critical, when different parts of the system are congested. Airports often have capacity-limiting constraints, affecting rate of flow and efficiency. There are many factors that make airports the bottle-neck of the air transport system [1]. While arrival and departure management systems have been in operation for some years now, an optimized use of taxi-ways and the apron is still within the scope of ongoing research [2] [3].

The era of unmanned aerial vehicles sharing the airport area is almost upon us. UAS technologies are expected to play an increasingly significant role in the air transport system for various functions ranging from cargo to surveillance operations. Several airport processes could benefit from automated services that unmanned and highly automated aerial vehicles (UAV) could provide. Therefore, airports will require additional surface management technologies to ensure separation with the future airport traffic zone users. Research organizations have questioned the inefficiency of airport surface operating technologies [4] [5].

Motivated by improving the safety level of airport surface operations beyond current targets [6], the authors of this paper have worked in this field with the notion of creating an innovative acoustic system able to track through passive noise source localization.

Compared with conventional radar, acoustic systems offer a number of advantages, including lower costs due to less expensive equipment, eliminating electromagnetic pollution, and providing the ability to detect objects with low radar signature (stealth, semi-hidden or flying at low altitude aircraft).

The goal of this paper is to introduce the idea or concept of adding acoustic sensing technology to the existing systems for the monitoring of surface movements at airports. Unlike the radar scanning, acoustic detection can be performed with fully passive sensors by only listening to the target's noise. This is an obvious advantage from the environmental point of view (no emissions of any kind), safety (no possibility of localizing the sensor in the absence of emissions, inability to drastically reduce target noise) as well as the cost (reduced energy consumption, inexpensive sensor components). Acoustic sensing may in fact be a viable technology to establish a non-cooperative surveillance system. In order to explore the prominence of improving ground surveillance systems by providing real-time aircraft and moving objects localization and tracking in airport areas, allowing for the enhancement of security and fluidity in airport areas. The first step was to explore the literature related to WSNs, and object tracking, followed by a comparison of the current airport ground technologies to analyse the advantages and disadvantages. An implementation study of the proposed distributed Wireless sensor nodes was also done. In the final part, simulations of the methods for tracking maneuvering objects were presented.

The article attempts to achieve the following objectives:

- Highlight the challenges and limitations of current airport ground surveillance systems.
- Offer a low cost technology that can help to meet the airport surveillance requirements, being especially suitable for small airports, or as a gap coverage filler at larger airports.
- Analyse, and evaluate the deployment of acoustic sensing to detect, localize, and track moving targets specific to MED V Airport.
- Solve complex tracking problems using Particle filter to track a single object, and GM-PHD filter to track multiple targets.

This paper is structured as follows: Firstly, we introduced the overall motivation to create a low-cost surveillance with the aim of increasing the level of safety at airports. Furthermore, an overview of the existing ground surveillance technologies, and a comparative benchmark based on their respective advantages and drawback are presented. In addition, there is a brief insight to the background of the wireless acoustic sensor networks. Moreover, we explain our tracking system based on WSNs, and present a case-study of Mohamed V airport, where we present tracking solutions to the most complex problems faced in that environment, we proposed two monitoring filters to detect, locate, predict, in a realistic way. We began with Monte Carlo framework to track a moving object in non-linear environment, Next, we introduced GM-PHD filter to accurately track multiple objects. Finally, the simulation results are presented, and a conclusion and guide to future works are provided in the final section.

2. GROUND SURVEILLANCE SYSTEMS

The International Civil Aviation Organization (ICAO) estimates that the passenger and freight markets will grow by 4.6% and 6.6%, respectively. To meet such rapidly growing demand for air travel, the international trend is to expand or enlarge airports and the airports in the 24-hour operating system are gradually increasing for efficient airport operations. To do so, it is necessary to operate the airport more quickly and safely, especially at night and in adverse weather conditions. There is a need to develop and promote more advanced related technologies in order to build an airport operating system that meets ICAO standards and recommendations [7].
Currently, international airports, most military airports and medium-sized airports, with the exception of small private airports, build and operate various types of equalization systems for the safety of navigation, in accordance with international standards.

The A-SMGCS is an important ground surveillance system that improves the efficiency of the ground controller by integrating monitoring, guidance and warning functions as illustrated in figure 1. It safely protects aircraft at night and weather conditions in certain conditions, it is the main equipment to increase airport ground surface safety. Most A-SMGCS have the following four functions.
1) Surveillance: Surveillance of aircraft / vehicles and other objects for accurate identification and location through the transmission of traffic information to pilots and mobile drivers.
2) Control: Detects any collision with other moving vehicles in the moving area and ensures efficient ground movement.
3) Orientation: This is the facility required to provide continuous, clear and reliable information on detected obstacles, runways and airstrips for aircraft and moving vehicles.
4) Routing: Minimizes delays due to potential conflicts with other moving vehicles and aircraft, as well as the planning and basic rules for moving quickly and safely from one place to another.

