DESIGN OF A PILOT-CENTERED VISUAL DECISION-SUPPORT SYSTEM FOR AIRBORNE COLLISION AVOIDANCE

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Abstract

In this work we present a pilot-centered visual decision support system for flight critical collision avoidance using “dynamic 4D trajectory management”. The system utilizes an underlying automation support system, which is connected to the onboard avionics, and the NextGen/SESAR enhanced flight deck technologies enabling new Communication, Navigation and Surveillance (CNS) and System Wide Information Management (SWIM) services. The overall automation support system which embeds “dynamic 4D trajectory management” is envisioned to a) provide the pilots with alternative trajectories as tunnels-in-the-sky through avionics displays on the console and head-up/augmented reality displays in real-time, b) provide the flight crew with quantified and visual understanding of collision risks in terms of time, directions, and countermeasures, and c) provide autonomous conflict resolution as an autopilot mode. Thus, ensuring highly responsive and adaptive airborne collision avoidance in face of ever challenging scenarios that involve blunders, weather/terrain/obstacle/new conflict hazards. The designed visual decision support system does not increase workload of the pilot and dilutes “tunneling effect” in interaction while increasing situational awareness. These algorithms and tools developed are currently being integrated on an Automation Support System for implementation on a Boeing 737-NG FNPT II Flight Simulator with synthetic vision and augmented reality.

Introduction

The Single European Sky ATM Research (SESAR) and the US NextGen programs envision that the ever increasing demand of air transportation will require new methods for ensuring safe and efficient airborne flight planning. Revolutionary concepts such a Free Flight means the basic air traffic controller tasks associated with short term conflict resolution between aircrafts can potentially reach an intractable level under dense airspace operations. One natural solution to this problem is to take some of the work off the controller by delegating separation responsibility to appropriately equipped flight decks. On such flight decks, real-time conflict detection and resolution technology should be provided as to aid the pilot with immediate to short-term flight planning in dense and rapidly changing airspace environment.

Over the last 50 years, systems and instruments on flight decks have been changed or modified to support the pilot in performing flight tasks. Systems for modern flight deck design are getting more automated and new design philosophies are emerging with crew alerting and messaging systems to support the flight crew in monitoring dynamical changes in the environment. These design philosophies and technological improvements provide for improved safety and reduced workload. The second-generation glass cockpit started during the late 1980s, these new-generation cockpits were the introduction of primary flight displays, navigation displays, multifunction displays and systems displays (Figure 1) which were designed to maximize situational awareness for the flight crew [1]. The newly designed flight decks have provided more integrated information enabling greater safety, efficiency and reduced cost.

Tomorrow's cockpits will also have to address new sky policies and functionalities driven by SESAR and NextGen projects (as seen in Figure 2). With the ever growing airspace capacities of the Flight plan 2020 and the 2050 vision, SESAR Program Master Plan [2] and the reshaping of the airspace [3] (with user preferred routing, non-segregated flight, new separation modes), and to further minimize the current shortcomings of the TCAS, the airborne collision avoidance needs to be supplemented with automation support systems that:
- Enhances the pilot situational awareness by not only utilizing the new SESAR/NextGen CNS and SWIM infrastructure but also using (and blending with) the on-board avionics that provide weather, ground/terrain and obstacle information,
- Provides alternative de-confliction routes in the event of performance and potential hazard limitations,
- Provides dynamic trajectory re-planning in the event of new conflicts and potential blunders,
- Enhances system robustness by modeling and taking into account uncertainty associated with data source errors/ failures and pilots’ intentions, and utilizes uncertainty and time propagation in dynamic trajectory planning,
- Provides the pilot with quantified and visual understanding of collision risks in terms of time and directions and countermeasures.

New functions like 4D trajectory, airport navigation systems or synthetic vision are expected to meet future mission management requirements. Due to the limited size of cockpit displays, the integration of these new applications on current displays will saturate the crew with information. The ongoing ODICIS project [4] provides a single large, curved, seamless, avionic display with tactile interfaces. With the touchscreen-based display concept, ODICIS plans to create a self-configurable display space and touchscreen surface enabling information to be presented for all types of aircraft and flight operations. Synthetic Vision and Augmented Reality Displays are emerging as enabling technologies within the future flight deck. Specifically, these systems are all aimed to provide the flight crew with significantly improved and increased awareness. Integration of these technologies to the cockpit is envisioned to provide a potentially unlimited field-of-

Figure 1. The new B 737-NG Simulator replica is being built at ITU for Flight Deck ATC Research – Courtesy of Flight Deck Solutions
regard awareness for terrain, obstacles, traffic, and airspace for the flight crew. As such, NASA recently conducted a preliminary evaluation of a viable technology (seen in Figure 3) to support the Enhanced Vision Operation (EVO) concept for approach and landing operations [5].

