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MILITARY LOGISTICS PLANNING MODELS FOR ENEMY TARGETS ATTACK BY A SWARM OF COMBAT DRONES

This article describes and investigates the planning aspect of military actions aimed at destroying enemy targets with the help of an attack drone swarm. This study attempts to solve the task of operational-tactical planning of a massive attack on enemy targets with the help of combat drones, which have different combat potential characteristics. It analyzes the problems of unmanned aerial vehicles (UAVs) swarms' usage, which ensures maximum efficiency during combat operations. The article shows that in order to plan effective military operations, it is necessary to form the following logistical sequence: identification of relevant targets set, formation of drones into a swarm to attack targets, distribution of drones by targets, and planning flight routes of a drone swarm in conditions of military threats. It concludes that for the effective use of a combat drone swarm, it is necessary to plan logistical actions in advance to inflict maximum damage on the enemy and successfully fulfill the operational and tactical goals of the military leadership. The purpose of this study is to create information technology models that will allow planning logistical military actions for the effective use of combat drone swarms to defeat enemy targets. This article describes a systematic representation of logistical military operations for combat drone swarms. It also analyzes enemy targets, which are represented in the form of a priority list with the characteristics of relevance, the necessary combat potential to hit the targets, the risks of approaching the targets, and the flight time of the drones. From the list of targets, a sublist is formed, considering the combat potential of the drone swarm and the necessary potential to defeat the selected enemy targets. The optimization model helps to distribute the swarm of drones into groups to achieve the enemy targets and destroy them. The movement of drones is planned considering flight zones, possible anti-drone actions of the enemy, and the risks of military threats. Any Logic agent simulation platform can be used to create a simulated flight model of a drone swarm to selected enemy targets. Modeling makes it possible to form rational flight routes of a drone swarm under conditions of military threats from the enemy. An example is given to illustrate the formation of logistical actions for planning a massive attack on enemy targets with the help of a drone swarm. The scientific novelty of this study is related to the solution of the urgent problem of planning logistical military operations for the effective use of a combat drone swarm to destroy enemy targets. The results of this study should be used for the operational and tactical planning of logistical military operations to defeat enemy targets with the help of a combat drone swarm.

Keywords: *combat drone swarm; enemy targets; drones groups formation; drones distribution by targets; drone flight routes planning; simulation modeling.*

1. Introduction

New technological solutions and innovations are a characteristic feature of modern hybrid warfare, such as new methods and technologies for positioning equipment [1], creating the possibility of network interaction of objects [2], tracking systems, and real-time decision-making [3]. At present, much attention is devoted to the use of unmanned aerial vehicles in the form of a swarm of drones on the battlefield, which can ensure the effectiveness of combat operations with the help of reconnaissance, targeting, and defeating targets. [4, 5]. Their use can change the nature of military operations (for example, the use of updated approaches to the interception of the enemy - the use of UAVs in the air, and when the enemy is detected, approach and neutralization [6], new approaches to the detection of enemy UAVs and their classification from the use using the Physical-Layer Protocol Statistical Fingerprint [7], flight planning with ticking of actions in case of enemy detection [8]). But the large-scale use of drones requires the analysis and formation of logistical military operations, which must be planned and executed according to the strategic and operational plans of the military leadership. At the same time, the question arises of using drones in a group or swarm formation, considering the optimal formation options, as proposed in [9]. At the same time, it is necessary to calculate its own trajectory for each of the drones in the swarm. For example, in [10] an overview of algorithms for determining trajectories. Therefore, a study is proposed in which the simulation of logistical military operations is carried out regarding the planning and control of a swarm of combat drones movement for effective destruction of enemy targets.