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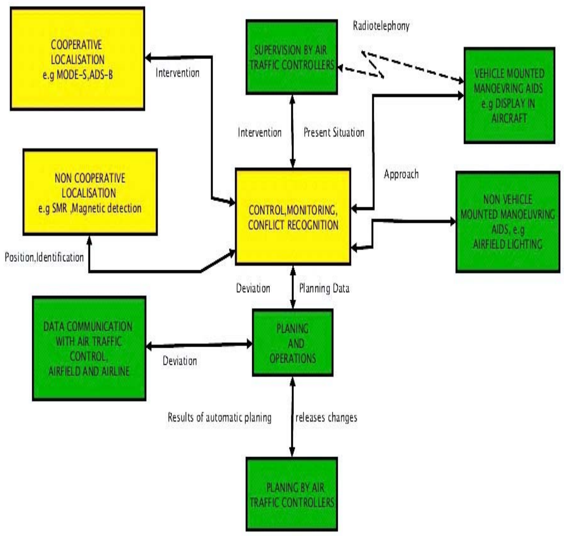

Figure 1: A-SMGCS Processes and Functions

The respective advantages and disadvantages of the technologies used in the A-SMGCS system can be summarized in the table below.

Table 1: Advantages/Drawbacks of Ground Surveillance Technologies.

Sensor type	Advantage	Drawbacks
ADS-B	High update intervals. The air/ground data link is provided. Small latency. High update rate. Position accuracy.	It all depends on the aircraft alone. Not all aircraft and vehicles are equipped with ADS-B. Time stamp errors. Risk of GPS failure.
MLAT	Secondary surveillance transponder are used to locate aircraft. Small latency. High update rate. Position accuracy.	Aircraft and other devices without transponders are not detected. Signals must be received correctly by at least 4 beacons. Coverage and connectivity of the beacons are problematic.
SMR	No on-board equipment is necessary to detect moving objects. High data integrity.	Shadowing effects. Multiple reflections. Targets cannot be identified. The altitude of aircrafts is unavailable. Low update rate. Electromagnetic pollution.
Magnetic sensing	Unaffected by weather conditions, and shadowing effect.	Measurements Affected by distance between sensors and sources. Still in the initial stages of research, and yet to be part of an A-SMGCS
Image-based tracking	Low cost equipment.	Improper detection and suffers from an occlusion problem. Detects only moving objects, stationary objects are not detected. Cameras need to be frequently calibrated. Still in the initial stage of research and not yet part of an A-SMGCS.

A-SMGCS systems are mainly based on surface movement primary radars (SMR) to track non-cooperative objects. This technology cannot identify targets and suffers from limitations such as multiple reflections, also the SMR causes electromagnetic pollution, which is something that must be reduced to a minimum. Therefore, a sensing technology is required in order to improve safety and efficiency of ground movements at airports. The general use of acoustic sensing to detect, localize, and track moving targets has been well studied and documented in previous literature [8]. However, very few studies have reported the use of this technology to detect and resolve ground traffic conflicts at airports. Such a system could potentially be much less expensive than technologies deployed on existing systems and could also improve the ability to provide a stand-alone, low-cost solution for small and medium-sized airports and complex coverage areas in larger ones.

3. INSIGHT INTO ACOUSTIC WSN

Since the early 2000s, sensor networking has combined the technology of modern microelectronic sensors, embedded computational processing systems, and modern computer and wireless networking methodologies. It is believed that sensor networking in the 21st century will be equally significant by providing measurement of spatial–temporal physical phenomena, leading to a better understanding and utilization of this information in a wide range of applications. Sensor networking will be able to bring a finer- grained and fuller measurement (using acoustic, seismic, magnetic, infrared (IR), imaging, and video data) to characterize the world to be processed and communicated, so that decision makers can utilize the information to take actions in near real time [9].

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A WSN can be defined as a network of inexpensive devices with which the goal is to detect and track moving targets, called sensor nodes, which are devices equipped with a processor, a radio interface, an analogue-to-digital converter, sensors, memory, and a power supply. The nodes are spatially distributed and work cooperatively to communicate information gathered from the monitored field through wireless links. The data gathered by the different nodes is sent to a sink, which is a base station used to collect and process data. Constraints from all factors (distribution of the sensors, limited processing capability, bad propagation conditions, non-uniform energy use among the nodes, non-robust networking protocols and network management software, etc.) can limit the proper operation of an SN and its ability to perform source and node localization. In many situations, it is useful for sensors to be aware of their relative or even absolute positions in the network. Since the number of sensors is usually large and the nodes are often randomly distributed, exactly locating all sensor positions is a nontrivial task. One possible solution is to equip each sensor node with a global positioning systems (GPS) device.

In existing methods for locating acoustic sources, three types of physical measurements are used. TDOA is adequate for broadband acoustics, requiring accurate measurements of delay time between sensors. DOA is estimated using the phase difference recorded by the sensors and can be applied when the sound source emits a coherent signal in a narrow band. However, the intensity or equivalent energy of the acoustic signal decreases with distance from the source, since the sound power emitted by the targets usually varies slowly over time. As a result, acoustic energy time series are sampled at a much lower frequency than raw acoustic time series. In addition, it is not necessary to update the position of the targets too often. As a result, very little data should be transmitted to a data fusion center. Based on the properties of this energy-based method, it is an appropriate operating mode for the sensor network proposed in the project [10].

