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Evaluating the Effects of a Bird Strike Advisory System

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Abstract

Bird strikes have operational impacts and cause economic loss to the aviation industry. In the worst case, the damages resulting from bird strikes lead to crashes. The highest risk for bird strikes lies in the area below 3000 ft and thus mainly in airport environments. Despite intense efforts from the airports in controlling the local bird populations, the number of bird strikes in these environments is still very high. Usually, Air Traffic Control is neither integrated into the process for reducing bird strikes nor do the controllers receive any specific information about the current bird traffic situation at the airport. For the project described in this paper, we assume a different situation: Air Traffic Control is provided with a tool supporting the controller with advisories to prevent bird strikes. The advisories are based on the current and predicted bird movements and the anticipated risk for air traffic. Potential advisories include rerouting or delaying of traffic. Especially when applying the latter, a reduced runway capacity could result. However, the effects of a bird strike advisory systems for Air Traffic Control have never been studied. The project in this paper therefore aims at investigating the consequences on an airport's safety and capacity when implementing such a system. For this purpose, fast-time simulations including varying conditions considering bird densities and air traffic volume will be performed. This paper describes the proposed research concept and the chosen simulation environment.

1 Introduction

Bird strikes cause negative operational impact, economic loss, damage and in the worst case hull loss of aircraft and loss of human life [1]. The risk for a collision between birds and aircraft is largest below 3000 ft [2]. Therefore, in civil aviation, aircraft are mostly endangered during departure and arrival which take place in the extended airport environment. For this reason, mitigation measures in civil aviation mainly focus on keeping birds off the airport grounds [2]. Despite these efforts taken at the airports, a large number of bird strikes still occur (cf. e.g. [3], [4], [5]). Hence, this study evaluates an additional approach for the reduction of bird strikes: Providing an airport's tower control with a bird strike advisory system which supports the controllers with specific advisories to prevent potential collisions between birds and aircraft. For this purpose, the system's underlying algorithm constantly calculates the risk for a bird strike based on current and predicted bird movements. Depending on the derived danger level, the controller could be advised to either reroute or delay the endangered aircraft.

Due to the nature of birds, their movements can only be predicted with a certain uncertainty [6]. Therefore, a system with very risk-averse settings might generate too many alerts and thus strongly influence the runway capacity. On the other hand, a system with less stringent settings and thus fewer influence on the runway capacity might miss a potential conflict. This study aims at investigating these effects on safety and capacity when choosing different settings for a bird strike advisory system. Based on the results as well as an evaluation on the technical and operational requirements for such a system, an algorithm for a prototype will be developed.

This paper is organized as follows: First the motivation for this study is elucidated. This is followed by the description of the intended concept for the operation of a bird strike advisory system to be tested within this study. Subsequently, the chosen approach is presented, conclusions are drawn and an outlook given.

2 Motivation

In civil aviation, the primary focus of wildlife hazard mitigation measures lies on the direct airport environment, as airports and their surroundings belong to the area with the highest risks for bird strikes [7]. The applied measures range from habitat management to exclusion, harassment, capture of and if necessary shooting birds [8]. There are three main reasons why these control efforts result in a limited effect: Firstly, birds grow accustomed to harassing methods, which limits their effectiveness over time. Secondly, unattractive grounds and fences around airports cannot entirely prevent birds from flying in the extended airport environment. Thirdly and most importantly, bird strikes are not just an airport problem, but actually a below 3,000 feet problem [2]. It is therefore not sufficient to repel birds within the airport perimeter. Instead, the horizon of bird strike hazard mitigation should be expanded beyond the airport fence [2]. This demand is supported by another study, which analysed trends in bird strikes below and above 500 ft between 1990 and 2009 [7]. The study concluded that while the number of damaging strikes below 500 ft has levelled out during the last observed years, there has been an increasing trend for damages resulting from strikes happening above 500 ft. As the main reason, the success of mitigation measures at airports since 2000 is named, whereas no actions have been taken outside the airport boundaries.

Furthermore, with three exceptions[1], neither ATC nor the pilots are involved in the wildlife hazard mitigation process within civil aviation – the responsibility for this task lies with the airport authority. As ATC and the pilots are in charge of controlling the flights, approaches to avoid bird strikes should therefore involve those stakeholders. [2].