1.1. Motivation

As practice shows, the use of drones is most effective when forming combat groups (swarms). This very use of drones can cause great problems for countermeasure systems [11], because even when using new approaches for their detection, as described in [12], there is still a high probability of completing a flight task. To use groups of combat drones, it is necessary: to analyze and select possible enemy targets, to describe the required number of drones in groups, considering their combat capability characteristics. For example, in the study [13], there is an algorithm for planning the execution of a task by a drone in hostile territory, considering possible losses of the device. In the study [14], it is shown how to navigate without the possibility of using GPS, to allocate groups of drones by targets [15], and to create conditions for the fully autonomous functioning of drones over enemy territory. In [16], a description of the possible autonomous use of drones during hostilities is given and attention is paid to the allocation of specific functions to individual drones, but it is not considered that during the execution of a combat mission, if one or several drones are lost, the task will be redistributed among the remaining drones. Next, form the drones flight routes logistics considering military threats and possible anti-drone actions of the enemy [17, 18]. The above statements highlight the importance of the research topic. The goal of this research is to model logistical actions for planning and managing a swarm of combat drones to defeat enemy targets and ensure the success of operational-tactical actions planned by the military leadership.

1.2. State of the Art and problem statement

Modern hybrid warfare, which includes innovations and new technological solutions, creates many challenges associated with the effective use of combat drones [19].

1. A variety of existing drones with different areas of use and both tactical and technical characteristics [20, 21] are available.
2. Forming drones into groups (swarms) and effective management and coordination of combat drone swarms [22, 23].
3. Determining enemy targets for destruction by a swarm of combat drones [24, 25].
4. Optimization of drone distribution by targets to ensure maximum military damage to the enemy, considering the combat capability characteristics of drones [26, 27].
5. Planning and identifying combat drone routes to the enemy's targets in the conditions of possible anti-drone actions [28, 29].
6. Operational management of drone groups' movement to enemy targets under conditions of military threats [30, 31].

New technological solutions and innovations in modern hybrid warfare, in which UAVs in the form of drones are used on a large scale, require the development of new models and information technology for planning logistical military operations and controlling the movement of combat drones to effectively destroy enemy targets.

Limitations and assumptions that were adopted in the simulation of realistic military actions that lead to the destruction of actual enemy targets by a swarm of combat drones:

- limited possibilities (for some objective reasons) of forming strike drones to attack enemy targets in the zone of military conflict;
- the assumption that controlling drones allows you to form a swarm of drones and manage them successfully;
- the assumption that a larger number of drones can be distributed for different purposes (a sufficient amount of autonomous operation time);
- the assumption that a larger number of targets, taking into account the necessary combat potential, can be hit by drones.

1.3. Objectives and methodology

Modern hybrid warfare lacks the requirements for the effective use of a combat drone swarm as a new innovative element. In addition, the existing methods and models lack systematic problem analysis related to the formation and planning of logistical military operations regarding the control of drone swarm movement to attack enemy targets. These topics are researched in the current publication, which presents models for the creation of information technology for the effective use of combat drone swarms in modern warfare.

The objectives of the research are as follows: systematic analysis of combat drone capabilities to deliver massive strikes against enemy targets using swarms of drones, rational distribution of drone groups according to targets, formation of the least risky flight routes in the conditions of military threats, and anti-drone actions of the enemy.

To achieve the research objectives, it is necessary to solve the following tasks:

1. Conduct analysis and form a set of enemy targets for destruction by a combat drone swarm.
2. Form multiple groups of combat drones to attack enemy targets.
3. Distribute a swarm of drones according to enemy targets.
4. Plan flight routes of a combat drone swarm to enemy targets.
5. Conduct simulated modeling of combat drone flight routes.
6. Provide an illustrated example of a combat drone swarm flight plan to destroy enemy targets.

The list of mathematical methods and models used for the study of a combat drone swarm: system analysis, lexicographic ordering of options, integer optimization and agent simulation modeling.

1. Analysis and formation of the enemy targets set to be defeated by a swarm of combat drones

Let experts and military leadership present the possible targets of the enemy, which must be analyzed and separated for the analysis of each i-th target. At the initial stage, it is advisable to use qualitative assessments. Each i-th target can be characterized by a linguistic variable y_{ij}, where i relates to the target, and j relates to its characteristics. The following target characteristics are used:

1. Relevance of enemy targets.
2. The required amount of combat potential needed to destroy enemy targets (for example, the amount of explosive material).
3. The risk of approaching the enemy target under conditions of military threats.
4. Time needed to approach the enemy targets.