4. CASE STUDY-TRACKING SYSTEM FOR MED V AIRPORT

In addition to aircraft carriers, the airport is the only place where aircrafts move. It has its own adapted structure and composed of different zones, each with its own specifications [11].

4.1 Airport Infrastructure

In this section an overview of the infrastructure at Casablanca Mohammed V airport is given, in order to understand the environment in which the proposed technology will be applied. The airport ground surface is composed from a traffic area and a movement area.

Traffic area: These are areas to perform various maneuvers such as the exit of the stand in reverse (push-back). each parking area is designed according to the category of airplane (A, B, C, D, E- ICAO), so there are some specific access rules, also the speed limit in this area is restricted to a maximum of 25 km/h.

Movement area: The movement area refers to the runways, taxiways, and other areas of an airport that are used for taxiing, take-off, and landing of aircraft, exclusive of loading ramps and aircraft parking areas. According to the International Civil Aviation Organization (ICAO), a runway is a "defined rectangular area on a land aerodrome prepared for the landing and take-off of aircraft". These are areas where aircrafts take-off or land at high speed. It is necessary here to sequence the aircraft while keeping in mind that some aircrafts will have the need to cross runways.

Mohamed V Airport is a large airport with two runways oriented 35R/17L and 35L/17R as it can be seen in figure 2.

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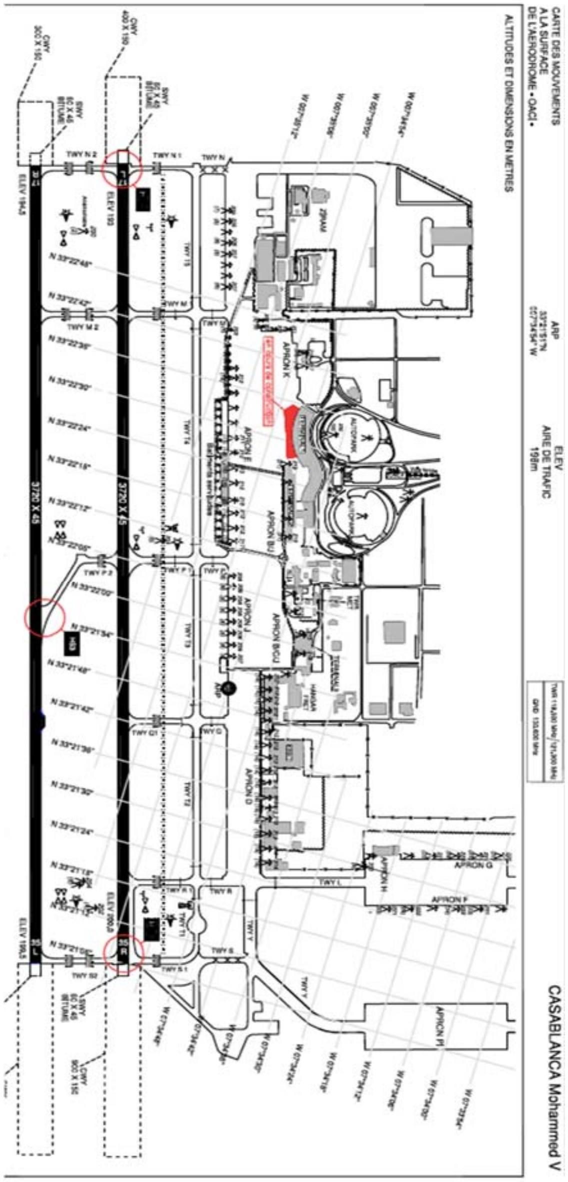

Figure 2: Map of Aircraft Surface Movement at Med V International Airport [11]

4.2 Airport Constraints

Casablanca Mohammed V International Airport is open for day and night operation. Air traffic services (ATS), ground handling and fueling services are available at H24. Operation is maintained in low visibility (LVP) [12] conditions: RVR < 800m and ceiling < 200 ft. The control tower provides aerodrome control service for ground traffic on the movement area, and in flight within the area of its responsibility. The aircraft remain in radio contact with the control tower from the request to start up on the parking lot until take-off (transfer to the radar approach) and vice versa. There is a lack of ground surveillance monitoring and guidance systems to assist the tower controller to ensure safety rules. The aerodrome controller has no display screen to monitor the traffic situation. During the average peak hour calculated by the airport authority, the total number of movements is estimated to average 24 movements. This traffic density corresponds to an average density (16 to 25 movements per runway, or a total of 20 to 35 movements on the aerodrome). In terms of monthly traffic, the Mohamed V platform recorded a number of movements of 7225 in October 2018 (44,59% of Moroccan traffic movement) an increase of around + 6.1% compared to the same period last year [13]. A runway incursion risk is high in the main conflicting area between aircrafts is 'P intersection', situated in the middle the both runways 35R/35L and the main taxiway "T". There is a lack of ground surveillance monitoring and guidance systems to assist the tower controller to ensure safety rules. The aerodrome controller has no display screen to monitor the traffic situation. The integration of a new system or technology needs to take into account the specific data and characteristics of the platform, this section is devoted to the analysis of relevant data to be taken into consideration when choosing a new technology to improve safety. It is highly recommended to implement a surface movement technology to improve safety and support the development of the platform and the traffic growth.