In this work we present a pilot-centered visual decision support system with synthetic vision and augmented reality concept for flight critical collision avoidance using “dynamic 4D trajectory management”. This trajectory management based on a hybrid and stochastic airspace model not only representing uncertainties associated with sensed and received airspace traffic and intent information, but also representing limitations associated with weather, terrain/obstacle and new conflict hazards. The system utilizes an underlying automation support system, which is connected to the on-board avionics, and the NextGen/SESAR enhanced flight deck situational awareness. This enhanced awareness is coming from new Communication Navigation Surveillance (CNS) services, trajectory based operations and System Wide Information Management (SWIM) implementations. The overall automation support system which embeds “dynamic 4D trajectory management” is envisioned to a) provide the pilots...
with alternative trajectories as tunnels-in-the-sky through head-up/augmented reality displays (Figure 3) and synthetic vision displays on the console (Figure 4) in real time, b) provide the flight crew with quantified and visual understanding of collision risks in terms of time, directions, and countermeasures, and c) provide autonomous conflict resolution as an autopilot mode. Thus, ensuring highly responsive and adaptive airborne collision avoidance in face of ever challenging scenarios that involve blunders, weather/terrain/obstacle/new conflict hazards. These algorithms and tools developed are currently being integrated on an Automation Support System for implementation on a Boeing 737 NG FNPT II Flight Simulator (seen in Figure 1) with synthetic vision (seen in Figure 5) and reality augmentation. Functional diagram of this test system including SESAR/NextGen functionalities for en-route operations is illustrated in Figure 2. Following section describes the conflict resolution decision support systems, our underlying algorithms and the associated visual decision support system and the display concepts.

Visual Flight Deck Decision Support for Conflict Resolution

Airborne Conflict Resolution Support in Current Technologies

Currently operational Airborne Collision Avoidance Systems (ACAS) and their implementations such as TCAS are based on infrastructure and operations of the ATM realm of the 20th Century. Specifically, in the mid-1990s Traffic Alert and Collision Avoidance System (TCAS) [6, 7] was introduced to prevent mid-air collisions [8] between aircraft. TCAS I, which is intended primarily for general aviation aircraft, provides traffic advisories (TA) to pilots. In TCAS II, in addition to TA, resolution advisories (RA) are introduced to instruct pilots on how to resolve conflict situations. In 2008, EUROCAE and RTCA have jointly revised operational standards of TCAS II, which is known as TCAS II version 7.1, to solve some safety issues [9] that caused mid-air collisions.

With SESAR and its technology developments [2], ACAS implementations can now rely on new Communication Navigation and Surveillance (CNS) services, trajectory based operations and System Wide Information Management (SWIM) capabilities

a) to improve on the short-comings of the existing collision avoidance systems and b) to meet the growing demanding needs of collision avoidance in the face of increasing flight and aircraft capacities.
[3]. For example, RTCA and Eurocontrol is further considering additional space based surveillance system integrations for supporting aircraft separation, including Automatic Dependent Surveillance Broadcast (ADS-B) [10, 11]. This will provide TCAS with new capabilities such as lateral and speed based avoidance, improved surveillance and tracking systems. In addition, NextGen is currently investigating more delegation of traffic separation responsibility to the pilot [12, 13]. In the system, pilots are assisted in predicting and resolving loss of separation by cockpit automation, known generally as Airborne Separation Assistance Systems (ASAS) [14, 15]. Early ASAS experiments showed promising results of assisted separation operations [16, 17].

