Overview of Application of Game Theory in Project Management

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Abstract:
The objective of the article is to review the research on applying game theory in the resolution of conflicts in project management. The author has analyzed game theory, types of games and based on conflicts in investment project management, the author proposed some algorithms that apply game theory in project management for experimental research and future application.

Keywords: *Game theory, project management.*

1. Introduction

According to PMBOK [1], large business operations are broken down into work segments, in which each project performs a separate task, is performed over a period of time and plays an important role in facilitating the state of the organization to a state other than special objectives. In which, the knowledge and skills of project management play a vital role to project activities. Project management is a crucial issue of the human economy, most activities in organizations and businesses are now organized according to the model of projects. Aspects of project management have been studied and published in many different works, notably the PMBOK document published by the Project Management Institute, but the conflict that occurred in the project is an important aspect that has not been addressed and handled properly.

Conflict in the definition of PMBOK [1] is differences in goals and behaviors between two or more subjects, differences in goals and behaviors that lead to differences in results or gains of object. According to PMBOK, in project management, the conflict that occurs during the management process is diverse, conflicts occur in each process of project management, the consequences of conflicts caused in management. The project is massive and unregulated even in the risk management process. In a few different studies, there are some interesting statistics such as: 60% of HR management time is spent dealing with conflicts, employees spend 2.8 hours per week dealing. with conflict. This equates to an equivalent loss of approximately $ 359 billion in wages (according to 2008 statistics with an average wage of $ 17.95 an hour in the US), or the equivalent of 385 million working days [2] .

Theoretically, the conflict issues are mentioned in PMBOK 6 more than the other versions, namely, in addition to the definitions, PMBOK has proposed a conflict management plan, however the The specific method is not clear. Finding a technical solution to model and generally solve conflict problems is a necessary and unresolved requirement. In understanding how to thoroughly resolve types of conflict in project management, game theory shows the relevance of theoretical significance and feasibility by research and publication of research. Game theory is a branch of applied mathematics, which studies tactical situations in which opponents choose different actions to try to maximize the outcome. Game theory was introduced in the 50s of the 20th century by many scholars, the theory has been applied to many different fields of society such as biology, economics, politics, information technology. believe, and play many important roles. In recent years, the application of information technology has been accelerated, especially in the construction of applications to support social and business operations. There are many different types of information technology applications, of which at the difficult and complex level of operational support are intelligent systems that help in making decisions for economic and social issues. Game theory, in current studies, has made a significant contribution to building theoretical models and applied products for those intelligent systems.

There are many universities or research institutes cooperating with companies and organizations that have research groups on game theory. These include: Game theory & computation seminar series at Harvard

University, Optimization and network Game theory group at MIT University, CS Theory Research group at University of Pennsylvania, Stony Brook center for Game theory at Stony Brook University. Or there are separate organizations researching game theory such as RAND Coporation, National Bureau of Economic Research, USA, SSRN - Social Science Research network, USA. The research on game theory is divided into the following main directions:

o Research on an algorithm for solving a subproblem of game theory: imperfect information game, or non-zero sum game [3, 4, 5];

o Research on how to apply the game theory model to social and economic purposes: politics, counter-terrorism, natural disasters, storms and floods, the society [4, 6, 7, 8, 9, 10];

o Research on how to apply game theory model to project management: risk analysis, assignment of tasks, cooperation, resource distribution, project selection [11, 12, 13, 14, 15, 16, 17, 18, 19];

o Apply game theory to some other information technology areas such as security, network security, data transmission, social networks [15, 20].

Game theory has been applied by many organizations and businesses around the world into management practice, changing the nature of people's thinking about management so far. Instead of thinking about your own personal wins and beating your competitors, game theory shows that good governance is a combination of competition and cooperation, management issues, and management of conflicts of interest in the implementation of a business is done under a win-win model.

In which, the research directions on the relationship between Game Theory and New Project Management stop at the angle of some in-depth articles analyzing a few solutions using game theory or Nash equilibrium in one number of small and specific problems. Examples are: game theory model for assignment of tasks [11], introduction of some game theory model algorithms related to scheduling problems [12, 13], security risks [15] and risks in the issue of terrorism [10]. From the study of international publications, it shows that there are two main issues in this research area: (i) there is no general study on the characteristics of all conflict problems in Project Management. project, (ii) there are still many other conflicting issues that can be converted to the Game Theory model but have not been explored and studied.

