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Anatolii Shyian, Liliia Nikiforova

TECHNOLOGIES FOR USING DRONE SWARMS ON THE BATTLEFIELD IN CONDITIONS OF ACTIVE ENEMY COUNTERMEASURES

Annotation. *Here, directions for the development of the use of drones for a large number of tasks are outlined. The use of drones in the conditions of war presents the greatest number of challenges, so our presentation is focused on these conditions. Below is a set of projects that will need to be completed on the way to creating a system of autonomous, hierarchically organized swarms of drones that will be able to replace people on the battlefield. For tasks of a civil nature, these results must also be obtained. For example, in the conditions of activity in space, this will be decisive.*
Keywords*: battlefield, drone industry, development, potential projects, applications, military, civilian.*

Introduction.

Drones are widely used in combat operations. Many articles are devoted to controlling the movement of drones, especially in conditions of active enemy opposition.

Transition to problem statement. Motivation.

Countermeasures against drones are widely used on the battlefield. Today, drones often have to perform operations in conditions with obstacles that affect their positioning on the battlefield. Those drones will win that will form local positioning systems and independently form target coordinates. The development of new technologies for countering enemy electronic warfare systems is also important. Drone swarm operations on the battlefield require new approaches to the formation of information technologies for visualizing the battlefield, saturated with electronic warfare and enemy countermeasures.

Today, a transition is taking place on the battlefield from the use of individual drones to the use of drone swarms. This puts forward new requirements for the number of approaches to the formation of such technologies.

Organization of swarm drone operations in the absence of global positioning.

A swarm enters a region of space where there is no global positioning (for example, electronic warfare equipment is operating, there is an obstacle on the communication path, etc.).

In this case, one can create local coordinates in this area. For example, in the general case, it can be four drones that form a tetrahedron in space (that is, a plane cannot be drawn through them). One of the drones will be used as the "origin of coordinates/point of reference".

Using various means (laser radiation, optical elements (rangefinders), radio radiation at certain frequencies (which are not jammed), etc.), other drones in the swarm get unambiguous positioning in these "local coordinates". Using the same means, the area of activity (as well as individual activity goals) of the pack is also fixed/set in these local coordinates.

A tetrahedron (that is, four drones that set local coordinates) can function for a relatively short time, provided that there are four drones in the swarm that have the ability to measure the distance both among themselves and to the required elements of the area/environment of activity (including changing the environment itself/goals both in coordinates and in time). The recalculation of coordinates from the initial state to the current state is elementary (requires elementary calculations, and therefore will not make special demands on microprocessors).

In some cases, three drones can be used, then the active drones will be considered as vertices of the "situational" tetrahedron. However, at the same time, it is necessary to fix the "top" and "bottom" sides in relation to the plane formed by the three drones that create local coordinates.

The model for three-dimensional space is described above. If there is an operational space, it can be represented as a plane in a certain approximation, then three drones make up a complete coordinate system. And using two drones and fixing the sides (“forward” and “back”) allows you to limit yourself to two drones.

In real cases, the drones that form the local coordinates may be far from the operational area for the drone swarm. For example, they can be far behind the front line to their territory, being at a high altitude, and the swarm can be several tens of kilometers deep into the territory of the enemy.

Local coordinates can be formed not only by drones. For this, depending on the situation, you can use airplanes, a set of towers, hot air balloons or airships, boats, etc.

Let’s emphasize that it is possible to use overlapping local coordinates. The overlap area will be used to move from the "previous" to the "new" local coordinates.

Similarly, it is possible to build local coordinates with drones that function (as supporting elements of local coordinates) for a very short time (for combat conditions, stealth of action, etc., this can be important). Then the "capture" of local coordinates can be carried out through the use of four drones of the swarm itself. The only important limitation will be that when the swarm goes outside the environment area that was "covered" by local coordinates, new local coordinates must be built (but in this case it is desirable to use the overlapping area of two local coordinate systems).

Countermeasures to EW.

Today, the field of electronic warfare (EW) is distinguished by the fact that drones do not have the ability to communicate both with human operators and with other drones. In these cases, they try to use other frequencies for communication. And it affects the intensity of the flow of information that the drone needs to send/receive. This is due to the fact that drones are used, which must be smoothly controlled by a human operator.

It is possible to try to control drones in the area of EW through the main communication channels. This can be optical fiber or metal wire (as it was used for anti-tank missiles back in the 1960s). Unfortunately, the peculiarities of the use of drones in the modern field of drones lead to a large number of specific problems. Among which should be highlighted the use of drones, for example, among the ruins of buildings, in plantings, etc. In addition, as a result, the battlefield will quickly become littered with fragments of optical fibers or wires, which will interfere with the movement of drones (fragments of wires in the air will affect the propellers of drones, and a tangle of wires on the ground will cling to the wheels, skin and weapons of drones).