**Conflict Resolution Support with Information Fusion for the future**

“Real World” factors such as uncertainty in sensing, information, intent and rationality, asynchronous data and information flow with delays, equipment malfunctions, lack of centralized decision-making in short to immediate term collision avoidance, make responsive and adaptive airborne collision avoidance challenging. The problem is further complicated by the fact that the process is governed by humans and real aircraft dynamics (and thus with limitations of an aircraft and a human). In addition weather, terrain/ground and obstacle hazards, and new conflicts appearing in dynamically evolving scenarios lead to a potentially unbounded Airborne Collision Avoidance (ACA) problem complexity. To design a conflict detection and resolution system, these factors should be considered in addition to increasing capacity demand and air congestion. Our dynamic modeling approach of the airspace hinges on hybrid systems methodology, which provides the framework for not only continuous dynamics but also discrete dynamics and logical jumps (and decisions). With the inclusion of stochastic processes and distributions, we model sensors, devices, information, intent, decisions and aircraft each with uncertainties and discrete/logical element under a coherent systems model. With regards to the representing aircraft dynamics, Mode Based Maneuver Automaton [18] is used. This finite state automaton can not only represent the full dynamics and the limitations of the aircraft, but also describe almost any maneuver with maneuver mode sequences. In addition, other aircraft’s intent is modeled through a stochastic risk-based decision model, which inherently captures all potential blunders and even irrational behavior.
The conflict detection methodology is based on the idea of spatial search phenomena for potential conflicts including aircraft-to-aircraft conflicts and collisions with the obstacles such as severe weather patterns, terrain, and no-fly zones. This search method relies on creation of probabilistic flight trajectory (4DT) envelopes for the aircraft in local airspace for every predefined time window. These envelopes also include uncertainty factors existing in weather patterns and the flight models. The flight models naturally embed the stochastic nature in which the rationality and irrationality of the flight crews within the common airspace is presented with probabilistic action patterns. This probabilistic flight envelope including uncertainties is seen as probabilistic distribution in Figure 6. The main idea behind the Modal Maneuver Based PRM (Probabilistic Road Mapping) Planning [18] is to divide an arbitrary flight maneuver into smaller maneuver segments (called maneuver modes – such as Level Flight Mode, Climb/Descent Mode, Lateral Loop Mode, Longitudinal Mode, Transition Mode and Roll Mode) and associate them with maneuver parameters (called modal inputs). The multi-modal maneuver search relies on a hybrid automaton (illustrated in Figure 7), which chooses maneuvers from a finite maneuver set and then chooses their parameters from a continuous dynamically feasible region. This selection is made randomly in order to cover the whole flight envelope. The trajectory distribution map, which is the set of the generated maneuvers in a probabilistic distribution, represents all potential positions of the aircrafts in the future (shown in Figure 6). If the generated 4D trajectory distribution maps conflict with ownship’s flight intent (blue track in Figure 6) at high likelihood rates,
this will serves as the alert for potential collision in a predefined unit time (or less).

4D conflict resolution methodology [18] hinges on solving relaxed forms of the detected collision avoidance problem and then gradually refining the problem using the flight tracks of approximate solutions. This approach is implemented into two layers. In the first layer, Trajectory Planning Layer, the algorithm rapidly explores the airspace with an enhanced Rapidly Exploring Random Tree (RRT*) [20], which includes asymptotic optimality property. This layer builds an approximate conflict-free route (yellow path in Figure 8) will guide further steps of the algorithm. In the second layer, obstacle/collision free paths are connected with dynamic B-Spline curves. The approximation is further verified for collision and dynamic feasibility by computing the first and second derivatives of the spline in which correspond to the instantaneous velocity and acceleration. If the generated curve is not feasible, probabilistic repairing can be achieved by randomized waypoint (control point) placement on the B-spline curves iteratively and then the unit flight time is expanded to limit the acceleration within a controllable regime [18]. Since B-Spline curves have a local support property, these repairing processes can be made on local path segments of interest without affecting the whole shape of the generated path. After obtaining the flight path (green path in Figure 9) with velocity history from the trajectory planning layer, segment identification readily decomposes the flight path into a sequence of maneuver modes and its parameters. Mode-Based Maneuver Automaton [17, 18] implements this decomposition while ensuring transition rules for dynamic feasibility. This decomposition is used to define the proposed solution with basic maneuver identifications (such as climb, descent, lateral loop etc.) enabling generating standardized aural alerts (like TCAS) to give additional support to visual alerts. The generated conflict-free trajectory is also translated to visualization as a tunnel-in-the-sky (seen in Figure 10) to provide the pilot visual understanding of the generated solution. Functional architecture of the whole CDR algorithm is illustrated in Figure 11. The authors refer the readers to references [18, 19] for technical details of the algorithm. The following section describes the concept of the visual flight deck demonstration to aid

Figure 9. Probabilistic dynamically feasible b-spline search for potential conflict resolution

the pilot for performing proposed conflict resolution maneuvers.

