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Air Sransportation Simulation to Runway Incursion Safety

SungKwan Ku[a], Hojong Baik[b] and SeokJae Yun[c]*

[a] Faculty of School of Aeronautical Science, Hanseo University, South Korea
[b] Faculty of School of Air Transport, Transportation and Logistics, Korea Aerospace University, South Korea.
[c] Ph.D Candidate of Department of Air Transport, Transportation and Logistics
Graduate School, Korea Aerospace University, South Korea.
[1]Orcid Id : 0000-0003-0530-5981, [2]0000-0003-2055-2534

Abstract

An aviation accident can have fatal consequences and thus, the industry requires a very high level of safety. Management for the assurance of safety levels must include analysis, validation, and evaluation for all quantitative and qualitative requirements. Previously, the main method to achieve this was to calculate and confirm speculative utilization of historical data for quantitative safety inspection. However, this method has the disadvantage of taking too much time for data collection and accumulation.

This study solves this problem by applying an air transportation simulation technique to confirm operational safety. This study is applied to airport ground operations in which very critical accidents occur using simulation techniques. Thereafter, situational occurrences involving runway safety were analyzed to confirm the operational safety of runway invasion during aircraft take-off or landing conditions.

The main research content of the air transportation simulation model is analyzed to reflect the characteristics of the information after performing accuracy analysis of existing airport ground surveillance information.

The process and results of this study can be utilized to check whether surveillance accuracy assures adequate safety for airport ground operations during construction of new airports or installation of surveillance equipment in existing airports.

Key word : Air transportation simulation, Runway incursion detection Simulation analysis, Trajectory analysis, Airport surface surveillance performance, Application program interface (API)

INTRODUCTION

It is important to find the best solution from among different circumstances in order to solve real problems. To do so, models are developed with certain assumptions for problem - solving in order to numerical value out the best answer. To this end, it is common to set up numerical models. However, numerical models impose overly strict assumptions in comparison with real situations, making it difficult to reflect reality. In practice, the surest way to find answers is to develop an execution identical to the actual situation, but this is almost impossible. To solve these problems, we can make use of simulations

Simulation is dynamic duplication of real or virtual models, which are utilized to solve complex problems and analyze results via phenomenon reconstruction. In addition, it means identifying the characteristics of the problem through repeating simulated operations after implementing similar conditions via the model or numerical value to the real world. In other words, simulation means implementation of the same conditions as actual conditions using virtual reality, and it can be implemented in cases with similar characteristics to real conditions when required. At present, the simulation is generally performed in this process more easily by computer and recent computer developments have helped to implement simulation at little cost.

However, simulation produces different result with varying degrees of reflecting reality in accordance with how the model is designed data levels are inputted. In particular, analysis of appropriate input data is an important factor in carrying out tests on how similar the simulation is to real conditions because its determination of real situations and degrees of similarity depend on a random number characteristics run among random input data.

This study performs safety analysis about airport ground movement using a simulation method related to the requirement for a very high level of safety(very low accident event). In order to solve the limits of stochastic analysis, this study builds a realistic simulation model to reflect real conditions, and then, validates safety level from the simulated result in accordance with real airport operations and similar operational results. For this, a simulation environment is set up through analysis of actual airport operational data and validation is undertaken about operational safety.

The main goal of this study is first, to design a simulation model for analysis of airport ground safety; second, to implement real operational data analysis to find the main input variables that accord with reality; and third, to validate the results and analysis of simulation for real operational safety.

RESEARCH MATERIAL AND DESIGN

Air transportation simulation

It is difficult to apply a formulation for aircraft movement in airfields owing to complex issues, such as error from surveillance and aircraft performance. The safety level that this study needs to confirm requires a lot of operational data. Thus, it is reasonable to use a Monte Carlo simulation to draw results through simulation testing.

