Nationaal Lucht- en Ruimtevaartlaboratorium
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NLR-TP-99307

Runway incursion alert using knowledge rules

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Summary

A runway incursion is a situation where two or more aircraft or vehicles occupy one runway simultaneously and as such create a potentially dangerous situation. We can think of many situations where two aircraft/vehicles occupy the same runway simultaneously, but do *not* cause a conflicting situation, e.g. two taxiing aircraft on a closed runway or a departing aircraft lining up behind a landing one. From the current increase of simultaneous aircraft movements and an increasing use of intersecting runways and runway crossings, there is a large potential for conflicts and a need for tower controller decision support in surveillance and monitoring. A Runway Incursion Alert tool enables ground movement capacity to be optimised, while maintaining safety.

In this paper, we present an advanced Runway Incursion Alert (RIA) tool, based on mode-of-flight tracking and as such taking into account the observed status of aircraft and other moving vehicles. The conflict detection function is Knowledge Based so that it can reason about active and inactive runways and takes into account the status of the aircraft. Detected conflicts will be displayed on an overlay of the airport lay out. A separate window will pop up, to contain additional conflict information. Tower controllers are given the capability to acknowledge conflicts.

A prototype demonstration of the proposed RIA function has been built.

Abbreviations

A-SMGCS	Advanced Surface Movement Guidance and Control System
FAA	Federal Aviation Authorities
HTML	Hyper Text Mark-up Language
RIA	Runway Incursion Alert
NEXT	NLR Engineering X-pert system Toolkit
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium (National Aerospace Laboratory, The Netherlands)
ATC	Air Traffic Control
HMI	Human Machine Interface
DEFAMM	DEmonstration Facilities for Airport Movement Management

Contents

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1 Introduction

Recently, an increase in the number of runway incursions is observed (Ref. 1). Size of an airport, in terms of number of movements, is one factor in the occurrence of runway incursions. Several other aspects play a role, such as complex runway configurations, taxiway connections, and runway operational procedures. Many airports operate two (or more) runways simultaneously. This is a possible cause for mistakes by pilots. Some airports have difficult taxiing procedures, including crossing other open runways. Besides, taxi-clearances are usually relative long and a cause for confusion and mistakes.

Several airports are currently investigating increasing their capacity by alternative usage of available runway infrastructure such as using intersecting runways, converging runways, runway crossings, and mixed mode operations. To further enhance airport capacity, reduced separation and other new operational procedures, such as land-behind and take-off-after, are examined. To sustain an acceptable safety level, early detection of runway incursions is of crucial importance.

Safety will primarily have to be guaranteed by adequate procedures, training, and other means. Work is ongoing to improve detection techniques, merely making greater advantage of new radar processing systems. On top of this, runway incursion alert functions will become necessary as a safety net. Research into conflict detection is one of the focus points of NLR for some time already. With improved ground surveillance becoming available, advanced runway incursion detection comes in sight. Runway incursion alert can be based on mode-of-flight tracking and as such take into account the observed status of aircraft and other moving vehicles.

In this paper, we will examine a runway conflict detection function for Amsterdam Airport Schiphol. The complex runway configuration makes the airport susceptible to runway incursion. Schiphol operates during peak hours in a multiple-runway configuration, so that often dependent runways are in simultaneous use. A good runway incursion alert function will make operations safer. The work in this paper is performed as an NLR internal research project, but consults with controllers from ATC The Netherlands have given valuable inputs to the work.

2 Background on conflict detection

Given the above mentioned aspects, it appears important that runway incursion monitoring is based on operational aspects of the runway concerned. Detecting whether two aircraft are using one runway simultaneously is one step. However, an inactive runway, an arrival runway, a departure runway, and a runway that is in mixed mode use, all have different rules to determine what is a conflict and what is not. Moreover, conflicts are determined based on their operational consequences and not so much on geometrical and predicted aircraft positions.

Apart from taking into account the observed aircraft positions, several other aspects should be used, such as the aircraft status (arrival, departure, ...), its mode (moving, standing, accelerating, ...), and its clearances. This aircraft information can be compared to that of other aircraft, and operational rules determine whether they are in conflict or not. For RIA, we used a Knowledge Based approach, enabling the possibility to specify conflict rules separate from the way they will be used in the reasoning algorithm. This gives a greater flexibility in the specification of the rules, better and easier validation and tuning, and a greater adaptability to local procedures.

The RIA Decision Support System

The knowledge base that is designed is a hybrid knowledge base, consisting of objects and rules. Objects specify the status of the runway. Based on the information from the surveillance function, objects such as *runway*, and *aircraft* are instantiated. When applicable, an *alert* object is created. The RIA system is implemented using NEXT (NLR Engineering X-pert system Toolkit), after which controllers validated a prototype implementation.