Visual Pilot Decision Support and Situational Awareness

Situation awareness (SA) refers to the operator’s understanding of the relevant environment state and the operator’s ability to anticipate future changes and developments in that environment [21]. Specifically, there are three levels of situational awareness constructed by humans. These levels are perception, comprehension and projection [22]. Progression of these layers, the level of Automation and the extend of SA does not indeed exhibit a simple 1-1 relation. For example, inappropriate levels of the automation can impact SA with results such as automation complacency, automation mistrust, increased workload, and automation transparency [23]. For

Figure 10. Tunnel-in-the-sky visualization layer with obstacles (no fly zone alert, weather patterns) and terrain proximity warning
example, high levels of automation can indeed create cases in which the pilot no longer actively processes information to maintain an awareness of the system state. In other words, pilot falls out-of-the-loop due to over-trust in the system. Such fall-outs effectively diminish the pilot’s ability to recover from automation failure [24]. When the pilot perceives the automation to be unreliable and gives excessive attention to monitor the automation, SA can also be diminished with high workload and result in a phenomenon called attention tunneling [25]. In attention tunneling, all attention is drawn only to the primary task at hand. SA is also reduced while interacting with a decision support system which requires extensive evaluation of alternatives and choices [26]. The additional workload associated with extensive evaluation and selection naturally reduces the resources available for maintaining SA. A system is “transparent” when the underlying information behind the automation can be accessible [27]. In a fully transparent system a pilot may be led to attend to “too much and too low level” system information, resulting in high workload and diminished SA [28].

By considering these factors, an expectation from a good decision support system is that it should provide transparency at a manageable workload level. In general, any form of automation support that unintentionally hides information seems to be in conflict with the responsibilities of the pilot (even if it might result in low workload and good performance). A cooperative process, in which the automation enables the pilot to be in-the-loop, is considered to be the optimal outcome of the design [29]. The conflict resolution experiments conducted in [23] support this proposition. For example, in the SA test scenarios it is observed that the response times of the operators to immediate questions about past, present, and future events were faster if the operator is in interactive and manual conditions. This is in comparison to response times when the operator is in fully automated condition (complacency). Relatively better SA in the interactive and manual conditions implies that conflict resolution systems
may profit from keeping the pilot actively engaged in the task. However, evaluating conflict-free flight plans with their alternatives, in both space and time, within various constraints, is a complex task especially in immediately emerging traffic situations (short term and mid term). The crew cannot be expected to perform such a complex task without some form of automated observation-evaluation-strategy generation support. Therefore, the pilot is located in-the-loop, but at a higher strategic level where he or she is constantly aided with “safe” flight plans and alternatives.

In our concept, this interaction with the aid/decision support system occurs in real-time while “flying”. This is in direct comparison to executing pre-negotiated and pre-planned trajectories. Specifically, the pilot can in real-time ignore a generated solution, and can either choose to skip current trajectory advisory (with page-down like haptic devices on yoke, or touch-screen gestures) for checking alternative solutions, or modify the solution by ignoring to follow the trajectory (augmented tunnel-in-the-sky). Once the flight plan is modified through actual implementation, the support system re-plans trajectory solution on-the-fly according to the current states. Following the proposed and visually demonstrated solution implies acceptance of the proposed solution and the pilot can also choose to send proposed trajectory to the autopilot for autonomous execution (through FMS link). Any deflection response (e.g. pulling stick) during the autonomous execution switches the system to self-execution state supported with advisories.

The proposed decision-support approach also addresses another issue in the human machine interfaces. In the persistent interfaces, the pilot gives her full attention to the interaction to keep track of the labels and pages visited in the process of discovering the correct action sequence [31]. This tunneling effect results in degraded flight deck efficiency and reduced safety margins. In the analysis of the American Airlines Flight 965 accident at Cali, Columbia, it is reported that the flight crew spent an inordinate amount of precious time heads-down

Figure 12. Virtual Tunnel-in-the-sky layer and real flight screen augmentation
trying to manipulate the FMS to perform an infrequent task, which is not well supported by the interface, and this inefficient interaction contributed to the occurrence of the accident with several other circumstances [32]. In our approach, this tunneling effect and persistent interaction has been diluted with lack of additional “channels to interact with”.