4.3 WSN Proposed Platform

The WSN platform implements the physical layer of the protocol stack and its main objective is to collect multimodal information on physical phenomena. The location acoustic support is designed for three reasons. First, the propagation of the acoustic signal tends to be isotropic in open terrain and has a predictable attenuation of the signal. Secondly, acoustic measurements allow reasonable accuracy to be achieved, even over large measuring ranges. Finally, acoustic sensors (i.e. microphones) and accelerators (i.e. sounders) are inexpensive and commonly available on WSN platforms.
In the external environment of Med V Airport, where obstacles to signal absorption are frequent, signal attenuation is one of the main challenges of long range. Sensor nodes must therefore generate sufficiently strong acoustic signals if we want to obtain reliable distance measurements. the chosen sensor is a leader in the field of navigation with a range of about 500 m in direct visibility to the outside. The nodes operate on a 2.4 GHz low-power

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Atmel radio (AT86RF230) based on the IEEE 802.15.4 standard with a transmission rate of 250 kbps. They operate with 2 AA batteries whose current consumption varies from 10 to 17 mA, depending on the radio's transmission power, and can support an energy recovery mechanism, and can be powered by solar energy, figure 3 illustrate the main components of the sensor node hardware.

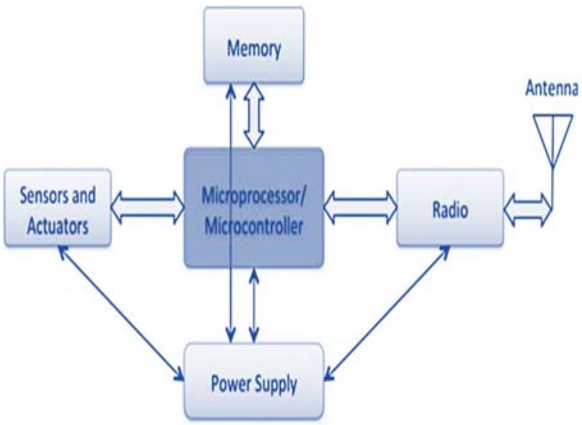

Figure 3: Sensor Node Hardware System

4.4 Coverage and Connectivity

In this section, the airport platform is modelled in nodes and vectors, and a coverage and connectivity study is presented. The surveillance system proposed is implemented over the 'P intersection' , one of the most congested areas of the airport, it's a hub gathering the departing and landing aircrafts and a center line between the runways 35R/35L and the rest of the airport zones. One of the main advantages WSN is connectivity. Sensor networks can be modeled using graphs where nodes are equivalent to vertices and communication links are represented by corresponding edges.
defined as G= (E, V) describes a set V of vertices and a set E of edges that connect the vertices.

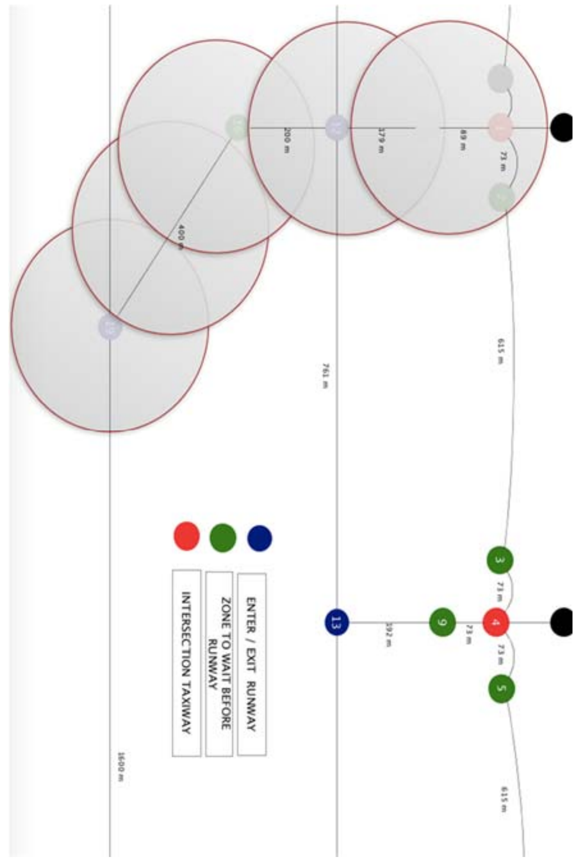

Figure 4: 'P intersection' graph

It is assumed that all communication links between sensor nodes are bidirectional. This means that if node A is in the communication area of node B, the opposite is also true. Sensor placement is a discipline in its own right and many research projects have been proposed in this area [14]. The main objective of any strategy is to ensure that the event to be monitored is at least within reach of the sensor at all times. The choice of a solution must therefore take into account the type of sensors to be installed, the deployment environment and the objective of the application being implemented. The deployment strategy proposed consists in ensuring coverage and connectivity, as illustrated in Figure 4 taking into account the topological specificities of MED V Airport.

