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Using Likelihood Alert Technology in Cockpit Displays of Traffic Information to Support Free Flight

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The future of air traffic control imposes two major challenges. On the one hand, the increase in air traffic flow will dramatically augment the already existing high levels of workload for air traffic controllers. As a result, this increase in traffic density may jeopardize flight safety. On the other hand, standard aircraft separation tactics commanded by air traffic controllers are neither optimally efficient nor cost effective. Consequently, this makes it difficult for airlines to maintain an economic advantage. A potential solution to these problems is the introduction of free flight. The main goal of free flight is to reduce the level of workload of air traffic controllers and increase the efficiency and cost-effectiveness of aircraft separation by allowing pilots to make their own deviation decisions. However, the safe and efficient implementation of free flight will require state of the art cockpit displays of traffic information (CDTI) as well as advanced decision support tools (DSTs), which will need to be coupled with effective alerting algorithms. The purpose of this paper is to suggest the implementation of likelihood alert technology in CDTI, which may lead pilots to make more accurate decisions by allowing them to distinguish which conflicts are more likely to occur.

The future of air traffic control inherently imposes two major challenges. On the one hand, the increase in air traffic flow will dramatically increase the already existing high levels of workload for air traffic controllers. As a result, this increase in traffic density may jeopardize flight safety (FAA, 2005). On the other hand, standard aircraft separation tactics commanded by air traffic controllers are neither optimally efficient nor cost effective. Consequently, this makes it difficult for airlines to maintain an economic advantage(Kreifeldt, 1980). The Radiotechnical Commission for Aeronautics (RTCA) proposed the concept of *free flight* to overcome these challenges.

Free Flight

In current terms, any effort that removes restrictions to flight is a move toward free flight (Planzer & Jenny, 1995). The future vision of free flight is not to undermine the role of air traffic controllers (Wickens, 1998). Instead, the goal is to provide pilots with more flexibility to make flight path adjustments to maximize efficiency without compromising the safety of air travel (Planzer & Jenny, 1995). The move toward free flight needs to be a gradual progress supported by a vast volume of literature and research.

Free flight adds some responsibility to pilots of safe separation from surrounding aircrafts to their already existing roles of controlling the aircraft, navigating, and communicating with air traffic controllers (Johnson, Canton, & Battiste, 2005). Furthermore, commercial aviation does not take place in a simple see and avoid environment as in general aviation. Therefore, pilots will need Cockpit Displays of Traffic Information (CDTI) to effectively perform their tasks (Johnson et al., 2005).

CDTI

In 1995, the RTCA stressed the need for CDTI to support free flight. Technological advances in graphical display integration, global positioning systems, and datalink communication have made possible the development and implementation of CDTI (Kreifeldt, 1980). The goal of CDTI is to allow pilots to make strategic maneuvers as opposed to tactical maneuvers, increasing situation awareness and efficiency, without increasing workload or compromising safety. Research suggests that pilots have a general high acceptance of CDTI, and that such technology can aid pilots make better decisions while in free flight (Thomas, Wickens, & Rantanen, 2003). However, before implementing CDTI in commercial aviation, it is necessary to examine the type of information that pilots will need to effectively conduct operations while in free flight (Hart & Loomis, 1980).

The core benefit of CDTI will depend on the DSTs implemented to aid pilots while in free flight. Effective alerting algorithms will be an essential component of CDTI to support free flight, especially because perfect detection and prediction of surrounding aircraft is almost impossible due to a variety of uncertainties, including, winds, track and speed deviations, weather, and pilots' intensions.

Alerting Algorithms

Automated alerting devices, particularly those used in air traffic collision avoidance, have a tendency to be imperfect, generating a high volume of false alarms (Thomas et al., 2003; Xu, Wickens, & Rantanen, 2005).). The main reason for this imperfection is that designers prefer to err on the side of safety by issuing alerts even when the slightest possibility of a conflict exists. This tendency, combined with the low base rate of potential conflicts, leads to a low ratio of true alerts over total alerts (Thomas et al., 2003). Given the nature of the strategic goal of CDTI, this tendency will be accentuated, leading to a higher volume of false alarms.

Although CDTI need to alert pilots with sufficient time for them to make strategic maneuvers, thereby increasing efficiency, using the time to loss of separation (TLOS) as the primary alerting algorithm without taking into account the probability of conflicts may lead to a cry-wolf effect (Breznitz, 1983). The cry-wolf effect is a loss of trust in the alert system that may lead pilots to disuse the decision support tools implemented in the CDTI. Therefore, using TLOS as the primary alerting logic may lose its primary purpose, which is to allow pilots to respond well in advance and avoid potential conflict in the most efficient manner.