2. Literature review

Studies that apply game theory or the Nash equilibrium in practice often appear in many economic studies, and more and more in recent years. In addition, there are not many studies that suggest a specific solution to automatically calculate and solve, finding equilibrium is not much, the studies focus on analyzing the theory, building mathematical models, theorems that prove the feasibility of the problem, the existence of Nash equilibrium. Therefore, in this section, we will only focus on research and research of international publications related to: (i) the concept of game theory, (ii) Nash equilibrium, (iii) specific issues in applicable project management and (iv) specific algorithmic settlement methods will have a direct effect on the content orientation of the study.

From the study of international publications, there are two main problems in this research area, the first is that there is not a comprehensive study on all conflict problems in project management, The second is that there are still many conflicting issues that could transform into the model of game theory which has yet to be investigated. Specific researches related to the topic will be presented in the following sections:

Author Brent Lagesse in [11], the study of modeling assignments is a small-scale study, which introduces the problem of assigning unsuitable tasks. delivery, causing a lot of conflicts and reducing the quality of the project. Subsequent research has identified the characteristics of the task (task) and players (managers and staff), thereby suggesting the implementation steps according to the Gale-Shapely algorithm.

Advantages: researching on a new problem, giving mathematical modeling of the problem according to game theory.

Disadvantages: the model of the problem according to Game Theory already exists but not clear enough, the study has few results, the total number of pages of the study is 3, the study does not specify the algorithm, the interpretation of the algorithm. Mathematics is only described in natural language, there is no software construction, no illustrative results.

The authors Birgit Heydenreich, Rudolf Muller, Marc Uetz, 2007, in [12], study the principle design and model design for scheduling computer operations, to solve problems. in two stages of production management management and operation management. Research does not show manipulation on any specific software, mainly builds general models for the problem of scheduling general operation based on the principles of Game Theory. The research defines players here as agents, who are related to each different scheduling issue, and have different names, for example project managers, project staff ... Agents has its own preferences and behavior, so to handle conflicts it is necessary to generally define agent properties. In addition, the study also proposed a equilibrium model for agent benefits based on those attributes [12].

Advantages: has given a good model of scheduling in general, transforms that model into a well-informed game theory model, fully distinguishes the types of scheduling and has a description. Overview according to Game Theory.

Disadvantage: the research stops at the model building step, has not introduced a specific modeling method that can be deployed into algorithms and software.

Author Eric Maskin, 2008, in [22], has focused on exploring the theoretical and applied aspects of genetic algorithms for Nash equilibrium. In particular, genetic algorithms are one of the methods of processing optimal problem classes with maximum objectives, especially suitable for problem models according to game theory with noncooperative games [23]. The study provides a set of data and evaluates the implementation of Nash equilibrium according to the genetic algorithm on the basis of comparison with other algorithms.

Advantages: the model is fully explained, there is a comparison between the genetic algorithm and the Pareto curve method, there is an analysis of the results obtained from the algorithm.

Disadvantage: there is no clear indication of the steps to apply the practice, the way to move from theoretical model to practice is vague.

The authors Piotr Skowron, Krzysztof Rzadca, 2014, in [13], studies the content related to solving problems of a multi-organization system (multi oganizational system) when each of these organizations has the ability to provide processor level for the common data warehouse, in addition the study also considers the tasks that need to be performed related to the data warehouse. The task cannot be interrupted, stopped, or transferred to another processor. The study also modeled a collaborative game-model scheduling problem, using Shapley values to determine the ideal schedule. In this scheduling issue, the study does not mention money-related factors, the influencing factors include: the influence of one organization on another, the consistency between tasks: flow and execution time, and relationship between resources in the execution of the calendar.

Advantages: providing a complete mathematical model in describing a good schedule for implementation in a multi-organization system, proposing a specific algorithm to handle, with experimental results

Disadvantage: the model is not suitable for the model being studied by the topic.

The authors DENG Ze-min, GAO Chun-ping, LI Zhong-xue, 2007, in [14] focused on a small problem in the project, which is the matter of scheduling payments between the developer and the distribution team. development in an information technology project on software production. A software project consists of many stages with different subdivisions, based on the completion of the project, the contract signed between the

investor and the development team will be divided into several batches. different math. There are many factors that affect this checkout process such as:

- Order of implementing project activities
- Project billing milestones
- The investor's interest rate or the development team's loss rate when the cost of the work is delayed

Based on the characteristics of such a problem, the study uses the network of project activities to model the operation of the problem on a processable data structure, and then apply genetic algorithms. , using game theory in solving the problem.

