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Deterministic Strategy Approach to the Problem of Decision Making

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Abstract: In this study, an overview of decision making with emphasis on two-person zero-sum game is presented. A deterministic approach, which assumes rational behaviour on part of the players are given. And finally, an overall control structure of a computer solution to solving a two-person zero-sum game is presented.

Key words: Decision making, two-person zero-sum game, game theory, deterministic approach, player, pay off determination, conflict, algorithm

INTRODUCTION

Power and intelligent play has come to characterize world polities. Nations across the globe and indeed corporate bodies and individuals across frontiers now deal with their supposed neighbours with suspicion. A powerful country is noted not by the numerical strength of her troops but by the amount of diplomacy and intelligence it can display to outwit others. For this reason, game analysis has become an effective tool in designing the economic and political policies of any country that is worth her salt in the 21st century.

Game Theory permits us to show mathematically, that dilemma can arise even in a population consisting entirely of altruists. Iikka (2000) opined that the fascination of game theory emerges from the fact that it shows us how we can not simply derive conclusions about outcomes in competitive setting form psychological facts about the competitors.

Competition is usually, a combination of conflicts and cooperation (Per, 1999). The purpose of this study is to model conflicts. For simplicity, it excludes elements that would lead to cooperation and concentrates solely upon situations of direct conflict. The theory of many competitive business situations are too complex to solve. In this study, we refer to competitive situation as "game". In a game, there will be conflicts between players in terms of what strategy to use, when to use a particular strategy and how best to maximize gain and minimize loss. We assume the game is not bias and every possible constraint is considered. No player is favoured, all are equally treated.

In decision making, actions of decision makers are either predictable (deterministic) or represented as being determined by a chance mechanism described by probabilities (Adeosun, 2002). These consequences have the attribute of predictability, at least in a probabilistic sense. We have a lot of important decisions problems around us today where the consequences of the decision maker's actions are determined partly by a few other decision makers whose interests are in direct conflict. Such problems are usually difficult to solve but are important from a conceptual viewpoint.

Game theory: Game theory embraces all competitive decision-making situations (Karin, 1999). It addresses possible approaches to decision-making under the assumption of complete ignorance (Carter and Price, 2001). The point of game theory then, is not prescriptive but descriptive analysis of a game permits us to locate equilibriums and thus to predict those states of play which will be stable, barring exogenous interference (Adeosun, 2002). For stipulate purposes, it is usual to say that the intervention of such an exogenous force changes the game.

In this study, we represent decision making in terms of a more intuitive language and our attention is restricted to zero-sum games, that is, to games in which no player can gain except at another's expense. Game theory is described in terms of players, payoffs and strategies.

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Decision making: Decision analysis is more of an art than a science (Carter and Price, 2001). It differs from the mathematical structure of many other areas of operations research in that it contains a high degree of uncertainty. The factors that must be considered in the decisions process often involve a dramatic degree of uncertainty simply by virtue of the extended time frame. Decision analysis can also be expressed as a problem of selecting among a set of possible alternatives or courses of action. Therefore, decision making is a form of play between 2 or more entities (Maynard, 1982). It has rules and regulations to follow and at times restrictions and conditions may be attached to the decision taken. After making a decision and at some future time, there will be a number of external, uncontrollable variables that will influence the final outcome (Carter and Price, 2001). These external variables are often referred to as states of nature or state variables. If it were possible to predict accurately the result of these external variables, then the final outcome would also be predictable and the correct alternative would become clear.

Conflicts are usually caused by opposing interests (Antonio, 2000). These conflicts are to be settled by one player gaining and the other loosing. Before this could be done, there is a need for decision making to determine who is to gain and who is to lose.

Two-person zero-sum decision making: The decision making involved only 2 players. There is just a play and the decision is made. A player will lose and the other will gain if both use their best strategies thus, resulting in zero-sum when the payoffs to both are added together. The strategy of a player is the decision rule he uses to decide which course of action he should employed. Each player chooses a strategy that enables him to do the best he can, given that his opponent knows the strategy he is following (Winston, 1991). This strategy may be of 2 kinds:

- A pure strategy where a player always select the same course of action.
- A mixed strategy where a player choose at least two of his courses of action with fixed probabilities. In this regard, a player decide to use just two courses or action with equal probability, he might spin a coin to decide which one to choose. The advantage of a mixed strategy is that an opponent is always kept guessing as to which course of action is to be selected on any particular occasion.

