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ASSESSMENT OF STRIKE EFFECTIVENESS AGAINST ENEMY LANDING GROUPS CONSIDERING SEQUENTIAL VOLLEYS AND COMBAT POTENTIAL REDUCTION IN COMPUTER SIMULATION

The object of research is a naval landing operations and interactions between anti-ship missiles and naval forces in a variety of simulation scenarios. Computer simulation is an essential tool for modeling and evaluating complex processes. Strategy-oriented video games allow model and interact with multi-layered systems in a modern warfare, in a variety of scenarios. This research presents a framework for modeling naval landing operation in a strategic wargame. The model focused on the interactions between attacking player using transport ships for naval landing, fire-support ships, minesweepers, electronic warfare units, and interceptor aircraft, and defending player which using anti-ship missile launchers and naval minefields. A key objective is to identify optimal defensive strategies under resource constraints, calculation possible unit interactions, to estimate possible outcomes, which can help that determine the best tools to prevent or execute successful naval landing operation.

The methodology was implemented using stochastic mathematical model to estimate the effectiveness of anti-ship missiles against different types of ships with different defensive setups. The methodology proposes different approaches, for the defending side player, targeting the most vulnerable or most important parts of attacking player convoy to ensure the most effective way to prevent naval landing operation.

Experiment results show the importance of dynamic targets prioritization for the defending player, and allows increase the efficiency of the provided resources up to two times compared to the basic targeting algorithm.

The given framework allows to improve realism of naval combat simulations in a video game and offers a scalable foundation for game balance adjustments or potential application in tactical training environments.

Keywords: *computer simulations, simulation framework, naval landing, anti-ship missiles, stochastic models.*

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1. Introduction

Within the spectrum of simulation games, the wargame genre represents a specialized field that focuses on the emulation of military systems, vehicles, and equipment. Wargames are distinctive in their capacity to recreate historical conflicts as well as to construct hypothetical scenarios.

The present research concentrates on naval operations, with particular attention to the interactions between anti-ship missile platforms, and naval forces in the context of naval landing operations. Realistic modeling of such scenarios, within video game engine, requires creating efficient frameworks which can be used in real time and required to create interactive and data-driven simulation for the players.

The literature introduced two guidance strategies based on differential game theory [1]. These strategies are developed from the attacker's point of view in a scenario with three main players: the attacker, the defender, and the target. The goal of these approaches is to let the attacker avoid the defender while keeping a safe distance from the target. An important feature is that the attacker does not need to know exactly how the defender or target are controlling their movements, which makes the strategies useful even when information is limited. This approach highlights how game theory can be combined with practical guidance methods to improve offensive operations in complex environments.

Another work describes an improved guidance method that helps groups of anti-ship missiles coordinate their strikes so they hit naval targets at the same time [2]. By synchronizing arrival times, the technique raises the missiles' chances of getting past ship defenses.

Studies provide mathematical models that describe how a combat ship behaves in both normal and damaged conditions [3]. The approach used is called Estimation-Before-Modeling, which first looks at individual state variables and parameters before analyzing overall patterns of hydrodynamic forces. The research compares the ship's performance when fully intact versus when it has sustained damage, focusing on how damage changes its ability to maneuver.

Another study argues that simulation games can go beyond entertainment or training to become valid tools for analyzing dynamic systems that involve human behavior, technology, and uncertainty [4]. Simulation games allow to build interactive, rule-based environments

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where players act, make decisions, and receive feedback, allowing them to explore more complex interactions and improve strategy.

The authors of another paper proposed a way to manage the growing complexity of modern engineered systems through a unified, model-based, and collaborative design methodology. And describe how mathematical models, sampling and sensitivity analysis can identify which parameters most influence outcomes [5].

To build foundation for the model, study uses various literature sources. Analyzing technical capabilities and effectiveness of anti-ship missiles allows to build better baseline for each variable in our model [6].

The proposed game framework has been structured to enable the simulation of a wide range of scenarios. At the core of the framework is a game engine database that contains all required parameters for each active variable in game scenarios. In addition, the framework provides the tools to enable evaluation of possible interactions between every active variable inside the scenario settings.

In this research, the framework provides models to describe interactions between anti-ship missiles and different types of ships and types of anti-missile tools to increase the simulation accuracy.

The object of research is a naval landing operations and interactions between anti-ship missiles and naval forces in a variety of simulation scenarios.

