Find the Best Answer in the Conflict Scenario of Fighters with Electronic Warfare and a set of Defense Radars without Having Complete Information from Each other

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ABSTRACT:
Choosing a strategy for electronic conflicts in the field of action and situations similar to the problem scenario is a matter of experience and will not necessarily be the best possible choice. Therefore, the importance of providing a reasonable and measurable decision-making method in choosing a strategy in real conditions is quite clear. One of the points that can be deduced from the study of common methods and techniques in electronic warfare is that none of these methods are considered absolute winners and the holder can't consider himself the undisputed winner of the field. Because there is more or less the opposite of any technique. Using a method or tool in a situation may be very effective, but with a change of method or change of tool by the competitor, it becomes a weakness. Therefore, in this battle, the correct and timely use of each technique, and with full knowledge of the opponent and in accordance with the actions performed by him can be considered a factor of success and all useful tools in this field can be used. One of the most useful tools in the field of strategic decision analysis is game theory. With the help of this mathematical tool, the decision-making process between two or more decision-makers can be examined and the results can be analyzed. It is also possible to observe the effect of various parameters involved in the result of the problem, and to plan the result in the desired direction. In this paper, selecting the best response in different stages of the conflict to solve various such problems is achieved and the main purpose is to present a new approach to adopt a strategy and select the radar and disruptive coping technique in case of incomplete information from each other, using a method It is mathematical and algorithmic, so that we have a better performance in the benefit function of the parties.

KEYWORDS: Modeling, Scenario, Electronic Warfare, Radar.

1. INTRODUCTION

Since the game theory approach can be a mathematical framework for choosing the best strategy based on the profit function of the parties involved in a situation where due to the contradiction of profit functions and the choice of technique and setting some parameters by each party in favor of their profit function and the effectiveness of choices and The parameters of the parties do not allow the use of conventional optimization methods, and in the case of electronic collisions between radar and disruptors, exactly the same conditions prevail. Our guess is that game theory can offer a new approach to radar and disruptors that despite imperfect information The parties ensure that the best selection of available techniques and their adjustable parameters are provided in different situations. In game theory, both discrete optimal choices (techniques) and continuous optimal selection, ie the parameters of each technique at each stage of the game can be obtained. It is also possible to solve such games with the Bayesian methods despite incomplete information from the opponent to find the best answer.

2. GAME THEORY

Game theory is the study of multiplayer decision problems, and is used to help make decisions to optimize a parameter while that parameter is related not only to known parameters and decision making but also to the uncertain decision of other actors. Conditions that we encounter in abundance in war, especially electronic warfare. The development of game theory has helped to solve problems in the absence of sufficient knowledge

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of the parties about each other and the environment. And you can use this useful tool in choosing decisions such as allocating disruptive power or radar or selecting a specific channel to jump the radar frequency or disrupting or making a momentary decision to turn on or off the radar or disruptive or choosing a counter technique and adjusting the parameters of that technique.

3. DIFFERENT MODES OF GAME THEORY

Game theory discusses four general types of games: Strategic games with perfect information, Extensive games with perfect information, Strategic games without perfect information, and Extensive games without perfect information. In this way, the game type is related to four concepts of equilibrium, which are Nash equilibrium, Nash equilibrium, Nash Bayesian equilibrium and Bayesian equilibrium, respectively. In the simplest form of games, which are static or strategic games with complete information, each game has:

- Number of players,
- Actions (selection, strategy, technique, etc.) available to any player who performs simultaneously (or without knowing the choice of others),
- The payoff is each player for each combination of player actions.

If we assume the number of players in the game to be n, we number the players from 1 to n and call a particular player the i-th player and denote the set of actions available to him with A_i if $(a_1, \cdots, a_n)$ is a combination of player actions such that$a_i \in A_i$ is the action profile, $u_i(a_1, \cdots, a_n)$ will be the player's payoff. Now we show the game as $G = \{A_1, \cdots, A_n; u_1, \cdots, u_n\}$.