For flight deck displays, there are currently a number of systems that provide different types of data such as Traffic Collision Avoidance System (TCAS), Enhanced Ground Proximity Warning System (EGPWS), Aircraft Communications Addressing and Reporting System (ACARS), and Weather Radar and Enhanced Vision System (EVS). As of today, these systems are not fully integrated / fused into a composite air, proximity and intent picture. This results in an increase in pilot workload and a less than optimum SA for potential hazards. These multiple systems carry only a primitive hierarchical integration and force the aircrew to sort through each system while simultaneously interfacing with ground controllers [31]. Therefore fused information display may indeed be the ideal solution to this problem, however with information fusion there are not only problems with tractable data quality and integrity, but also problems with cluttered screens with excessive amount of information types. For example, in the experiments [33] conducted by NASA Advanced Control Displays Unit, pilots provided a number of ideas for clutter mitigation. One thing that is explicitly reported is that during short-term collision avoidance operations, the non-conflicting aircraft or the aircraft away from a specified distance from the ownship should be removed from the display. This naturally suggests that allowing the pilot to choose and progress in time horizons is more in-line with strategic decision-making process.

In order to mitigate clutter in our conceptual design, the flight deck is equipped with two different displays. The first display is a Primary Augmented Flight Screen (PAFS), which provides flight information augmented with short-term hazard and collision information including visual terrain, no-fly-zone (e.g. military operation zone, disaster response zone etc.) and weather pattern alerts. Figure 5 and 10 show the designed transparent virtual layer which includes the no fly zone alert (red), terrain model (white-transparent) and tunnel-in-the-sky guidance (green). This layer is augmented with real flight screen through head-up-display or flight goggles.

Helmet-mounted displays (HMDs or HUD) or head-worn displays (HWD – goggles) can create spatially integrated and large field-of-view augmentation. Although these display technologies are not new technologies, especially within the context of military operations, component miniaturization and maturation are progressing to the point where they can be considered in commercial and business aircraft operations [5]. Transparent screens are another candidate technology for augmented reality integration to the flight deck. However, because of the collimation problem, it is not possible to directly use such devices without further improvements. The collimation refers to the concept of making the image appear to be coming from a distance much further than the display surface. In [34], collimation levels of the transparent screen as an ATC environment interface are compared with respect to response times of the operators. The experiments conducted proposed that operators using simulated collimation in transparent projection

Figure 13. 2D decision support page of the Touch-screen enabled synthetic vision

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screens showed a significantly slower response when performing a visual search task, compared to performing such tasks on non-collimated display. On the other hand, it should be noted that transparent screens do not require additional head-tracking system while flight goggles need this technology for both pilots and copilots.

In our test system, to test the basic idea, we created aligned layers (i.e. virtual reality layer and flight simulator screen layer) by aligning two different projectors. The colored virtual reality display, which is a transparent-background browser application, is coded by using Python. The visual drawings (canvases) are generated by using WebGL library. Figure 12 shows virtual augmentation of flight simulator screen with the tunnel-in-the-sky visualization.

It is important to note that the designed Primary Augmented Flight Screen (PAFS) is a transparent head-up technology and that PAFS only contains colored warnings for potential short-term hazards with fixed field-of-regard. To further increase the effectiveness and range of PAFS, a second touch-screen enabled console screen (i.e. a head-down Synthetic Vision Display) is designed. This second display provides the same information of PAFS, however with opaque drawings (contour terrain, weather volumes, no-fly-zones and aircraft) as seen in Figure 4 (in 3D page) and Figure 13 (in 2D page). In comparison to the Primary Augmented Flight Screen (PAFS), the Synthetic Vision Display (SVD) can provide unlimited field-of-regard image. This is because of the fact that there are no physical properties or limitations associated with changing the viewpoint orientation, direction, or field-of-view (FOV) within the computer-generated image. In the opaque screen the pilot can also choose to see potential mid-term and long-term air conflicts by sweeping a distance slider. Out of sight aircrafts are shown as arrow marks coming from the edges of the screen. Pinching the screen also adjusts this distance. Another page in the display provides the same information set, however this time from the top view (Figure 13). In that particular page, trajectory tunnels morph into lines and other drawings naturally turn into 2D demonstrations. Real-time evaluated potential points of conflict between the aircrafts are marked and pilot is supported with potential time of conflict information (Figure 13).

The response times of the input devices which allow the decisions and the tasks to be directed to the flight system are also critical. In the experiments conducted in [30], four technologies; rotary controller, trackball, track pad and touch screen are compared with regards to the required times as to input tasks. The outcome of the experiments supports the use of the touch screen for the control of menu-based tasks in the flight deck. However, in these experiments, physical location of the input device/display in relation to the pilot and the effects of vibration are not considered. Especially in a naturally vibrating flight environment, touch screen input devices may bring additional workload to the pilots. Therefore in our tests, in addition to touch screen-enabled displays, we plan to integrate different types of input devices to better understand the response characteristics during safety critical operations.