It is possible to increase the list of target characteristics depending on the operational-tactical tasks of the military leadership. For each j-th characteristic of the i-th target, we add the following qualitative values:

$$y_{i1} = \begin{cases} \text{A – high relevant;} \\ \text{B – relevant;} \\ \text{C – low relevant;} \\ \text{D – irrelevant,} \end{cases} \tag{1}$$

$$y_{i2} = \begin{cases} \text{A} - \text{low combat potential to hit the target;} \\ \text{B} - \text{average combat potential to hit the target;} \\ \text{C} - \text{high combat potential to hit the target;} \\ \text{D} - \text{very high combat potential to hit the target.} \end{cases} \tag{2}$$

$$y_{i3} = \begin{cases} \text{A} - \text{low risk reaching the target;} \\ \text{B} - \text{average risk reaching the target;} \\ \text{C} - \text{high risk reaching the target;} \\ \text{D} - \text{very high risk reaching the target.} \end{cases} \tag{3}$$

$$y_{i4} = \begin{cases} \text{A} - \text{short time needed to reach the target;} \\ \text{B} - \text{satisfactory time needed to reach the target;} \\ \text{C} - \text{long time needed to reach the target;} \\ \text{D} - \text{very long time needed to reach the target.} \end{cases} \tag{4}$$

With the help of linguistic variables, each i-th enemy target can be represented as a "word", in which the most significant characteristic will be in the first place, and the least significant characteristic will be in the last place.

For example, let's arrange the characteristics of the targets in the "word" as follows:

- in the first place - the relevance of the goal,
- in the second place - the combat potential required to destroy the target,
- in the third place – the risk of approaching the target,
- in the fourth place - the time to approach the target.

Then, the "word", for example, will look like this:

B, C, A, C, (5)

where B – the target is relevant,

C – high combat potential necessary to destroy the target,

A – low risk of approaching the target,

C – long time to approach the target.

Let the list of 4 possible targets be presented in the form of "words":

1. B, C, A, C,
2. A, B, C, B,
3. C, A, B, B, (6)
4. A, C, B, C.

The list of targets can be ordered using lexicographic ordering (as in a dictionary) considering the importance of the target characteristics.

The ordered set of targets has the following form:

2. A, B, C, B,
4. A, C, B, C,
1. B, C, A, C, (7)
3. C, A, B, B.

Thus, at the top of the list will be the "word" for the most relevant target, and at the bottom will be the "word" for the least relevant target.

2. Formation of multiple combat drone groups to destroy relevant enemy targets

To distribute a drone swarm into groups, it is necessary to assess the available combat potential of a set (M) of drones, which will be used to defeat selected relevant enemy targets (Q). At the same time, it is necessary to consider the characteristics of each i-th enemy target, first of all, the necessary combat potential to destroy the i-th target. Comparing the existing combat potential of drones (P_M) with the required combat potential for hitting targets (P_Q) the following cases arise:

$$\begin{aligned} &1.\ P_M > P_Q. \\ &2.\ P_M \approx P_Q. \\ &3.\ P_M < P_Q. \end{aligned} \qquad (8)$$

In the first case, a part of the combat drone potential can be used to hit multiple targets (Q). In the second case, it is necessary to use the entire set of drones (M) to destroy the actual enemy targets. In the third case, it is necessary to conduct an effective distribution of drones by targets, considering the relevance of the targets.

Let's consider the third case in more detail.

To distribute the set of drones (M) according to the targets (Q), we will use quantitative estimates of the combat potential (P_M) and the necessary combat potential to destroy the targets (P_Q). Let's create an algorithm to distribute drones by targets, considering the values of P_M and P_Q in the form of a step sequence:

Step 1. Let’s analyze the first (most relevant) "word" in the ordered list of targets. These cases are possible:

1. $P_M \approx P_{Q1}$. In this case, the entire set of drones (M) must be directed to the first, most relevant target.

2. $P_M > P_{Q1}$. In this case, the set of drones is divided into groups in such a way as to hit not one, but several targets. It is necessary to:

$$P_M \approx P_{Q1}+\ldots+P_{Qi}+\ldots+P_{Qe1}, \qquad (9)$$

where e1 – position in the ordered list of «words» in the list of relevant targets Q.

