Thesis/Dissertation Data

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Abstract :

In the last decade, the commercial values of Unmanned Aerial Vehicles (UAV), defined as devices that are capable of sustainable flights in the atmosphere that do not require to have a human (pilot) on-board, become widely recognized. As UAVs are becoming cheaper and more user-friendly, many companies are motivated to incorporate them in their everyday business. All of commercial prospective applications for UAVs, however, can only be achieved once the vehicles are fully integrated into the airspace system. Therefore, the problem of safe UAV integration into the airspace is the selected topic for this research, especially in the development of Conflict Detection and Resolution (CD&R) systems.

The main goal of this research is to define and evaluate systems for detecting and resolving possible mid-air conflicts of UAVs, specifically to support safe beyond visual line-of-sight operations in an integrated airspace. This goal is achieved by addressing four research questions are formulated as follows: (1) What structure can be defined to manage the CD&R system for UAVs operating in an integrated airspace? (2) How can the diverse UAV CD&R approaches be classified into a comprehensive taxonomy that is compatible with the current airspace? (3) How can the safety parameters of the integrated airspace, under influence of a heterogeneous CD&R approaches, can be determined? (4) How can an autonomous CD&R system for UAVs be defined to handle potential conflicts, seeing the vehicle as part of the integrated traffic in the airspace?

To address the first question, this research proposes a taxonomy of CD&R approaches for UAV operating in an integrated airspace. From the generic approaches in the taxonomy, a multi-layered architecture is developed in this research, managing CD&R procedures in the airspace that are compatible with the manned flights, while also embracing those that are unique to UAVs'. Six CD&R approaches from the taxonomy are further selected as the safety layers, which included the layer of (1) Procedural, (2) Manual, (3) Cooperative, (4) Non-cooperative (5) Escape, and (6) Emergency approaches.

Answering the second research question, the previously proposed taxonomy is attributed to available CD&R methods in the literature, in order to determine their fitness and whether they are complementary or interchangeable from one to another. Using the taxonomy, the position of each approaches in the overall safety management scheme, such as by using a multi-layered architecture, can be defined. The taxonomy potentially can aid both developers and authorities in deciding an adequate CD&R approach(es) to ensure safety of an upcoming BVLOS flight in an integrated airspace.

The third question is addressed by setting up a series of Monte Carlo simulation to derive two safety parameters, i.e. the frequencies of near mid-air collisions (NMAC), and of mid-air collisions (MAC). The use of the Monte Carlo simulations is meant to overcome the limitation of available analytical methods in literature, by incorporating the effect of distributed CD&R system, as well as the heterogeneous condition setup for the airspace. Due to its significantly time-consuming process to obtain any meaningful results, this research simulated in high-density setups, of which results are scaled down latter on, to more realistic densities of an airspace.

The fourth question is addressed in this research by introducing two novel CD&R algorithms which are adequate to fill in specific layers in the CD&R architecture explained before. The first algorithm is the Selective Velocity Obstacle (SVO) method, an extension of the Velocity Obstacle method (VO-method) with additional criteria for implicit coordination. The second algorithm is the Three-dimensional Velocity Obstacle (3DVO) method that represent the VO-method in three-dimensional space, obtaining a much wider range of resolution possibilities.

Compared to back in mid 2011 when this research was initiated, commercial use of UAVs are increasingly getting exposed to the general public. Regulations are being updated to define UAVs' airworthiness. Operator awareness of the regulations is also increasing, and at the same time, drone advocacy groups are assembled to push regulatory policies. These indicates that UAV integration into the airspace is inevitable, and that CD&R systems to support safety in such airspace is urgently needed. Therefore, at one point perhaps it is best for the authorities to simply start to accommodate the flight in the airspace, allowing both UAVs and their CD&R system to mature based on experience they can gain in a real situation. As it has been shown in the history of manned-flight deregulation, this can create a competitive environment that pushes both manufacturer and operator to continuously strive for safety improvements in an integrated airspace system.