In comparison to civil aviation, the bird strike risk outside the airport perimeter is considered in military aviation: For example, Europe and the United States of America (USA) both use large-scale radars - surveillance and/or weather radars – to track bird movements. The derived information serves as input for short-term flight planning [10], [11]. Taking into account the military approach as well as the technical possibilities for tracking of birds, a concept for further mitigating bird strike risk in civil aviation is proposed. It is described in the next chapter.

3 Concept

In the concept to be evaluated, ATC tower control is provided with a bird strike advisory system that determines the risk for bird strikes for arriving and departing aircraft. In the case of a predicted conflict between birds and aircraft, specific advisories for rerouting or delaying air traffic are presented to the controller. For this purpose, the system relies on sensors, for example avian radars or infrared sensors, that can detect and track birds. Based on the information obtained from the sensors, the system calculates the current situation of bird movements. Taking into account the current situation as well as further factors such as typical flight patterns, the development of the bird situation is predicted for the upcoming minutes. This prediction is compared to the planned aircraft movements and tested for potential conflicts. If a conflict is forecast, an appropriate advisory is generated (cf. Figure 1).

The sensors for detecting and tracking birds in the area of interest have to perform this task with a certain resolution in real-time and in all weather condition to ensure that all bird movements are identified. It should be ensured that the controllers only receive relevant alerts to limit potential negative effects on the operations and to assure the controller's trust in the system. By nature, bird-movements are only predictive up to a certain extent [6]. Hence, the uncertainty of the predicted tracks should be taken into account by the system's algorithm. Furthermore, the required prediction horizon, depending on the needed alert time and the distance of the expected collision point from the airfield should be

[1] To the authors knowledge, there are three airports where Air Traffic Control (ATC) is supported with specific information on bird movements in the critical areas: Durban (South Africa), Riga International Airport(Latvia) and Warsaw-Modlin Mazovia International Airport (Poland) [9]

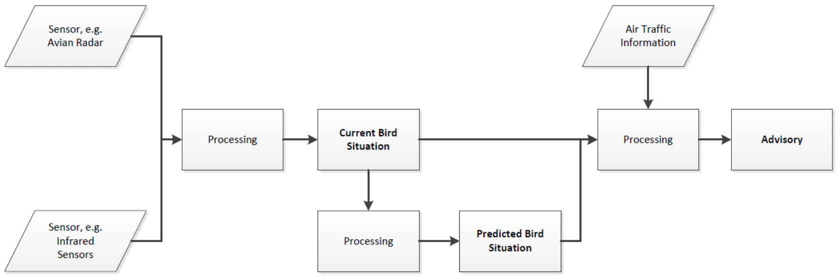

Figure 1: Set-up of a bird strike advisory system

considered. Additional factors such as size, number and speed of the conflicting birds could serve for a threat assessment. Outside the airport boundaries, it is suggested to take into account only groups of birds in order to minimize the number of false alerts – flocks do not change their tracks as frequently as individual birds and are thus easier to predict [10], [6].

Depending on the calculated threat and the flight phase of the aircraft which is predicted to collide with birds, the controllers should be provided with a predefined set of measures for conflict mitigation. The highest risk for consequential bird strikes occurs in the take-off phase [4]. Hence, the highest priority for alerts should lie on aircraft in this phase of flight. For a predicted conflict during take-off, it is proposed to stop air traffic until the birds crossed the runway. This is justified by the relatively small prediction time required to cover the take-off phase. For the subsequent climb phase up to 3000 ft, for which a larger prediction horizon is required, two options are suggested. If the aircraft, which is about to take off, is predicted to collide with a flock of birds, a delay is proposed. On the other hand, if the prediction is uncertain or the danger limited, pilots could also be advised to use a high vertical speed to pass the critical altitude before the birds reach the area around the aircraft's flight path. For landing aircraft, a greater prediction horizon is necessary than for aircraft taking off, because approach legs specified in the Aeronautical Information Publication (AIP) can take up to 25 nm below 3000 ft. Thus, an accurate prediction of bird movements for the entire arrival corridor seems rather unrealistic. For this reason, approaching aircraft should only be rerouted or sent into holdings when there is a high risk for a bird strike. In more uncertain situations, pilots could be provided with informations about the expected positions or altitude bands of the birds in focus.