3. $P_M < P_{Q1}$. In this case, it is necessary to compare P_M with P_{Q2}. Possible comparison options are 1, 2 and 3, where 2 will be: $P_M \approx P_{Q2}+\ldots P_{Qi}+\ldots P_{Qe2}$.

Step 2. If $P_M < P_{Q2}$ is true for the second "word" in the ordered list of targets, then move down in the ordered list of relevant targets

...

Step k. If $P_M < P_{Qk}$ is true for k-th «word» in the ordered list of targets, then move to (k+1) «word» and compare 1, 2, 3. For case 2 it results in: $P_M \approx P_{Q(k+1)}+\ldots+P_{Qi}+\ldots+P_{Qe(k+1)}$

...

Step N. This step corresponds to the analysis of the current targets list last element (N). If $P_M \approx P_{QN}$ is true, then the entire set of drones (swarm) will be directed to the target, which is the last in the target list (Q). If $P_M > P_{QN}$ is true, some drones remain to be used when hitting new targets. In case $P_M < P_{QN}$, it is necessary to increase the number of drones to hit relevant targets and perform combat tasks.

It is possible to create swarms from existing drones, for this it is necessary to equip them with equipment for interaction with each other (communication for redistribution of goals). As strike drones that are successfully used in military conflict areas, the following can be noted: Bayraktar TB2, Predator, IAI Harops, and others. It should also be noted that various modifications of copter-type drones are used, on which the application of this approach is easier to implement. However, they have a significant limitation, which is related to the maximum time that this class of drones can stay in the air. The area in which it will be possible to perform a military operation using copters is much smaller than that when using mini or midi UAVs.

3. Distribution of drone swarms according to enemy targets

The main condition for the distribution of drones according to enemy targets is a comparison of the existing combat drone swarm potential (P_M) and the required potential (P_Q) to destroy the targets, $P_M \geq P_Q$. A drone swarm can have different types of drones to use when assigning them to targets. To distribute drones, we will use the boolean programming approach. Let's introduce the boolean variable x_{ij}, which has the form:

$$x_{ij} = \begin{cases} 1 - \text{in case j} - \text{th drone is used} \\ \quad\ \text{to hit the i} - \text{th enemy target;} \\ 0 - \text{in other cases.} \end{cases} \qquad (10)$$

It is necessary that the combat potential of a drone swarm to destroy enemy targets meets:

$$P_M \geq P_Q,\ P_Q \approx P_{Q1}+\ldots P_{Qi}+\ldots+P_{QN}, \qquad (11)$$

where P_{Qi} – combat potential, required to destroy i-th target.

To destroy i-th target it must distribute drones in such a way, that:

$$P_{Mi} \geq P_{Qi},\ i = \overline{1, N}, \tag{12}$$

considering variables x_{ij}, let’s form drones combat potential required to destroy i-th target:

$$P_{Mi} = \sum_{j=1}^{M} x_{ij} p_j, \tag{13}$$

where p_j – combat potential (such as the amount of explosive) of j-th drone.

An important parameter for successful execution of a combat task is the time required to approach the enemy target. The reduction in time makes it difficult for the enemy to use anti-drone means in a timely manner. Then, as the main parameter (optimization objective function), we can use the time (T) required to approach an enemy target by a swarm of drones:

$$T = \sum_{i=1}^{N} \sum_{j=1}^{M} x_{ij} t_{ij}, \tag{14}$$

where t_{ij} – time required to approach i-th target by j-th drone

It is necessary to minimize the enemy target approaching time by the swarm of drones:

$$\min T, T = \sum_{i=1}^{N} \sum_{j=1}^{M} x_{ij} t_{ij}, \tag{15}$$

considering:

$$P_{Mi} \geq P_{Qi},\ i = \overline{1, N},$$

$$\sum_{i=1}^{N} x_{ij} = 1, j = \overline{1, M}. \tag{16}$$

$$t_j \geq t_{ij},\ i = \overline{1, N},\ j = \overline{1, M},$$

where t_j is the autonomous operation time of drone j.

