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FEATURES OF COMBAT USE FOR A SWARM OF DRONES

Abstract. The problem of the combat use of a swarm of drones is still at an underexplored level. At the same time, the variety of drones that have lethal weapons is growing. Therefore, the problem arises of controlling a swarm of drones on the battlefield. In this case, a swarm can consist of both the same units and units that have different properties. The purpose of the report is to describe promising approaches for modeling the behavior of a swarm of military drones on a battlefield.

Keywords: military drone, swarm, model, behavior, battlefield.

The drone industry is developing in several directions. First, the drones themselves are improving. New flying, floating (on the surface and underneath), walking (on two, four or more legs), creeping, etc. constructions appeared. They develop both in the direction of increasing size/mass (for example, flying drones that can carry missile weapons) and in the direction of miniaturization (for example, reconnaissance drones). Secondly, hardware and software for controlling individual drones are being developed. Thirdly, models, methods and programs are developed for communication between drones (for example, they combine actions for coordination).

Perhaps today one of the main constraints for the development of the drone industry is the existing software for using a large number of identical drones to perform a joint task. For example, significant limitations are the need to control a human operator (these restrictions are due to the small computing resources of individual drones). This limitation is important for increasing the number of drones that can perform coordinated actions.

In [1] attention is focused on ideas and concepts that can be promising for the development of the swarm robotics direction, especially when applied to specific tasks. As the most promising directions for the development of swarm robotics, the authors single out “an increasing need for a swarm engineering, that is, a need for methods for: (1) requirement modeling and specification, (2) design and implementation, (3) verification and validation, and (4) operation and maintenance”. Three areas authors distinguish as important. The first is the requirements for both models and drones/robots. The second is the creation of universal approaches to the design and implementation of collective behavior, based on the behavior of the drone itself and ending with the behavior of the swarm as a whole. Third is the problem of communication and human-swarm cooperation.

In recent years, in the directions described in [1], a number of new and interesting results have been obtained. We note such ones.

So, in [2], an algorithm was considered for organizing four types of collective movement based on the movement of the swarm “behind the leader”. However the leader is identified quite randomly.

In a number of works, for example [3, 4, 5], the attention of researchers is focused on the development of models for avoiding collisions in a moving swarm.

Quite a lot of papers are devoted to the transition from local movement of a drone to the organized movement of the swarm as a whole. In [6], drones with limited sensory capabilities are considered, which “feel” only a few nearest neighbors and “know” only one constant direction of movement. The management model proposed by the authors is very promising, but needs further development before application. However, it indicates one of the directions of further development. In [7], a control model for the distribution of a swarm in space is presented in order to achieve a given density of the number of drones. It also relies on information about the local position of the drones in the swarm. In [4], the swarm behavior model is based on the consideration of “collisions” (proximity to the minimum distance) of drones. The paper also considers the ability to change tasks that are performed by drones. In [8], as in [4], the decentralized problem is also considered. Attention in this work is focused on studying the effect of internal noise or interference on collective movement. It is proposed to overcome interference using the presence of communication links between drones.

In [9], the requirements for the interface of an operator that controls drones in a swarm are considered. However, the operator must still pay attention to each of the drones in the swarm.

In [10], the authors proposed “a two-step scheme which consists of task partitioning and autonomous task allocation to address these issues. In the first step, the original task is partitioned into simpler subtasks to reduce the complexity of designing fitness functions. In the second step, evolutionary approaches are adopted to synthesize a composite artificial neural network-based controller to generate autonomous task allocation for the robotic swarm”. For this, the task is decomposed at the hardware level of the drone itself.

In [11], a situation is considered when a swarm is divided into groups with the same number of drones. Drones have both firmware (fixed, embedded programs) and regular programs for their traffic. Group of drones is controlling from the command centre. In our proposed models, individual clusters in a swarm may consist of a different number of drones. In addition, a drone coordinator, rather than a human operator, can be used as a command center for a cluster.

In [12], a swarm model with a central control agent is described. In the model, several drones are located above the swarm and serve as repeaters to control the swarm. In [13], the comparison between centralized and distributed control in a swarm of drones was studied. It was revealed that centralized control is more profitable in contrast to distributed control. However, centralized management has significant scalability limitations. In [14], a set of requirements was considered for both drones and organization of swarm control.

However, the problem of the combat use of a swarm of drones is still at an underexplored level. At the same time, the variety of drones that have lethal weapons is growing. Therefore, the problem arises of controlling a swarm of drones on the battlefield. In this case, a swarm can consist of both the same units and units that have different properties.

The purpose of the report is to describe promising approaches for modeling the behavior of a swarm of military drones in a battlefield.

The vast majority of people in the community simply follow a given program of action (behavior). This is most clearly seen in the example of a firm: functional responsibilities at a given workplace do not matter who exactly is in a given place (gender, race, age, nationality, etc. does not matter). The main thing is that this person does exactly what is established by these functional responsibilities.

