Applying game theory to solve the sea dispute and find the optimal solution using NSGA-II

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July 23, 2022

Abstract

The sea has an extremely important geopolitical and geo-economic position with its surrounding countries; therefore, sea disputes among adjacent countries are raising a worldwide concern that need to be solved together. Dispute in the sea mainly focuses on two classifications: sovereignty and exclusive economic zone with actions: assert sovereignty over the sea and islands, infringe sovereignty, take aggressive actions. In general, we are going to build a win-win model if involved countries are cooperative ,otherwise lose-lose model if they are uncooperative so that game theory and Nash equilibrium are easily applicable in this situation. In our paper, we are going to introduce a mathematical model formed on Unified Game-based model of game theory which is easily applicable to this dispute because it involves many countries and relates to the balance of benefits among countries.The NSGA-II Algorithm is implemented in this research to find the balance point in Nash equilibrium which involved countries could minimize the taken risks as well as share benefits with others. The result of this finding could be a scientifically promising solution for the involved country governments to choose the best optimal strategy.

Keywords: Game theory, Dispute, The Sea, NSGA-II

1 Introduction

The sea plays a major role in the development of its adjacent countries as well as the whole world in terms of geographical position and resources [1]. Firstly, the sea could be considered as the gateway for international trade that links countries and continents together through shipping routes. Secondly, the sea also provides abundant resources such as seafood, gas, and minerals to adjacent countries as well as the whole world. Hence, adjacent countries have dispute strategies to gain optimal benefits in the Sea. Each country has a different strategy depending on the force of those countries such as military force, and economic force. Weak and medium force countries want to establish a suitable environment to settle disputes and common challenges cooperatively. They also look for peaceful solutions to settle disagreements and disputes through dialogues in a straightforward and constructive manner based on international law. In addition, because of the sustainable development in the sea, these countries want to cooperate in all fields such as economics, and the environment [2]. While strong-forces-countries often take aggressive actions such as: asserting sovereignty over seas and islands unreasonably, and infringing sovereignty illegally. They also occupy control as well as develop a vast military infrastructure in illegal territories [3]. Moreover, these countries often take provocative actions like impeding exploitation of marine resources, prohibiting fish catching, and illegal arrests [4]...

For "game theory" definition, it is the academic study of competition and collaboration among players, who represent persons or other objects such as animals, items, organizations, groups ... [5]. Theory of games's principles provide a mathematical basis for simulating, structuring, analyzing, and comprehending game schemas. It also provides useful mathematical models and tools for understanding potential tactics that players may adopt when connecting or cooperating in game situations. The field of games that game theory can be applied to is nearly endless: amusing games, political situations, corporate competitions, international geopolitical challenges... This branch of applied mathematics is today employed in a variety of fields, including philosophy, computer science, international relations, politics, and the social and behavioral sciences[5].

For Nash equilibrium, it was named after an American mathematician who discovered it. With his contributions to game theory development , he was also given the Nobel Prize in Economics in 1994 [6]. When playing a non-cooperative game with no incentive for cooperation, Nash Equilibrium, a concept from game theory, finds the optimum course of action. If all other players stick to their original plans, players will not benefit from changing their strategy under the Nash equilibrium. In a game, there might be numerous Nash equilibria or none at all. [7].

In these above publications, the authors have mentioned the role of sea resources, the reason why adjacent countries participated in sea disputes, and strategies that are suitable for the condition of each country... Therefore, it could be said that they have just indicated the problem and its reasons. There is also a lack of specific solutions for involved countries. Finally, in this paper, by applying game theory and Nash equilibrium, we are going to fill this gap by finding the most optimal solution that balances the benefits among participating countries.

2 Literature review

In recent years, the situation in the world and in the region continues to be complicated and unpredictable, with many potential risks of dispute and conflicts, while the position of ASEAN countries on the sea is not consistent. Meanwhile, with the "Gray Zone" tactic – a method of increasing aggression and harassment but below the threshold of conflict, some countries have been raising tensions and threatening the peaceful environment in the region. Recently, through the "Tu Sa legal tactic", China, which has economic and military potential, continues to strengthen the activities of Law enforcement forces and militia fishing vessels into Vietnam's southern continental shelf, in order to implement a plot to monopolize the East Sea [8]. In addition, the strategic pivot of the US and the activities of some countries in the region has at times pushed up the risk of conflicts and disputes. It can be seen that this is not a small challenge for countries and will even be difficult for researchers, the solution to this problem depends on the unique characteristics of each situation and then apply different algorithms.

Surya Wiranto, Hikmahanto Juwana, Sobar Sutisna, and Kresnno Buntoro established a method based on UNCLOS 1982 and Ac No.17 of 1985 in facing conflict dispute resolution maritime territory in the south China sea [9]. Given that Indonesia is a legal nation, the law must serve as a guide in resolving the problem. This is done to establish legal certainty that can assist a variety of marine concerns, such as sovereignty and law enforcement, and to give the Unitary Republic of Indonesia's border firmness and certainty. Xinhui Zhong conducts the study by elaborating on some of these elements while employing three theoretical talks on realism, liberalism, and game theory: the South China Sea's distinctive features, including as its abundant natural riches, reversible location, considerable geopolitical importance, and

Asian viewpoint on sovereignty; China's and the US's interest and worries in this region [10]. Sacha Army at CUNY City College established a solution called "The ASEAN Way ", this kind enables communication between ASEAN leaders without making the conversations public, preventing humiliation that can cause additional strife [11]. The United Nations Convention on the Law of the Sea was used by Asif Khan and Maseeh Uliah, this offered coastal governments a greater case for claiming larger marine zones and related land areas; this did not lead to military confrontation, but rather to improved ties [12].

About Michael Perry, he finished this dispute game by using Multiple Fisheries and that situation was thoroughly resolved with costs imposed by patrols, response function for patrols,... [13]. Two methods MSI – SOM and Nash equilibrium MSY were used in the research of Niclas Norrstro¨m, Michele Casini, and Noel M. A. Holmgren. The functions were calculated for the more comprehensive methodological scope of dealing with sea disputes, and the MSI - SOM was employed for simulations of fisheries impacts on the interacting stocks. Nash developed a multiplayer game solution that claims that an equilibrium of strategies exists when applied to a multi-species MSY - oriented fishery that ensures the interest of increasing the output of each fishery while taking into consideration the ecological consequences on other stocks [14]. Folk theorem and Nash equilibrium have been shown clearly in "Economics of the oceans" by showing formulas and practical examples to give the most accurate results [15].