If the enemy actively uses means of anti-drone combat, it is advisable to minimize the risks (R) of approaching targets by a drone swarm for successful combat mission execution:

$$\min R, R = \sum_{i=1}^{N} \sum_{j=1}^{M} x_{ij} r_{ij}, \tag{17}$$

considering the following conditions:

$$P_{Mi} \geq P_{Qi},\ i = \overline{1, N},$$

$$\sum_{i=1}^{N} x_{ij} = 1,\ j = \overline{1, M}, \tag{18}$$

where r_{ij} – is the risk of approaching i-th target by j-th drone.

In case all drones have the same type, the number of drones (s_i), required to destroy each i-th target, can be calculated as follows:

$$S_i \approx \frac{P_{Qi}}{P_{Mi}},\ M = \sum_{i=1}^{N} s_i, \tag{19}$$

where P_{Mi} – combat potential of a single drone.

4. Plan combat drone swarm routes to enemy targets

The main requirement for planning the flight routes of a combat drone swarm is to ensure a reduction in the time it takes to approach the enemy targets. To form the flight trajectory, the enemy’s anti-drone combat capabilities should be considered. To form drone flight routes, it is necessary to form a set of zones (Z) in which there are navigation points for flight control. The presence of flight control in zones will help to correct and change drone flight routes, taking into account the emergence of military threats and active anti-drone combat. Thus, it is possible to create a drone group flight plan in the form of a control zone sequence. To form the flight routes, we will use an event-based simulation, where the drone will be presented in the form of a simulation application. The following original algorithm was proposed to find the route with the minimum time (T) to approach the enemy targets. Let's take a closer look at the main steps of the algorithm:

Step 1. The starting point for launching a swarm of drones is the first zone (all possible zones in the set of zones (F) must be numbered).

Step 2. From the first (and then the k-th) point of the drone flight, applications (drones) in the form of multiple copies (clones) of the original application will spread simultaneously in all possible directions to neighboring zones.

Step 3. When an application (clone) arrives at the neighboring i-th zone, it is marked by an incoming application (clone).

Step 4. New applications (clones) are distributed in parallel from all adjacent zones marked by applications (clones) to the next adjacent zones.

Step 5. If an application (clone) arrives in a zone marked by an application that arrived earlier, the further movement of this application (clone) is blocked. In this case, the application (clone) is destroyed because of its later arrival relative to the application (clone) that arrived earlier. Thus, applications (clones) that are not competitive are blocked and destroyed, and only those applications (clones) that have the shortest time to approach the target move further.

Step 6. When an application (clone) arrives at the final zone (target), the time of arrival is noted, which corresponds to the minimum flight time of a drone swarm to the enemy target.

Step 7. To form the flight path of a drone swarm, we should follow the marked zones, starting from the target zone.

In the case of dividing a drone swarm into groups, each of which is launched from its origin zone, the proposed algorithm allows for parallel simulation of the drone group flight process and formation of flight routes to enemy targets. If the enemy actively uses anti-drone means, then to find routes with minimal risks, the proposed algorithm must change the time parameter to risk.

The developed algorithm for simulating drone swarm flight can be used to replan flight routes when flight conditions change due to enemy anti-drone actions. In this case, it is necessary to analyze the circumstances upon reaching each i-th flight control zone. If the circumstances change due to the actions of the enemy, it is necessary to replan the flight routes in real time to form new, relatively safe, flight routes.

