Automated Collision Avoidance Systems

Control theory to date has achieved tremendous success in the analysis and synthesis of automatic guidance systems in aerospace. Aircraft and spacecraft autopilots are elegant schemes that employ a hierarchical structure. For example, pilots can fly today’s commercial jets by programming into their onboard flight management system a set of waypoints describing the desired flight path over time. These waypoints are automatically translated into a sequence of guidance commands for the aircraft, and these in turn into the actuator commands for the aircraft throttle and control surfaces. In recent years, this success of guiding single aircraft has been extended to the relative control of two or more vehicles in the design of airborne collision avoidance systems and tactical separation assurance tools in air traffic control (ATC). Although many of these systems have been developed as prototypes within the research community, several have been tested and are now operational in NASA’s Center TRACON Automation System (CTAS).

Collision avoidance and separation assurance tools can be classified into three groups according to the time horizons over which they operate. The Traffic Alert and Collision Avoidance System (TCAS) operates over a time horizon of less than a minute and is called an immediate collision avoidance scheme. New automated methods for both ground-based and airborne collision avoidance, known as midterm collision avoidance schemes, are being designed for a time horizon of a few minutes. Tactical air traffic control schemes provide separation to aircraft and generally operate over a longer time horizon of about 30 minutes. These are denoted as separation assurance schemes. Separation assurance is an air traffic control responsibility for aircraft to maintain a separation of 5 nautical miles (lateral) and 1000 feet (vertical).

In the TCAS protocol, when an intruder aircraft is declared to be a “Threat” to the “TCAS” aircraft, the Resolution Advisory (direction and rate) is designed, based on range and altitude tracks, to give the most separation at the closest point of approach (CPA).

Today, TCAS is installed on all commercial aircraft with at least 30 passenger seats operating in the U.S. It receives and displays bearing and relative altitude information about all other aircraft within a 40-mile radius and provides alerts and its Resolution Advisory with respect to the aircraft that poses the greatest potential threat.

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Methods for analyzing the safety of collision avoidance systems have also been developed. One such method uses reachable set technology to determine the unsafe configurations of one aircraft with respect to another. As an aircraft approaches the boundary of the unsafe region, corrective action must be applied. This control action is computed automatically as part of the reachable set calculation. The figure on the left shows two aircraft arriving at Oakland airport. At the position labeled 6, both aircraft are inside the reachable set, indicating an unsafe configuration (loss of separation in 3 minutes). In the actual scenario, the controller performed an altitude change to resolve the conflict.