By applying three games Prisoners' Dilemma or Chicken game as a method, Andrea Eline Ringstad Eliassen provides the spectator a helpful summary of a specific scenario or conflict, while also learning about a state's strategy and interactions with other states As a result, game theory is a good initial step in studying and comprehending a state's strategy [16]. Kaveh Madani and Sona Gholizadeh established cooperative concepts which are beneficial in determining a fair and efficient allocation of the increased gains from collaboration among collaborating parties [17]. Hendrik F. van Hemmen, P.E. (FL), Hannah van Hemmen (AM) Martin and Ottaway used Nash equilibrium and the Nash approach which was developed by John Nash in 1950. These might also be useful in determining fleet make-up (high-low ship mix) in the face of rivals, and could be decided via neural network calculations rather than rigorous algorithmic techniques [18].

The non-cooperative fishery game model was used by Wang Lei, Chen Hua, Kang Meize, Ma Xiaochuan in "Game Theory Analysis of Marine Rights Protection" [19]. To increase the effectiveness of maritime rights protection, it is advised that current national rights protection forces be optimized and integrated, and that a variety of rights protection technological methods be developed. A professional research institution is advantageous for the countermeasure of rights protection, working with rank and file employees to resolve unresolved contradictions in everyday rights protection, and formulating strategic forecasts and emergency deployment.

"A Review of Game Theory Applications for Seaport Cooperation and Competition" employs game theory and Nash equilibrium [20]. The effects of service level differential in inter- and intra-port competition when two ports compete for cargo transshipment. The Hotelling and Cournot models were used to create the game. Profits were highest near vertically divided ports, according to the findings. Furthermore, a Nash equilibrium evolved from the vertically segregated Landlord Port rivalry.

Anton Nugroho, Avando Bastari, and Okol Sri Suharyo employ Defense and Security Theory to tackle this challenge [21]. The defense viewpoint on maritime security was subsequently broadened to include a broader range of threats. Most of the indicators of what is meant by security may be found in UNCLOS, including the treatment of "innocent passage" and the designation of a series of acts that would be inconsistent with the truth and thus damaging to the coastal state's peace, good order, and security. "Strategies, Conflict, and the Emergence of Territoriality: The Case of the Maine Lobster Industry" employs Game Theory once more [22]. They indicate that providers are more motivated to offer resources in cooperative allocation games.

Their study, on the other hand, looks at the allocation problem in a multi–resource setting. In the table below, several noteworthy articles and their variables are listed:

Authors	Publications	Methods
Surya Wiranto et al [9]	"The Disputes of South China Sea From International Law Perspective"	Used UNCLOS 1982 and Ac No.17 of 1985 to create legal certainty that can support a wide range of maritime such as sovereignty and law enforcement
Xinhui Zhong [10]	"The gaming among China, The Philippines and The US in the South China Sea Dispute"	GT was used to model the game and find out a strategy profile
Sacha Amry [11]	"An Analysis of the South China Sea Dispute: Focusing on the Assessment of the Impact of Possible Solutions on the Economies of the Region"	Conducts the study by elaborating on some of these elements while employing three theoretical talks on realism, liberalism, and game theory
Asif Khan et al [12]	"South China Sea Dispute Under Law of Sea"	The United Nations Convention on the Law of the Sea
Michael Perry [13]	"Analyzing a Complex Game for the South China Sea Fishing Dispute using Response Surface Methodologies"	Response Surface Methodologies focused on developing a response surface methodology to analyze the conflict
Niclas Norrströ¨m et al [14]	"Nash equilibrium can resolve conflicting maximum sustainable yields in multi-species fisheries management"	MSI – SOM and Nash equilibrium focused on developing a response surface methodology to analyze the conflict
Paul Hallwood [15]	"Economics of the oceans"	Folk theorem and Nash equilibrium discussed some modern cases where countries sign treaties, though do not definitely commit to rules making them work
Andrea Eline et al [16]	"A game-theoretic analysis of Chinese maritime strategy in the Senkaku/Diaoyu Islands dispute in the period 2010 to 2013"	GT showed how the players make their decisions through preferences for different outcomes
Kaveh Madani et al [17]	"Game Theory Insights for the Caspian Sea Conflict"	Cooperative concepts

Hendrik F. van Hemmen et al [18]	"Game Theory for the Maritime Professional"	Nash equilibrium and The Nash approach
Wang Lei et al [19]	"Game Theory Analysis of Marine Rights Protection"	The non-cooperative fishery game model was the struggle for maritime rights, that is, to realize the declaration and control of the sea area by rights protection, such as the Diaoyu Island dispute
Karlis Pujats et al [20]	"A Review of Game Theory Applications for Seaport Cooperation and Competition"	Game Theory and Nash equilibrium
Anton Nugroho et al [21]	"Strategy and Policy in stability of the ranaiteritory in the South China sea conflict"	Defense Theory and Security Theory
Jame M.Acheson et al [22]	"Strategies, Conflict, and the Emergence of Territoriality: The Case of the Maine Lobster Industry"	Game Theory

Table 1: Highlight publications and their factors

After all, literature evaluations show that traditional approaches can be conclusive and exact, but they often have downsides such low performance, time cost, user authentication procedures, resource status, and loading time and balance when using cloud resources. As a consequence, we conducted this study in order to address the remaining flaws by employing the theoric game strategy and the EMM algorithm. Game theory is used to investigate scenarios involving two or more people in which the result of one of their activities is impacted not just by that person's actions, but also by the actions of other participants in the game. The theoretical outcome of the game is shown as strategic combinations most likely to achieve the participants' aims based on the information provided to them. Strategic combinations are regarded to represent the player's equilibrium tactics when there are no players with an incentive to modify their behavior. As a result of these considerations, we feel that Game Theory is the most effective method for resolving the Sea Dispute. Exhaustive algorithms usually outperform deterministic algorithms in tests. However, deterministic algorithms are wasteful in these contexts, making them unsuitable for resource allocation issues in a growing environment. Maritime conflicts, on the other hand, are an open environment that needs great scalability and flexibility to satisfy user expectations. The writers of the aforementioned articles discussed the importance of marine resources, the reasons for nearby nations' involvement in maritime conflicts, and tactics that are appropriate for each country's situation. As a result, they may be considered to have simply stated the problem and its causes. There are also no precise solutions for the countries concerned. Finally, we will address this vacuum in this study by using some methods to discover the most optimum tactics that balances the benefits among participating nations.