The subject of research is structured around a two-player confrontation. The attacking player is tasked with escorting a convoy of transport ships into the defending player landing zone in order to execute a landing operation. This offensive force typically consists of multiple categories of units, including transport ships (responsible for delivering ground forces), defense ships (providing defensive cover for the convoy), missile cruisers (capable of delivering retaliating fire), fire-support and minesweepers (which providing support during the landing operation), electronic warfare (EW) ships (specialized in jamming anti-ship missiles), and interceptor aircraft (designed to counter incoming enemy missiles). The defending player forces primarily centered on coastal missile launchers and, in some scenarios, defensive minefields that protect the designated landing zones.

The aim of this research is to decrease the success probability of the landing operation by strategically neutralizing transport ships and their support ships with anti-ship missiles, using the given number of resources.

To achieve this aim, the following tasks were accomplished:

1) to build a stochastic model which defines all interactions between each variable of the naval landing operation, such as defense ships and fire support, and calculate possible damage from a missile strike to rival player ships;

2) to identify an optimal strategy for the defending player to decrease the success change of the landing operation, and find the most optimal targets, and trying to use the given resources in a most effective way.

2. Materials and Methods

First player has the convoy of ships. Based on established strategies and tactical guidance from the literature, it is important to identify and define the core elements of a naval convoy for the landing operation [7]. It consists of 3 types of ships: transport, fire support, defense, and minesweepers. Let's assume that if full convoy will successfully reach the landing zone without any losses, then the success chance of the landing operation will be $P_{\max}$. Each type of group of ships has different impact on success of landing mission. The main factor is a transports ships, if none survives then the success chance is zero. For the minesweepers and fire-support groups the main task is to protect the transport ships during the landing. So, if convoy will lose the fire support or minesweepers, then without them the first player will lose some transport ships during the landing, and the chance for the landing success will be decreased.

For each task the defending player is assigned the specific number of missile launchers and anti-ship missiles. To effectively accomplish the given task, the player must find the most optimal use of the given resources and prevent the attacking player landing operation.

Let's assume that there is a one type of missile launcher which can load and launch only 4 missiles at a time, after that it has to be reloaded which takes some time. The baseline scenario also assumes that the attacking player doesn't have information about the first missile launch from the defending player, and will be ready to retaliate, by trying to destroy the missile launchers, only at the time of the second launch, and so on. So, from the defending player standpoint, there is increasing chance after each launch to lose some missile launchers. If defending player will lose all missile launchers before destroying the required amount of attacking player's transport ships, then it can be accepted that the landing operation was successful and defending player will lose a match.

Literature sources were used to define baseline parameters for all components inside the model, such as ships characteristics, missiles range and damage capabilities, anti-air systems and aircraft stats [8].

In the base version of proposed model, the exponential distribution formula will be used to determine all interactions in the simulation. Model is using similar but simplified version of a structure proposed in a paper [9].

To make a calculation for a potential damage of a missile strike to the defined target group, it is required to calculate the possible impact for each element of attacking player forces [10]:

- calculate the number of missiles that were destroyed by anti-air, interceptor jets and EW systems of attacking player ships;
- calculate the impact on a success chance of landing operation by each type of ships in naval convoy, such as transport ships, escort ships and minesweepers;
- calculate the chance of destroying the missile launchers by enemy missile cruiser after the retaliation strike.

To calculate the amount of the missiles which can evade interceptor jets with the formula

$$Q_{fa}(m,n)=1-P\left(1-e^{\mu_f \frac{m}{n}}\right), \quad (1)$$

where P – the probability for interceptor to strike down a missile; m – a number of interceptors; n – the total number of missiles; μ_f – a coefficient which defines effectiveness of a interceptor jet.

Formula to find the number of missiles, which will avoid the landing convoys total anti-air systems, could be defined similarly to interceptors. To do so, it is required to find a coefficient which will define anti-air capabilities of each ship group.

The anti-air capabilities of each group of ships inside the attacking player convoy could be calculated with a formula

$$\mu_t = K_t \sum_{k=1}^{N} \mu_{aak}^t, \quad (2)$$

where N – the number of ships inside the defined group; μ_{aak} – a coefficient that defines an anti-air potential of ships in a selected group; K_t – combat efficiency coefficient for the respective type of ships.

For each group of different types of ships, it is necessary to calculate the probability for a missile to avoid anti-air systems with a formula

$$Q_{aa}(n)=e^{-\frac{\mu_t}{n}}, \quad (3)$$

where n – the total number of missiles fired in a single launch.