Advantages: providing the direction of modeling the problem on game theory form, while analyzing the expression of the model by the genetic system, providing solutions for mutation, hybridization and reality. solutions with simulated data.

Disadvantages: project data is self-created, there are no quotes, analysis of project data, in addition, the results obtained do not match the constraints on the order of implementation of the input, there was email Discussed with the author about this issue, however there was no response.

Walid Saad, Tansu Alpcan, Tamer Bas and Are Hjørungnes have studied and proposed a quantitative model for managing security risks in an organization [15]. Research to explore the possibility of cooperation between independent parts of the organization in the treatment and assessment of risks with the aim of minimizing security risks. Collaborative game, which represents the linkage between the parts, is structured into a cooperative model based on an analysis of positive and negative dependencies. The properties of those security risks, in this study, are modeled on Nash equilibrium using Linear programming algorithms in the proposed computation.

Advantages: giving a mathematical model to model the dependencies, interactions between parts of the organization, for both models: the interaction model and the non-interaction model. There are simulated data and analysis results.

Disadvantage: only meant for reference to the topic, in the direction of implementing another Game Theory problem. No help software and experimental results.

Manufacturing companies are increasingly dealing with higher requirements for flexible, fast deployment of supply chain operations. Among these requirements, bidding is an important activity in purchasing in general, in the supply chain in particular. The very suitable expansive and flexible problem solving is converted into a problem in the form of game theory. The study explores how to model the procurement and bidding problem in this form. The research contents of Günther Schuh, Simone Runge, 2014 in [16] include: model analysis, problem identification and giving a K + objective function including the values of purchasing costs, ability We are, under the assumption, interested in buying, selling, bidding and storing it until it is deployed to a customer or production unit. The bidding results are processed to save the most costs for investors. Some of the issues addressed in this study include:

- Define the parameters related to bidding and procurement
- Determine the objective function K + of the desired problem
- Define the situations that occur, the attached conditions for optimal calculation of bidding results
- Present a model to process information from the Game Theory problem
- Model analysis

Advantages: closely related to a research direction of the topic, defining the parameters and cases of the problem logically, capable of applying, and improving in the topic that the postgraduate is implementing. .

Disadvantage: the model and the order of implementation steps are still general, just the proposed model, when deployed into the algorithm, there are still many problems. Research also does not show specific programming methods, so when modeling into an algorithm requires more research work.

The goal of the study of Guoming Lai, 2009 in [36] is to provide a framework for problems related to: automated multi-round negotiation, application of genetic algorithms. Negotiation issues involve many parameters of many different negotiated issues, carried out in a consistent time, while need to satisfy the win - win calculation of both parties, research contents. The following specialist includes the following components:

o Model theory of games and uncooperative game problems, analysis of models and Pareto optimization;

o Artificial intelligence model, proposing and analyzing frameworks such as agenda- based, case-based, non-biased and comparing with game theory model;

o Proposing a model for negotiating multiple parameters with 3 main focuses: imperfect information problem from game theory, Pareto optimization, building a bridge to solve difficulties between theoretical models and actual fluctuations.

Advantages: analyzing carefully the proposed framework, proposing an implementation algorithm to operate under the framework. There are examples and implementation results from the algorithm, analyzing the above results. Good reference to be able to compare with algorithms from genetic algorithms and game theory on topic problems - things that involve negotiation, have many parameters and fluctuate over time .

Disadvantages: refer to and compare with the current topic for a number of reasons: using Pareto optimally, analyzing the specific model of game theory is not much.

The research of Y. B. Reddy1, N. Gajendar1, S.K.Gupta, 2001, in [17] applying genetic algorithms to a game theory model for the problem of determining the sound band distributions of radio waves. The study analyzes the suitability of the application of genetic algorithms in the model of game theory, then the study shows the model of game theory with the applied math table. Proposing method of solving the problem using the tool "gatool" in MATLAB to solve the optimal problem based on genetic algorithms.

Advantages: having suitable analysis related to the topic in applying genetic algorithms in game theory. Proposing to use a tool in MATLAB to process and execute the model

Disadvantages: the analysis is too general, does not have a mathematical model, or detailed parameters when deployed according to the genetic algorithm. The research only opens up ideas of application and implementation direction, but cannot be applied in current research.