This study considered aircraft movement and the airport surface detection equipment(ASDE) surveillance error from operating airports. An air transportation simulation model is necessary as follows:

- to import geographic data to model the airport geometry (runway and taxiway);
- to simulate aircraft with flight performance data;
- to perform batch processing for multi-run; and
- to generate imaginary positions of aircraft (i.e., radar error) during simulation

When the simulation tool is implemented directly, there are temporal limits of this study that must be considered, which are linked to connectivity with ground operations of aircraft as well as airspace use by aircraft to take off and land. Therefore, this study utilized commercial air transportation simulation model (AirTop) air transportation analysis. The simulation model used provides a user-application programming interface to add plug-in with simulation in order to generate the required surveillance error for this study. As a result, the study can implement aircraft position error by running the simulation.

Runway safety and surveillance performance

Runway safety

The landing aircraft are more exposed to risk factors than in-flight aircraft, as shown by frequent crashes between aircraft on the ground, as the rapid speed of landing aircraft increases the risk of collision with ground obstacles. In particular, runways for landing and take-off are associated with high accident risk. Thus, the runway is a very important component of airport operational safety and is a critical site when accidents occur.

Aviation authorities have collected operational statistics for runway safety and have managed runways by establishing safety goals, including those in the United States and Europe. In addition, research is being carried out on safety management with development systems, such as the runway status light of the FAA, the advanced surface movement guidance control system (A-SMGCS) of Eurocontrol, and aviation safety technology research for airport operations from the Republic of Korea.

The following two factors impede runway safety: first, runway incursion and excursion are direct causes, and second, environmental causes include bird strikes, wildlife, and foreign object damage.

Runway incursion

Runway incursion is any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle, or person in the protected area of a surface designated for the landing and take-off of aircraft. It means all situational events that cause the entry of aircraft, vehicles, or people within a given area, such as the holdline when the aircraft is using a runway for landing or take-off. For example, when aircraft have take-off clearance or landing clearance, there should be no aircraft, vehicles, people, or obstacles on the runway. To cope with breaches, the aircraft has to have contingency plans to, for example, increase or decrease air speed, stop, go around, or change altitude.

Airfield surveillance system performance

Detection of alert situations for airport grounds, including the runway, is very important in safety management. Reasonable standards for false alert levels in alert situations should be recognized clearly in risk situations in airport operations. The A-SMGCS system for airport ground control involves a required fail rate for surveillance and probability of false alert (PFA) for airfield surveillance performance. This is also clearly proposed as 1.0E-3 in Eurocontrol.

Target surveillance performance

Defined target probability of false alert on runway incursion

To check runway incursion events from the surveillance system starts with the recognition of whether the runway sector has been invaded, because the ASDE detection target is invasion of the runway holdline.

At this time, acceptable monitoring performance is required for 1.0E-3 by surveillance information.

The goal of this study to check and ensure airfield operational safety in the present system after applying the required probability of false alert under 1.0E-3 for the surveillance system performance.

Influential runway incursion

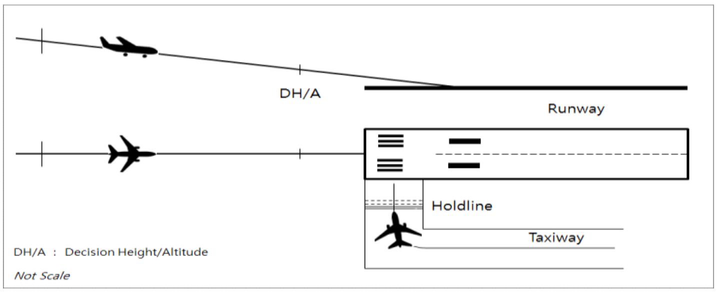

Figure 1: Aircraft approach and hold short of runway

This study assumes a situation in which the landing aircraft is within 3 nm of the runway threshold when the aircraft is ready to take off or land. In the case of an aircraft entering the runway holdline on standby to take off, this equates to runway incursion. In addition, this study assumes the same situation as a major event occurs when the aircraft is at an altitude of less than 200 ft from the ground for landing.

SIMULATION SETUP

Simulation design

An air transportation simulation model was designed for this study. In considering how to make the simulation, there was a need to apply the development of customized application program interface (API) to reflect on surveillance data characteristics. The testing process is as follows.