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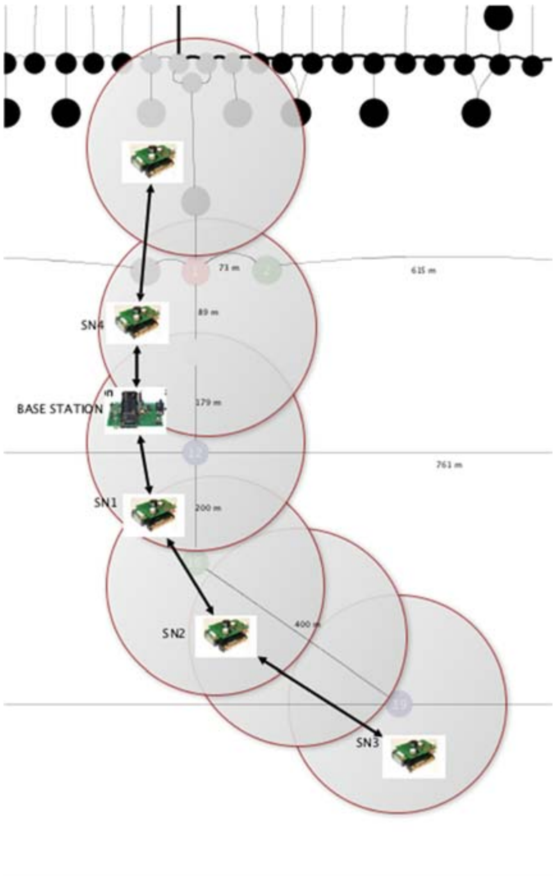

Figure 5: Sensor Network Mapping

Assuming that communication range between sensor nodes is *Rc* = 200 m and that the communication model is binary (when inside the communication range nodes can communicate, outside the range they cannot), then any two nodes whose Euclidean distance is less than *Rc* have a corresponding graph edge in the equivalent communication graph. Equivalently, if two nodes lie in each other's communication disk, then there is an edge between them. Therefore, the sensor network is modeled using a specific type of graph known as a unit disk graph, which admits a graph edge between two vertices if their Euclidean distance is less than a fixed threshold. For communication networks, this graph is commonly referred to as the communication graph of the network. As illustrated in Figure 5 The disks around each node represent the communication range *Rc* of the nodes.

4.5 Tracking Filters Implementation

Target tracking refers to the problem of using sensor measurements to determine the location, trajectory and characteristics of objects of interest. Typical objectives of object tracking are the determination of the number of objects, their identity and condition, such as their position, speed and, in some cases, their characteristics. In the aforementioned context, the problem of object tracking is to determine the number of aircrafts in the monitored area, their speed and position, all based on sensor measurements. There are a number of sources of uncertainty in the problem of tracking objects that make it an important task. For example, the movement of objects is often subject to random disturbances, objects may go unnoticed by sensors and the number of objects in a sensor's field of view may change randomly. Sensor measurements are subject to random noise and the number of measurements received by a sensor from one look to another can vary and be unpredictable. Objects may be close to each other and the measurements received may not distinguish between them. The typical object tracking problem is essentially a state estimation problem as illustrated in figure 6, where the states of the object to be estimated from corrupted noise and false measurements are kinematic states such as position, velocity and acceleration. Target tracking technology can be classified by sensor type, tracking method or the number of targets to be tracked. Depending on the quantity of targets, target tracking can be divided into single target tracking (STT) and multiple target tracking (MTT). STT includes the tracking of a single target by a single sensor and the tracking of a single target by multiple sensors. MTT includes the tracking of multiple targets by a single sensor and the tracking of multiple targets by multiple sensors.

The most widely known Bayesian filter method is the Kalman filter. However, the application of the Kalman filter is limited to linear models with additive Gaussian noises. Extensions of the Kalman filter were developed in the past for less restrictive cases by using linearization techniques. The non-linearity of the out-door airport environment and the multiple non-Gaussian noises such as wind is an important task, to track in such environment we propose in this section using The Particle Filter Method, which is a Monte Carlo technique for the solution of the state estimation problem. Also we propose a solution for multiple target tracking where the number of targets may not be known and varies with time by implementing The Gaussian mixture Probability Hypothesis Density (GM-PHD) filter, the predictive density is approximated by a Poisson point process to track potentially many targets, including birth, death and spawning of targets automatically.

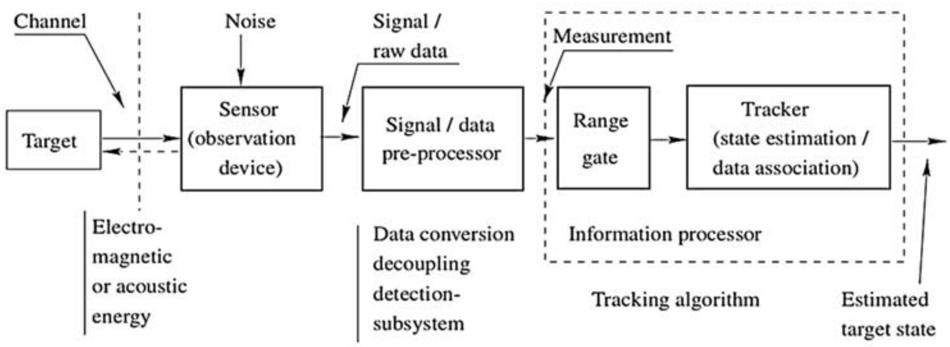

Figure6: Typical Object Tracking System

So that the sensors can be able to estimate the positions of an unknown number of targets, based on observations of the targets corrupted by noise.