The purpose of solving the game is to get the choices that each player will have as a rational decision-maker in order to get the most payoff. In a game, the best performance for any given player generally depends on the performance of the other players. So when choosing an action, a a^* player must keep in mind the actions that other players choose. In Nash equilibrium definition that the performance profile of a in a strategy game with sequential preferences is a Nash equilibrium if for each player i and each action a_i of player i, a^* at least well prefers the action profile (a_i, a^*_{-i}) in which player i selects the function a_i and the other players select the function according to a^*. Equally for each player i and each action a_i, we have:

$$u_i(a^*) \geq u_i(a_i, a^*_{-i}) \tag{1}$$

So to solve the game, the following problem can be solved for each player:

$$\forall i \quad \max_{a_i \in A_i} u_i(a_i, a^*_{-i}) \tag{2}$$

If the solution of the game leads to Nash equilibrium, it does not mean that any combination of practical profiles for a particular player will not be better than this Nash equilibrium action profile, but it does mean that no player prefers to deviate his choice from this equilibrium. More generally, players' choices can be possible combination of actions available to them, and the concept of Nash equilibrium will be slightly more complete. In general, suppose player i has a K choice of action or so-called pure strategy, ie $A_i = \{a_i^1, \cdots, a_i^K\}$. Player i's mixed strategy can be the probability $p_i = (p_i^1, \cdots, p_i^K)$ on A_i distribution p_i^kprobability of choosing the net strategy a_i^k by player i, which of course we must have:

$$\forall i, k = 1, \cdots, K \quad 0 \leq p_i^k \leq 1 \ , \ \sum_{k=1}^{K} p_i^k = 1 \tag{3}$$

For simplicity, and of course in accordance with the needs of leading research, we consider the number of players to be two, the expected payoff of player i will be as follows:

$$U_i(p_1, p_2) = \sum_{k1=1}^{K1} \sum_{k2=1}^{K2} p_1^{k1} p_2^{k2}\, u_i(a_1^{k1}, a_2^{k2}) \tag{4}$$

When K1 and K2 the number of player net strategies is 1 and 2, respectively. The performance profile for the mixed strategies mode is shown as $p = (p_1, \cdots, p_n)$ that p_i, as mentioned above, is the mixed strategy of player i, which is a probability distribution on A_i of the set of actions available to player i.

The definition of Nash equilibrium in the more complete form of mixed strategies can be improved as if the performance profile of p^* in a strategy game with Von_Neumann – Morgenstern, which is a mixed strategy profile, is a Nash equilibrium if for each player i and each The mixed strategy p_i from player i, the expected payoff of player i from p^* is at least greater than the expected payoff from (p_i, p^*_{-i}) in which the other players have chosen their mixed strategy according to p^*. Equivalent to each player i and p_i mixed strategy,

$$U_i(p^*) \geq U_i(p_i, p^*_{-i}) \tag{5}$$

So to solve the game, the following problem can be solved for each player:

$$\forall i \quad \max_{p_i} U_i(p_i, p^*_{-i}) \tag{6}$$

To solve games as a pure strategy, there is not necessarily a Nash balance for each game, but by considering the possibility of mixed play, it can be proved that there must be at least one Nash balance for each game.

4. EXAMINING THE SUGGESTED MODES

In the scenario of confrontation between the invading Fighter(s), carrier of electronic support equipment and electronic warfare attack and hard attack with a set of search and tracking radars and defense missiles and anti-radiation missiles while informing both sides of the capabilities and possibly the profit functions of the parties are not complete. Numerous factors such as route selection, selection of different jamming techniques and different modes of radars and determination and adjustment of some adjustable parameters such as power, frequency range, etc. on both sides during the conflict can be to the advantage of each other. Be very effective. Our task is to find the best answer at each stage of the scenario to how to select techniques and set adjustable parameters.

The defense side may be from a general set of surface-to-air missiles [command and launcher guidance (which have a link to the launcher and determine the position of the missile and the target of the launcher radars and calculate the best path in the launcher). Semi-active (where the radar receiver is on the missile and the transmitter is on the launcher and the missile computer is guided by it), TVM (which is like a semi-active missile but the route calculations are done on the launcher, so like command-guided missiles with links Launcher communication), active (equipped with a fully active radar and no need to be guided from the launcher), mounted on beam and anti-interference missiles to counter disruptors, can launch one or more missiles to defend its facilities But the information on the offensive side is not of the type of these missiles and the capabilities of each. Also, defense radars may or may not have separate antennas for sending and receiving, and the type of scan and target tracking mechanism in these radars can be monopulse (amplitude or angle) or multipulse with conical or petal scanning. Defense radars can also be equipped with CFAR, Doppler and MTI processing or not, and also use normal gate gate or ascending edge technique in board processing and have the ability to use variable frequency jump and PRF or not.