We make use of the available object oriented features for a declarative description of the knowledge. The runway status is the "kernel"-object, see figure 1. This object consists mainly of a number of flags that describe the current operation, such as landings/arrival, mixed/segregated mode, dependency on other runways, alert status, and finally, a configuration link with all aircraft that currently occupy the runway.

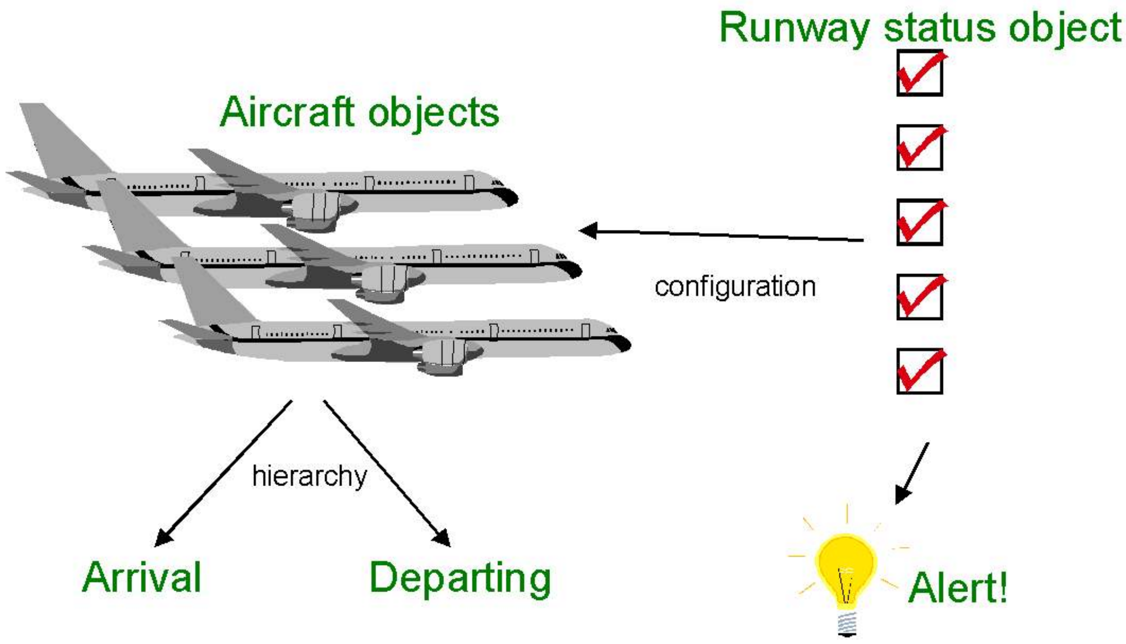

Fig. 1 RIA objects

The aircraft objects are specified generically. Only when we are talking about a *departure* or an *arrival*, objects are instantiated.

In a two-step approach, a geometric algorithm is used to determine whether two or more aircraft occupy the same runway movement area. Through the use of object oriented technology, only those aircraft, which are actually at the runway safety area are taken into account for conflict detection. The runway safety area includes aircraft that are in the final approach phase. When an aircraft is detected, an object is automatically instantiated by the system.

In the second step of conflict detection, a number of rules are specified to determine what is a conflict or not (so-called procedural knowledge). An inference engine is used which determines if a rule could possibly apply for an observed situation. Rules are specified as relations between the attributes of the objects. For example, the departing aircraft has attributes as "position", "heading", speed", etc. Additional information is obtained from surveillance information, such as accelleration, designed to account for the Mode-Of-Flight. This Mode-Of-Flight can be derived from advanced trackers (like Eurocontrol's ARTAS) to specify intentions of the aircraft. The information is of probabilistic nature: is an aircraft approaching the runway safety area decelerating before a stop bar or not? With this information, we can win seconds in the conflict detection process, which gives a lower false alarm rate and may make the difference between an incursion-alert and a collision.

3 Human Computer Interface

Information about moving vehicles is graphically depicted in real time on an airport map for advanced surveillance. RIA information is overlaid on this picture. To alert controllers, labels of conflicting moving vehicles are displayed in red. In addition, information about the conflicting objects is displayed in a pop-up window. Upon acknowledgement by the controller, the colour of the label can be returned to its default setting, while the information in the pop-up window remains available to the controller, see figure 2.

The HMI is based on earlier work on human interaction in the DEFAMM project (Ref. 4). In the figure below, a detail of the interface is shown, which shows an aircraft that has just landed at runway 27. Another one is lining up behind it for a take-off. This is allowed, so even though there are two aircraft at one runway, no conflict alert is given. However, as soon as the departing aircraft starts accelerating, an alert is given.