The particulate filter method was developed to represent the posterior density in terms of random samples and associated weights. In the literature, Monte Carlo methods, usually referred to as particulate filters, among other designations, do not require the restrictive assumptions of the Kalman filter. The particulate filter is therefore adapted to the airport's external environment, which is a non-linear model with non-Gaussian errors. Next, we introduced the GM-PHD filter that incorporates the concept of detection and survival rates of non-ideal objects at birth, as well as false alarms in multiple target tracking problems. We have shown that even with a high footprint and non-ideal detection / target survival (which are commonly encountered in real field applications), the GM-PHD filter is still able to track multiple targets with good accuracy. More importantly, it is likely to recover lost targets if a sufficient number of Gaussians are introduced.

4.5.1Particle Filter

It is proven that the particle filter deals with the nonlinear nature of the moving target tracking problem successfully. Several types of filters can be designed depending on the system model and noise type. In the case of the particle filter introduced in this paper, it is known that the filter is applied to non-linear models with non-Gaussian error [15].
to Implement Particle Filter algorithm to track an object, three main steps were followed. First to predict the position of the object using particles. followed by weighting step where particles are assigned weights by probability distribution over the space. Once weighting is done re-sampling is applied in order to avoid replication of particles resulting in localization of the object at different time step.

✓ Initialization:
the list of parameters which need to be set before starting the main step of particle filter are:
F the Linear Sate Transition model; ***Q***: process noise; ***R*** the measurement noise; ***H*** matrix is created to convert state of the model to measurement space.

✓ Sampling: Predict the position of the object using probability density function.

- Prediction equation

$$\tilde{x}^{(i)} \sim f_{k|k-1}*(x_k|x_{k-1}{}^{(i)}) \qquad (1)$$

- Weighting for each measurement

$$\tilde{w}^{(i)} = g_k(z_k|\tilde{x}^{(i)}) \qquad (2)$$

✓ Resampling: Re-sampling is performed whenever the effective sample weight $\tilde{\boldsymbol{w}}_k{}^{(i)}$ drops below a certain threshold.

$$\tilde{w}_k{}^{(i)} = N_k(x^{(i)}, u, cov) \qquad (3)$$

✓ Results of Particle Filer:

To analyze the results for particle filter we perform different parameters which are important in changing the behavior of the filter.

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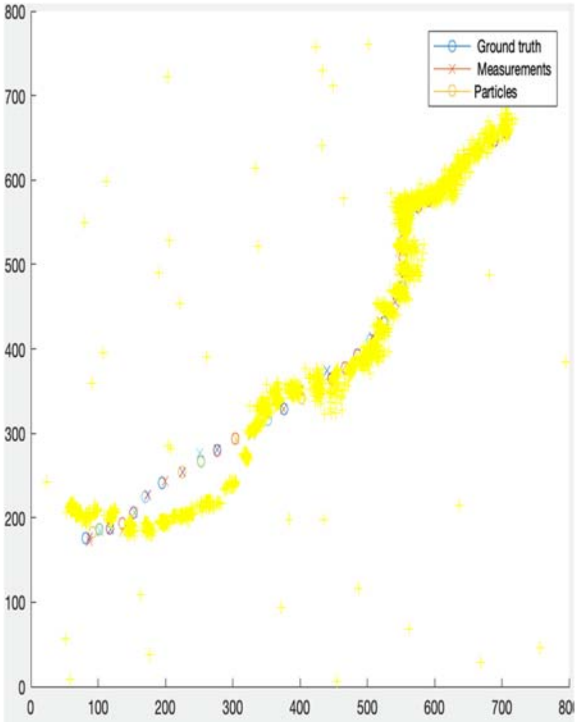