If there is a ship with active EW systems in the attacking convoy, then there will be used the coefficient Q_{ew} to define the effectiveness of this systems against the anti-ship missiles.

Probability to destroy a ship in a targeted group could be calculated with the formula

$$W_i(m,n)=1-e^{-\frac{nP_{cap}Q_{aa}Q_{fa}(n)Q_{ew}Q_{tech}}{\omega_i}}, \quad (4)$$

where P_{cap} – the probability for a missile to successfully target a ship inside the group; Q_{tech} – the coefficient which defines number of missiles without technical issues; ω – number of hits needed to fully disable one ship.

The total mathematical expectation for the estimated number of destroyed ships inside the targeted group will be calculated with a formula

$$N=\sum_{i=1}^{N}W_i. \quad (5)$$

The missile cruiser role in a convoy to provide the retaliation fire against the anti-ship missile launcher of the defending player.

Probability of retaliation fire

$$S=S_m m_f l, \quad (6)$$

where S_m – a basic retaliation fire hitting chance of a missile cruiser ship; m_f is number of missile cruiser ships in a convoy; l is a number of missile launcher which defending player has.

After calculating the results of each strike, model will update the status for every ship in the order, depending on the total number of destroyed ships. And it is required to recalculate the potential changes for the chance of success for the landing operation for the attacking player. Model will use the simplified approach proposed in a literature [11] to calculate changes for the landing operation success.

In a convoy there are three types of ships which actively involved in naval landing and have a direct impact on a mission success: transport ships (T), which carry the troops and equipment for the landing; fire-support ships (F), which provide fire support to suppress defending player retaliation means; minesweepers (M), which will clear the way to the landing site for other ships, in case if defending player planted naval mines near the landing sites.

To calculate the probability of mission success chance, it is necessary to take into account the number of surviving ships at the beginning of the landing operation:

$$x_t=\frac{t}{T},\ x_f=\frac{f}{F},\ x_m=\frac{m}{M},$$

where t, f and m – the number of survived ships after approach.

Transport ships are essential, if none survive, success chance is zero

$$G_t=x_t. \quad (7)$$

Fire-support reduces losses of transports during landing. If degraded, the success probability suffers a bounded penalty

$$G_f(x_f)=1-B_f(1-x_f), \quad (8)$$

where coefficient B_f defines the maximum penalty for the landing success chance if all fire-support ships are destroyed.

Minesweepers protect transports against mines around the landing site; the formula penalty is similar to fire-support ships

$$G_m(x_m)=1-B_m(1-x_m), \quad (9)$$

where coefficient B_m defines the maximum penalty for the landing success chance if all minesweeper ships are destroyed.

The overall landing probability is

$$P=P_{\max}G_T G_F G_M, \quad (10)$$

where $P_{\max}$ – a maximum chance for the landing mission success, in case if all ships in the convoy will reach the landing zone.

This model assumes independent multiplicative contributions from each class of ships.

The quantitative coefficients assigned to different ship attributes, and missile specifications were systematically derived through a comprehensive review of multiple literature sources and openly available technical specifications. These values were processed and incorporated into the game engine's internal database, forming the foundation for scenario calculations.

The given framework is purely mathematical, so it could be implemented in any type of simulations, such as warfare simulation games, similar to ARMA 3, or any other software.

3. Results and Discussions

3.1. Experiments

For future experiments and model test, for different scenarios, calculations will use simplified values for all coefficients. One missile hit is enough to fully disable a ship.

1. *The first setup* for a rival player force will contain 12 ships in the transport group, 4 ships in defense group and 4 minesweepers. The defending player forces will include 3 launchers and 24 total number of anti-ship missiles. Attacking player forces don't have active air support and no active EW.

Base chance of naval landing operation success P_{max} = 0.95.

Coefficient for minesweepers loses B_m = 0.4.

Q_{fa}, and Q_{ew} coefficients will be equal to 1, because in the current setup there is no air support and EW.

In current scenario, anti-air means are present only on defense ships and in a smaller amount on transport ships.

For the ships in transport group, the coefficient defining their anti-air capabilities μ_{aa} = 0.1, which is taken from the game database. Main purpose of ships in the transport group in to transport personnel, because of that they have relatively small anti-air damage capabilities.

Anti-air damage coefficient for fire support ship μ_{aa} = 1, because ships of this type have better anti-air capabilities.