A great deal of emphasis has been placed on developing the alerting algorithms used in CDTI. However, there is a lack of research on the impact of such algorithms on human performance. In a human-machine system, where the human component has ultimate responsibility for safety and efficiency, the key factors are related to how humans will interact with the technology (Cashion, Mackintosh, McGann, & Lozito, 1997). False alarms can have detrimental effects on human operators, particularly if they expect automated systems to operate near perfect levels.

A potential solution to this problem is to present pilots with different types of alarms based on the likelihood of a potential loss of separation. Prior research suggests that likelihood alarm systems improve decision-making (Bustamante, 2005), decrease workload (Fallon, Bustamante, & Bliss, 2005), increase trust (Fallon, Bustamante, Ely, & Bliss, 2005), and enhance situation awareness (Fallon, Bustamante, & Bliss, 2005). Implementing a likelihood alert algorithm in CDTI may lead pilots to make more accurate decisions by allowing them to distinguish which conflicts are more likely to occur. Nevertheless, it is important to note that the effectiveness of implementing likelihood alert technology in CDTI will depend on quality of the detection algorithm.

Detection Algorithm

Yang and Kuchar (1997) developed a detecting algorithm incorporates aircraft current state information, and utilizes future predictors, such as heading, speed, climb or descend trajectory, and intent information obtained from GPS and datalink communication. The detection algorithm follows a probabilistic model, which is estimated by conducting 500 Monte Carlo simulations per second. Each simulation introduces uncertainties in the estimation of the ownship and surrounding aircrafts' current speed, altitude, and heading parameters. Furthermore, the simulation also introduces uncertainties in the ownship and surrounding aircrafts' projected future trajectories. Based on these predictions, the algorithm counts the number of times a projected trajectory enters the ownship's protected zone, defined as a 10 nm in diameter and 2000 ft in altitude solid around the ownship. The algorithm then estimates the likelihood of a conflict by diving the number of times a potential intruder enters the ownship's protected zone by the number of iterations (i.e., 500).

Using likelihood alert technology, CDTI could present alerts to pilots in a graded fashion. There could be a series of levels of alerts, depending on the severity of the problem. Alert levels depend on the likelihood of each conflict and the time to loss of separation (TLOS). Canton, Refai, Johnson, and Battiste (2005) suggested that because uncertainty is inversely related to TLOS, this made it possible to integrate both sources of information into a single type of alerting algorithm. However, although uncertainty in the estimation accuracy of the likelihood of a conflict may be inversely related to TLOS, the actual probability of a conflict may be independent of TOLS. Therefore, the integration of these two sources of information may not be as simple as Canton et al. (2005) suggested.

The purpose of this paper is to suggest the use of likelihood as the primary alerting algorithm, and use TLOS to differentiate conflicts that have the same likelihood of occurring. Depending on the likelihood of a conflict, surrounding aircrafts could be differentiated using a color scheme following urgency mapping principles (e.g., red should be indicative of a more urgent conflict than yellow). This color-coding scheme could be used to present the likelihood dimension in discrete levels to avoid information overload.

Furthermore, if two or more surrounding aircrafts have the same likelihood of colliding with the ownship, TLOS could be mapped using the flashing frequency of each aircraft. Research suggests that the most effective way of presenting urgent information is through flashing signals (Kroemer, Kroemer, & Kroemer-Elbert, 2001). The idea is that surrounding aircraft with shorter TOLS are presented with a higher flashing rate to indicate to pilots that they need to address that particular conflict before they address other, less time-critical conflicts.

Research Needs

Before implementing likelihood alert technology in CDTI to effectively support free flight, researchers need to address some human factors areas of concern. First, it is important to examine the number of likelihood levels that are required for pilots to effectively make deviation decisions without increasing their workload. Another issue that researchers need to investigate is the use of color to map the likelihood dimension. Perhaps other methods of representing the likelihood dimension could be more feasible, such as the use of different symbols. Last, another area of concern is the flashing rate used to represent the TLOS dimension. Researchers need to examine whether this dimension needs a continuous mapping function to accurately represent the TLOS, or whether it could be categorized into discrete levels as the likelihood dimension.

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