The authors, Franklin Y. Cheng, Dan Li, 1996, in [37] studied the analysis of maximum target optimization modes, focusing on using genetic algorithms and game theory. Proposing a processing method Genetic algorithm based on Pareto curve. Provide parametric analysis, making the Pareto-based genetic algorithm more flexible. The main contents of the study include [37]:

o Analysis of target optimization;

o Evaluate the optimal application of Pareto use;

o Simple genetic algorithm model;

o Analysis of possible algorithms for integration with Game Theory;

o Integrating genetic algorithms and maximizing targets into specific problems of controlling geological structures, a problem with many fluctuations and many parameters.

Advantages: Having objectives and implementation methods that are much related to the research topic, with much analysis on the application of combining both Pareto and genetic algorithms, which are two different ways to solve the problem. Optimal.

Disadvantages: The research is still scattered, suggesting many different methods and algorithms, but not going into any specific model. Special mentioning to many genetic algorithms, but there is no analysis of the specific configuration of the algorithm, consistent with the problem of the study, as well as the model of game theory.

Regardless of the authors published internationally, with domestic studies, no scientific studies related to the content of Game Theory are found, the studies are mainly at a few levels. The book is about the application of Game Theory in economics, or university student thesis which is synthesized and translated from foreign studies and mostly in the research of the economic field. Some related claims can be named Research on some of the tools of applied game theory in business decision making, 2014 [7], or Applying game theory cooperated in savings. pollution remediation fee, 2015 [8] are all theoretical studies. A few of the books found could be Game Theory and Application in Management - Business [6] or Business Intelligence and Game Theory [9], which has a lot of introductory and analytical nature.

3. Framework

3.1. Game Theory

Game Theory (GT) is a branch of applied mathematics used to analyze competitive situations where the outcome does not depend on the choice of one party or the choice of the other players. Therefore, the outcome will be up to all players' decisions, with each player trying to predict the choices of the remaining players to be able to make the best choice for themselves. Some ideas about game theory date back to the 18th century, but it was not until the 1920s that game theory developed greatly through mathematicians Emile Borel (1871-1956) and John Von Neumann. (1903-1957). A decisive event in the development of this theory was the publication of the book "Game theory and economic behavior" by Von Neumann and Oskar Morgenstern in 1944. In the 1950s, game theory model Beginning to be used in economic theory, political science and psychology began to study human behavior in experimental games. In the 1970s, game theory was used for the first time as a tool in evolutionary biology. Thereafter, game theory gradually dominated microeconomic theory, social sciences and other behavior [1].

There are many definitions of game theory, among which Maschler, Solan and Zamir define that: game theory is a method that uses mathematical tools to model and analyze states. involves many decision-makers - players. Game theory, according to Osborne and Rubinstein, is a package of analytical tools designed to help us understand the phenomenon that we observe when decision-makers interact with each other [35].

Game theory is applied to many disciplines and fields such as politics, ethics, economics ... and especially computer science applied in artificial intelligence and cybernetics. Game theory gradually plays an important role in logic and computer science. Some logic theories have basis in game semantics, simulating interactive computations [36, 37, 38].

The games studied and considered in game theory are well-defined mathematical objects. A game in game theory needs to fully define factors such as: people participating in the game; Information and actions are available to each player at each decision time (also known as a set of strategies) and payoffs corresponding to each combination of strategies. All of these factors are often used with a chosen solution concept so that it is possible to infer a balanced set of strategies for each player. Equilibrium strategies define an equilibrium of games or a steady state, in which either an outcome occurs or a series of outcomes occurs with a known probability.

There are usually two common ways to represent a game: Strategy game representation and Expansive game representation [3].

Strategy game representation (also known as normal form): is a form of representation matrix of reward and penalty for players' situations. This representation is a common representation of a game in which the players simultaneously make choices about their strategy. The reward and penalty results are presented in a table with each cell representing each pair of strategies. This form of representation is suitable when players are simultaneously making a decision without knowing the other person's actions. In a game in strategic form, the game model is represented by a data set consisting of 3 components (N, (Ai) $i \in N$, (ui) $i \in N$), where N is the set of players. Who is the strategy set of player i, ui is the payoff function for player i [35].