5. Combat drone flight routes simulation modeling

The simulation model is built on the Any Logic platform and includes the following simulation agents (Fig. 1):

1. Formation of a possible zone set that is used by drone swarms to approach enemy targets (Flight Zones Set).

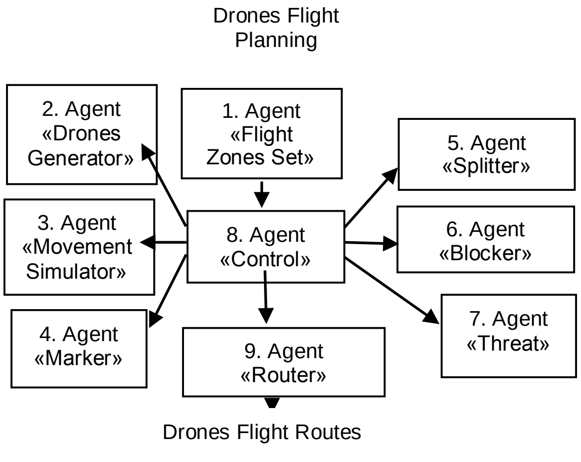

Fig. 1. Structure of the agent based simulation model

2. Drone Swarm Generator (Drone Generator).
3. Drone movement between adjacent control zone simulator (Movement Simulator).
4. Marker to mark the zone reached by a drone (Marker).
5. Clone application splitter (Splitter).
6. Application (clone) of movement blocker (Blocker).
7. Simulator of military threats (Threat).
8. Control module (Control).
9. Router to form the flight path of a drone swarm (Router).

Fig. 1 presents the structural diagram of the agent based simulation model.

6. An illustrated example of combat drone swarm flight planning

The illustrated example demonstrates the effectiveness of the proposed approach for planning the flight of a drone swarm to defeat relevant enemy targets.

Let the list of relevant enemy targets (Q) be represented as "words" list (item 1), and have the following form:

1. B, 10, C, B.
2. B, 5, A, C.
3. A, 30, B, B.
4. B, 20, A, C.
5. A, 25, B, C,

where the first «word» position is the target relevance, second is the combat potential required to destroy the targets (represented quantitatively in the form of an explosive material mass in kilograms required to destroy the target), third is the target approaching risk, and fourth is the target approach time.

Let's lexicographically order a list of relevant targets. Then, the ordered list will have the following form:

3. A, 30, B, B.
5. A, 25, B, C.
4. B, 20, A, C.
1. B, 10, C, B.
2. B, 5, A, C.

Suppose that a drone swarm contains three identical combat drones (kamikaze drones) with a total explosive substance of 18 kg (6 kg per drone).

Let’s analyze the possibility of using the existing combat drone swarm to destroy enemy targets. In accordance with the algorithm (item 2), we move along the ordered list of targets ("words") from top to bottom and find targets 1, 2, for which the available combat potential of the drone swarm exceeds the necessary potential to destroy targets 1, 2 (18 > 10 + 5). In such a case, a drone swarm can be directed to destroy enemy targets 1, 2.

Next let's calculate the number of drones per target. Since combat drones are all of the same type, the required number of drones for the first target is 2 drones (12 > 10), and for the second target – 1 drone (6 > 5).

Next, it is necessary to form a list of possible drone flight zones to plan the flight route. Let's represent the list of drone flight zones in the form of graph G (Fig. 2), where the vertices of the graph correspond to the flight control zones, and the edges of the graph G are possible movement paths between the zones. The first vertice corresponds to the drone swarm launch zone. An example highlights 11 possible drone flight zones. Consider the route search example with the lowest drone flight risks, which is connected with the possibility of the enemy actively using anti-drone measures. All possible paths between zones (edges of graph G) need to be assessed in advance by risk r_i (Fig. 2):

$$r_{1,2} = 1,\ r_{2,5} = 3,\ r_{5,8} = 5,\ r_{8,10} = 8,\ r_{1,3} = 5,$$
$$r_{2,6} = 2,\ r_{3,6} = 2,\ r_{6,8} = 1,\ r_{3,7} = 3,\ r_{7,9} = 3,$$
$$r_{7,6} = 2,\ r_{6,9} = 5,\ r_{9,10} = 6,\ r_{1,4} = 3,$$
$$r_{4,7} = 1,\ r_{9,8} = 3.$$

