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MODELS AND METHODS OF DISTRIBUTED HIERARCHICAL CONTROL IMPLEMENTATION FOR AUTONOMOUS DRONE SWARM ON THE BATTLEFIELD

Abstract. *Control of a drone swarm as a unity requires decentralization and hierarchy. Decentralizing control of drone swarm is necessary to free the human-operator from having to constantly control the behavior of the drones within the swarm. Hierarchical control of a drone swarm is necessary so that human-operator can adjust the activity of the swarm as a unity. The following separate roles have been identified for the implementation of decentralized hierarchical control of swarm activity: the activity of a separate drone, the activity of a drone-coordinator, and the activity of human-operator. The control hierarchy consists of a human-operator who controls the change in the behavior of the drone-coordinator. The drone-coordinator controls the changes in the programmed behavior of individual drones. This approach is an analog of the management of human-workers who perform assigned work, that opens up several possibilities. First, it is possible to use formal models of performance people's behavior in social teams. Second, formal models can be used for decision-making and optimization for controlling a drone-coordinator in a swarm. Thirdly, computer modeling can be applied to the behavior of a drone swarm, which will allow choosing the optimal behavior of the swarm for different conditions of its activity.*

Keywords: drone swarm, autonomous, battlefield, control, distribute, hierarchy, modeling.

Introduction.

Today, the world has accumulated a lot of experience in using drones in various situations. However, this experience is usually limited to either the control of the drone/drones by a human operator, or the use of drones in automatic mode. This next stage is the transition to social systems that will consist of people and drones. At the same time, they will perform a joint task. However, the formation of such systems requires new approaches, especially to the organization of management of joint activities. One of the main challenges is that it is necessary to develop new approaches to modeling the distribution of control for drone swarms. First, many individual elements of drone behavior must be performed individually. Secondly, drones must perform a large array of behaviors together, as part of a single swarm. Thirdly, it is important to manage the communication between humans and drones for such a social system aimed at the joint achievement of goals.

Concept.

There are two main approaches to modeling drone swarm behavior. In detail see [1].

The first approach is based on the fact that existing drones need to be combined into a single structure. Today each drone, as a rule, are either controlled by a person or has uniquely programmed behavior (and therefore highly specialized). As a result, the behavior of a drone swarm, in the final case, will be defined as the control of one or several drones by a person. The other drones in the swarm mimic (in one sense or another) the behavior of the human-controlled drones. As a result, the majority of the swarm should consist of drones that are arranged in the same way, and that have practically unambiguous behavior. All this significantly reduces the stability of the swarm's adaptation to the changing environment.

The second approach is based on the fact that drones should form a certain "social system". Here, each of the drones can show a kind of "personality", that is, show unique behavior and have unique capabilities. In such a "social swarm of drones," there can be a "leader" (ringleader, superintendent, coordinator, etc.), who directs the behavior of the entire swarm. But even when fulfilling a joint goal, individual drones in a swarm show a certain level of individual behavior and carry out their adaptation to the changing environment. At the same time, the stability and adaptive properties of the swarm will be sufficiently high. The predictability of the behavior of an individual drone in a flock under these conditions sharply decreases.

Below will be considered one of the possible options for implementing the second approach. At the same time, the swarm will have a drone-coordinator (thus the swarm will have a hierarchical structure). Its task is to manage the methods and technologies of achieving a given goal, set before the swarm as a single entity. The behavior of an individual drone will have individual features that will distinguish one drone from another. This makes it possible to also create drone swarms, which differ from each other in methods, technologies, and tools for the manifestation of their activity. Such a swarm can perform tasks in autonomous (offline) mode. The human-operator will influence only the drone-coordinator, and during the operation only in exceptional cases.

Note. This organization of control of swarm behavior corresponds to the management of human teams. They consist of workers who perform simple work. As a rule, a human worker is taught to perform a certain set of simple actions for a long enough time. It is the simple and “programmed” actions of people today that are increasingly becoming automated. But each team has a person who performs the functions of managing workers and works. This person is focused on management functions, that is, his activity is to make decisions and adjust, and change the program of activities for individual people. This person coordinates the activities/behavior of the workers in such a way that the goal of the joint activity is achieved as a result. Examples include an officer/sergeant in the military or a lower-level manager in an industry or enterprise. This is distributed and hierarchically organized management.

The article will consider the behavior of the swarm directly during the operation. Getting the swarm to the location of the operation is a fairly obvious task (however, some aspects of this will be discussed below).

Algorithm for modeling the behavior of a drone swarm.