3.2. Types of games

Simultaneous games and sequential games:

Simultaneous game is a form of game where players will simultaneously make moves without knowing the moves at the same time of the other opponents. They simultaneously make decisions at the same time and are often described in terms of strategy play. The equilibrium of the game is reached when both make a reasonable decision and there is no reason for them to change it. A good example of this kind of game is the "Prisoner dilemma" problem. Sequential game is a game where players take turns making moves after knowing the moves of the players ahead. In a sequential game the following player has some information about the previous player's actions, but this information is not complete about all the actions of the previous player [4]. For example, player 1 may know that player 2 has performed specific actions before, but that player is not aware of player 2's other available actions. played in the form of a game tree, has a time axis and is also known as an extended game. Meanwhile, the game is simultaneously represented as a matrix of rewards and penalties, has no time axis and is a form of strategy game. An example of a sequential game is the "Fair cake cutting" problem in which the cake has different topping layers, the cake cutting is considered reasonable if it does not affect the decoration of the coating such as: cubes, fruits, and slices should be properly divided with the recipient who has a preference for the coating [68].

Symmetrical and asymmetric games:

Symmetrical games are games where the benefit of playing a particular strategy depends only on the strategy being used, not on who is playing. The reward and punishment mechanism for a particular strategy depends only on the tactics used. If the identities of the players could be changed without altering the benefit to the playing strategy then a game is symmetrical. Math problems similar to the prisoner's dilemma are all symmetric games [4]. Asymmetric games are games where the tactics used by each player are different. The majority of the asymmetric games studied were games that set different strategies used by two players. However, in some cases the game still has the same strategy for both players but is still asymmetric. An example of a symmetric game is the "prisoner's dilemma" problem introduced in section 1.2.1, the example of an asymmetric game is the "Ultimatum game" problem in which the word The initial money is given, the player must share with another player, that player can choose to agree or reject, when choosing to decline the two-sided strategy set becomes asymmetric.

The game has a zero sum and the game has a zero sum:

A zero-sum game is one where the player's total score is zero, the number of benefits gained by one player is equal to damage from another player. A zero-sum game is a special case of a constant sum game, in which the player's choice does not change the available resources. In this game, for every combination of strategies, the total score of all players in the game is always zero. Classic game types such as chess and chess are an example of a zero-sum game. Non-zero-sum games are games where the player's benefit is not necessarily derived from another player's damage or that player's benefit is not necessarily proportional to the other player's losses. It is

possible to convert any game into a zero-sum game by adding a puppet player so that the puppet player's damage compensates for the other players' total harvests [4]. The prisoner's dilemma is an illustration of a zero sum game because there are some outcomes where the sum is greater or less than the sum, and chess is an example of a zero-sum game.

Game information perfect and game imperfect information:

A perfect informational game is a game where the player knows all of the opponent's moves and is a subproblem of a sequential game. Hence only sequential games can be perfectly informational games. Most of the games studied in game theory are games of imperfect information except for some games such as Go, chess which are games of perfect information. Perfect information is often confused with the concept of complete information. Sufficient information requires that each player is aware of the strategies and achievements of other players, but not necessarily of their actions.

An imperfect information game is a game where the player does not know enough information about the moves of another player. The game is richer with information that is not exactly perfect for players to choose from. Modeling and evaluating strategic information is a strength of game theory.

Cooperative games and non-cooperative games:

A cooperative game is one in which binding commitments form between players. And in Non-Cooperative Games this doesn't happen. Usually exchanges between players will be allowed in cooperative games. In these two types of games, the noncooperative game can model the situation to the smallest details and give accurate results. Cooperative games focus on games of great complexity. A considerable effort has been made to align the two approaches because in practice many problems are a combination of no and no cooperation. That approach is called a Hybrid Game, which consists of both cooperative and noncooperative components [5]. One example of this type of cooperative game is the fisheries management problem outlined in [71] in which the conflict between two sides sharing the same water resource area, the two sides are forced to cooperate while remaining have its own calculations. In the noncooperative game, which is the more common one, the "Prisoner Dilemma" problem is a prime example because in calculating strategies, two players mainly choose the method of not cooperating with together

4. Conclusion

Some algorithms apply as follows:

NSGA-II algorithm

NSGA-II algorithm was developed on the basis of original GA algorithm and NSGA. NSGA is a genetic algorithm that uses a dominate strategy in evaluating the adaptive function of individuals in populations. It can be understood that NSGA uses the above concept to rank individuals, then find out the Pareto Front set. In addition to the above criterion, in fact NSGA also uses one more criterion: coverage, the solution with greater coverage (the further away from other solutions), the higher priority. This is an additional criterion to ensure that the solution set is diverse, not clustered.