The aircraft side can also be equipped with an electronic support system with the ability to identify some of the techniques and parameters that can be detected by radars. Also equipped with a variety of countermeasures such as the use of chaff, artificial aiming and noise interference and deception with RGPO and RGPI techniques and angle deceleration with cone scanning and petal disruption techniques for multipulse tracking radars and ground reflection and flashing and Formation In contrast to monopulse radars.

Each of the techniques and capabilities of the parties include adjustable parameters such as the direction, speed and time of opening the chaff or the amount of search radar power or MTI filter order and non-adjustable parameters such as gain and main beam width of the antenna.

Some of the choices of the parties become apparent to the other party after execution, such as the choice of type and amount of PRI by the radar or the selection and application of some disturbance techniques such as noise disturbance by Fighters, the reaction of the parties to these choices. By mastering the action of the parties, it forms an asynchronous or sequential game. In contrast, some choices, such as the use of CFAR mode radar or the application of Formation technique by the electronic warfare system to deceive the tracker radar, are not recognizable to the other party and the parties must make their decision without knowing the other party's decision and choice. This form of game is called concurrent games, which can form part or parts of sequential games. The game is generally played asynchronously and in several stages of the game, some of which may be simultaneous. The complete sequence of a conflict can be as follows:

Surveillance:

Detection ➡ Acquisition ➡ Identification
➡ **Targeting:** Initiation ➡ Tracking
➡ **Attack Coordination**
➡ **Weapon Launch:** Mid-course Guidance
➡ Detection ➡ Acquisition ➡ Tracking
➡ **Terminal Maneuvering**

I n general, the scenario of infiltration of Fighters into the area under the care of the defense can be expressed as follows:

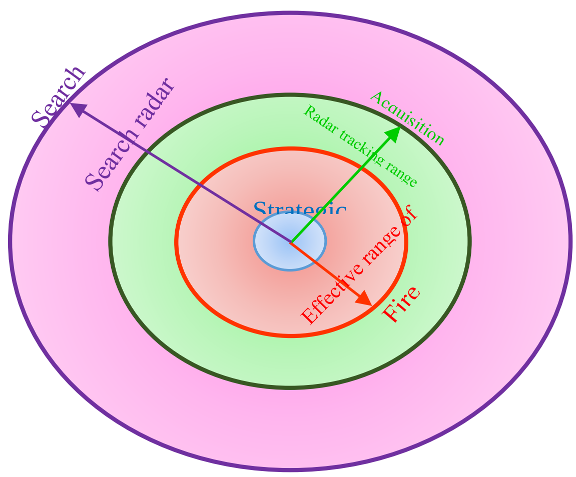

Fig. 1. Area under defense care.

The blue zone is the protected facility of the defense forces and the pink zone is the deadly range of the defense weapons and the green zone is the radar range of the tracker and the purple zone is the search radar range and the arrival of Fighters in each zone can take the game to a new main stage. For simplicity, we reduce the game to two general stages of search and tracking. At each stage, the two sides seek to optimize their benefit function (which is a function of the selected techniques, adjustable and unadjustable parameters of both parties). If we identify the parties with the indices R and B, respectively, according to the red and blue forces, the benefit function of each party in each step can be shown as follows:

$$U_j^i\left(ST_j^i, CP_j^i, ST_j^{-i}, CP_j^{-i}, NP_j^{-i}\right) \quad (7)$$

Where i can be any of the players and -i represents the other players who become other players in two-player games, alsoU_j^i is a function of the benefit of force i (offensive or defensive) in stage j and ST, CP, NP Selective techniques and a set of adjustable parameters and a set of non-adjustable parameters for each side, respectively. The set of non-adjustable parameters of the insider for the cost function of each side is assumed to be fixed numbers and is not represented as an argument.

In the sequential steps of ST and CP, the other party in the interest functions of each party becomes a fixed number and will no longer be a parameter.

In games with complete face information, the benefit function is much less complex in practice. Complete information means the intelligence of the parties on each other's capabilities and not on the choices and settings of adjustable parameters available during the conflict, and of course such a situation is not possible in the real world and can be solved with game solving methods with incomplete information.