Figure 7: Particles = 40, Time Step k = 40

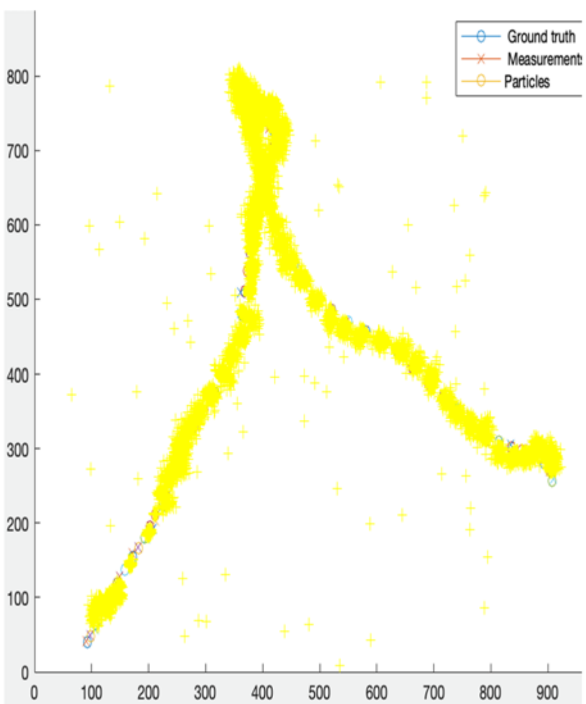

Figure 8: Particles = 80, Time Step k = 80

It can be seen clearly the object was not tracked properly for set of steps in figure 7, as it need some times step to start converging to the place where object is located, by increasing the number of particles and time steps in figure 8 the object is tracked more robustly. If less number of particles are used with small time step the convergence of particles is very rare with the original observations. the more the number of particles the better the tracking result of the object is with the ground truth model. the more the number of steps we use the better particles prediction results in with high convergence to simulator measurements as could be seen in figure 7 and 8 below.

4.5.2 GM-PHD Filter to Track MMT:

The GM-PHD filter is a multi-object tracking algorithm that probabilistically determines all object-observation order pairs that can be considered and solves this problem without additional algorithms. In other words, the GM-PHD filter solves the data association problem by weighing all the ordered pairs that can come out between all the objects being tracked and the object observations obtained from that frame, based on the probability that each ordered pair is true. The multiple target states of the GM-PHD mixture are determined from the Gaussian components with the highest weights. Instead of propagating the multi-target posterior density in time, the PHD filter propagates the posterior intensity, a first-order statistical moment of the posterior multi-target state [16]. This strategy is reminiscent of the constant gain Kalman filter, which propagates the first moment (the mean) of the single target state. In a multi-target environment, not only do the states of the targets vary with time, but the number of targets also changes due to targets appearing and disappearing (dictated by surviving rate, Ps). Often, not all of the existing targets are detected by the sensor (dictated by detection rate, P_D). Moreover, the sensor also receives a set of spurious measurements (dictated by lambda) not originating from any target.

The following figures displays how our GM-PHD filter tracks moving targets in different environments- noiseless (lambda=0)- moderate noise (lambda=5)-noisy (lambda = 20).

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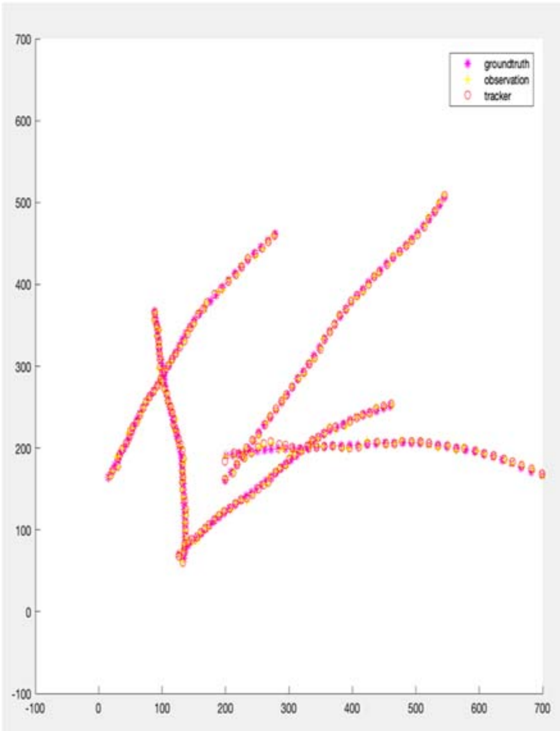

Figure 9: 5 Targets, Time step k = 40, Lambda =0.

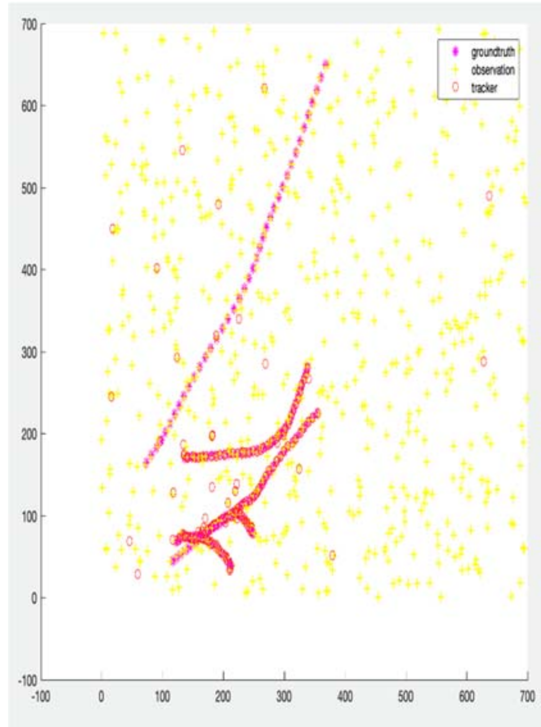

Figure 11: 5 Targets, Time step k = 40, Lambda = 20.

