Chapter 46
Information Technology for the Coordinated Control of Unmanned Aerial Vehicle Teams Based on the Scenario-Case Approach

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EXECUTIVE SUMMARY

The authors present a dynamic scenario-case approach to coordinated control of heterogeneous ensembles of unmanned aerial vehicles, which use coordination patterns of activity in similar situations described as spatial configurations affected by observed events. The method of obtaining deviations for approximate spatial configurations, which allows obtaining elements of the safe vehicle's trajectories. The method of qualitative safety assessment is presented. It uses a soft level topology to obtaining blurred boundaries of dynamic safety domains using fuzzy soft level sets and allows finding suitable compensations of vehicles' activity scenarios that can both keep the spatial configuration and satisfy all safety restrictions. The authors demonstrate that the proposed approach significantly reduces the computational complexity of problem solving and provides the acceptable performance.

BACKGROUND

Modern complex technical systems are becoming increasingly sophisticated, with a mixture of unmanned vehicles (UV) being used to solve various tasks that are dangerous to human life. In recent years UVs

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are widely used in various fields. The modern UVs are not remotely controlled by a human operator or a computer program, but they are autonomous and therefore are equipped with sophisticated sensors, actuators, and on-board computer programs for intelligent control. Thus, autonomous vehicles must be able to make their own decisions in a highly dynamic, partially observable, and unpredictable environment. Significant advances in modern technologies ensure availability of various UVs of different sizes, equipment, and purposes working together in various environments as a team (Waslander, 2013).

One of the applications that motivates the use of multiple unmanned vehicles is forest fire fighting (Yuan, Zhang & Liu, 2015), where unmanned aerial vehicles (UAV) should provide surveillance and situation monitoring (Merino, Martínez de Dios & Ollero, 2015), and a variety of unmanned ground vehicles (UGV) such as bulldozers, excavators, fire hydrants, cisterns, trucks, etc., can be used as a team to combat forest fires. Obviously, each vehicle has different role and functions, but it executes a certain scenario jointly and simultaneously with the other UVs to achieve a mission objective (Sherstjuk, Zharikova & Sokol, 2018). Due to differences in vehicles features, destinations, their roles in a team, and various environments, such team is called heterogeneous ensemble of UVs. The ensembles may include objects moving in different environments. It is essential that such ensembles are very difficult to coordinate and control remotely . The most important role in such teams is played by UAVs. Due to lower cost of UAVs, it is possible now to build very large teams, which can perform search-and-rescue, first response, defense tasks etc (Sharifi, Mirzaei, Zhang & Gordon, 2015). Teams of vehicles are useful for complex, long-term, multi-task, multi-stage operations, and usually based on the swarming or flocking behavior (as birds or insects) (Toner & Yuhai, 1998).

However, in many cases the team of universal UAVs used as swarm is excessively expensive solution. This is particularly essential for forest fire-fighting and military applications where the cost of universal UAVs can be quite significant. The joint use of specialized UAVs of different classes aimed at solving very specific problems in complex missions, could be more appropriate solution. A team of vehicles can be organized in much more complicated way than a swarm; it may include a certain order and assign specific roles for vehicles in this order. At the same time, vehicles should select autonomously a relevant scenario of activity in dynamic environments within their role.

In general, the heterogeneous ensemble of UAV is a uniform ordered set of vehicles with different roles and functions, which jointly and simultaneously execute their scenarios of activity within a specified mission to achieve the objective. At the same time, the more complicated the ensemble structure and functions are , the more difficult the coordination of UAVs is. In the following, we will consider the complex structure of the UAVs' team as ensemble. One of the most important tasks of the ensemble's activity is a joint motion of its vehicles (Chen, Zhang, Xin & Fang, 2016). As a rule, the joint motion is limited by the space, by the given positional and functional restrictions, by the taken normative rules, and by the reaction of an environment, which gives rise to the different dynamic, navigation and situational disturbances into different points of space (Sherstjuk, Zharikova, Sokol & Tarasenko, 2017). Nevertheless, the most important limitation of the joint motion is a guaranteed safety of vehicles, so the problem of its maintenance is very essential. A growth of vehicles number and their size, a significant increase in their speed and density of movement within the confined space have lead to increase in the number of incidents and accidents, which in turn raises an important problem of ensuring a safe motion control. Beside that, the difference in the laws and features of UV motion in different environments leads to another significant impact. For example, UAV cannot stop on the fly as well as change its motion direction abruptly, while the most of UGVs can. Unfortunately, the problem of coordinated real time motion control for heterogeneous vehicles' ensembles still remains open, and has a great interest for research.

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