

A Methodology for Collision Prediction and Alert Generation in Airport Environment

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ABSTRACT

Aviation safety is one of the key focus areas of the aerospace industry as it involves safety of passengers, crew, assets etc. Due to advancements in technology, aviation safety has reached to safest levels compared to last few decades. In spite of declining trends in in-air accident rate, ground accidents are increasing due to ever increasing air traffic and human factors in the airport. Majority of the accidents occur during initial and final phases of the flight. Rapid increase in air traffic would pose challenge in ensuring safety and best utilization of Airports, Airspace and assets.

In current scenario multiple systems like Runway Debris Monitoring System, Runway Incursion Detection System, Obstacle avoidance system and Traffic Collision Avoidance System are used for collision prediction and alerting in airport environment. However these approaches are standalone in nature and have limitations in coverage, performance and are dependent on onboard equipment. There is a need to have an integrated solution for collision prediction and alerting to enhance the capacity and operational efficiency of the airports and airspace at the same time ensuring the safety of aircrafts and personnel.

This paper proposes a comprehensive, fool proof, integrated solution employing multiple sensor technologies to seamlessly predict collisions in all the zones of airport environment and generate alerts and guidance to prevent the same. Proposed system employs multiple sensor technologies like Optical and Infrared cameras, Laser Range finders, and Primary and Secondary surveillance radars for object monitoring, adopt latest technologies such as advanced image processing, sensor fusion for object detection and path tracking [1], collision prediction and synthetic visual environment for enhanced situational awareness and video based alert generation in real time. Simulation results of a synthesized data analysis that obtained through application of data fusion on multiple data sources and 3D path tracking algorithms are explained in the case study section.

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INTRODUCTION

In spite of advancement in technologies and safety solutions being incorporated into airspace and ground segments, accidents in airport ground and airport airspace areas are increasing due to ever increasing air traffic and human factors in the airport. It is estimated that, in commercial aviation, 70% of fatal accidents both in flight and ground are related to human error and rest due to equipment failures and other causes and 90% of the accidents happen in airport surroundings i.e. initial and final phases of the flight.

Figure 1 shows the accident statistics by phase of flight. Ramp/Apron accidents alone accounts to \$10 billion losses according to a study (Source: IATA). It is predicted that air traffic will see a 31% increase by 2017 (Source: IATA), the collision detection and prevention in airport is a formidable challenge to the aviation industry.

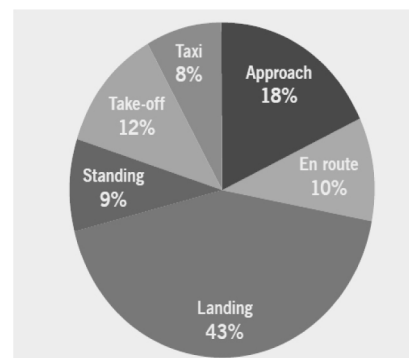


Figure 1. Accident statistics by Phase of Flight (Source: ICAO).

Table 1. Existing standalone systems and their limitations

System	Description	Phase of Flight	Performance	Limitations
Secondary surveillance radar (SSR)	A radar based system used in air traffic control (ATC), detects and measures the position of aircraft i.e. range and bearing and sends interrogation signal for identification.	- Takeoff - Initial Climb - Final Approach - Landing	Range: 9.3km (Standard) 19km (Monopulse) Threshold (Accuracy): 25ft (Mode S) 100ft (Standard / Monopulse)	- Limited radar sweeping coverage (only airspace). - Manual detection of collision is prone to human error. - Cannot detect smaller objects like UAVs, Gliders, and Hot Air Balloons.
Runway Debris Monitoring System	Monitors debris on runway and alert operators or ground staff to take action.	- Landing - Takeoff	Range/Threshold: Runway Zone	- Monitors runway zone only - No Visual alerts generated. - Manual alerting is prone to human error.
Runway Incursion Detection System	Monitors un authorized aircraft entering into runway and alert operators or ground staff to take action.	- Landing - Takeoff	Range/Threshold: Runway Zone	- Monitors runway zone only - No Visual alerts generated. - Manual alerting is prone to human error.
Traffic Collision Avoidance System (TCAS)	This system is installed onboard the aircrafts, interactively interrogates the transponders of the aircraft and negotiates collision avoidance in case of threat in air.	- Climb - Approach	Range/Threshold: 20 seconds (<1000 ft AGL) to 48 seconds (> FL200) for Traffic Adv 15 seconds (<2350 ft) to 35 seconds (> FL200) for Resolution Adv. Note: Below 1000 ft AGL, RA's are inhibited.	- Transponders needed in every flying object to be able to detect that object. - Covers limited phases of flight (limited to avoiding mid-air collision).
Terrain Awareness and Warning System (TAWS)	TAWS/EGPWS is onboard the aircraft help in approach and landing phases to avoid any high rise obstacles.	- Climb - Approach - Takeoff - Landing	Range: 0.5 nm to 10nm;	- Pertains to high rise obstacles and covers limited phases of flight. - No Synthetic vision for situational awareness is provided.
Enhanced Ground Proximity Warning System (EGPWS)				
Obstacle avoidance system	This system is ground based, uses radar mounted detection mechanism on or near the obstacle to detect proximity between aircraft and other objects.	- Taxi - Load/Unload - Parking - Towing	N/A	Pertains to taxi strike and covers limited phases of flight.
Synthetic Vision	Synthetic Vision onboard the aircraft provides pilot with computer generated imagery of the outside environment for low visibility conditions.	- Taxi - Load/Unload - Parking - Towing - Takeoff - Initial Climb, Climb - Initial Approach, Final Approach - Landing	N/A	Provides only synthetic vision to pilot for situational awareness in low visibility conditions and auto collision alert generation is not in the scope.