Best strategy is defined on the basis of the minimax criterion of optimality (Liebrand *et al*., 1986). It means that if a player lists the worst possible outcomes of all his potential strategies, he will choose that strategy which corresponds to the best of these worst outcomes. The implication of this criterion is that the opponent is an extremely shrewd player who will ensure that whatever our strategy, our gain is kept to a minimum.

The following are the restrictions to a two-person zero-sum decision making:

- Repetition is not allowed, just one play and then the decision is made.
- Decisions of both players are made individually prior to the play.
- There is no communication between the players.

Decision are made simultaneously and announced simultaneously so that neither player has an advantage resulting from direct knowledge of the other player's decision.

Payoff determination/calculation: The next aspect of decision analysis is to consider the possible outcomes or payoffs that would result from each possible combination of decision and state variables. A method that is concisely describing this type of problem is called a payoff matrix. The rows correspond to the possible states while the columns represent alternatives and the entries in the matrix describe the outcomes associated with each possible combination of the problem variables.

A decision consists of a simultaneous selection of one strategy by player A and one by player B. This is the end of the game and the payoff is then determined.

$$\text{Player A's payoff} = \alpha_{ij}$$

$$\text{Player B's payoff} = -\alpha_{ij}$$

or

$$\text{Player A's payoff} = -\alpha_{ij}$$

$$\text{Player B's payoff} = \alpha_{ij}$$

The above results are gotten from zero-sum property of two-person zero-sum games. That is, the payoff to A and the payoff to B sum up together to zero.

$$\alpha_{ij} + (\alpha_{ij}) = 0$$

or

$$(-\alpha_{ij}) + \alpha_{ij} = 0$$

Therefore, in any two-person zero-sum decision making A's gain is B's loss and vice versa.

nXm possible payoffs representations: From the aforementioned, there are nXm possible payoffs, represented by Table 1.

We assumed the payoffs to player A and player B in two-person zero-sum game are shown in Table 2.

Ideally, we are supposed to use 2 tables, one to represent the payoffs to player A and the other to represent payoffs to player B but the convention is to show the payoffs to A, knowing that it is also the loss to B. This does not imply, however, that A always wins and B always loses.

We also assumed that both players know the whole payoff table shown in Table 2. They know not only the possible payoffs to themselves but, equally well, they know those of their opponents. In Table 2, player B has n = 4 courses of action while player A has m = 3 courses of action. In the same vein, we assume the payoffs to A happen to be all positive numbers. Table 2 shows that A will gain something between a minimum of 18 and a maximum of 30. Player B will lose the corresponding quantity. However, the exact size of this transfer of value from B to A is determined by the decisions of both players.

The first step in finding deterministic solution to a game problem is to find A's best solution assuming that B would know it in advance and counter it. This is called A's best nonsecret strategy. The reasoning is simple and is represented by rows in Table 3 for the game specified above.

The first row in Table 3 shows that if A selects his first course of action and B knows this choice in advance, B would select this third course of action B_3, to limit his loss to 20. After repeating this reasoning for A_2 and again for A_3, B would select second and first courses of action B_2, B_1, to limit his loss to 25 and 18 respectively. A can finally select his best nonsecret strategy. From Table 3, it is A_2 because A_2 has the greatest payoff for A. He knows that B will select B_2 and the payoff will be 25.

Table 4 is used to illustrate B's Best nonsecrete strategy. The first row in Table 4 shows that if B selects his 1st course of action B_1 and A knows this choice in advance, A would select this first course of action A_1, to maximize his gain to 30. After repeating this reasoning for B_2, B_3 and again for B_4, A would select 2nd course and 3rd course 2 times for corresponding actions to maximize his gain to 25, 27 and 28, respectively. B can finally select his best nonsecret strategy. From Table 4, it is B_2 because B_2 has the greatest payoff for B. He knows that A will select A_2 and the payoff to A will be 25. Therefore, 25 is the smallest loss attainable from a nonsecret strategy and it is B's best nonsecret strategy.

