

Keywords: human-computer interaction, data visualization, human factors in aviation, augmented reality, helicopters

Introduction

Many aircraft accidents each year are caused by encounters with unseen airflow hazards near the ground such as vortices, downdrafts, low level wind shear, or turbulence from surrounding vegetation or structures near the landing site. While such hazards frequently pose problems to fixed-wing airplanes, they are especially dangerous to helicopters, which often have to operate in confined spaces and under operationally stressful conditions (emergency search and rescue, military operations, shipboard operations).

The difficulty with airflow hazards is they are invisible, and thus the pilot may not be aware of being about to fly into "bad air." Pilots learn to rely on performance charts, operational envelopes, and their intuition, but nevertheless, lives are lost and millions of dollars in aircraft damage sustained each year due to vortex and downdraft encounters.

Proposal

Providing helicopter pilots with flight-deck visualization that a hazard exists may be of significant benefit. However, the form such a visualization might take, and whether it does indeed provide a benefit, has not yet been studied.

We propose to develop a set of airflow hazard visualizations, based on existing knowledge of airflow data visualization techniques and human factors in aviation, and perform a user flight simulation study with experienced military and civilian helicopter pilots. To present the visualizations to the pilots, we will modify the source code of a state of the art commercial rotorcraft flight simulator that has the capability of modeling both the helicopter flight characteristics as well as the ship air wake data. Data will be gathered both subjectively from the pilots' evaluations of the visualizations (including pilot ratings of takeoff/landing difficulty, etc.), and objectively from the pilots' performance during the takeoff/landing simulations.

At present our results will be based on archived data gathered from flight tests, wind tunnel tests, and computational fluid dynamics. However, technological advances in sensor technology, especially [Doppler lidar](#) and [PIV \(Particle Image Velocimetry\)](#), offer the potential for helicopter-based sensors which can gather such airflow data in real-time. Within a few years, it may be possible to gather and display real-time airflow hazard data to pilots in the form of visual cues presented on a head-up display.

Prior Work

Most related research falls into one of two categories:

- unsteady airflow visualization designed to be viewed on the ground to help scientists and engineers understand the nature of the turbulent flow, or
- visual aids for the pilot in the cockpit consisting either of "synthetic vision" which focuses on making terrain features visible to the pilot during instrument conditions, or artificial navigational aids.

Although airflow hazards are known to be a major problem, turbulent airflow is very difficult to model or predict. There have been some attempts to visualize wind shear and recently a cockpit display system for visualizing wake vortices of other aircraft [Flight-Deck Display of Neighboring Aircraft Wake Vortices, Holforty, PhD thesis, Stanford June 2003] based on new aerodynamic predictions. We believe that work in this area is about to increase significantly, as within a few years, airflow sensors using lidar will be light enough and accurate enough to be placed on helicopters, enabling a cockpit display of airflow hazards.

Research Questions

There are many interesting and important questions to resolve here. The issue of somehow making transparent air more visible has been considered for quite a while in the aviation industry. But some of the obvious ideas (coloring some of the particles of air such as in a cloud of smoke) have been impractical to implement due to the inherent complexity of air particle motion.

Typical techniques for airflow visualization used in computational fluid dynamics and other situations take a significant amount of computer time to generate, and are visually rich and complex. They are very useful in helping aeronautical engineers understand unsteady flow, but could be distracting to a pilot making split second decisions.

There are also many human factors issues to consider, because it is important not to increase pilot workload nor cause a dangerous distraction. For example, movement in the pilot's peripheral vision can be very distracting, perhaps dangerously so if it takes the pilot's attention away from the target landing site at a critical moment. However, a hazard reporting system must call some attention to itself in order that the pilot not overlook a present danger. Further, since the pilot may be navigating based on limited visual references, it is important that any airflow hazard visualization not obscure critical outside visual references.

Further questions include:

- How do we present the visualization to the pilot?
- How do we determine what constitutes a hazard?
- Is our visualization dependent only upon external data, or should we factor in the gross weight, center of gravity, and engine power of the helicopter?
- What type of display is best?
- Are visual cues effective? Distracting? Is some distraction necessary?
- Should we consider aural cues as well?
- Does the visualization improve performance, degrade it, or have no effect?
- How does one present the three-dimensional nature of the airflow hazards in a natural way?
- Should there be different visuals for different types of hazards (e.g. vortices vs. wind shear) or should we keep it simple?
- How do we avoid presenting too much information and overloading the pilot?
- Conversely, how do we prevent oversimplification and the loss of key information?

So this project involves merging knowledge from many different disciplines, including aerodynamics, aviation, computer science, data visualization, 3D graphics, psychology and human factors.

Summary

We intend to develop several different types of flight-deck visualizations of airflow hazards during helicopter takeoff and landing operations, and evaluate their effectiveness with usability studies. There is a clear need for greater knowledge of these invisible hazards in order to reduce the rate of aircraft incidents and accidents. We will produce code for a helicopter simulator and perform tests with military and civilian helicopter test pilots and flight test engineers to develop and refine the airflow visualization technique that will provide the most help to the pilots during critical shipboard operations. Although we will study helicopter operations, we believe that the results will be applicable to other aircraft categories as well.

Our hope is that this work will lead to the production of an airflow hazard detection system for pilots that will save lives.