Anti-air coefficients for the transport and defense groups can be calculated using formula (2):

$$\mu_t=12\cdot 0.1=1.2,\ \mu_d=4\cdot 1=4.$$

Coefficient of ships combat efficiency, which are stored in a game database:

K_t = 0.45, K_d = 0.55.

Resulting total anti-air coefficient

$$\mu_{aa}=0.45\cdot 1.2+4\cdot 0.55=2.74.$$

With formula (3) can be calculated the probability of missiles to evade core group ships anti-air systems

$$Q_{aa}(n)=e^{-\frac{2.74}{12}}\approx 0.7959.$$

After each strike it is required to recalculate the anti-air probability and coefficients, because of changes in number of each type of ships and possible amount of missile launched.

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For simplicity, calculation of the probability of a missile to successfully capture designated target P_{cap} value will be with an assumption that missile always targets the designated type of ships

$$P_{cap}=\frac{1}{n},$$

where n – a number of ships in a targeted group.

Let's define coefficients for the missile reliability and the number of successful hits to disable targeted ship:

$$Q_{tech}=0.95,\ \omega=1.$$

Math expectation of destroying ships in each group will be calculated with formula (4)

$$W_i(m,n)=1-e^{-\left(\frac{m\cdot\frac{1}{n}\cdot 0.7959\cdot 1\cdot 0.95}{1}\right)},$$

where m – a number of missiles in a salvo; n – a number of ships in the targeted ships group.

After each strike on designated target ships group, can be recalculated the new potential chance of success for landing operation, which can define the estimated effectiveness of our decision to prioritize the chosen ship group, using formula (10). Current convoy setup is missing the fire-support ships, so only losses to transport ships or minesweepers will impact the resulting landing success chance

$$P=0.95\frac{t}{T}\left(1-0.4\left(1-\frac{m}{M}\right)\right).$$

Let's make calculations for the first launch of 12 missiles targeting the different types of ships and calculating the resulting possible success chance for the landing mission of attacking player.

Current example has 24 missiles and 3 launchers. Assuming that it is required to use all resources, defending player can make 2 strikes, using 12 missiles in each. Math expectation for each targeted group after the first launch of 12 missiles:

– for transport group:

$$W_i=1-e^{-\left(\frac{12\cdot\frac{1}{12}\cdot 0.7959\cdot 1\cdot 0.95}{1}\right)}=0.51,$$

$$N_t=12\cdot 0.51=6.13\approx 6,$$

$$P=0.95\cdot\frac{6}{12}\cdot\left(1-0.4\left(1-\frac{4}{4}\right)\right)=0.475.$$

The loses of half of the transport ships will decrease the success chance of landing operation by half;

– for defense group:

$$W_i=1-e^{-\left(\frac{12\cdot\frac{1}{4}\cdot 0.7959\cdot 1\cdot 0.95}{1}\right)}=0.883,$$

$$N_t=4\cdot 0.883=3.53\approx 4,$$

$$P=0.95\cdot\frac{12}{12}\cdot\left(1-0.4\left(1-\frac{4}{4}\right)\right)=0.95.$$

Because ships from defense group aren't directly involved in naval landing operation, the loses of defense ships don't decrease the success chance of landing mission. But it will decrease the anti-air capabilities of the convoy against the future strikes for minesweepers group:

$$W_i=1-e^{-\left(\frac{12\cdot\frac{1}{4}\cdot 0.7959\cdot 1\cdot 0.95}{1}\right)}=0.883,$$

$$N_t=4\cdot 0.883=3.53\approx 4,$$

$$P=0.95\cdot\frac{12}{12}\cdot\left(1-0.4\left(1-\frac{0}{4}\right)\right)=0.57.$$

The loss of full minesweeper group will decrease the success chance of landing operation by ~ 40%.

Next step is to calculate the second launch of 12 missiles. For the second launch defending player will always prioritize transport ships, but will make calculations from the different states which was calculated after targeting the transport group in a first strike:

$$W_i=1-e^{-\left(\frac{12\cdot\frac{1}{6}\cdot 0.814\cdot 1\cdot 0.95}{1}\right)}=0.76,$$

$$N_t=6\cdot 0.769=4.613\approx 5,$$

$$P=0.95\cdot\frac{1}{12}\cdot\left(1-0.4\left(1-\frac{4}{4}\right)\right)=0.109.$$

