

Collision Avoidance Interface for Safe Piloting of Unmanned Vehicles using a Mobile Device

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ABSTRACT

Autonomous robots and vehicles can perform tasks that are unsafe or undesirable for humans to do themselves, such as investigate safety in nuclear reactors or assess structural damage to a building or bridge after an earthquake. In addition, improvements in autonomous modes of such vehicles are making it easier for minimally-trained individuals to operate the vehicles. As the autonomous capabilities advance, the user's role shifts from a direct teleoperator to a supervisory control role. Since the human operator is often better suited to make decisions in uncertain situations, it is important for the human operator to have awareness of the environment in which the vehicle is operating in order to prevent collisions and damage to the vehicle as well as the structures and people in the vicinity. In this paper, we present the Collision and Obstacle Detection and Alerting (CODA) display, a novel interface to enable safe piloting of a Micro Aerial Vehicle with a mobile device in real-world settings.

Author Keywords

Mobile; touchscreen; helicopters; UAV

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation: User Interfaces - Graphical user interfaces

General Terms

Design; Human Factors

INTRODUCTION

Recent advances in Unmanned Aerial Vehicles (UAV) and smaller Micro Aerial Vehicles (MAVs) have resulted in field use for a variety of military and civilian applications. Although the term MAV originally referred to a vehicle less than six inches in diameter, it can now refer to a broader range of small UAV systems. For these smaller, portable unmanned vehicle systems, the user interface technology has shifted toward small, portable handheld devices. By allowing the user to obtain immediate and current information about his or her surroundings, the systems are ideal for local observation and surveillance tasks, whether on the battlefield, in a disaster area, or for scientific observation.

While there is an increased interest in MAV systems recently, their widespread use will be limited unless a few key hurdles are overcome. As MAV usage moves away from highly



Figure 1. CODA display integrated in MAV-VUE interface, for use in navigating in an outdoor environment.

trained individuals in the military to everyday users in the real world, the user interface needs to have minimal training requirements. In addition, for these systems to successfully operate in crowded urban areas, unknown battlefield environments, or constrained indoor spaces, they must have the ability to cope with uncertainty and unexpected obstacles, especially since most of these operations occur beyond the operator's line of sight. Thus, user interfaces that support collision avoidance are essential for effective operation.

The challenge is integrating this additional information about potential obstacles into the user's display without affecting the usability of the interface or increasing the operator's mental workload, or increasing the required training. For most systems, the small form factor and portability of a mobile display provides a key advantage, but limits the display size and screen real estate. By presenting this information to operators in an intuitive, embedded way that does not increase mental workload, the system could improve the effectiveness of operators and lead to further adoption of UAVs and MAVs in a wider range of applications.

In this paper, we extend previous work on MAV user interfaces by presenting techniques for supporting obstacle awareness and collision avoidance using visual and haptic mechanisms on a mobile device. We introduce the collision and obstacle detection and avoidance (CODA) system [1] which incorporates these techniques in a working MAV controller. With this work, we take steps towards making MAVs usable enough to operate safely, effectively, and consistently, and facilitate wider adoption of MAV technology.

CODA USER INTERFACE

From observations during prior work and factors pertaining to the expected operating environment, the following requirements for the collision notification system emerged:

- The display must warn the user of potential collisions in the vicinity, both within and outside the field of view.
- The display must show information about location and distance of potential obstacles.
- The display must integrate effectively into an existing display on a mobile device described below.

Existing mobile interface - MAV-VUE

The CODA interface extends the Micro Aerial Vehicle Visualization of Unexplored Environments (MAV-VUE) interface, an iPhone-based application that could be used by a minimally-trained operator to accomplish local surveillance tasks. For a full description, the reader should refer to [2]. MAV-VUE's *nudge control* mode allows for fine-tuned position inputs once the vehicle reaches an area of interest. This allows an operator to explore a unknown area out of his or her line-of-sight, relying on visual feedback from the device. The user gives flight controls through natural gesture inputs. To enable the controls, the user presses the 'dead-man switch', which is a type of fail-safe that requires constant active input to remain active and prevents unintentional control commands from affecting the system. While holding this switch, translational movement commands are given by tilting the device in the desired direction of motion, with the degree of tilt corresponding to the magnitude of the input. Rotational commands require a one-fingered swiping motion around the circle in the center of the display. Altitude commands involve a pinching motion, where the magnitude of the resulting command is proportional to the size of the pinching input. In all three cases, the interface provides visual feedback in that the desired inputs have been received.

CODA design

The CODA interface consists of a combined visual and haptic alerting system to increase the operator's awareness of potential hazards in the environment. The three alerting levels, shown in Figure 2, simplify the information presented to the operator. The visual indicators dual-code each level using size and opacity, and a vibration accompanies the highest alert level for added saliency.

Two main factors contributed to the design: the anticipated environment and the capabilities of the hardware platform. The display must work in a variety of lighting and environmental conditions. A mobile device, or "smartphone" serves as the hardware platform for controlling the MAV due to its portability, functionality, and commercial availability. The screen is 2-inches by 3-inches, so screen real estate is limited. The system has audio capabilities, and can play a number of built-in alert tones along with an unlimited number of sound files, but is volume-limited. The only haptic alerting mechanism consists of vibration feedback.

CODA Visual Display

For the design, it was assumed that the system would be equipped with one or more distance sensors that could provide information about objects in a two-dimensional plane. Some distance sensors, like a laser rangefinder, can return many distance measurements every second, which may cause

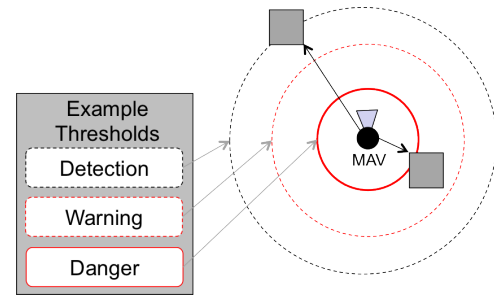


Figure 2. Alerting structure with three thresholds, corresponding to distance from the vehicle.

information overload if displayed to the user directly. To simplify the information presented to the operator, the alert system had three stages (Figure 2). Three distance-based thresholds are defined such that the alert increases in distinct steps, rather than gradually. Each indicator consists of a triangle and two arcs (Figure 1). The triangle precisely indicates the obstacle location, and the arcs increase in size and salience as the distance to the obstacle decreases, without obscuring the main control interface. Due to the limited screen size, the indicators were overlaid on the camera image instead of positioned elsewhere, as that would require shrinking the camera display. The visual alert indicators were placed on the top of the navigation circle, rather than at the edge of the screen, which allowed them to be more central to the field of view.

CODA Haptic Feedback

Based on pilot tests, haptic vibration feedback was incorporated to increase the salience of the collision alert. The haptic alert is triggered when the user enters the highest alert threshold and occurs simultaneously with the appearance of the largest visual display indicator. The alert consists of a single vibration which occurs for a duration of approximately 1.5 seconds.

CONCLUSION AND FUTURE WORK

We presented the CODA interface, which provides useful information about obstacles in the environment and warnings of potential collisions, without substantially increasing the required training or mental workload. We have begun to deploy the system outside in a simple course with obstacles as a technical demonstration that the platform functions as intended and can be further expanded to study collision and obstacle avoidance interfaces for MAVs. We then will be running additional studies both outdoors and in simulated indoor environments to test the user interface.

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