Existing Systems and Limitations

Currently various systems in use for detection and avoidance of collisions in airport environment such as Runway Debris Monitoring System, Runway Incursion Detection System, Obstacle avoidance system and Traffic Collision Avoidance System. These systems have limitations that are broadly categorized as, coverage limitations, inability to cover blind spots, standalone systems, need of additional equipment on the air/ground vehicles and unavailability of the unresponsive system etc. [Table 1](#) summarizes the existing systems for collision detection and avoidance in airport environment with the details of various aspects such as flight phases covered, performance parameters and limitations.

DESCRIPTION OF THE SOLUTION

The integrated solution discussed in this paper provides a novel, comprehensive and fool proof solution. Technologies employed for this solution are multiple sensor data fusion for estimation and prediction accuracy, advanced image processing techniques for detecting and identifying objects, real time processing of huge data to seamlessly detect collisions in all the zones of the airport environment, advanced synthetic vision for situational awareness and communication interfaces for generating alerts and guidance to prevent the collisions.

This solution covers collision detection of all phases of flight in an airport environment compared to the existing independent or standalone systems that cannot cover all phases of flight. [Figure 2](#) shows the phases of the flight (encircled) in which the proposed system functions monitor for collision threats and avoid the collisions.

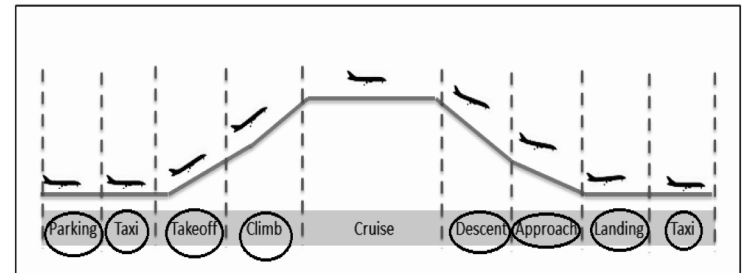


Figure 2. Phases of Flight covered by the system

A. System Functions

System functions are described below with a high level functional view of the system. System generally monitors different zones of the airport environment such as runways, taxiways, parking areas and airport airspace. Huge visual data from digital and infrared cameras supplemented by laser range finders for distance parameters, positional data from Radar is consumed and stored by the central computing system employing the big data technologies. Sensor fusion is performed in the central computing system for data accuracy and path estimations, collisions are predicted and visual and audible alerts are generated for air traffic controllers, operators, ground staff and pilots. [Figure 3](#) below depicts the functional diagram as explained above.