There are two ways out. The first is the use of a swarm of drones, which consists of an observer/coordinator drone (it moves outside the EW area) and a collection of executive drones (which perform operations in the EW area). The observer/coordinator drone determines a set of targets and sets their coordinates outside the EW area using a local coordinate grid (described above). Corner reflectors one may to use either in the optical range or in the ranges that do not suppress EW will be used as a coordinate grid. The performing drone is guided to the target independently, using corner reflectors as reference points of the local coordinate system. For stationary targets in this case, the accuracy of hitting will be high. For moving targets, it is possible to use the prediction of the trajectory of these targets by the observer/coordinator drone, which is outside the EW area and can set the aiming point by interpolating the target's trajectory. For this, he can use, for example, the powerful computer capabilities of operators who are on their territory far from the battlefield. Note that in this case, several executive drones can attack one moving target, each of which is aimed at different aiming points (which are calculated under different assumptions about the further movement of the target).

The second direction of operations by executive drones in the EW area is as follows. The performer drone is controlled by signals from the observer/coordinator drone, which are provided at discrete time intervals. It can be a scattered laser beam, a signal at a different frequency, etc. At the same time, the letters of the M2 language will be used to control the movement of the performing drone. Thus, the discrete control of the drone will be carried out.

Finally, marks can be dropped on the target (for example, at night), which consist of an angular reflector, which the performer drone is directed to. It is advisable to use laser radiation.

Visualization of the battlefield with EW and countermeasures (own and enemy).

Creating a 3D map of the battlefield. The map itself is 2D. The vertical axis is the level of danger for drones that fly (moving on the ground, swimming, moving under water). Danger can be from EW, countermeasures, artillery, machine guns, etc. The probability of damage to the drone can be plotted along the vertical axis.

In this case, visualization of the battlefield is achieved. Simulating attacks uses information about the availability of countermeasures (similarly, the task of protecting the battlefield takes into account its own capabilities).

Attack optimization boils down to finding trajectories and attack conditions for drones that move in space/plane and should minimize a given utility function (eg, the minimum amount of damage for an optimal trajectory). Also, such simulations allow you to choose both the number and the nomenclature of drones to obtain the planned effect.

Visualization also allows the commander/officer, by applying knowledge, experience and intuition, to reduce the number of necessary calculations.

The defense of one's own battlefield is carried out in a similar way, while the location of one's own forces is optimized to counter existing enemy forces.

Discussion and outlook.

At the stage of starting work, one can take the patents for both methods/technologies and devices. For devices, the number of patents can be quite large, because they will take into account the activity depending on the specifics of the environment. The patents can be used not only for military activities, but also for civilian ones. All proposed projects can be optimally implemented within the framework of international teams of scientists. We are open to such research.

More detailed approaches to the technologies for using drone swarms on the battlefield are given in [1-4].

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Шиян Анатолій Антонович *– кандидат фізико-математичних наук, доцент, доцент кафедри управління та безпеки інформаційних систем, Вінницький національний технічний університет, Вінниця, вул. Хмельницьке шосе, корпус 95, проф. 20021, e-mail: anatoliy.a.shiyan@gmail.com. ORCID https://orcid.org/0000-0002-5418-1498*

Нікіфорова Лілія Олександрівна *– к.е.н., доцент, доцент кафедри менеджменту та безпеки інформаційних систем, Вінницький національний технічний університет, м. Вінниця, вул.Хмельницьке шосе, буд.95, інд.20021, електронна пошта: nikiforovalilia@gmail.com. ORCID https://orcid.org/0000-0002-7034-607X*

Shyian Anatolii Antonovych *– PhD in Physics and Mathematics, Associate Professor, Associate Professor in Department of Management and Security of Information Systems, Vinnytsia National Technical University, Vinnytsia, Khmelnytske Shosse St., Building 95, Ind. 20021,*
e-mail: anatoliy.a.shiyan@gmail.com. ORCID https://orcid.org/0000-0002-5418-1498

Nikiforova Liliia Oleksandrivna *– PhD in Economics, Associate Professor, Associate Professor in Department of Management and Security of Information Systems, Vinnytsia National Technical University, Vinnytsia, Khmelnytske Shosse St., Building 95, Ind. 20021, e-mail: nikiforovalilia@gmail.com. ORCID https://orcid.org/0000-0002-7034-607X*