The total chance of a mission success is reduced to 11% from 95% after targeting the defense ships:

$$W_i=1-e^{-\left(\frac{12\cdot\frac{1}{12}\cdot 0.956\cdot 1\cdot 0.95}{1}\right)}=0.577,$$

$$N_t=12\cdot 0.577=6.92\approx 7,$$

$$P=0.95\cdot\frac{5}{12}\cdot\left(1-0.4\left(1-\frac{4}{4}\right)\right)=0.401.$$

The results show that after destroying the defense ship group, the anti-air capabilities of a convoy have decreased, but the difference is pretty small after targeting the minesweeper ships:

$$W_i=1-e^{-\left(\frac{12\cdot\frac{1}{12}\cdot 0.7959\cdot 1\cdot 0.95}{1}\right)}=0.51,$$

$$N_t=12\cdot 0.51=6.13\approx 6,$$

$$P=0.95\cdot\frac{6}{12}\cdot\left(1-0.4\left(1-\frac{0}{4}\right)\right)=0.278.$$

By targeting minesweepers ships and transport ships, defending player can reduce the mission success rate to ~28%, and it also can be very effective way to decrease chances of success for the attacking player naval landing operation.

2. *For the second setup* let's include all the possible variables for a naval landing group, except for the minesweepers. The convoy will contain 20 ships in the transport group, 8 ships in defense group, 4 ships in fire-support group, 2 ships with EW systems and 4 interceptor jets.

The defending player forces will include 4 launchers and 48 total number of anti-ship missiles.

Base chance of naval landing operation success $P_{\max}=0.95$.

Coefficient for fire-support ships loses $B_F = 0.35$.

Coefficient for EW systems will be equal $Q_{ew} = 0.5$.

Anti-air coefficients for transport and defense ships $\mu_{aat} = 0.1$, $\mu_{aad} = 1$.

To calculate the interceptor jets defense against the anti-ship missiles will be used formula (1). Using the coefficients from the game database for a given type of jets, $P = 0.75$, $\mu_f = 2.5$

$$Q_{fa}(m,n) = 1 - 0.75\left(1 - e^{2.5\frac{4}{16}}\right) = 0.65.$$

Because many possible variations in the given example, to simplify our experiment, it is assumed that attacking interceptors will be active only during the second missile launch.

Similarly to previous example, next steps will calculate the possible changes in landing operation success chance after prioritizing different groups of ships in the convoy. It is assumed that defending player is using all available missile launchers and missile ammunition during each strike.

To make calculation after the first strike (Table 1), similar to first example, it is required to calculate the math expectation to destroy a ship for each targeted groups, the total estimated number of destroyed ships in the group and updated chance for landing operation success after calculated damages.

Table 1

Calculations after the first strike

Target group (number of ships)	Transport (20)	Defense (8)	Fire-support (4)	EW (2)
W_i	0.227	0.475	0.725	0.92
N	4.55	3.8	2.9	1.84
P	0.73	0.95	0.708	0.95

Looking at the results after the first launch, defending player can see that the most impactful target is the fire-support ships. Targeting defense and EW ships seems non impactful, but if defending player decide to destroy them, it should drastically increase the power on our next strike.

Let's make calculations for the second strike, to analyze which type of anti-air defenses defending player should target to maximize the effectiveness of given resources. Calculations will start from 2 different states, based on which ships were targeted during the first launch, after targeting defense group, and destroying 4 ships (Table 2) and after targeting and destroying full group of 2 EW ships (Table 3). During the second launch enemy interceptor jets will also be active.

Table 2

Calculations after targeting the defense ships

Target group (number of ships)	Transport (20)	Defense (4)	Fire-support (4)	EW (2)
W_i	0.175	0.618	0.618	0.855
N	3.5	2.48	2.48	1.71
P	0.78	0.95	0.74	0.95

Table 3

Calculations after targeting the EW ships

Target group (number of ships)	Transport (20)	Defense (8)	Fire-support (4)	EW (0)
W_i	0.285	0.569	0.814	–
N	5.72	4.55	3.257	–
P	0.678	0.95	0.679	–

After analyzing given results, it is proven that decision to target EW ships during the first launch is more effective than targeting the Defense group, even accounting for active interceptors of attacking player.

Now let's continue our calculation, from a state, after targeting EW ships during the first launch (Table 3) and make same calculations after targeting each group of ships in the convoy: after targeting the transport ships (Table 4), defense ships (Table 5) and fire-support ships (Table 6) to find the most effective way to decrease enemy chances of successful landing operation.