According to [2], ATC is rather reluctant to the idea of working with bird information - for one, there are concerns that ATC is held liable for bird strikes that still occur despite applying an advisory system. On the other hand, a disproportionate increase in workload is apprehended. By providing the controllers with specific advisories how to react to a certain bird strike risk, the personal responsibility can be limited. Another solution could be that ATC provides the pilots with specific information while the decision about a potential collision mitigation measure lies with the pilots [12]. To avoid a potential significant increase in workload, it is vital to integrate this system in a feasible way into the current work environment. The two latter aspects lie beyond the research goal of this project.

4 Method

The primary focus of this study lies on the evaluation of the effects of a bird strike advisory system. It is expected that such a system leads to a reduction in the number of bird strikes and as such to an increase in safety. On the other hand, delaying of traffic could lead to a reduction of runway capacity. The relations between the settings of the bird strike advisory system and the named effects are anticipated to be deterministic.

To test the stated hypothesis, fast-time simulations of two different scenarios involving air and bird traffic will take place. In the first scenario, bird- and air-traffic run unimpeded and the number of strikes are counted. This scenario corresponds to a situation where no bird-strike advisory system is in service. In the second scenario, a bird-strike advisory system preventing all bird strikes and not causing any false alarms, is simulated. In a first step, this is achieved by delaying air traffic: Air traffic that would hit birds during take-off and climb will be delayed by the minimum time that is required to just miss the birds. Arriving traffic has to adjust its speed profile as far as possible in this flight phase or is sent into holding. By taking into account measures for both, departing and arriving traffic, the maximum operational impact of a bird strike advisory system can be determined.

The runway delay that results from these measures will be calculated. The obtained results of both scenarios will give an indication of the capabilities of a bird strike advisory system under ideal conditions - namely when all potential bird strikes are prevented by causing a minimal delay and thus a minimal impact on runway capacity.

The simulations will be performed by using the BlueSky Open Air Traffic Simulator. This simulation environment is described in the subsequent chapter. This is followed by the presentation of the input sources for bird movement information. Finally, the simulation variables and the framework for the simulations are introduced.

4.1 BlueSky Open Air Traffic Simulator

The BlueSky Open Air Traffic Simulator, a development by Delft University of Technology, supports real- and fast-time simulations to visualize and analyse air traffic flows as well as Air Traffic Management (ATM) concepts. It provides the user with a Graphical User Interface (GUI) which consists of an adaptable radar display as well as a console for user input (cf. Figure 2). The user can choose to run predefined traffic scenarios or create and modify traffic directly from this console. The simulator is based on open data exclusively and is programmed in the open source language Python. Because of its open character, the simulator

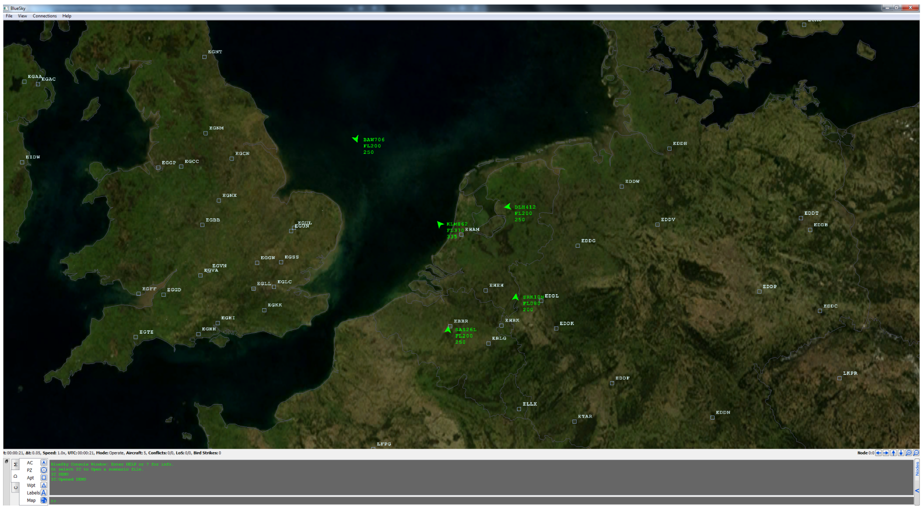

Figure 2: BlueSky GUI with sample air traffic

can be downloaded[2], used and modified by any party interested in performing research in the field of ATM. [13].