The algorithm for choosing the optimal behavior of a drone swarm can be specified in the following stages.

1. The geographical relief of the place of operation is specified and a set of targets for the manifestation of drone activity is determined.

2. The method of forming a drone swarm is specified. It is formed from drones that are capable of performing a given activity for a given set of targets (which have the necessary set of tools for this).

3. The path (trajectory) is set for 1) the formation of the swarm (because not all the necessary drones can be in one place) and 2) the swarm movement to the operation area. During the swarm movement to the operation area, the requirements for the ‘trajectory tubes” for each of the drones can be weakened (for example, practically straight lines).

4. A set of operation execution scenarios is specified. It takes into account geographical features and the specificity of the behavior of targets and possible obstacles. The possibility of damage and loss of a certain number of drones is also taken into account.

5. According to the set of scenarios, corresponding sets of “trajectory tubes” are formed for each of the drones at each stage of the scenario execution.

6. According to points 3-6, a coding system is formed for possible variants of the behavior of each of the drones.

7. Taking into account 3-6, a set of operation execution scenarios is structured. Including, a tree of possible solutions is formed (in the sweep of the operation in time) for changing the scenarios, using fragments of different scenarios.

8. Considering 3-6, codes are created for the formed set of scenarios and a tree of possible decisions (behavior) for the drone-coordinator, which will make decisions regarding the control of the behavior of each of the drones in the swarm.

9. A set of possible behavior of the targets and a set of obstacles is specified, taking into account their geographical reference and deployment in time.

10. Computer simulation of the operation is carried out. The parameters by which the results are optimized are as follows (the list is not exhaustive):

1) swarm drift trajectories and speeds;

2) characteristics of “trajectory tubes” for each of the drones (including different probabilities for stochastic manifestations);

3) characteristics of targets and obstacles;

4) mission performance characteristics (for example, number of successful drone activity results, drone damage, number of lost drones, changes in target characteristics as a result of swarm activity, etc.).

11. The optimal option (variant) is selected and the drones in the swarm and the drone-coordinator are programmed.

12. A series of natural (field) experiments is carried out.

13. Client massively multiplayer online games in real-time (for example, World of Tanks, massively multiplayer online role-playing games, massively multiplayer online first-person shooters, etc.) can be used as field (natural) experiments too.

14. Taking into account the results of field experiments, points 1-13 may be repeated. In such computer simulations (especially with the participation of real people-players), a database is created regarding possible choices of geographic references and target reactions, operational obstacles, etc.).

15. The database of the results of computer simulations (supplemented by the description of real field experiments) can be used to optimize both the behavior of individual drones during the operation (as well as to form requests for their modernization) and to train for drone-coordinator. Tournaments can also be used as drone-coordinator training, where one/several drone-coordinator is pitted against another drone-coordinator (one or several). This allows us to determine the best programs for a set of drone-coordinator.

A detailed description of the algorithms for the computer simulation of the behavior of the drone swarm during the operation will be determined by the purpose of the operation.

Conclusion.

Effective control of a drone swarm must be decentralized and hierarchical. At the same time, communication between the swarm and the human-operator should be reduced to the necessary minimum. As a result, part of the decision-making should be transferred directly to the swarm. In other words, tasking decision-making for the swarm should be decentralized between the human and the drone(s). Control of the swarm under these conditions must be carried out by a special drone (drone-coordinator). It must make decisions in typical situations and control other drones in the swarm. The drone-coordinator will communicate with the human-operator only in cases that go beyond the typical. Thus, control in the swarm will be carried out according to the hierarchical principle too.

Thus, it is possible to distinguish the following separate roles for the implementation of decentralized hierarchical control of the swarm activity: the activity of a separate drone, the activity of a drone-coordinator, and the activity of a human-operator. This approach allows us to consider the control of a drone swarm as analogous to the management of human workers who perform their assigned work.

This opens up several important possibilities. First, it is possible to use methods of formalizing the behavior of people in social teams. For example, at the level of formal models for their functional duties. Second, formal models can be used for decision-making and optimization for the drone-coordinator control in a swarm. Thirdly, a computer simulation can be applied to the behavior of a drone swarm, which will allow choosing the optimal behavior of the swarm for different conditions of its activity.

An important fact is that there will be no training phase for drone swarms, unlike human teams. For human teams, it is this stage that is often the limiting factor for learning to be passed experiences. In the case of drones, all the gained experience is loaded into drones already at the level of their manufacture.

The most obvious analogy between a swarm of drones and a team of people is manifested at the level of lower-level military groups (branch, platoon, etc.).

References.

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