3 Problem Description

Since the dawn of time, the sea has had a significant impact on our world. But as we grew in size and our domain got greater, we needed to discover more space and opportunities. This is when maritime disputes come into play. Sovereignty and exclusive economics are the two classifications that are at the center of the maritime conflict. Within each person's mind, a society, or a territory, sovereignty is what defines that authority[23]. In political philosophy, the term "sovereignty" refers to the capacity of another person to create or modify a legal system [24]. An area of the sea known as the "Exclusive Economic Zone" is one in which a sovereign state has particular rights for the research and utilization of marine resources, including the generation of water-based energy and wind. Informally, it is sometimes known as a maritime continental margin and may also refer to the continental shelf [25]. The territorial sea grants total sovereignty over the waters, as opposed to the exclusive economic zone, which only allows certain activities. International waters make up the surface waters, as indicated on the map[26].

Sovereignty and the "nine-dash line" between the Philippines and China serve as examples for this categorisation. After many incidents between the two countries, Philippine authorities raised the alarm and reaffirmed the 2016 decision of an international arbitral tribunal that rejected China's earlier claims. Chinese officials downplayed the military presence and discounted the decision and its repercussions. But covertly, China keeps bolstering a new, contentious presence in the South China Sea that could lead to confrontation [27]. And in response to these dangers, China has started to explore for a means to increase its rare earth supply. The only approach for China to assure ongoing access to this seabed would be to treat these waters as sovereign territory, which is the topic of our debate, especially in light of the new mining code coming out of the International Seabed Authority.

It also leads to the second classification, an exclusive economic zone. China is a large nation that wishes to grow even bigger, as is common knowledge. In the 21st century's great economic race, its nation is fiercely competing with other world powers. It should therefore come as no surprise that they would assert that China owns all nearby territories, giving them access to a larger market and more stakeholders [28]. New definitions and disagreements involving maritime boundaries emerged in the late 20th century. Each coastal state has always asserted sovereignty over a territorial sea that is quite close to its coastline. Some states made claims to a significantly bigger sea region as a result of fishing disputes in the 1970s. The Third United Nations Convention on the Law of the Sea (UNCLOS), which was established in 1982, established a number of territorial definitions that have been widely accepted. A 12-nautical-mile (approximately 19-kilometer) territorial sea is included in the territorial sea's full scope of sovereignty. Control of maritime resources is also extended to an Exclusive Economic Zone (EEZ) that extends 200 nautical miles (370 kilometers) from a country's coastline (land at lowest tide) [29].

The developing country and the developed country are the two main players in this game, as we have previously explained. Each nation asserts that its island and sea are theirs for a variety of reasons that are distinct from one another. For instance, China claims ownership of the whole Nanhai Zhudao, including any features that fall inside the "U-shaped line" that has been depicted on Chinese maps of the South China Sea since 1948. [30] Taiwan refers to the four "island groups" as the Xisha, Nansha, Dongsha, and Zhongsha separately (Zhongsha is actually a group of underwater features plus the Scarborough Shoal). The Hoang Sa and Truong Sa are claimed by Vietnam, and Scarborough Shoal and the "Kalayaan Island Group," which includes all of the Spratly Islands except for Spratly Island, are claimed by the Philippines. [31] These claimants are participating in a zero-sum game as a result. They can either gain control over every island group feature or nothing; there is no room for negotiation. Due of their strength, other countries start to dominate the sea and grab its resources. For instance, a country with nuclear power is unquestionably stronger than a country with only wind or water power. It is not just about power; it is about all of the characteristics and capabilities of powerful states as opposed to those of a developing one. To determine which side will benefit more from an advantage over the other, we must compare the traits of these two players[32]:

- The developed country has more manpower than the developing country due to its Population.
- The developed country has more surface area than the developing country therefore they have much more resources.
- The developed country has far more advanced technologies compared to the developing country because they develop much faster and sooner.
- Because developing countries still try to "develop" in order to keep up with other countries,

they do not have the time and budget to focus on war. On the other hand, developed countries have already moved to the part where they have to show their strength in the war to see.

In order to make our comparison more convincing, we should look into the number and let the number speak for itself:

	Developing country	Developed Country
Population	97,358,383	1,412,120,000
Avalible for military	30,000,000	382,821,101 km2
Surface Area	331,230km2	9,600,310
Annual GDP	342,941 M	17,458,036 M
Military Budget	6.2 Billion USD	252 Billion USD
Tanks	1590	5750
Air Force	274	4630
Nuclear Power	No	Yes
Nuclear Warhead	None	258

Table 2: Comparison between Developing and Developed Country

(Defect, Defect) is the sole pure Nash equilibrium, and both parties receive reward 1. The player who is cooperating can increase his payout in every other situation by switching to Defect. This is significantly worse for them both than if they play (Cooperate, Cooperate), which is also the socially optimal choice and where their combined rewards are highest at 6. Because of this, the socially optimal solution in particular is not a Nash equilibrium. The social optimum is (Defect, Defect) since criminals are mentioned in this scenario. Other games with comparable payout schemes are conceivable. For instance, why don't the two nations work together to maximize their rewards rather than battling over territory that is both theirs and the other's? (6). However, in this world, no country wants to share its territory with another and coexist peacefully, therefore both countries are at odds (Defective, Defective). However, in the exceptional case of a two-player zero-sum game, their approach equates to the polynomial-time solution of a linear program.
The linear program to be solved to find the column player's equilibrium strategy y in a two-player, zero-sum game is:

The primary purpose The payout from the column player to the row player is shown as eT p. Scalar 1 is made up of e and f. A is the Player 1 payout matrix. E and F are matrices with 1 m and 1 n units, respectively. We must resolve the dual problem in order to get the matching equilibrium strategy x for the row player. A solution to the primary problem determines a solution to its dual according to the strong duality theorem. The first program's duel is where the variables have the same definitions as in the previous example. In a two-player, zero-sum game, the solution of these linear programs is sufficient to identify the Nash equilibrium. If the game is in regular form, then the entries of A can be determined by reading the game's description[34].

