Methodology for determining the optimal composition of the raid squad

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Abstract
Technological development of the warring parties, the introduction of new forms and methods of armed struggle, the trend of transition to a network-centric war necessitates the search for ways to improve the effectiveness of carrying out tasks behind enemy lines. The effectiveness of a raid squad in accomplishing its tasks will largely depend on the optimal distribution of available forces and assets over enemy targets. Therefore, the methodology for determining the optimal composition of the raid squad presented in the article is based on the most acceptable in terms of optimality algorithm based on the method of two functions. The proposed methodology takes into account the probability of a particular enemy object being hit by the units available in the raid squad and the coefficients of operational and tactical importance intended for destroying (disabling) enemy objects. The methodology is intended for use in raid actions planning.

Key words: raid actions, efficiency of raid actions, method of two functions, probability of defeat, coefficient of operational and tactical importance.

Introduction

The experience of modern warfare testifies to a significant increase in the intensity of warfare by the warring parties, causes a rapid change in the operational and tactical situation and increases the volume of combat tasks to be solved during their conduct, especially during the conduct of raid actions. At the same time the domination of one of the warring parties cannot fully ensure the success of the combat operations. The capabilities of the warring parties are becoming increasingly difficult to measure simply by the existence of a number of calculated combat units, since these units may have different qualitative characteristics, and at the same time the ability to combine them temporarily to carry out a combat task greatly increases their effectiveness in use. Performing combat tasks under such conditions requires commanders to use new tactical ways (techniques) of conducting combat operations behind enemy lines.

A promising way to improve the effectiveness of raid actions is to determine the optimal composition of forces and equipment needed to accomplish the combat mission. This will enable the commander to form raid squads from the available forces and assets that can most effectively accomplish the combat tasks of the raid actions.

Material and methods

The analysis of publications in open sources (Drol O., Guzchenko S., Telyukov S.; Barabash O., Zuyko V.; Collection of Tactical; Babenko R., YaroshenkoYa., Nikitenko A., Bazilo S., Zverev O.) has shown that considerable attention is paid to the issue of determining the optimal composition of forces and equipment needed to perform combat tasks. However, it should be noted that the available methodologies are mainly aimed at military formations that conduct one type of combat, or consider a separate type of support. On the other hand, the specificity of conducting raid actions provides for a combination of all types of combat. In this case, the known mathematical models are quite difficult to apply to determine the optimal composition of a raid squad needed to perform combat tasks.

Therefore, the aim of this article is to select the scientific and methodological apparatus for determining the optimal composition of the raid squad required to defeat enemy objects during raid actions.

Results and discussion

Regarding the choice of scientific and methodological apparatus, given the conditions of raid actions and the composition of forces and means involved, it should be noted that we are talking about the distribution of resources of different types between different types of enemy objects. Sufficiently simple and accurate methods in these conditions are methods of nonlinear programming (Fundamentals of Simulation; Bevzin E., 1974; Pashchenko T., 2011; Zagorka O., Mosov S., Sbitnev A., Stuzhuk P., 2005). One of these methods is the method of two functions, which allows taking into account both the diversity of forces and means involved and the diversity of enemy objects.

According to the method of two functions, the practical problem of determining the optimal composition of a raid squad required to fire on an enemy object can be formulated as follows. There are N different-type units in the raid squad. Each of them when under fire action on the l ($l = 1,...S$) enemy object, has a relative importance (coefficient of operational and tactical importance) A_l defeats it with probability P_{kl}. It is necessary to find such a distribution of units from the raid squad in which the enemy objects will receive the maximum (set) degree of fire damage.

The methodology for determining the optimal composition of a raid squad required to defeat an enemy object consists of blocks: determination of initial data, simulating the process of defeating enemy objects and a block for determining the optimal composition of a raid squad. The general block diagram of the methodology for determining the optimal composition of a raid squad is shown in Fig. 1.