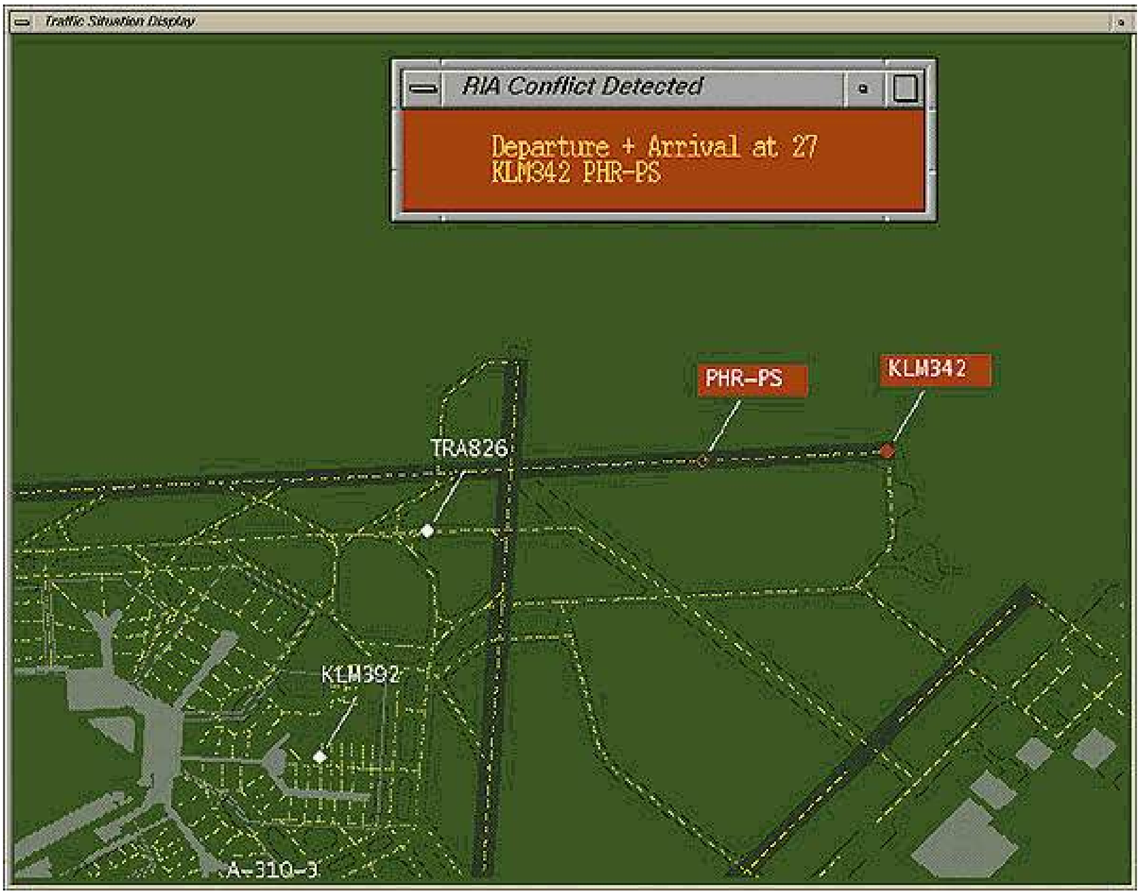

Fig. 2 HMI for detection of runway incursion

4 Conclusion

To show the feasibility of a knowledge based runway incursion system and an accompanying HMI, a prototype system has been designed. Specific situations that are incursion sensitive have been examined. With this approach, it is possible to distinguish several kinds of conflicts.

For the implementation, the NEXT expert system toolkit was used. With this, a quick prototype is easily constructed. The prototype is build to examine the usage of a runway incursion system and its HMI. Controllers have evaluated the demonstration system, mainly to check operational aspects of the system.

The prototype uses a Mode-Of-Flight based surveillance function and enhanced radar information. This information can be crucial to detect intentions of the aircraft and as such may detect runway incursions earlier and reduce the false alert rate. The prototype was build using NEXT, the NLR Engineering X-pert System Toolkit, which enables a hybrid knowledge representation. Objects specify the airport status and aircraft movements, while rules determine what situations cause conflicts. The use of expert system technology enables an incremental delivery of a tool.

An HMI has been designed, based on earlier experience. Controllers are alerted through a pop up window and labels of the aircraft concerned displayed in red. Controllers can acknowledge conflicts by clicking on the label so that these are displayed in their normal colour again. The pop up window remains active as long as the conflict is valid.

5 References

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