1. Each country has 2 strategies or options to choose from: Defective or Cooperate.
2. Outcome for each country is analyzed from 3 perspectives:
    (a) Natural resources acquisition
    (b) Military cost
    (c) Relations in international business or trade
3. Each advantageous outcome of each perspective: +1
4. Each disadvantageous outcome of each perspective: -1

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="4">Developed Country</td></tr>
<tr><td colspan="2">Cooperate</td><td colspan="2">Defective</td></tr>
<tr><td rowspan="2">Developing Country</td><td>Cooperate</td><td colspan="2">Resources: +1
Military cost: -1
Relations: -1</td><td>Resources: +1
Military cost: -1
Relations: -1</td><td>Resources: +1
Military cost: -1
Relations: -1</td></tr>
<tr><td>Defective</td><td>Resources: +1
Military cost: -1
Relations: -1</td><td>Resources: +1
Military cost: -1
Relations: -1</td><td colspan="2">Resources: +1
Military cost: -1
Relations: -1</td></tr>
</table>

Table 3: Outcome of Corporate and Defective between developed and developing country

And since there is so much organization in the globe today—the 21st century—one nation cannot go to war with another at will. Many other countries are against the war. If colonial or maritime control continues, the planet will descend into chaos. However, it is legitimate to safeguard what belongs to us, in this situation, the sea that is nearest to our lands or countries. As previously indicated, a developed nation has adopted a different strategy by invading a separate marine domain (dispute sea). In order to threaten its adversary's country and start a conflict. However, the underdeveloped nation chose against going to war with a powerful opponent. Instead, they appeal for assistance from other nations and organizations. In order to determine the outcome of this zero-sum game, we have compiled all the information into a single table.

		Developed Country	
		Cooperate	Defective
Developing Country	Cooperate	-1,-1	-1,1
	Defective	1,-1	1,1

Table 4: Net outcome between Developing and Developed Country

4 Models

4.1 Game theoretical model formulation

Unified Game base model creates an approach for a game model and for players by analyzing many general through mighty structures. Besides, Nash equilibrium is a mixed strategy game theory model to solve the problem between many players. The game theory aims to solve the problem between the two sides of the sea dispute. It is used widely in a range of social science, and computer science, . . . and each player's strategy is optimal when considering the decisions of other players[35]. The Unified Game-Based model will be applied as below:

$$G = P_0, P_1, S_0, S, F(4.1)(1)$$

Where:

- P_0: is the normal player which represents for a developed country
- P_1: is the normal player which represents for developing country
- S_0: set of strategies for country planning the sea dispute distancing cost efficiency for the nation.
- S: a set of strategies for countries such as defect or co-operate based on the sovereignty and natural resource rate.
- F: is the normal player (country)‘s payoff function of corresponding to each strategy

Payoff function for normal player:

As we introduced from the problem description, quantifies is defined by many attributes cost of each player. Each player will contribute a part of the elements to the game to make a difference: a relation in the international business, natural resources, military, Sovereignty, fine, ... In sea disputes, special players don't appear due to their unclear definition of entity or particular player who can stand up to solve the problem in each game's strategies. The Unified Game Base Model is described as follows:

$$U_i = \frac{A_1 Rs_i + A_2 Ns_i - A_3 Ms_i + A_4 Ss_i + Fs_i R}{A_1 Rs_i + A_2 Ns_i + A_3 Ms_i + A_4 Ss_i + Fs_i R} \tag{2}$$

Where:
- U_i: percentage of quantifies the total cost of player i
- A_1, A_2, A_3, A_4 are the expert setting values to weigh the significance of these four factors on the cost for each strategy.
- Rs_i: is the Relation in international business or trade of player i
- Ns_i: is the Natural resources of player i
- Ms_i: is the Military Cost of player i
- Ss_i: is the Sovereignty Cost of player i
- Fs_i: is the Fine Cost, defined by country of player i
- R: quantifies the transmission risk of player i

4.2 Nash equilibrium formula

For example, in the case of a driver in the US and a driver in the UK. The first person to move their car in the US will have to go right like everyone else, and the second person moving with their car will have to go left accordingly. If the driver or the player here does not follow the traffic safety rules in each case, the different countries will not have the reward and must receive the consequences. Therefore, we need to have the best optimal direction to achieve the highest payoff for each game player.

In this research, These linear programs' solution allows for the determination of a Nash equilibrium in a two-player, zero-sum game. Nash equilibrium is a solution to reduce conflicts between countries on the sea. Because of sovereignty and exclusive economics of sea area, many conditions will be closely evaluated to give an optimal solution on other sides of each country. The players here on the disadvantaged side will rely on legal factors to claim their personal rights with clear evidence against other players who want to break the law in international courts. Besides, Relying on international map documents is a factor for players to rely on to make claims with other players. For example, Through the International Court of Justice (ICJ), Indonesia and Malaysia were able to settle their dispute over the islands of Ligitan and Sipadan in 2002. [24]. Almost all developing countries will try to cooperate with other players and try to minimize conflicts and damage costs for the country. On the contrary, developed countries try to create more pressure to increase their profits(territory, natural resources, . . .) by optimizing the available conditions with technology, military, and economy to show prestige by illegally encroaching on the territory. Finally, Along with the cooperation of countries and international intervention, provide a separate orientation for each country and common judgments for the game to minimize damage cost to players(countries).

Based on the Thomas-Kilmann model with five mode modeling for handling conflict presented. The Nikaido Isoda function presents the sum of the change between profit and loss of all players. With the Nikaido Isoda function, applying the gradient descent algorithm, our approach converges to a stationary Nash equilibrium under the convexity assumption on payoff functions, the same popular setting [37]. Hence, Nash Equilibrium measures the distance between each player and can be necessary and easily applied in the game base model. So, the Nikaido Isoda function defines Nash Equilibrium described as the Unified Game-Base Model:

$$f(x*, x) = \sum_{i=1}^{n}(f_i(x) - f_i(x[y_i])) \tag{3}$$

where x[yi] is the vector obtained by changing from vector x according to i from 1 to n. By using the Nikaido-Isoda function, Nash Equilibrium found a solution to the dilemma and it was appropriate to combine the elements to give the formula for the multi-objective algorithm to apply in-game. Therefore, from the above formula evidence, we can easily conclude that using Nash equilibrium is a method to solve the game and is a valid merit function for multi-player games, and presents an approximate descent algorithm.