1. Gathering actual ground surveillance data in the airport.

2. Analysis of surveillance data characteristics.

3. Developing a tool for radar error production and validation of surveillance data for simulation input.

4. API development.

5. Developing and implementing simulation scenario.

6. Analyzing the simulation results.

ASDE trajectory data

ASDE is a type of radar to provide target information to ground controllers, and it detects movement of, for example, aircraft and vehicles on the grounds of the airport. ASDE is short-range detection of radar in and around airports, but has a high accuracy specification. However, the radar provides positional information using energy wavelengths reflected from the surface of an object. By this radar characteristic, ASDE has the disadvantage of lowering the accuracy of a target because of such factors as distance from antenna, target position, and weather condition; thus, position error could appear even in the case of observation of a perfectly still object.

Position error (target movement) occurs around aircraft on standby runways for landing other aircraft. It makes error in the determination of intrusion of the runway holdline in actual situations. There are two types of error. One is that it guarantees the runway distance but considers the information indicating invasion status as false data. The other is that it shows the runway distance invaded but the information indicating safety status is indicated as false data.

This study analyzed ASDE target information of an operating airport, and the simulation input data utilized target error information. For this, we analyzed data of waiting aircraft target in the runway holdline for landing aircraft at Jeju International Airport in the Republic of Korea on April 1, 2015.

We analyzed target data (waiting aircraft target in the runway holdline by landing aircraft) for 103 number of Flight, with trajectory points of 10,380. Figure 2 shows a 3D histogram of the surveillance target positions. The histogram appears ridge-shaped by, for example, radar target error of ASDE, stopped aircraft position error, and gap of aircraft size.

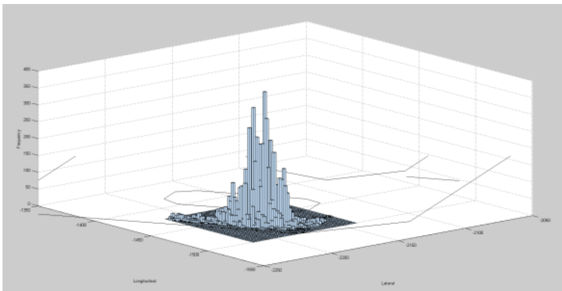

Figure 2: Runway hold aircraft trajectory 3D histogram

Simulation input data—virtual ASDE trajectory

For the purpose of this research, positioning error may be applied to aircraft for waiting in the runway holdline. This study used multivariate normal distribution in order to implement radar position error laterally as well as longitudinally at the same time, and it used the “mvtrnd” function of MATLAB to build a radar error generator that follows the distribution.

The generator is operated when the departure aircraft waits at the hold short of the runway on the simulation. At this time, an aircraft simulation position generates a radar error of multivariate normal distribution from the center of gravity (CG) position after choosing a random by uniform distribution in which one of the aircraft is at the center of each of ASDE trajectory analyses.

Figure 3 shows the actual ASDE observed value and the generated target, as applied to the simulation based on the runway holdline / taxiway. The simulation confirms that both the observed value and the generated random error for simulation are located on the left side of the taxiway centerline, and about 10 targets move out of the runway holdline. Thus, we are assured that the target was invaded in the runway area. As a result, it is appropriate to use the radar error generator.