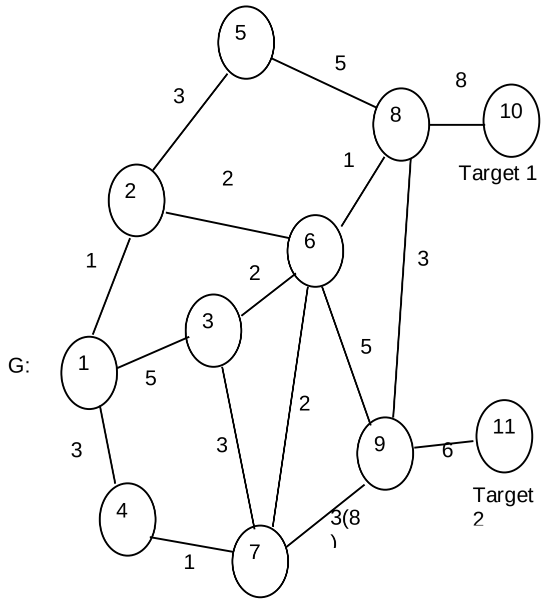

Fig. 2. List of drone swarm flight zones

The least risky combat drone flight route was found using the developed algorithm (see item 3). For the first group of drones (2 drones, the first target) the route has the following form: 1 – 4 – 7 – 6 – 8 – 10, with total risk $\sum_i r_i = 15$.

For a drone aimed at a second target, the least risky route is: 1 – 4 – 7 – 9 – 11, with total risk $\sum_i r_i = 13$.

Suppose, when a drone aimed at a second target reaches zone 7, the risk of the drone flying to the 9-th zone is significantly increased because of the active anti-drone actions of the enemy ($r_{7,9} = 8$). Then, by replanning the flight route, using the least risky route search algorithm (see item 3), a new drone flight route from zone 7 was found: 7 – 6 – 9 – 11, with total risk $\sum_i r_i = 13$.

7. Discussion

This article presents an example that forms a list of enemy targets for destruction by drones and distributes drone groups by targets, taking into account the combat potential. The formation of drone flight routes demonstrates the practical application of the proposed approach for planning logistical military operations to strike enemy targets with a swarm of combat drones, considering the minimization of risks associated with possible anti-drone actions by the enemy. The example uses the main components of the developed toolkit, in particular, a model for analyzing and identifying enemy targets, lexicographic ordering of targets, distribution of drones by groups, considering the required combat potential, and agent-based simulation of the drones' movement towards enemy targets. A complex of logically connected models allows the planning of combat drone swarm military operations in advance, the identification and analysis of enemy targets, taking into account the required combat potential of a drone swarm, and the planning of flight routes of a drone swarm to a target in the conditions of enemy anti-drone actions. The methodology for planning logistical military operations using a combat drone swarm consists of the following stages:

1. The enemy targets analysis to identify priority from the military leadership operational-tactical action view.
2. Formation of a drone swarm with the necessary combat potential to destroy enemy targets.
3. Distribution of drones according to enemy targets for effective destruction.
4. Drone swarm flight route planning under conditions of military threats.

The models were implemented using the agent-based simulation software platform Any Logic, which provides a convenient interface for planning military operations using a combat drone swarm. This is relevant in the conditions of a hybrid war, in which a strike drone swarm can be used as an innovative element for massive destruction of enemy targets. Future research will focus on the creation of information technology for military specialists in the field to control unmanned aerial vehicles as combat drone swarms and plan flight routes for effective destruction of enemy targets.

8. Conclusions

This article investigates the topic of logistical military operation simulation before combat drone swarm flight planning for massive enemy target destruction. This study analyzes existing problems related to the use of a combat drone swarm in the conditions of modern hybrid warfare with innovative elements and new technological solutions. The research creates a system representation of the enemy relevant targets ordered list. It carries out the distribution of drone groups, considering the existing combat potential of drones, and the necessary combat potential to destroy enemy targets. When using different drones in a swarm, their distribution by targets has been optimized considering the characteristics of the drones. Using the agent-based simulation, a model was created to plan drone routes in the presence of military threats and enemy anti-drone actions. The following data exchange protocols can be used to communicate with drones in a swarm: LTE, SUCOM, LoRaWAN. It is also possible to create a network based on Adhoc, then you can use technologies such as IEEE 802.11, 3G/LTE and satellite communication. This article provides an illustrated example of drone swarm creation, the division of the swarm into groups to attack relevant enemy targets, the planning of drone flight routes, and the re-planning of routes in the event of military threats. The suggested approach makes it possible to analyze and form a list of relevant enemy targets, create a drone swarm to attack targets, divide the swarm into groups, and plan drone flight routes, which contributes to the effective solution of operational and tactical tasks of the military leadership.