5 Algorithm with NE

5.1 Solving the problem and finding Nash equilibrium.

This research offers a unique formulation, which we refer to as "behavioral uncertainty" for the remainder of the paper, that allows for justifiable departures from model-defined optimal responses. This formulation is comparable to near-Nash equilibria, as will be explained. The formulation described here stands out for its special quality of being robust, which enables a decision-maker to plan for the worst-case scenarios about an adversary's departure from his model-defined optimal behavior.

Understanding how decision-makers interact is the aim of game theory. It is a game in the traditional sense—"a competitive activity... in which players compete against one another under predetermined rules." It has been applied in both computer science and a variety of social science domains. A balance between the decision's benefits and drawbacks is necessary to manage the expenses of addressing the sea conflict issue that affects many people. Under the assumption that players cooperate in an effort to come to a consensus, the benefit value represents the caliber of each player's track record of activities. [37]

5.2 Definition and NSGA-II algorithm steps.

A reliable multi-objective algorithm with many practical applications is NSGA-II. Even though it is now outdated, NSGA-II is still quite useful, if only as a reliable benchmark for testing. The next generation is selected by NSGA-II based on nondominated sorting and crowding distance comparison after producing children using a certain kind of crossover and mutation. [37] The flow chart of the NSGA-II algorithm is shown in Fig 1, and the basic steps are as follows: 1. Assemble a populace. Pt (t = 0): Randomly generate an n-person parent population using the process.

2. First-generation population generation: This is the process of classifying data according to Pareto principles and calculating each person's degree of crowding following population initialization.

3. A sophisticated NSGA-II algorithm technique called binary tournament selection can locate people with the best genetic features.

4. Fusion of parent Pt and offspring Out: The parent and offspring are combined to prevent the loss of exceptional genetic traits in parent individuals throughout the generation of offspring. Then, the top scale n individuals are chosen from the combined population to continue inheritance..[37]

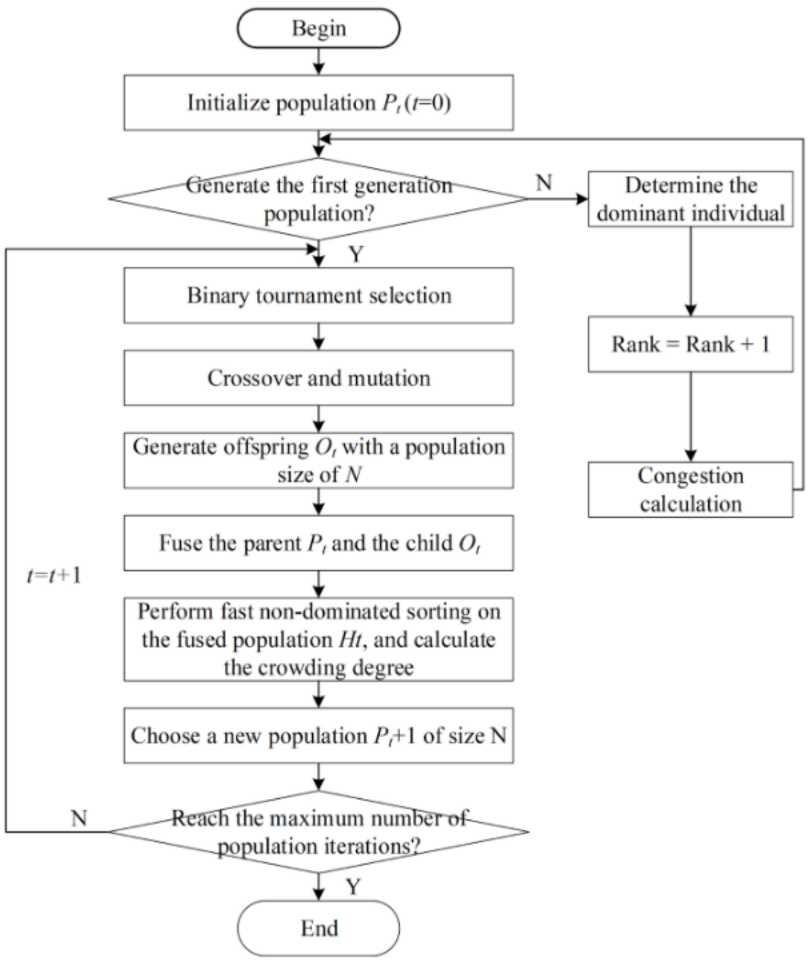

Fig 1. NSGA-II's flowchart [37]

5.3 Pseudocode

Initialize a parent population Pd randomly
Pd randomly = (u1, u2,...) = non$_d omination_s ort_m od(Pd)$
$fori = 1, i >= 0, i + +do$
$foreachuiPd$
$AssignlevelbasedonPareto - sort;$
$Generatesetsofpotentialsolutions;$
$Determinecrowdingdistance(ui, i = 0);$
$endfor$
$whiledemandislessthanproductvolumedo$
$useselection$
$crossover$
$mutationtomakeanewstrategy$
$createanewstrategyinnewU$
$endwhile$

$CombinePandU(forelitism)$
$Evaluatetheabovecombination$
$returnui;$
end

The NSGA-II separates the individuals from parent and offspring populations while taking non-dominance into consideration in order to produce multiple fronts for each generation (Lines 10 and 11). The initial front is made up of all non-dominated solutions. The second has a single resolution that outweighs all other options. Up until all of the solutions are categorized, fronts are built, with the third front featuring solutions that are predominately dominated by two other solutions.