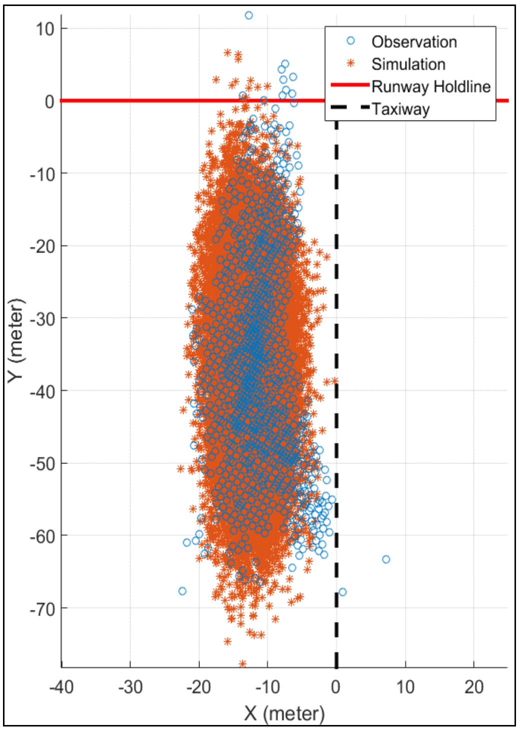

Figure 3. Input error data for simulation

SIMULATION APPLICATION AND ANALYSIS RESULTS

Simulation scenario

The test scenario for implementation of simulation is as follows. We use a layout similar to the actual ASDE data collection airport to reduce the uncertainty of applying the measurement. This sets up the minimum distance between arrival and departure or take-off and landing to maximize valid conditions (landing approach—hold on the runway). Each aircraft is implemented in the Monte Carlo simulation using repetition, such as‘#1 aircraft arrival—#2 aircraft departure hold—#1 aircraft landing—#2 aircraft runway line-up and wait—#1 aircraft exit of runway—#2 aircraft take off and departure.

Table 1: Simulation scenario

Condition	**Set / Application**
Approach Class	Category - 1
Decision Height	200ft
Arrival Separation on Final Approach Fix(FAF)	random between 2min 45sec and 3min 15sec
Departure Separation on Parallel Taxiway	random between 2min 45sec and 3min 15sec
Arrival Approach Speed	random between 130kt and 150kt on FAF
Touch Down Speed	random between 125kt and 135ft on Touch Down Zone
ASDE Targeting Time interval	every 1sec (60Hz/min)

Table 1 is the simulation scenario condition on the Monte Carlo simulation in this research. The arrival aircraft has a randomly generated 2 min 45 sec to 3 min 15 sec. After the setup, the random approach velocity of between 130 kt and 150 kt is changed to between 123 kt and 135 kt when the aircraft touches down. The departure aircraft has a randomly generated 2 min 45 sec to 3 min 15 sec in a parallel taxiway nearby runway; it departs after waiting for takeoff and the landing of the arriving aircraft. The surveillance position is applied with the aircrafts' actual position of simulation and noise. Their updated frequency time is implemented in 1-second intervals, which is the actual detection interval of the ASDE.

Simulation trial

This study was simulated five times with about 1 million departure to obtain more accurate test results that are clear and solve uncertainty. This confirmed the propriety of simulation by comparing the result per trial case to the total result using average value.

Figure 3 shows the runway incursion situation as a scene in the simulation implementation, when the departure aircraft is waiting on the holdline. The plug-in developed in the study is assigned to the aircraft at the CG (yellow point, below the aircraft point) of the radar target with the assumed actual stop position of aircraft, and the radar error (green point, above the aircraft point) is assigned from this point. When the arrival aircraft is 71 m away from the threshold, the observation point with radar error shows the runway holdline is invaded in Figure 3.

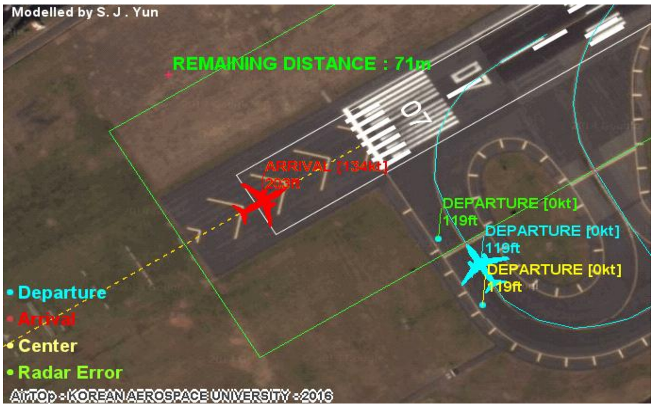

Figure 3. Example of simulation animation

Simulation output

When performing the simulation, the recorded simulation log results are shown in Table 2. The recorded information types are simulation clock, distance to arrival aircraft from the threshold, position, including radar error applied to the departure aircraft, and whether to invade the holdline of the position.