Thus, there is a rather large area of models that can describe both the behavior of people and the behavior of technical objects. Today, as technology becomes more intelligent, this area is expanding rapidly.

The report discusses a set of models that may well describe technical objects with behavior that resembles human behavior. Such technical systems can be called “artificial communities”.

For example, let one consider a real platoon from humans. In them, soldiers have different weapons and can exchange them. Each soldier on the battlefield independently chooses his own behavior, choosing him from a relatively small number of trained him. The platoon of such soldiers is controlled by issuing orders to several sergeants or officers, of whom there are few.

The report introduced the several models for describing the control of a swarm of drones on the battlefield. These models make it possible to take into account the basic elements of human behavior that have been developed over the many millennia of their participation in a wide variety of wars. The developed models make it possible to organize the control of a quantity of such a number of operators, which is many times less for the number of drones in the swarm. Also, the developed models make it possible to identify specific requirements for individual drones. If such requirements to drones are met, in a swarm they can be successfully controlled.

Thus, there is an opportunity for significant progress both in the design of drones with new properties, and in their use as part of a swarm. This allows one to move to a new level in the art of war.

Therefore, the materials in this report create approaches to building artificial communities that can demonstrate the behavior of small and large groups of people on the battlefield. It is important that this behavior of groups of people be sufficiently formalized. That is, each individual should have a fairly formal behavior, which can be sufficiently described by formal mathematical models.

In fact, with this approach, a person differs from a drone only in various mathematical functions that describe it. However, it should be noted that in the modern world there are a huge number of situations in which a person is obliged to exhibit only such formal behavior.

Modern technical systems increasingly imitate human behavior. The “man (people) → technical device (device set)” method is being intensively studied today. However, there is also a “device set → people set” method, which is used much less frequently. At the same time, this method allows us to use the behavior models of technical systems in the study of certain aspects of the behavior of social groups or communities.

Models described the organization of commanders on the battlefield with the actions of a number of soldiers armed with various weapons.

We hope that the described models will be of interest to a wide circle of researchers. The results obtained can serve as a kind of bridge between researchers working in various fields of science (for example, in the fields of war science, social sciences, management, and technology).

References

1. Brambilla M, Ferrante E, Birattari M et al. (2013) Swarm robotics: a review from the swarm engineering perspective. Swarm Intell 7: 1–41.
2. Sueoka Y, Sato Y, Ishitani M et al. (2019) Analysis of push-forward model for swarm-like collective motions. Artif Life Robotics 24: 460–470.
3. Ravankar A, Ravankar AA, Hoshino Y. et al. (2020) Safe mobile robot navigation in human-centered environments using a heat map-based path planner. Artif Life Robotics 25: 264–272.
4. Mayya S, Wilson S, Egerstedt M (2019) Closed-loop task allocation in robot swarms using inter-robot encounters. Swarm Intell 13: 115–143.
5. Yaguchi Y, Tamagawa K (2020) A waypoint navigation method with collision avoidance using an artificial potential method on random priority. Artif Life Robotics 25: 278–285.
6. Coppola M, Guo J, Gill E et al. (2019) Provable self-organizing pattern formation by a swarm of robots with limited knowledge. Swarm Intell 13: 59–94.
7. Jang I, Shin H, Tsourdos A (2018) Local information-based control for probabilistic swarm distribution guidance. Swarm Intell 12: 327–359.
8. Rausch I, Reina A, Simoens P et al. (2019) Coherent collective behaviour emerging from decentralised balancing of social feedback and noise. Swarm Intell 13: 321–345.
9. Dousse N, Heitz G, Floreano, D (2016) Extension of a ground control interface for swarms of Small Drones. Artif Life Robotics 21: 308–316.
10. Wei Y, Hiraga M, Ohkura K et al. (2019) Autonomous task allocation by artificial evolution for robotic swarms in complex tasks. Artif Life Robotics 24: 127–134.
11. de Melo VV, Banzhaf W (2018) Drone Squadron Optimization: a novel self-adaptive algorithm for global numerical optimization. Neural Comput & Applic 30: 3117–3144.
12. 13. Najafi M, Ajam H, Jamali V, Diamantoulakis PD, Karagiannidis GK, Schober R (2018) Statistical Modeling of FSO Fronthaul Channel for Drone-Based Networks. 2018 IEEE International Conference on Communications (ICC), Kansas City, MO: 1-7.
13. Hu J, Bruno A, Zagieboylo D, Zhao M, Ritchken B, Jackson B, Chae Joo Y, Mertil F, Espinosa M, Delimitrou C (2018) To Centralize or Not To Centralize: A Tale of Swarm Coordination. arXiv.org. https://arxiv.org/pdf/1805.01786. Accessed 2 October 2021.
14. Akram RN, Markantonakis K, Mayes K, Habachi O, Sauveron D, Steyven A, Serge C (2017) Security, privacy and safety evaluation of dynamic and static fleets of drones. IEEE/AIAA 36th Digital Avionics Systems Conference (DASC), St. Petersburg, FL: 1-12.

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