To maintain the variety of solutions, another sort is conducted using the crowding distance for the same-front solutions (Line 12 of Fig. 2). Following calculation, the solutions are organized at decreasing distances. The crowding distance establishes how far apart a particular solution's neighbors are. The solutions at the edge of the search space benefit from large values of the crowding distance since the responses are more varied but have fewer neighbors.. [38]

5.4 Data Sets

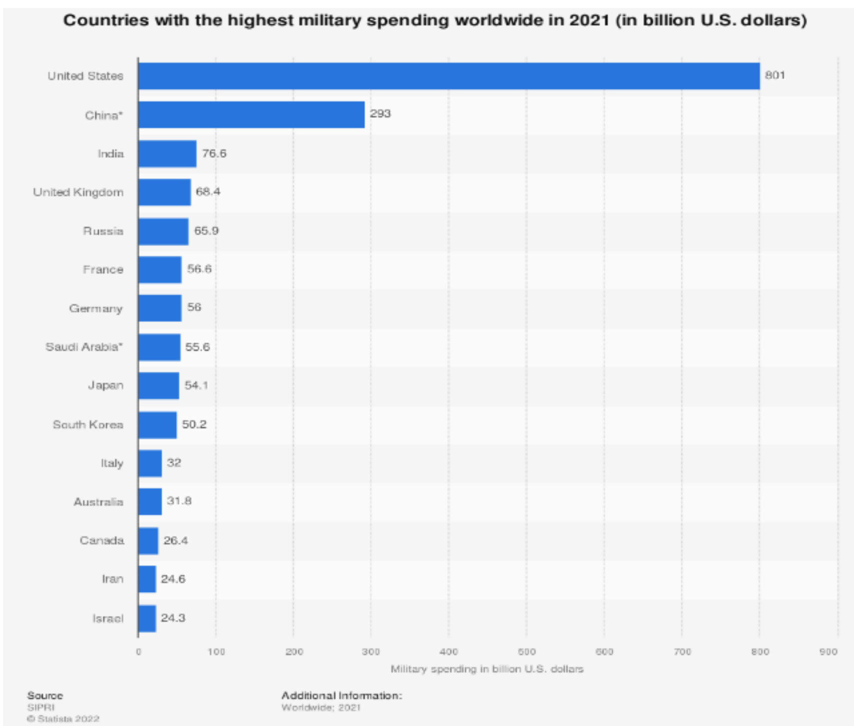

Figure 2. Countries with the highest military spending 2021 [39]

Figure 2 demonstrates that the United States led the list of countries with the highest military spending in 2021, with 801 billion dollars allotted to the armed forces. Of the 2.1 trillion dollars spent on military expenditures worldwide that year, that amounted to 38

According to estimates from the U.S. Congressional Budget Office, defense spending will have climbed from a low of $596billionin2014to915$ billion by 2031. The majority of the budget goes to the Departments of the Navy and the Air Force. Between 2013 and 2022, the US is anticipated to spend 392 billion dollars on nuclear weapons, 97 billion on missile defenses, and 100 billion dollars on environmental and health-related expenses. [40]

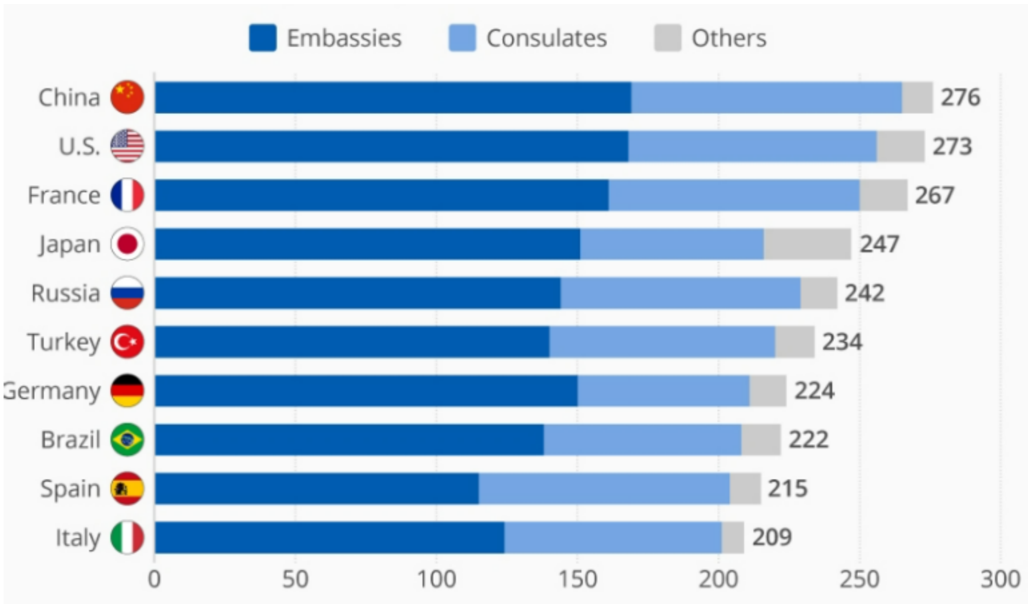

Figure 3. Countries with the most diplomatic posts abroad [41]

In terms of the number of diplomatic missions, China surpassed the US in 2019. The United States maintains 273 diplomatic missions abroad, while China has 276 of them, including 169 embassies.

A huge network of diplomatic missions has been constructed by China, some of which are located in isolated areas, such as the pacific island nations of Vanuatu, Micronesia, and French Polynesia, where the Chinese mission is the sole diplomatic representation. New diplomatic posts have recently been received in Burkina Faso, the Dominican Republic, and El Salvador; China seeks to strengthen its connections with these countries because they frequently traded with Taiwan.

Prior to 2016, China was rated third, behind the United States and France. In 2019, there were roughly 6,000 diplomatic posts worldwide, including 3,944 embassies, 1,588 consulates, and 414 other diplomatic posts. [41]

