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Fuzzy option prioritization for the graph model for conflict resolution

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Abstract

A fuzzy option prioritization technique is developed to efficiently model uncertain preferences of DMs in strategic conflicts as fuzzy preferences by using the decision makers' (DMs') fuzzy truth values of preference statements at feasible states within the framework of the Graph Model for Conflict Resolution. The preference statements of a DM express desirable combinations of options or courses of action, and are listed in order of importance. A fuzzy truth value is a truth degree, expressed as a number between 0 and 1, capturing uncertainty in the truth of a preference statement at a feasible state. A fuzzy preference formula is introduced based on the fuzzy truth values of preference statements, and it is established that the output of this formula is a fuzzy preference relation. It is shown that fuzzy option prioritization can also be used when the truth values of preference statements at feasible states are completely based on Boolean logic, thereby generating a crisp preference over feasible states that is the same as would be found by employing the existing crisp option prioritization, making the crisp option prioritization technique a special case of the fuzzy option prioritization methodology. To demonstrate how this methodology can be employed to represent fuzzy preferences in real-world decision problems, fuzzy option prioritization is applied to an actual dispute over groundwater contamination that took place in Elmira, Ontario, Canada.

Keywords: Graph model; Preference statement; Fuzzy truth value; Fuzzy score interval; Fuzzy option prioritization; Fuzzy preference

1. Introduction

Decision making is a common activity in everyday life. To make decisions easier, a number of methodologies have been developed including linear and non-linear optimization [1,35], multiple-criteria decision analysis [13], game theory [38], fuzzy decision making [10,30], and the Graph Model for Conflict Resolution [11,28]. In these decision making techniques, decision makers' (DMs') preference information, expressed implicitly or explicitly, is an essential

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component. Preference information may be given in various forms, for instance as utilities (as in classical game theory [38]), as fuzzy utilities (as in fuzzy decision making [10,30]), via option prioritization (as in the Graph Model for Conflict Resolution [12,22,32,33]), or simply as pairwise relative preferences over the feasible states or scenarios (as in a crisp or fuzzy Graph Model [2–4,11,20,28]). In whatever form a DM's preference information is provided, the objective is always to represent a crisp or fuzzy preference relation over the states or scenarios.

A crisp or ordinary preference relation is composed of the binary relations "is (strictly) preferred to" and "is indifferent to". A crisp preference describes the certainty of the preference for one state over another which, in general form, may or may not be transitive. A fuzzy preference relation is expressed using numerical values between 0 and 1, interpreted as pairwise preference degrees. A preference degree for one state over another indicates the degree of certainty of the preference for the first state over the second. A degree of certainty of 1 is equivalent to the crisp binary relation "strictly preferred to" while a degree of certainty of 0 is equivalent to equal certainty but in the reverse direction.

In multiple participant–multiple objective decision problems, DMs interact through their decisions, and often have opposing (or inconsistent) preferences. Consequently, strategic conflicts are obvious in these decision problems. A number of formal methodologies have been developed to facilitate the analysis of these problems and to advise on possible resolutions. These methodologies include game theory [38], metagame analysis [24], conflict analysis [16], drama theory [25], and the Graph Model for Conflict Resolution [11,28]. These various methodologies all share fundamental characteristics: they represent and analyze decision situations with at least two DMs, each of whom has one or more options and distinctive preferences over the outcomes [27].

This paper is specifically addressed to the Graph Model methodology. To apply this methodology, there are two steps: modeling and analysis. In the modeling step, feasible states and moves among them are usually constructed using the option form [11,28]. A feasible state is a feasible combination of options, selected or not selected. To make clear how a real-world decision problem is formulated within the Graph Model framework, an environmental conflict in Elmira (a small town in Ontario, Canada) is described here. This conflict began in late 1989 when the Ontario Ministry of the Environment (MoE) found that an underground aquifer in the town was contaminated by a carcinogen. The main suspect was a chemical company in Elmira, Uniroyal Chemical Ltd. (UR), which produced the same carcinogen as a by-product. MoE issued a control order demanding that UR take necessary measures to rectify the contamination. However, UR appealed the control order. The Local Government (LG) was another DM of the conflict as it attempted to represent local interests. These DMs had differing objectives; for example, MoE wanted to require UR to rectify the contamination, while UR wanted the control order lifted or at least modified. The dispute is modeled as a Graph Model, in which each DM has one or more options that it either selects or not. For instance, to attempt to reach a preferable outcome, UR could delay the appeal process, accept the original control order, or abandon its Elmira operation.

An important input to the analysis step of the Graph Model, and to GMCR II [12,32], a decision support software that implements the Graph Model methodology, is each DM's preference information. Modeling preferences by pairwise comparison is a challenging task for DMs as well as for analysts. Rather, it is easier for a DM to provide a priority sequence of what he or she likes to see about the available courses of action. This idea was formalized as option prioritization [12,32,33]. A DM's preference is modeled using a priority list of preference statements. These statements are composed of options using logical connectives, such as "and", "or", and "if–then", and listed from most preferred to least. The option prioritization methodology relies on the truth values ("true" or "false") of each preference statement at each state, where the truthfulness of a more important preference statement dominates its falsity in calculating a DM's preferences. For example, in the Elmira model, LG's most important preference statement is "UR does not close its operations in Elmira"; so any state or scenario in which UR closes its operations in Elmira is less preferred than any state in which UR continues its operations.

A limitation of preference modeling by option prioritization is that it assesses a preference statement based only on whether it is "true" or "false" at a state. For example, to model its preference in the Elmira dispute, LG may consider the proposition "insist on the application of the original control order" as one of its preference statements. It may be reasonable to restrict the truth value of this preference statement to either "true" or "false" at states in which UR is delaying the appeal process. However, the truth value of this statement at a state in which UR accepts a control order (original or modified) may not be precisely "true" or "false"; rather, it may be more reasonable to assume a fuzzy truth value, a degree of truth, taken from a fuzzy truth space, usually the closed unit interval [0, 1]. A truth degree of 1 for a preference statement at a state indicates that the preference statement is true, while a truth degree of 0 implies

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