Contribution of authors: a systematic representation of the military operations logistical process regarding the use of a combat drone swarm of combat drones – **Oleg Fedorovych**; distribution of a drone swarm into groups – **Dmytro Kritskiy**; optimization of drone swarm distribution by targets – **Leonid Malieiev**; agent based flight simulation of a drone swarm – **Kseniia Rybka**; an illustrated example of a drone swarm combat planning simulation – **Andrii Rybka**.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Use of Artificial Intelligence

The authors confirm that they did not use artificial intelligence methods while creating the presented work.

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МОДЕЛІ ПЛАНУВАННЯ ЛОГІСТИЧНИХ ВІЙСЬКОВИХ ДІЙ ЩОДО УРАЖЕННЯ РОЄМ БОЙОВИХ ДРОНІВ ЦІЛЕЙ ПРОТИВНИКА

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Формується та вирішується задача дослідження планування військових дій щодо ураження цілей противника за допомогою рою ударних дронів. Дослідження, яке проводиться, пов’язане з вирішенням завдань оперативно-тактичного характеру планування масованого удару по цілям противника за допомогою бойових дронів з різними характеристиками бойового потенціалу. Аналізуються проблеми використання безпілотних літальних апаратів (БПЛА), які згортаються у групи у вигляді рою, що забезпечує максимальну ефективність при проведенні бойових дій. Показано, що для планування ефективних військових дій необхідно сформувати логістичну послідовність у вигляді: виявлення множини цілей – формування групи дронів у рої для ураження цілей – розподіл дронів за цілями – планування маршрутів польотів рою дронів в умовах військових загроз. Робиться висновок, що для ефективного використання рою бойових дронів необхідно заздалегідь планувати логістичні дії для нанесення максимальних збитків противнику та успішного виконання оперативно-тактичних цілей воєнного керівництва. Тому, актуальна тема пропонованої публікації, в якій аналізуються та досліджуються можливі логістичні військові дії для ефективного ураження цілей противника за допомогою рою ударних дронів. Метою дослідження є створення моделей для прикладної інформаційної технології, які дозволять планувати логістичні військові дії щодо ефективного використання рою бойових дронів для ураження цілей противника. Створюється системне представлення логістичних військових дій щодо використання рою бойових дронів. Аналізуються та виявляються цілі противника, які представлені у вигляді пріоритетного ряду з характеристиками актуальності, необхідного бойового потенціалу для ураження цілей, ризиків досягнення цілей, часу польоту дронів. З множини цілей відокремлюється підмножина, яка планується для ураження з урахуванням бойового потенціалу рою дронів та необхідного потенціалу для ураження виділених цілей противника. За допомогою оптимізаційної моделі проводиться раціональний розподіл рою дронів на групи для досягнення цілей противника та їх ефективного ураження. Планується рух дронів за допомогою відокремлених зон польоту з урахуванням можливих протидронових дій противника та ризиків військових загроз. Створюється імітаційна модель польоту рою дронів до виділених цілей противника за допомогою агентної платформи моделювання Any Logic. Моделювання дозволяє сформувати раціональні маршрути польоту рою дронів в умовах військових загроз противника. Наведено ілюстрований приклад формування логістичних дій для планування масованого удару по цілям противника за допомогою рою дронів. Наукова новизна дослідження пов’язана з вирішенням актуальної проблеми планування логістичних військових дій для ефективного використання рою бойових дронів щодо ураження цілей противника. Результати дослідження доцільно використовувати для оперативно-тактичного планування логістичних військових дій щодо ураження цілей противника за допомогою рою ударних дронів.

Ключові слова: рій бойових дронів; цілі противника; формування груп дронів; оптимізація розподілу дронів за цілями; планування маршрутів польоту дронів; імітаційне агентне моделювання.

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