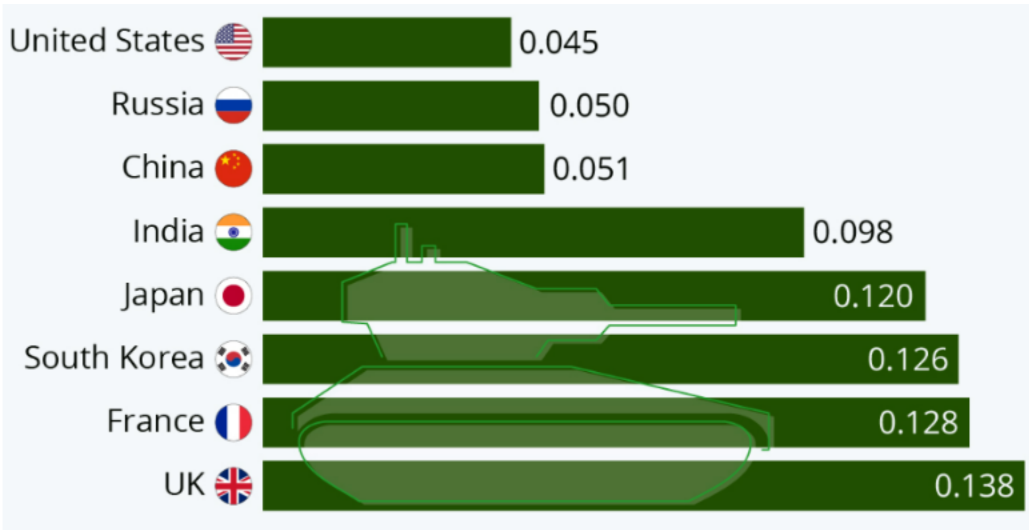

Figure 4. The world's most powerful militaries [42]

No military in the world can match China's in terms of manpower, according to Figure 4. According to projections from Global Firepower, the People's Republic has roughly 2 million active military personnel. Although it has a much smaller military than other countries (1.4 million), the United States leads all other countries in terms of military power, followed by Russia and China in second and third place, respectively. [43]

The Russian military buildup around Ukraine and increased Kremlin aggression seem to be increasing the chance that at least one of the world's most powerful militaries will use its strength in a large new fight. It is unknown how Russia will respond given that diplomatic efforts have so far been fruitless. There are also other areas where China and the United States could clash over Taiwan. [43]

6 Conclusion

Sea disputes are raising worldwide concerns that need to be resolved as soon as possible with the cooperation of involved countries. Because of the complexity of this problem that relates to many countries and balancing benefits among involved countries, we proposed a mathematical model based on the Unified Game-based game theory model with NSGA-II algorithm to find the most optimal solution. Our research introduced a different way that uses game theory and Nash equilibrium to resolve this global problem. Hopefully, based on our research, sea dispute-involved countries may find a suitable strategy for their own country.

7 References

1. The role and significance of the East Sea to the world, the region and Vietnam - National Defence Journal. (2022). Retrieved 7 July 2022, from http://tapchiqptd.vn/en/research-and -discussion/the-role-and-significance-of -the-east-sea-to-the-world-the-region-and-vietnam /17442.html

2. For a cooperative and peaceful East Sea — Videos — Vietnam+ (VietnamPlus). (2022). Retrieved 7 July 2022, from https://en.vietnamplus.vn/for-cooperative-and-peaceful -east-sea/197524.vnp

3. Linh, L. (2022). VIETNAM'S DIFFERENT NEGOTIATIONS WITH CHINA OVER TWO ISLANDS DISPUTE: PARACEL AND SPRATLY. Retrieved 8 July 2022, from http://tiara-tu.ac.th/uploadFiles/151550$_b$934e8a3294e6d4b1eee954708f72078.pdf

4. Overview of the East Sea Dispute - News VietNamNet. (2022). Retrieved 8 July 2022, from http://english.vietnamnet.vn/fms/in-focus/104409/overview-of-the-east-sea-dispute .html

5. Burguillo, Juan. (2018). Game Theory. Retrieved 8 July 2022, from https://www. researchgate.net/publication/321806355$_{g}ame_{t}heory$

6. Myerson, R. B. (1999). Nash Equilibrium and the History of Economic Theory. Journal of Economic Literature, 37(3), 1067–1082. http://www.jstor.org/stable/2564872

7. Nash Equilibrium. (2022). Retrieved 8 July 2022, from https://corporatefinanceinstitute .com/resources/knowledge/economics/nash-equilibrium-game-theory/

8. Nld.com.vn. Cung nhau giu Bien. https://nld.com.vn. Retrieved 5 July 2022, from https://nld.com.vn/bien-dao/cung-nhau-giu-bien-20220219203121182.htm

9. Wiranto, S., Juwana, H., Sutisna, S., amp; Buntoro, K. (1970, January 1). The agreement of South China Sea from International Law Perspective. The Southeast Asia Law Journal. Retrieved July 5, 2022, from https://www.neliti.com/publications/233634/ the-disputes-of-south-china-sea-from-international-law-perspective

10. (2022). Retrieved 5 July 2022, from https://projekter.aau.dk/projekt er/files/76994735/Thesis$_{f}inal_{e}dition.pdf?fbclid =$ $IwAR0ZA7.Y_{Z}MlZcjGOTrtcNTPdIvq3jVtHKS4wM1 - zoPpB098ZW3_{G}jpx$

11. (2022). Retrieved 5 July 2022, from https://academicworks.cuny.edu/c /cgi/viewcontent.cgi?article=1338context=cc$_{e}tds_{t}heses$

12. (2022). Retrieved 5 July 2022, from https://www.researchgate.net/publication /327564800$_{S}outh_{C}hina_{S}ea_{D}ispute_{U}nder_{L}aw_{o}f_{S}ea$

13. (2022). Retrieved 5 July 2022, from https://arxiv.org/ftp/arxiv/papers/2110 /2110.12568.pdf? fbclid=IwAR1nibdhQ02$_{h}1l1ChC9kM04GPy6Q5pfbq_{g}D5Ul1yZgoP82Odpv33Fyhsc$

14. (2022). Retrieved 5 July 2022, from https://www.diva-portal.org/smash/get/diva2:957471/ FULLTEXT01.pdf?fbclid=IwAR322LXwflH7eqvYHilbTyp3L$_{L}h8WCHtpV8TMA4SZOoLtVtEHW7YKkIi$

15. hallwood, p. (2022). Sci-Hub — Economics of the Oceans (Rights, Rents and Resources) —— — 10.4324/9780230083611. Retrieved 5 July 2022, from https://sci-hub.hkvisa.net/10.4324/9780203083611?fbclid=IwAR2EGPSHcE7vPFPiZE2sgVKCxhWNtTsEz-nhFQTXJTmpbml4stDxxs4Hq3s