4.1. The First Stage

4.1.1. Defense benefit function

In the first stage, the defense gain function is a kind of information value and increases with increasing radar range coverage, and by increasing the radar power to the maximum value and using variable PRF and frequency jump to remove more ambiguity than normal non-ambiguous radar range can reach the maximum Achieve your board coverage. This information value can be proportional to the angle covered by the radar or the information value of different areas is not uniform and the area of different parts with a weight specified in the function appear. On the other hand, increasing power and using some revealing capabilities can increase soft and hard threats. Soft threats, such as gathering information and identifying as many radar features as possible by an adversary or even third countries that are not currently considered imminent. A serious threat is the opponent's anti-radiation missiles. Both of these threats increase with increasing radar power and radar on time. The extent of these threats can be modeled on a cost function. The final defense benefit function in the first stage can be the information value obtained from the radar coverage range minus the cost function.

4.1.2. Offend benefit function:

The offense benefit function can depend entirely on the purpose of the offensive operation. If the offensive's goal is to create a trap for the defense to gather signal information, its benefit function will increase as the defense decides to turn on other defense systems, so the Fighter(s) will try to persuade the defense to take further action. Whereas when the target of the intrusion offensive is for reconnaissance or sabotage operations, quite the opposite will be to defraud the defense's subsequent actions to buy more time and try to prevent detection and detection by defense radars, their benefit function is the opposite. The benefit function for the defense force increases with decreasing radar visibility, minus the use of different weights in the weighting of different parts under the radar potential coverage, as the routes of operation and flight of the Fighters can be more important to the offensive forces. And try to further reduce radar visibility in these directions. Also, reducing the opponent's radar range by using various types of interference can cause soft and hard threat costs. Soft threat such as identifying disruptive features such as direction and location and countermeasures. Even if a disruptor is used on invading Fighters, it can detect them itself. Also a serious threat is the opponent's anti-radiation missiles.

4.2. Second Stage

4.2.1. Defense benefit function

In the second stage, the benefit function of the defense force can be determined based on the tracking and persistence of the radar lock on the Fighters and the specified time for the missile to fire and reach the target and the probability of hitting or being in the effective explosive range of the missile based on distance and guidance system. It is assumed that if the Fighter succeeds in breaking the radar lock and the radar notices that the lock is broken, a new phase begins, which requires a certain amount of time to re-search and re-lock, and the radar gain function is determined as in the second phase. If the radar does not notice the breaking of the lock, we will not enter the new stage and the radar will not benefit.

4.2.2. Defense benefit function

In contrast, for an offensive force whose purpose is to identify or destroy, we know that the closer it fires its missile at the target facility or the deeper it detects the area, the more likely it is to succeed (destroy the facility or get better). The higher the firing range, the more likely it is to escape the effective range of the defensive missiles. Therefore, the benefit function of the offensive force is determined based on the probability of success in destroying the facility or the success of detection and the probability of escaping from the danger zone. When the offense aims to collect signal information from enemy systems, its benefit function increases with the likelihood of detecting different signal parts of the enemy weapons system and the possibility of successfully sending the collected data before being destroyed by the systems or escaping the deadly weapons area. Offensive anti-electronic measures to break the radar lock at this stage may cause the lock to be broken and give the offensive force more opportunity to infiltrate or escape, as well as breaking the radar lock by deceptive actions if the purpose is to collect signal information. It can lead to the collection of information about some capabilities of the enemy system, such as the ability of their EP[1] systems and the speed of search and re-lock, and so on. In some cases, offensive electronic support systems detect the success or failure of breaking the lock, and in some cases, they cannot detect it. If the offensive force realizes its failure to break the radar lock, the game enters a new phase in which the offensive force performs another technique or the same technique to break the lock. The game ends when the offensive Fighter(s) either leave the deadly area of the defensive weapon or are hit by defensive missiles.

5. CONCLUSION

Given that the choice of strategy in electronic conflicts in the field of action and the best choice will not be possible, so the importance of a reasonable and measurable decision and calculation in choosing a strategy in real life is quite clear. Given that one of the most useful tools in the field of strategic decision analysis is game theory. With the help of this mathematical tool, the decision-making process between two or more decision-makers can be modeled and the results can be analyzed. It is also possible to observe the effect of various parameters involved in the result of the problem, and to plan the result in the desired direction. In this article, while solving the mentioned problem, how to model the battle scene and choose the best answer in different stages of the conflict to solve various such problems was obtained. Finally, this research and similar research can pave the way for providing a comprehensive algorithm for modeling and obtaining the best responses in various electronic conflict situations.

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