Table 2: Example of simulation output format

Simulation clock	**Event number**	**Distance from threshold of arrival aircraft**	**Radar error location of departure aircraft**		**Runway incursion**
Int(sec)	**Int**	**meter**	**Longitude(E)**	**Latitude (N)**	**Boolean**
39633	1	6212	126.4692	33.4990	0
36934	1	6125	126.4692	33.4989	0
36935	1	6038	126.4692	33.4991	1
39636	1	5952	126.4692	33.4990	1

The recorded arrival aircraft position is classified in two areas. One is between 3 nm (Area 1) from the runway threshold and the other is between DH (Area 2) and the runway threshold. The aircraft while landing, in the case of the arrival aircraft in Area 1 (hereafter, Area 1 condition), has an average runway incursion rate is about 5,100 per 1 million departures. When the arrival aircraft is in Area 2 (hereafter, Area 2 condition), the average runway incursion rate is about 920 per 1 million departures.

ANALYSIS OF RESULTS

The probability of runway incursion is shown in Table 3, by which we can observe that arrival aircraft within the Area 1 condition could not identify 1.0E-03 as a target probability of false alert in this study. This means it is necessary to improve airfield surveillance performance or to develop extra safety measures for runway incursion detection.

Table 3. Result of simulation

Simulation set	**Number of departure**	**Number of incursion**		**Probability of false alert**	
		Area 1	**Area 2**	**Area 1**	**Area 2**
Set 1	1 million	4,917	877	4.92E-03	8.77E-04
Set 2	1 million	5,217	951	5.22E-03	9.51E-04
Set 3	1 million	5,321	973	5.32E-03	9.73E-04
Set 3	1 million	5,105	907	5.11E-03	9.07E-04
Set 3	1 million	5,144	941	5.14E-03	9.41E-04
Total	5 million	25,704	4,649	5.14E-03	9.30E-04

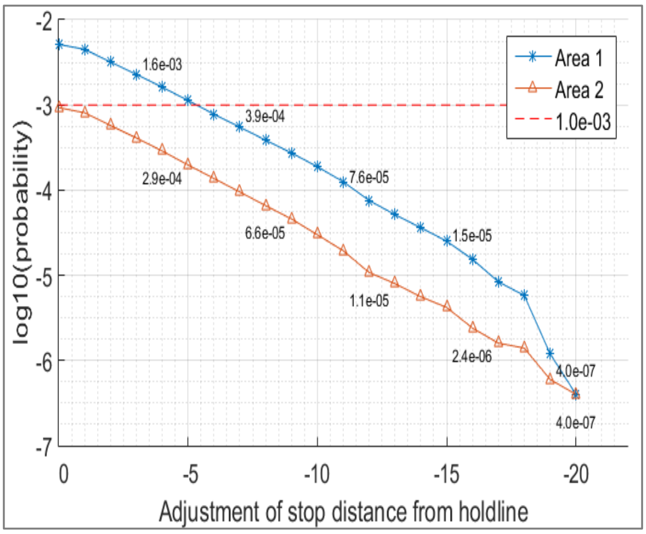

Figure 4: Surveillance performance for the safety condition

CONCLUSION

This study researches the safety of airport ground movement using simulation. For accurate simulation results, after gathering data with ASDE radar trajectory from an actual airport, it analyzed radar error of waiting departure aircraft from the runway holdline. After checking how appropriate this position error is with multivariate normal distribution, it confirmed operational safety applied to air transport simulation. The simulation result could not satisfy the probability of false alert, such as the 1.0E-03 condition, with ASDE surveillance position error of currently collected case.

Generally, safety and efficiency are related to trade-off. This causes efficiency reduction of airports that perfectly satisfy a safety target. The results of this study mean that runway incursion safety increases through movement of the aircraft hold position but this could decrease runway capacity. The limitations of this study are left for future research.

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