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Trust and cooperation from a fuzzy perspective

M.S. Al-Mutairi [a,*], K.W. Hipel [a,1], M.S. Kamel [b,2]

[a] *Department of Systems Design Engineering, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1*
[b] *Department of Electrical and Computer Engineering, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1*

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Abstract

The well-known game of Prisoner's Dilemma, which reflects a basic situation in which one must decide whether or not to cooperate with a competitor, is systematically solved using a fuzzy approach to modeling trust. When involved in a dispute, two or more parties need to make decisions with fully or partially conflicting objectives. In situations where reaching a more favorable outcome depends upon cooperation and trust between the two conflicting parties, some of the mental and subjective attitudes of the decision makers must be considered. While the decision to cooperate with others bears some risks due to uncertainty and loss of control, not cooperating means giving up potential benefits. In practice, decisions must be made under risk, uncertainty, and incomplete or fuzzy information. Because it is able to work well with vague, ambiguous, imprecise, noisy or missing information, the fuzzy approach is effective for modeling such multicriteria conflicting situations. The fuzzy procedure is used to take into account some of the subjective attitudes of the decision makers, especially with respect to trust, that are difficult to model using game theory.

Keywords: Cooperative games; Fuzzy logic; Decision making; Prisoner's dilemma; Trust

1. Introduction

Game theory is a widely accepted procedure for addressing problems arising in engineering, economics, psychology, biology, business, and politics [7,13,18,22,27,44]. The modern development of game theory dates back to the year 1944 when von Neumann and Morgenstern published their seminal book entitled *The Theory of Games and Economic Behavior* [49]. John Nash [39], who introduced the concept of a *Nash Equilibrium* into classical game theory, won the Nobel Prize in Economics for this insightful concept.

When a group of decision makers or agents (referred to as players in game theory) interact with each other, they are faced with conflicting objectives. While they are trying to maximize their profits or minimize their costs, it might be in their interest to help others achieve their goals. This could be as a result of expecting to be reciprocated in future interactions or to achieve a better situation that seems unachievable without the others' assistance.

Cooperation is the situation in which people work together to achieve their individual goals that without some type of unified action would not be reached or reached but with less rewards. When engaging in a cooperative action, the chances of success are dependent on joint actions and the number of partners involved. This creates risks and

* Corresponding author. Present address: Hafer Albatin Community College, PO Box 1803, Hafer Albatin, 31991 Saudi Arabia. Tel.: +1 519 888 4567x7736 (Canada); fax: +1 519 746 4791 (Canada).
E-mail addresses: mutairims@gmail.com (M.S. Al-Mutairi), kwhipel@uwaterloo.ca (K.W. Hipel), mkamel@pami.uwaterloo.ca (M.S. Kamel).
[1] Tel.: +1 519 888 4567x2830; fax: +1 519 746 4791.
[2] Tel.: +1 519 888 4567x5761; fax: +1 519 746 3077.

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uncertainties. Thus, it could be claimed that trust is a necessary condition for cooperation and that it is a product of successful cooperative actions [36]. Trust is a good way of motivating cooperative actions but might not be sufficient alone. Besides trust, there should be some sort of common goals, shared values, or even a kind of reciprocation. The role of trust in the case of cooperation is mainly in the elimination of fear of being betrayed or not being reciprocated [32]. The two main conditions to be met besides trust to facilitate cooperative actions are [32,34]:

1. Having a common goal or sharing some values.
2. Expecting others to cooperate.

If any of the above two conditions is not satisfied, the chances for cooperation are relatively low. In general, one could say that cooperation occurs when there is a non-mutually exclusive goal in which everyone wants to reach a better situation. On the other hand, the presence of distrust could eliminate any chances for cooperation. In his book of 2000, Gambetta, on page 219, states that "if distrust is complete, cooperation will fail among free agents" [23].

When trying to maximize his or her expected payoff, a person investigates the possibility of cooperating or joining a coalition that promises enhanced individual expectations. In such a highly subjective occurrence, nothing is guaranteed. The situation is subject to many unpredictable and hard-to-evaluate factors. Not being able to predict the commitment of the game players, the influences of the surrounding environment, and the game roles, one is unlikely to be able to forecast the outcomes. Such uncertainty, imprecision, or vagueness is best modeled through the use of fuzzy logic.

Fuzzy set theory [52] is appropriate for employment when dealing with vague, imprecise, noisy or missing information. Instead of using the Boolean $\{0, 1\}$ values, fuzzy sets try to map the degree to which an element belongs to a certain group in a continuous scale between [0, 1].

When interacting with someone in a conflicting or cooperative situation, it is vitally important to know some of the mental and social characteristics of the opponent. Since such subjective characteristics are difficult to estimate using crisp values (whether experimentally or in real life), a fuzzy procedure is employed to overcome this problem.

This research is an enhancement and expansion of the earlier work of Al-Mutairi et al. [1]. The current research focuses on exploring the close relationship between trust and cooperative behavior. It also uses a fuzzy logic approach to study the attitudes of the decision makers in an attempt to incorporate it into an operational concept for describing human behavior under conflict.

Section 2 reviews the well-known Prisoners' Dilemma game which constitutes a basic cooperative situation. In Section 3, the repeated version of the Prisoners' Dilemma along with some of its well-known strategies are reviewed. Section 4 acknowledges and highlights the close relationship between trust and cooperative actions. The evaluation process of risk in Prisoners' Dilemma using a fuzzy approach to trust is introduced in Section 5. The results of a stability analysis of the Prisoner's Dilemma game using the solution concepts of Nash, general metarational, symmetric metarational and sequential stability, are presented in Section 6. A realworld groundwater dispute referred to as the Elmira Conflict is studied in Section 7 using the new developments presented in this paper while some concluding remarks and insights are given in Section 8.

2. Prisoner's dilemma

In 1984, Axelrod [3] analyzed cooperation by means of a 2×2 non-zero-sum game called "Prisoner's Dilemma". In this game, the two players have two strategies: either "cooperate" (called strategy C) or "defect" (labeled as strategy D). While both gain equally when cooperating, if one of them cooperates, the other one who defects, will gain more. If both defect, both lose (or gain very little). Table 1 summarizes the complete game situation and its different states or outcomes. Notice in this table that player 1, or prisoner 1, controls the row strategies while player 2 controls the column strategies. When each player selects a strategy, an outcome or state is formed, which is represented by a cell in the matrix. The double letters given at the top of a cell represent the strategies of the players where the letters on the left and right stand for the strategies of players 1 and 2, respectively. Hence, the cell given as CD is the state in which player 1 cooperates and player 2 defects. The two numbers given in parentheses in the middle of a cell represent the preferences of player 1 (left entry) and player 2 (right entry), where a higher number means more preferred. The hypothetical negative quantities given in parentheses at the bottom of a cell are meant to represent the years in prison where the left and right entries are for players 1 and 2, respectively. They are represented using negative signs since staying in prison is not a desirable situation.