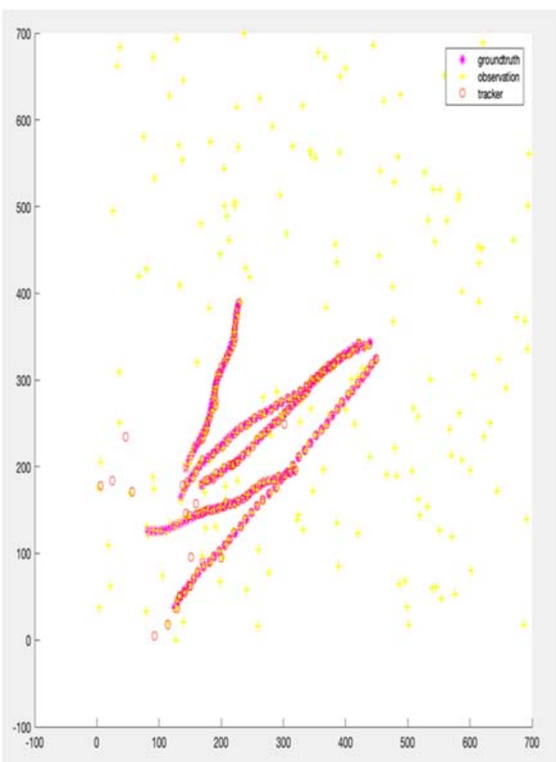

Figure 10: 5 Targets, Time step k = 40, Lambda = 5.

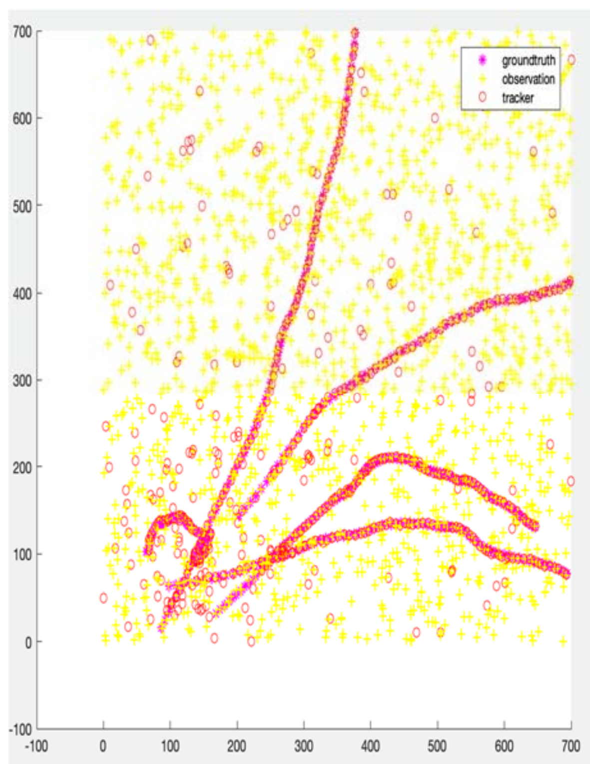

Figure 12: 5 Targets, Time step k = 40, Lambda = 20-number of Gaussians increased.

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we see that with no or moderate false alarms, the GM-PHD algorithm is capable of tracking all the moving targets without loss. In figure 11 (lambda = 20), one target is lost at an early stage, and we can observe some attempt of re-tracking by the filter, which all end up failing. In figure 12 we apply the same false alarm rate, but allow more Gaussian to propagate to the next iteration. By propagating more potential trackers to the filter, all targets are successfully tracked.

5. CONCLUSIONS

Throughout this paper, we have focused on presenting a non-cooperative tracking system using WSN, which is a low-cost solution for airport ground surveillance system. we have endeavored to answer some of the questions: what sensors will be effective to the external environment of the airport, how to connect the sensor network, and how to detect the presence of a target in an airport environment, and once detected, how to locate it and relay the tracking from node to node? This type of system strategy requires knowledge of the environment to be monitored, but also knowledge of the type of targets and their behavior in order to choose the most appropriate technology for the given situation. We then applied the use the tracking system to the study-case of Mohammed V Airport. To solve the complex target-tracking problems. We proposed two monitoring filters to detect, locate, predict, in a realistic way single and multiple targets. We began with Monte Carlo framework (Particle Filter) to track a single object in non-ideal environment. Next, we introduced GM-PHD filter which incorporates the concept of Birth-Gaussian, and survival rate as well as false alarms into multi-target tracking problems. We showed that even with high clutter and non-ideal detection / target survival (which are commonly encountered in real airport environment), GM-PHD filter is still capable of tracking multiple targets with good accuracy.

We noted that it is necessary to choose the solution best suited for target monitoring using wireless sensor network. The environment where the target moves and the various types of moving objects ought to be well studied in order to obtain the best tracking performance. The work we have carried out offers many interesting perspectives from our point of view. First, testing the feasibility of proposed solutions on sensor networks seems to be an obvious step. Indeed, the studies so far have only been validated by simulations. The behavior of the algorithms on the platforms of Mohamed V Airport is a decisive factor for evaluation.

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