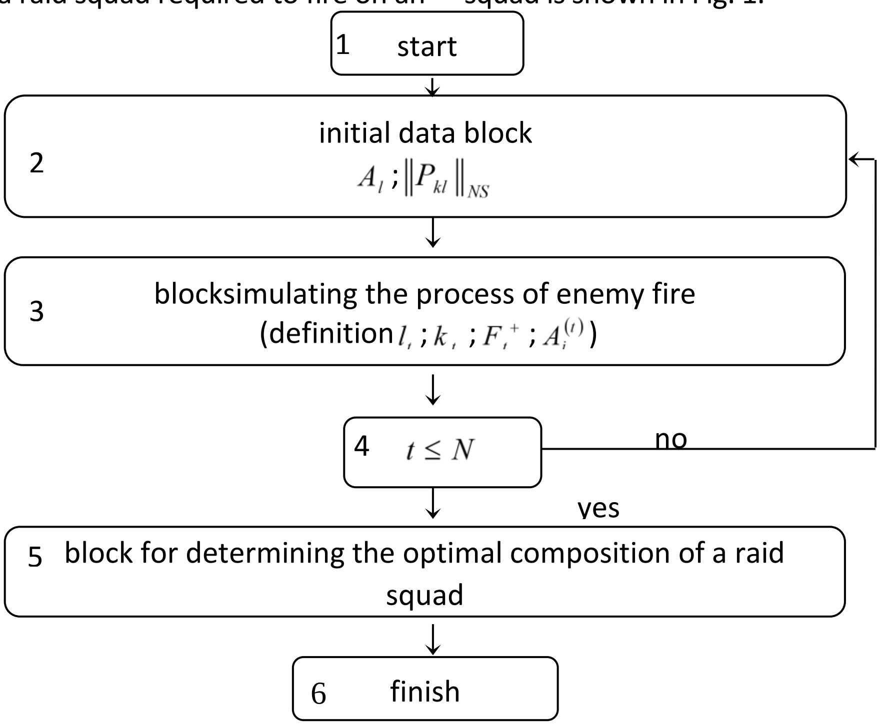

Figure 1 – Block diagram of the methodology for determining the optimal composition of a raid squads

The initial data block is formed on the basis of the analysis of the possible number of enemy objects by type within the raid zone (direction), raid squad units and units that are attached to it or support it

Along with this, the coefficients of operational and tactical importance are calculated for destroying (disabling) enemy objects according to the method outlined in (Zagorka O., Mosov S., Sbitnev A., Stuzhuk P., 2005; Oliinyk V., Danyliuk I., 2020; Oliynyk V., Kokoyko A., Golda O.,2020) and the probability of hitting the enemy object *l* by the *k* unit is calculated. The presence in the composition of the *k* unit of different types of means of fire (small arms, anti-tank weapons, armament of combat vehicles, artillery, etc.) requires determination of the probability of fire defeat of the *l* enemy object by these different types of means by the methods outlined in (Handbook, 1979; Wentzel E., 1964).

The block simulating the process of engaging enemy objects in fire (Tab. 1) determines the optimal method of selecting and assigning *k* units of the raid squad to *l* enemy objects while maximizing the target function:

$$F = F(\delta) = \sum_{l=1}^{S} A_l \left(1 - \prod_{k=1}^{N} \varepsilon_{kl}^{\delta_{kl}} \right) \qquad (1)$$

and constraints on variables:

$$\sum_{i=1}^{S} \delta_{kl} = 1, \quad k = 1,\dots,N \qquad (2)$$

$$\left.\begin{matrix} \delta_{kl} \in \{1;0\} \\ 1 \geq (\varepsilon_{kl} = 1 - P_{kl}) \geq 0 \\ A_l \succ 0 \end{matrix}\right\} \begin{matrix} k = 1,\dots,N \\ l = 1,\dots,S \end{matrix} \qquad (3)$$

where: N – the number of *k* units in the raid squad;

S – enemy object;

A_l – coefficient of operational and tactical importance of the *l* enemy object;

P_{kl} –the probability of defeat by the *k* raid squad unit of the *l* enemy object;

ε_{kl} –conditional probability of not hitting the *l* enemy object by the *k* raid squad unit;

δ_{kl} – a *k* raid squad unit assignment indicator at the *l* enemy object.

Simulation of the process of defeating enemy objects by fire occurs step by step. In the first subblock at each step of the distribution *t* the enemy object is determined, intended to be hit – l_t, depending on the weighting factor, the probability of its defeat and subject to the maximization of the expression:

$$A_l P_{kl} + \frac{A_l P_{kl}}{\varepsilon_{kl}} \prod_{k=1}^{N} \varepsilon_{kl} \to max \qquad (4)$$

Determining the unit k_t on the enemy object l_t selected in the previous subunit is done in the second subunit, in compliance with the maximum value of the dependence:

$$\left[max \left(A_l P_{kl} + \frac{A_l P_{kl}}{\varepsilon_{kl}} \prod_{k=1}^{N} \varepsilon_{kl} \right) - \sum_{l=1}^{S} \frac{A_l P_{kl}}{\varepsilon_{kl}} \prod_{k=1}^{N} \varepsilon_{kl} \right] = \Delta_{kl_t} \to max \qquad (5)$$

where Δ_{kl_t} – the value of the incremental gain function, which provides the distribution of the k_t unit to the selected l_t enemy object.

