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Automatic identification of risky weather objects in line of flight (AIRWOLF)

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ABSTRACT

Adverse weather conditions are hazardous to flight and contribute to re-routes and delays. This has a negative impact on the National Airspace System (NAS) due to reduced capacity and increased cost. In today's air traffic control (ATC) system there is no automated weather information for air traffic management decision-support systems. There are also no automatic weather decision-support tools at the air traffic controller workstation. As a result, air traffic operators must integrate weather information and traffic information manually while making decisions. The vision in the Next Generation Air Transportation System (NextGen) includes new automation concepts with an integration of weather information and decision-making tools. Weather-sensitive traffic flow algorithms could automatically handle re-routes around weather affected areas; this would optimize the capacity during adverse conditions. In this paper, we outline a weather probe concept called automatic identification of risky weather objects in line of flight (AIRWOLF). The AIRWOLF operates in two steps: (a) derivation of polygons and weather objects from grid-based weather data and (b) subsequent identification of risky weather objects that conflict with an aircraft's line of flight. We discuss how the AIRWOLF concept could increase capacity and safety while reducing pilot and air traffic operator workload. This could translate to reduced weather-related delays and reduced operating costs in the future NAS.

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1. Introduction

Adverse weather conditions create safety hazards for pilots and constrain the flexibility of air traffic control operations (Collins, 1991). Thunderstorms are the most significant weather phenomena that contribute to aviation hazards and flight delays. Thunderstorms can generate multiple flight hazards such as lightning, heavy rain, hail, turbulence, icing, and wind shear. In-flight icing caused by low temperatures and water vapor (or droplets) is a major problem for aircraft that lack de-icing equipment. Obstructions to visibility (e.g., precipitation or fog) can reduce a pilot's ability to perceive the layout of runways, to perceive the surrounding terrain, and to perceive the position of other aircraft. Wind shear and microbursts are convective and non-convective phenomena that include gust fronts and wind shift lines. These phenomena affect approach and departure routings, especially pilot landing decisions on final approach. Unexpected and sudden changes in wind direction at airports can cause operational disruptions. Ahlstrom (2004) used a Cognitive Work Analysis (CWA) framework to assess the impact of these weather phenomena on light single engine, light twin, turbo prop, small turbo jet, and commercial jet aircraft. He found the highest impact rating for thunderstorms, microburst, and snow and ice, regardless of aircraft type. The CWA analysis also showed a clear trend where light single engine and light twin aircraft had the highest impact rating, followed by turbo prop, small turbo jet, and with commercial jet showing the least impact of all aircraft types. Taken

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together flight operations in adverse weather conditions affect all aircraft types and always imply some degree of risk (Wong et al., 2006).

Adverse weather conditions also contribute to the re-routes and flight delays that increase operating costs. In today's air traffic system, weather increases the workload for personnel who must plan new routes around weather affected areas (Ahlstrom and Friedman-Berg, 2006). Currently, there is no automated weather information for air traffic management decision-support systems. There are also no weather information feeds to decision-support tools at the air traffic controller workstation. As a result, air traffic operators must integrate weather information and traffic information manually while making decisions. This manual integration of weather and traffic information for decision-making is problematic. First, every decision maker has a different experience and mental model of air traffic operations and the effects of hazardous weather. Additionally, variations in human decision-making under periods of high mental workload and stress often yield inconsistent and rigid solutions in response to weather constraints (Harrington, 2009). Because of the problems with manual integration of weather information, one of the Next Generation Air Transportation System (NextGen) goals is to implement a weather and decision-support system that automatically translates weather information into air traffic impacts. This type of system would shift human judgment and decision-making from manual decision-making to active monitoring of automated systems. Granted, human expertise and decision-making will still play a role in the NextGen effort to reduce weather impacts, but the specifics of this role have yet to be determined.

The NextGen is a required transformation of the entire national air transportation system to meet future demands and to increase the efficiency of air transportation. Several new air traffic concepts and technologies are included in the NextGen omnibus plan (JPDO, 2008; ATCA, 2006). Some of the significant changes include a change from current ground-based technologies to more dynamic satellite-based technologies, a move from current voice-based communications to data-linked communications between air traffic controllers and flight crews, and network-enabled information-access for all NextGen operators. This includes plans to implement a network-enabled weather-support service that provides a common weather picture across the entire airspace system. The goal is to reduce the weather impact by providing a near-real time dissemination of weather information to all ground and air users. Weather information will also be used to evaluate the expected impact of weather hazards on individual 4D aircraft trajectories and to support tactical and strategic decisions.

A key component in the NextGen effort to reduce the impact of weather is trajectory-based impact evaluation. In trajectory-based impact evaluation, air traffic providers will use problem-resolution and decision-support tools with integrated weather information. Under this concept, future tools will identify aircraft trajectories that are affected by weather and provide a resolution that reduces flight-path disruption and thereby increases safety and the effective use of capacity. Consequently, re-routes around weather affected areas will no longer be a manual decision process but will be handled automatically by weather sensitive traffic flow algorithms. Similarly, the scheduling algorithms responsible for flights in and out of terminal airspace will also be weather sensitive, thereby optimizing the capacity during adverse conditions.

In this paper, we outline a generic weather probe called automatic identification of risky weather objects in line of flight (AIRWOLF). The degree of risk associated with a penetration of a weather hazard primarily depends on the aircraft size, equipment, and pilot experience. Some weather hazards are innocuous for larger and well-equipped aircraft piloted by experienced pilots but are extremely hazardous for smaller and unequipped aircraft with inexperienced pilots.

We discuss the concept and operation of our weather probe in four main sections. First, we describe the structure of grid-based weather data. Second, we present the process of deriving polygons and weather objects from our data. Third, we show the steps by which the AIRWOLF probe identifies conflicts between aircraft and weather objects in an aircraft's line of flight. Fourth, we suggest possible implementations and use of this weather probe for air traffic control operations. We conclude the paper with a discussion of our weather probe concept and the weather sensitive algorithms proposed in the NextGen vision.

2. Method

2.1. Weather data

For the AIRWOLF implementation, we used available weather data from the National Weather Service (http://www.nws.noaa.gov/). Specifically, we used grid-based weather data for precipitation, visibility, ceiling, and icing conditions (i.e., icing probability and icing severity). Except for the icing data (which updates on an hourly basis), these data sources update every 5 min. The weather data is defined in relation to a spatial grid with positional information (lat/long), vertical and horizontal grid size information (m), altitude information (ft), and cell index values that represent intensity. For example, precipitation data has grid cell values that represent intensity as measured in dBZ (e.g., values >50 dBZ indicates *extreme* precipitation in air traffic control). Icing data index values represent either the probability of icing (e.g., 55 = 55%) or the level of icing severity (e.g., 1 = light, 2 = moderate, or 3 = heavy).

2.2. Creating polygons (weather objects) from weather data

In the following section, we outline our algorithm that identifies weather areas in the grid-based data sets. To evaluate the AIRWOLF concept, we used weather data from an area large enough to cover a generic en route sector (i.e.,