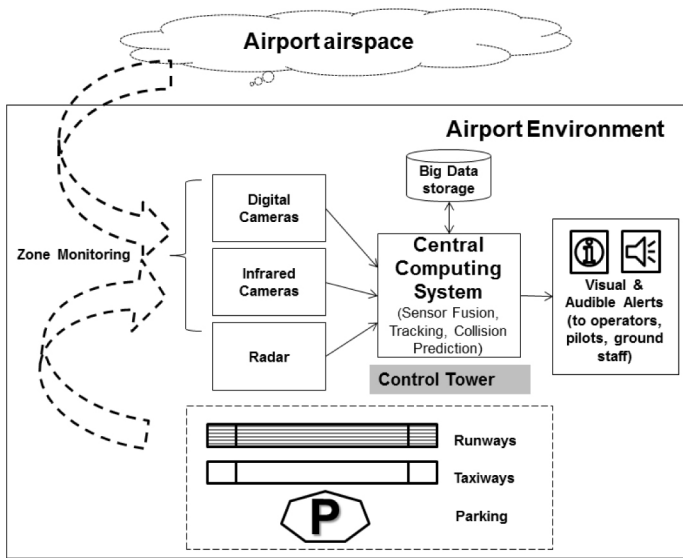


Figure 3. Functional block diagram of the Airport Monitoring and Collision Alert System

1. Air Traffic Monitoring for Collision Detection and Guidance for Collision Avoidance

The proposed system monitors airport approach and departure airspace for unwanted flying objects like Aircrafts, UAVs, and Gliders etc. for possible collisions with the aircrafts during flight phases like descent and climb.

2. Monitoring of Unwanted Flying Object in Airport Airspace

This system monitors airport perimeter airspace for unwanted flying objects like UAVs, Gliders etc. for possible collisions with the aircrafts during flight phases like final portion of descent, approach, landing, and take off and initial portion of climb and low flying objects for phases of Taxi.

3. Runway Incursion Monitoring and Alert

This system monitors runways for unauthorized aircrafts and ground vehicles for possible collisions with the aircrafts during flight phases like landing, and take off.

4. Runway Debris Monitoring and Alert

This system monitors runways for unauthorized aircrafts and ground vehicles for possible collisions with the aircrafts during flight phases like landing, and take off.

5. Taxiway and Ramp (Apron) Area Monitoring for Taxi and Parking Collision Alert

This system monitors taxiways for possible collisions of aircrafts with other aircrafts, ground vehicles and other obstacles during flight phases like taxiing and parking.

B. System Architecture

System architecture broadly comprises four stages as listed below that combine functions of various components to collaborate and implement the overall system. Figure 4 shows the architectural view of the airport monitoring and collision alert system with four functional stages shown in dotted blocks. System functional stages are:

1. Data Acquisition and Storage
2. Data Processing
3. Synthetic Visual 3D Simulation
4. Advisory and Control Communication

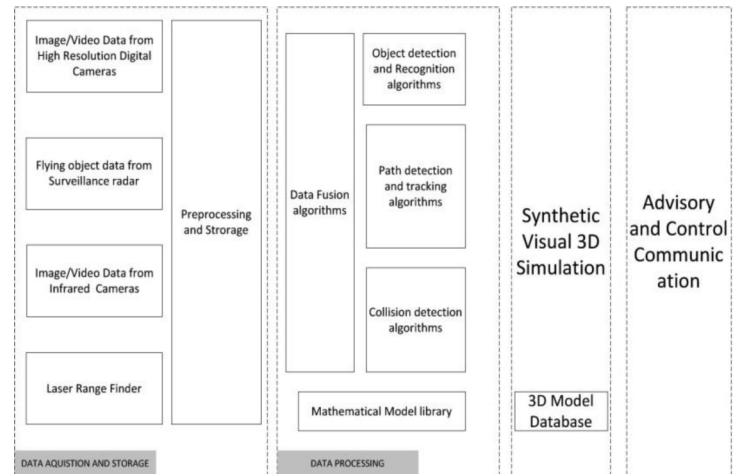


Figure 4. Architectural block diagram of the Airport Monitoring and Collision Alert System.

Details of the processing done at various stages are explained along with execution flow in the following section.

1. Data Acquisition and Storage

Sensor system consists of High definition Electro optical Digital Cameras, Infrared cameras for Night vision [2], Laser Range Finder, Primary/Secondary Surveillance radar. Data from multiple sensors listed above is acquired at pre-determined rates and is preprocessed to filter out the unwanted data and is stored for easy retrieval for further processing. As the Airport under monitoring could be of considerable in size, typical size of a synthetic 3D airport model and objects model libraries can run into Giga Bytes. The no. of sensors employed across the airport can run into multiple of tens if not hundreds in case of big airports. With each sensor generating the streaming data of video and digital information amount of information which needs to be processed, will pose considerable challenge for conventional computing environments and requires a scalable storage and distributed strategy for data querying and analysis. This makes this solution an ideal candidate for applying Big Data techniques and tools like Apache SPARK framework for storage and analytics. Preprocessed data is stored and organized in databases for easy access by the data processing stage.