The BlueSky Open Air Traffic Simulator was chosen as a simulation environment for this study due to its open character and modifiability. By reason of the simulator's modular structure, a new module representing bird track information could easily be integrated to the existing structure. Furthermore, a module which uses this track information as well as flight information from the existing air traffic module was created in order to detect and record bird strikes. A third module which performs trajectory prediction to avoid collisions between aircraft and birds will follow.

4.2 Input Sources

To generate bird traffic within the simulation, two main sources are used: Avian radar and weather radar. Avian radars are designed to track individual birds as well as flocks of birds. Depending on the antenna type, small individuals can be detected one to two kilometres from the radar, flocks up to 20 kilometres. [14]. For this study, historic track data from the avian radar at Eindhoven Airport (NL) is used. This radar is a horizontal X-Band radar with a coverage of up to 2.5 kilometres for small and up to 5 kilometres for large birds. The obtained data contains time-stamped two-dimensional positions which can be transformed to flight trajectories. Altitude information is added based on a distribution specified in [15].

The input data of the avian radar is used for bird tracks within the airport perimeter. For tracks in the arrival and departure corridors, which lie beyond the range of the avian radar or are shadowed by obstacles, weather radar information is used. Here, data from the weather radar in De Bilt (NL) could be obtained.

[2]the latest version can be downloaded from `https://github.com/ProfHoekstra/bluesky`

This radar is a C-band Doppler weather radar, which measures the bird density from ground up to four km altitude whithin the range of five to 25 km distance [16] [17]. Considering that the distance between the radar and Eindhoven airport is approximately 75 kilometres, this seems not ideal. However, it can be assumed that the recorded bird migration over De Bilt is broad front migration, which is strongly comparable to the one over Eindhoven (Hans van Gasteren, Royal Netherlands Air Force, personal communication, 4/12/2016). The output of the weather radar data consists of bird densities per cubic kilometre in altitude bins of 200 metres between zero and four kilometres ([18]). Furthermore, information on flight direction and speed are provided, which offers the opportunity to randomly create bird tracks per altitude band above Eindhoven.

4.3 Simulation Framework

Bird movement information was obtained for the environment of Eindhoven airport. For this reason, air traffic will follow the arrival and departure routes published by Air Traffic Control The Netherlands ([19]) in the simulation. To generate air traffic, flight plans with different traffic intensities will be generated. By testing different traffic intensities, it can be evaluated from which runway saturation a bird strike advisory system causes significant delays.

Bird distribution and density varies over the course of the year [20]. To take this fact into account, one week per calendar month between October 2015 and September 2016 will be simulated. With this choice, the variations due to seasonal effects can be considered without excessively increasing the required simulation time. As the tracking qualities of radar decrease with increasing intensity of precipitation, weeks with as little precipitation as possible are chosen [14]. Possible measures to compensate for the drawbacks considering different flight patterns on rainy days are currently being discussed with operational experts.

5 Conclusions and Outlook

This study aims at evaluating the consequences on aviation safety and capacity when implementing a bird strike advisory system for ATC tower control. In this paper, the underlying concept as well as the study's setup are described: To evaluate the effects of a bird strike advisory system, fast-time simulations covering one year and considering different air traffic intensities will be performed. In a subsequent step, the applicability of such a system based on currently available technology will be tested. Therefore, requirements in terms of traceability and predictability of bird movements will be defined based on the results of this study. Furthermore, historic bird tracks will be analysed in order to find patterns for a predicting algorithm. From the controller perspective, requirements related to alert time, accepted number of missed targets and false alerts will serve as input for the system to be tested.

In the presented study, collision mitigation is achieved by delaying and rerouting air traffic. Future work could include simulations that consider varying measures to avoid the bird strikes. For example, adjusted altitude or speed profiles could be taken into account to minimize the number of delays.

A bird strike advisory system for ATC based on technology that identifies all relevant bird movements in the extended airport environment and an algorithm that accurately predicts bird movements could significantly improve aviation safety. The target of this study is to support the development and introduction of such a system with a proof of concept.

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