Table 4

Calculations after targeting the transport ships

Target group (number of ships)	Transport (14)	Defense (8)	Fire-support (4)	EW (0)
W_i	0.528	0.731	0.92	–
N	7.39	5.85	3.71	–
P	0.313	0.678	0.455	–

Table 5

Calculations after targeting the defense ships

Target group (number of ships)	Transport (20)	Defense (3)	Fire-support (4)	EW (0)
W_i	0.459	0.98	0.95	–
N	7.39	2.9	3.81	–
P	0.514	0.95	0.455	–

Table 6

Calculations after targeting the fire-support ships

Target group (number of ships)	Transport (20)	Defense (8)	Fire-support (1)	EW (0)
W_i	0.458	0.98	0.99	–
N	9.17	2.9	0.99	–
P	0.379	0.95	0.6175	–

The results show that during the third launch it is absolutely useless to target defense group of ships, because defending player used all its resources and defense ships do not impact the actual landing operation. And the most effective way for the defending player to decrease the landing operation success chance is to target fire-support and transport ships in any combination, after decreasing as much as possible convoy's anti-air capability during the first launch.

In the given example, the most effective strategy for the defending player is to target EW ships during the first launch, then target transport ships and fire-supports during the second and third launches.

Let's make calculations using only basic targeting logic, targeting only transport ships (Table 7) to compare the results and effectiveness of both algorithms.

Table 7

Calculations after targeting only transport ships on each launch

Target group (number of ships)	Transport (20)	Transport (16)	Transport (13)
W_i	0.227	0.191	0.333
N	4.55	3.06	4.33
P	0.73	0.614	0.457

After using algorithm which targets only transport ships, the overall success chance of naval landing operation for attacking player is ~ 46% higher than if defending player used adaptive targeting algorithm.

3.2. Limitations of research and directions for its further development

This research proposes a model which calculates possible interactions between different variables of naval landing operations, from both player sides. Using game engine database with all specification of many types of ships, missile, interceptors, which different types of provided utility, it is possible to create and predict many outcomes for the players decisions in any scenario, which could be presented in the simulation.

Given stochastic model is not fully covering all the possible nuances of naval interactions, but it allows to increase the realism and accuracy for calculations for each type of interactions between different types of units which required more attention for the players. It is easily scalable to account for much more complex states and situations in the simulation scenarios, such as technical wear of ships and missile launchers, possible weather effects, more complex calculation of ship damage, etc.

Also, given models, allows to use much more complex algorithms, which can calculate and estimate much more precise targeting from the defending player for each active missile launcher separately targeting different types of ships in succession. Such algorithms will allow to find the most efficient strategy for the defending player, and allows attacking player to better counteract it with different setups for landing forces.

4. Conclusions

1. Build a framework for the computer simulation for analyzing two-player naval landing scenario, by integrating anti-ship missiles, ships anti-air capabilities, EW systems, fighter jets and other variables. The model covers all possible interactions between forces from each player side in a context of given scenario. The model allows to calculate all possible outcomes for each of the possible strategies used by the players. This type of simulation gives an advantage on a preparation step for the expected scenario of the upcoming naval operation.

2. Using the presented model, this research proposes a new algorithm to find the optimal strategy for each player in a multiple scenarios of naval landing operation. For the defending player, model allows the real-time calculations for each state of the simulation, to find the best targets to minimize the attacking player landing operation success rate. Experimental calculations confirm the effectiveness of this algorithm, and for some scenarios demonstrate an increase in the efficiency of using the defending player's resources up to two times. From the attacker's perspective, this algorithm allows for calculations to be made for a variety of possible outcomes prior to the landing operation. Which allows to find the most optimal naval convoy setup to increase the operation success rate.

With the possible extensions for each part of the model and future empirical calibration, this model and algorithms can evolve into a robust tool for both game balance tuning and even tactical training simulations.

Conflict of interest

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

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Data availability

The paper has no associated data.

Use of artificial intelligence

GPT-4o was used to help find relevant literature sources based on main topics of research, such as naval warfare, computer simulations and military video games.

The authors carefully checked and verified the reliability and relevance of the provided literary sources.

Authors' contributions

Oleksii Neizhpapa: Conceptualization, Methodology, Validation, Investigation, Writing; ***Maksym Maksymov***: Conceptualization, Methodology, Formal analysis, Investigation, Supervision; ***Oleksandr Toshev***: Conceptualization, Methodology, Validation, Investigation, Writing.

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