Table 1: nXm possible payoffs

	B_1	B_2	B_3	...	B_n
A_1	α_{11}	α_{12}	α_{13}	...	α_{1n}
A_2	α_{21}	α_{22}	α_{23}	...	α_{2n}
A_3	α_{31}	α_{32}	α_{33}	...	α_{3n}
⋮	⋮	⋮	⋮		
A_m	α_{m1}	α_{m2}	α_{m3}	...	$\alpha_{m,n}$

Table 2: Payoffs to player A and player B

	B1	B2	B3	B4
A1	30	24	20	23
A2	28	25	26	27
A3	18	23	27	28

Table 3: A's best nonsecret strategy

If A selects	B would select	A would receive
A_1	B_3	20
A_2	B_2	25
A_3	B_1	18

Table 4: B's best nonsecret strategy

If A selects	B would select	A would receive
B_1	A_1	30
B_2	A_2	25
B_3	A_3	27
B_4	A_4	28

Table 5: Calculations for saddle-point or deterministic solution

	B1	B2	B3	B4
A1	30^A	24	20^B	23
A2	28_A	25^B	26	27
A3	18^B	23	27^A	28^A

Deterministic solution to the game: Selection of courses of action mentioned above between player A and player B is in fact made without knowledge of the opponent's choice. If game theory can tell player A how he should behave, it must also tell player B how player A will behave i.e., if a solution of this type exists it must be a nonsecret solution. Therefore, the best nonsecret solutions, if they coincide, are the best solutions to the game. For the example given above, the best nonsecret strategies do coincide:

A's Best Nonsecret Strategy is A_2;
expecting B to select B_2
B's Best Nonsecret Strategy is B_2;
expecting A to select A_2

Each player expects the other to do what is in fact his best nonsecret strategy. When these coincide, the game is said to have a saddle-point or deterministic solution. Deterministic in the sense that player A can predict with certainty that B will select B_2 if he is confident that the assumptions of the game model are true (that B is rational, that the payoffs in the table are perceived by B to be the correct payoffs and so forth. If there is no point where the 2 best nonsecret strategies coincide, then there does not exist a deterministic solution. A saddle = point or deterministic solution exists if one cell in the table is the smallest entry in its row and simultaneously the largest entry in its column. The efficient method of finding saddle-point solution is:

- Find the smallest entry for each row and mark it with a B because it is B's best countermove if B knew that A would select that row. It is possible for smallest entry not to be unique in row considered therefore, all the entries that are the smallest entry must be marked with B_3.
- In each column, find the largest entry and mark it with an A because it is A's best countermove if A knew that B would select that column. If the largest entry is not unique, mark all equal ones with A_3.
- If at least one entry has been marked with both an A and a B, it is a saddle-point or deterministic solution. If no entry is marked twice, there exists no saddle-point solution. It means that player A cannot predict with certainty what B will select and he is not confident that the assumptions of the game model are true. Table 5 illustrates the above in details.

In Table 5, there is a saddle-point (deterministic) solution. A will select A_2 and B will select B_2 and the payoff will be a transfer of 25 units from B to A. This model accurately describes the problem and can confidently predict the outcome and the value of the game.

Algorithm for solving games problem (deterministic solution): The algorithm for solving games problems deterministically is given:

```
Transfer 0 to Saddle_Point_Menu
Display and Accept Menu_Choice
If Clicked = "A's BestStrategy_Method" then
    Do_A's BestStrategy_Method
Else
    If Clicked = "Do_B'sBestStrategy_Method" then
        Do_B'sBestStrategy_Method
    Endif
Endif
Display_Platform_form
Endif
```

CONCLUSION

Conclusively, the overview of decision making with respect to two-person zero-sum game had been analysed. The importance of decision making in theory of game has also been emphasized. Finally, algorithm for solving game problem based on the deterministic solution was presented. Evidence has shown that Game is being applied to business management. It is also applicable in military, sciences, business executives are employing games with digital computers that stimulate the operation of their business. Games of this type allow the executive to keep on active study of his employees, to learn more about his company and to simulate all activities of his company. The knowledge of game theory promotes the maximization of profit and minimization of loss to any organization that is related to the one discussed above. Finally, the use of game theory can not be ruled out, neither can it be overemphasized in this present era of competitions, suspicion and political theater. Every country seems to be suspecting her neighbour so also does every company. It is therefore, just auspicious that individuals, bodies and even nations should actively monitor what their competitors may be doing lest they are caught unawares on the board of power and intelligent play.

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