After assigning the appropriate k_t unit to the selected l_t enemy object, the third subunit determines the current value of the target function F_t^+:

$$F_t^+ = F_{t-1}^+ + \Delta_{k_t l_t}^+ \quad F_o^+ = 0 \qquad (6)$$

In the fourth subblock, taking into account the impact of the k_t unit on the l_t enemy object, the value of the coefficient of operational and tactical importance $A_i^{(t)}$ is listed after the *t*-step of the distribution by the expression:

$$A_i^{(t)} = A_i^{(t-1)} - F_t^+ \qquad (7)$$

In the process of optimization by the method of two functions the order of distribution of raid squad units is provided, at each step the largest gain function Δ_{kl}^+ is guaranteed with the smallest possible values of the loss function Δ_{kl}^-, i.e. the process of sequential distribution of the specified units of the raid squad occurs at maximization of the sum of gain function and loss function at each step:

$$\Delta_{kl} = \Delta^{+}_{kl} - \Delta^{-}_{kl},\ k = N^{(t)},\ l \in 1,\dots,S \quad (8)$$

$$\Delta^{+}_{kl} = A_l P_{kl} \quad (9)$$

$$\Delta^{-}_{kl} = \frac{A_l P_{kl}}{\varepsilon_{kl}} \prod_{kl}^{N} \varepsilon \rightleftarrows_{kl} \quad (10)$$

The step-by-step simulation of the engaging the enemy objects process is carried out in compliance with the condition $t \le N$, i.e it is completed when all available units of the raid squad have been distributed.

Table 1 – Tabular method of simulating the process of fire damage to enemy objects

t	*k,j*	*i,l*				Δ_{kl_t}	$k_t l_t$	ΔF
		1	2	…	*S*			
		$A_i^{(0)}$						
		$A_1^{(0)}$	$A_2^{(0)}$	…	$A_S^{(0)}$			
1	1	$\Delta_{1_1 1_1}$	$\Delta_{1_1 2_1}$	…	$\Delta_{1_1 S_1}$	$\Delta_{1_1 l_1^{(max)}}$	$\Delta_{k_1 l_1^{(max)}}$	ΔF_1
	2	$\Delta_{2_1 1_1}$	$\Delta_{2_1 2_1}$	…	$\Delta_{2_1 S_1}$	$\Delta_{2_1 l_1^{(max)}}$		
	3	$\Delta_{3_1 1_1}$	$\Delta_{3_1 2_1}$	…	$\Delta_{3_1 S_1}$	$\Delta_{3_1 l_1^{(max)}}$		
	…	…	…	…	…	…		
	k	$\Delta_{k_1 1_1}$	$\Delta_{k_1 2_1}$	…	$\Delta_{k_1 S_1}$	$\Delta_{k_1 l_1^{(max)}}$		
		$A_i^{(1)}$						
		$A_1^{(1)}$	$A_2^{(1)}$	…	$A_S^{(1)}$			
2	2	$\Delta_{2_2 1_2}$	$\Delta_{2_2 2_2}$	…	$\Delta_{2_2 S_2}$	$\Delta_{2_2 l_2^{(max)}}$	$\Delta_{k_2 l_2^{(max)}}$	ΔF_2
	3	$\Delta_{3_2 1_2}$	$\Delta_{3_2 2_2}$	…	$\Delta_{3_2 S_2}$	$\Delta_{3_2 l_2^{(max)}}$		
	…	…	…	…	…	…		
	k	$\Delta_{k_2 1_2}$	$\Delta_{k_2 2_2}$	…	$\Delta_{k_2 S_2}$	$\Delta_{k_2 l_2^{(max)}}$		
		$A_i^{(2)}$						
		$A_1^{(2)}$	$A_2^{(2)}$	…	$A_S^{(2)}$			
…								
N	*k*	$\Delta_{k_N 1_N}$	$\Delta_{k_N 2_N}$	…	$\Delta_{k_N S_N}$	$\Delta_{k_N l_N^{(max)}}$	$\Delta_{k_N l_N^{(max)}}$	ΔF_N
		$A_i^{(N)}$						
		$A_1^{(N)}$	$A_2^{(N)}$	…	$A_S^{(N)}$			

Based on the results of calculations performed during the simulation of the process of engaging enemy objects by fire (Tab. 2),

Table 2 – Matrix of optimal distribution of raid squad units

k, j	*i, l*			
	1	2	…	*l*
1	$j_1 i_1^{(max())}$		…	$j_1 i_l^{(max())}$
2		$j_2 i_2^{(max())}$	…	
…	…	…	…	…
k	$j_k i_1^{(max())}$		…	$j_k i_l^{(max())}$

a matrix of optimal distribution of raid squad units is formed. This matrix shows the optimal value of the target function *F*, the sequence of assignment and selection of $(k_t,\ l_t)_S$ units k_t to objects l_t at each t-step of distribution, and the optimal composition of the raid squad to be engaged for the defeating enemy objects.

Conclusions

Thus, the proposed methodology makes it possible to determine the optimal composition of a raid squad, taking into account the infliction of maximum losses on the enemy object while minimizing their own losses as much as possible.

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