**Functional Flight Deck Integration**

These algorithms and tools developed are currently being integrated on an Automation Support System for implementation on a Boeing 737 NG FNPT II Flight Simulator with synthetic vision and augmented reality. The augmented situational awareness is represented through console avionics displays (Synthetic Vision Display) and head-up displays (Primary Augmented Flight Screen) in real-time. The HUD/AR implementations to be tested include a) standard pilot-centered HUD, b) enhanced pilot-centered augmented reality goggles c) flight-deck centered Augmented Reality Screen Overlay Projection. Augmented decision aiding implementations will include new touch screen and haptic input devices/switches for moving through HUD and Augmented Reality Display pages and switching/choosing between alternative trajectories represented as tunnels-in-the-sky illustrations. These enhanced functions and the associated in-cockpit avionics within Flight Deck Simulator are illustrated in functional diagram, which is given in Figure 2.

In the functional diagram, the Traffic and Weather Generator is used as a scenario generator. Flight Simulator Software visualizes these generated scenarios. The Traffic and Weather Generator (T&WG) replays both artificially generated scenarios including air congestion and severe weather conditions, or collected live WX and ADS-B data (ITU CAL currently operates a ADS-B radar and
Eurocontrol EGNOS DCN at Istanbul Ataturk Airport) transmitted from planes operating in Eastern European Airspace. The T&WG feeds the SWIM cloud in real-time, and any external Air Traffic Monitoring System or simulator can be connected to the flight-deck network by establishing connection to the SWIM. The Flight Deck Information Management (FDIM) system is a local in-cockpit data management system, which gathers all information (such as traffic, capacity, weather, terrain etc.) via communication avionics emulators; parses and broadcasts them to their clients. For detected potential conflicts (including mid-air and ground), the Air Conflict Detection and Resolution (CDR) system generates dynamic conflict resolution to provide the pilots support with its alternatives and these 4D trajectories and corresponding obstacles are visualized through head-up-display (HUD), with Augmented Reality (AR) and Synthetic Vision display. The associated flight-deck pilot interface and the underlying algorithmic generators are illustrated at Figure 14.

Through the flight-deck pilot interface, the pilot can switch between alternative dynamically generated solutions via touch-screen, switches and haptic devices. In order to extend situational awareness of the pilot over entire flight operation, the Synthetic Vision display also offers additional pages including long-term, mid-term and short-term threat screens as explained.

Conclusion

In this paper we have presented our conceptual design of the pilot-centered visual decision support system for flight critical collision avoidance using “dynamic 4D trajectory management”. New technologies coming through NextGen/and SESAR (such as CNS, SWIM, ADS-B etc.) programs, not only enables enhanced situational awareness in the flight deck, but also allows the possibility to take some of the work off the controller by delegating separation responsibility to appropriately equipped flight decks. Towards this goal, we have developed an automation support system which embeds “dynamic 4D trajectory management”. The system is envisioned to a) provide the pilots with alternative trajectories as tunnels-in-the-sky through avionics displays on the console and head-up/augmented reality displays in real-time, b) provide the flight crew with quantified and visual understanding of collision risks in terms of time, directions, and countermeasures, and c) provide autonomous conflict resolution as an autopilot mode. In our conceptual design, the flight deck is equipped with two different displays which fuses all flight critical information including weather, terrain and traffic. As a primary display, a head-up Primary Augmented Flight Screen (PAFS) is designed. The display provides a transparent head-up transparent visual augmentation of short-term hazard alerts (such as terrain, no-fly-zone and weather pattern alerts) and visual conflict resolution advisory (tunnel-in-the-sky demonstration to guide the pilot to solve potential conflicts). As a secondary display, a touch-screen enabled head-down Synthetic Vision Display (SVD) is provided. The display provides the same information as supplied by PAFS, however this time with opaque drawings where the pilot can also choose to see potential mid-term and long-term air conflicts by sweeping a distance slider in 2D and 3D pages. The designed visual decision support system enhances situational awareness and does not increase workload of the pilot with “tunneling effect”. Different projection technologies associated with PAFS are going to be tested for visual decision aiding quality.

References


Acknowledgements

This project is supported in part by TUBITAK 111M167 Project Grant.

31st Digital Avionics Systems Conference
October 14-18, 2011