16. (2022). Retrieved 5 July 2022, from https://projekter.aau.dk/projekter/files/76994735/ Thesis$_{f}inal_{e}dition.pdf?fbclid =$ $IwAR0ZA7Y_{Z}MlZcjGOTrtcNTPdIvq3jVtHKS4wM1 - zoPpB098ZW3_{G}jpx$

17. Sci-Hub — [American Society of Civil Engineers World Environmental and Water Resources Congress 2011 - Palm Springs, California, United States (May 22-26, 2011)] World

Environmental and Water Resources Congress 2011 - Game Theory Insights for the Caspian Sea Conflict — 10.1061/41173(414)293. (2022). Retrieved 5 July 2022, from https://sci-hub.hkvisa.net/10.1061/41173(414)293?fbclid=IwAR1ZB-jwbVfkciFd-cS$_OPBbK7ZZ6AP1cyurXKm4jYADyBzXXVp3O6eUNyU$

18. (2022). Retrieved 5 July 2022, from https://martinottaway.com/wp-content/uploads/2018/04/Game-Theory-for-the-Maritime-Professional.pdf

19. Game Theory Analysis of Marine Rights Protection. (2022). Retrieved 5 July 2022, from https://www.engineering.org.cn/en/10.15302/J-SSCAE-2019.06.015

20. (2022). Retrieved 5 July 2022, from http://ptolreco.com/DFI

21. Nugroho, A., Bastari, A., Suharyo, O. S. (2021). STRATEGY AND POLICY IN STABILITY OF THE RANAI TERRITORY IN THE SOUTH CHINA SEA CONFLICT (CASE STUDY OF INDONESIA, CHINA AND UNITED STATES). JOURNAL ASRO, 12(4), 1-11 http://asrojournal-sttal.ac.id/index.php/ASRO/article/view/416/335

22. Acheson, J. M., Gardner, R. J. (2004). Strategies, conflict, and the emergence of territoriality: the case of the Maine lobster industry. American Anthropologist, 106(2), 296-307 https://sci-hub.hkvisa.net/10.1525/aa.2004.106.2.296

23. (2022) Retrieved 5 July 2022 from https://www.cfr.org/global-conflict-tracker/conflict/territorial-disputes-south-china-sea

24. (2022) Billy Hayton. Retrieved 5 July 2022, from https://www.iseas.edu.sg/articles-commentaries/iseas-perspective/2022-25-how-to-solve-the-south-china-sea-disputes-by-bill-hayton/

25-26. What is the "EEZ"?: Exploration Facts: NOAA Office of Ocean Exploration and Research. (2022). Retrieved 9 July 2022, from https://oceanexplorer.noaa.gov/facts/useez.html

27. (2017) Patrik Berglund 5 July 2022, from https://www.xeneta.com/blog/south-china-sea-dispute

28. (2014) S. Jayakumar Retrivied 5 July 2022, from https://www.e-elgar.com/shop/gbp/the-south-china-sea-disputes-and-law-of-the-sea-9781783477265.html

29. Zhao Hong (18 Feb 2013) THE SOUTH CHINA SEA DISPUTE AND CHINA-ASEAN RELATIONS, https://www.tandfonline.com/doi/abs/10.1080/03068374.2012.760785?journalCode=raaf20

30.(2022) Leticia Simões Jun 23 2022 The Role of ASEAN in the South China Sea Disputes,https://www.e-ir.info/2022/06/23/the-role-of-asean-in-the-south-china-sea-disputes/

31.(2022) Ulises Granados Chinese Ocean Policies Towards the South China Sea in a Transitional Period, 1946—1952. Retrieved from 5 July 2022 from, https://www.jstor.org/stable/23462012

32.Retrieved 5 July 2022 from, https://countryeconomy.com/countries/compare/vietnam/china

33.(2022) Retrieved 5 July 2022 from, https://blogs.cornell.edu/info2040/2018/09/18/the-south-china-sea-conflict

34. (2022) Cheng Yong Lau, The Game Theory: Malaysia's position in South China Sea towards China's String of Pearls strategy. Retrieved 5 July 2022 from, The$_GameT_heory_Malaysia_{s_p}osition_in_South_China_Sea_towards_China_{s_S}tring_of_Pearls_strategy$

35. Chen, J., 2022. Nash equilibrium. Investopedia. Available at: https://www.investopedia.com/terms/n/nash-equilibrium.asp: :text=The

36. Zehao Dou, Xiang Yan, Dongge Wang. (2019, October 29). ArXiv:1910.12075v1 [cs.GT] 26 Oct 2019. Retrieved July 7, 2022, from https://arxiv.org/pdf/1910.12075.pdf

37. pymoo - NSGA-II: Non-dominated Sorting Genetic Algorithm. (2022). Retrieved 9 July 2022, from https://pymoo.org/algorithms/moo/nsga2.html

38. Rui A. Matnei Filho, Dec 2016: A multi-objective test data generation approach for mutation testing of feature models at https://www.researchgate.net/figure/Pseudocode-of-NSGA-II-adapted-from-Coello-et-al-2006$_fig7_3$05662662

39.Ranking: military spending by country 2021 — Statista. (2022). Retrieved 9 July 2022, from https://www.statista.com/statistics/262742/countries-with-the-highest-military-spending/?fbclid=IwAR2uH74DUj8n7r8h5M-hNsuQXHXKO-FOev67EDn4MZ0$_iXyDgX77_OALtj4$

40. McGee, R. (2017). U.S. Military Spending: A Look at Some Statistics. SSRN Electronic Journal, from https://papers.ssrn.com/sol3/papers.cfm?abstract$_id = 2927550$

41.Infographic: China Has Most Diplomatic Ties, Overtaking U.S. (2022). Retrieved 9 July 2022, from https://www.statista.com/chart/20138/countries-with-most-diplomatic-missions-in-the-world/?fbclid=IwAR3fiYHgc65gItQ76e-9ONQ9AvIc9Sb8ih9FVC1yApeg9UULHsNbUjgukvE

42. Infographic: The World's Most Powerful Militaries. (2022). Retrieved 9 July 2022, from https://www.statista.com/chart/20418/most-powerful-militaries/

43.Bayoumi, T., Hewitt, D., Symansky, S. (1993). The Impact of Worldwide Military Spending Cuts on Developing Countries. SSRN Electronic Journal, from https://papers.ssrn.com/sol3/papers.cfm?abstract$_id = 883816$