An overview of the NSGA steps:

- Random individual trainings.
- Hybrid and mutation.
- Rate then select.
- If satisfied, stop, if not, start back to step 2.

NSGA-II improved over NSGA in the Pareto Front classification step.

GDE3 algorithm

GDE3 algorithm is also based on genetic algorithm, however, in GDE3 there is no hybrid, only mutation and selection. The idea of GDE algorithm is to mutate individual x into x 'according to a certain rule. Then compare x with x and see which individual is better. GDE2, GDE3 were later developed on the basis of GDE. GDE3 extends mutation modality with M-Objectives and K-Constraints. The selection rules of GDE3 are as follows:

o Both are not feasible: the new is chosen if the violation of the constraint is less than the old;

o When there is 1 viable and 1 viable item, the viable item is selected;

o Both are possible: the new instance is selected if the dominate is weaker than the old one in the target function, the old instance is selected if the new instance dominate. Choose both if neither instance dominates any;

o After 1 generation, the number of individuals may increase. If this is the case, then decrease the size of the population like NSGA-II.

The PESA2 algorithm

In algorithms such as PAES or PESA, the target space is divided into hyperboxes, each of which is occupied by objects used for selection. Describe the hyperbox division as shown in Figure 1.8. A maintained archive contains only non-dominant solutions, and instance selection is performed from this set only. The adaptive function of an instance is calculated by the number of other solutions in the same hyperbox with that instance. The PESA2 algorithm is based on the standard principle of an evolutionary algorithm, maintaining two populations: an internal population of a fixed size and an external population, such as a population. There is no fixed number of individuals, but limits on population size [56].

The local population stores the solutions generated from the archive by various transformations, and the archive contains only the dominant solutions that are discovered during the search. A decision grid is created over the target space to maintain population diversity. The decision grid is divided into multiple hyperboxes. The number of solutions in a hyperbox is called the density of the hyperbox and is used to differentiate solutions in two important processes of a multi-goal evolutionary algorithm (MOEA): selection based on hybridization and sifted from the environment. Unlike other MOEA algorithms, the hybridization in PESA-II is done by region rather than by individual. A hyperbox is first selected and then the instance selected for evolution will be randomly selected from the selected hyperbox, so larger hyperboxes will not contribute more instances than the lesser hyperboxes [58].

During environmental selection, candidate instances in the internal population in turn are added to the archive set if it is not dominated by any of the individuals in the population, and is not dominated by any of the items in the archive. When an instance is added to the storage set, the storage set changes and the grid hyperboxes. First, instances in the archive dominated by candidate instances are discarded to ensure that only non-dominant instances are in the archive. The grid is then checked to see if its boundary has been modified by adding and removing instances. Finally, if adding an element causes the storage set to fill, a random word in the largest hyperbox will be removed [58].

E-NSGA-II algorithm

ε-NSGA-II comes in 4 versions and they are built on NSGA II. This algorithm expands NSGA II by applying the concepts ε-dominance, adaptive population sizing and self termination [59]. Users can pre-determine the accuracy they want with the optimal Pareto solutions obtained. Basically the idea is to apply a grid (size based

on the value set by the user) to the search space. The larger the value ε, the faster the algorithm can run but has fewer solutions and vice versa, the smaller ε will take longer, but give us more solutions.

The solutions will have its own adaptive value, from this suitability value we can refer to the solution in a separate area. Solutions in the same region will be compared against each other using NSGA II, solutions that are dominated will be excluded. This results in each region leaving less than one non-dominate solution, resisting clustering and leading to more diverse solutions [59]. The population was further duplicated to 4N individuals for use in the next run of ε- NSGA-II. The algorithm is paused to allow a user to judge if the ε-dominate set has reached a certain precision.

The SMPSO algorithm

SMPSO is initialized with a random group of individuals (solutions) and then find the optimal solution by updating generations. In each generation, each individual is updated according to the two best values. The first value is the best solution to date, called Pbest. Another optimal solution that the individual follows is the globally optimal solution Gbest, which is the best solution that the neighbor has so far. In other words, each individual in the population updates its position according to its best position and that of the individual in the population up to now [19]

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