Hierarchical Graph Models for Conflict Resolution

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(多层次冲突图模型研究)

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Preface

Conflicts occur in any human society and at any possible time, ranging from divergence of opinions among individuals to fierce antagonism between social groups. In general, conflicts may arise because of interpersonal incompatibilities, disagreement in viewpoints, and opposition to the approach to the task in a group. People involved in conflicts may compete for power, status, or share of resources. In particular, the struggle over social and environmental resources is at the root of many conflicts. In the real world, a dispute often involves smaller conflicts that are connected spatially or logically. These connected conflicts are called hierarchical conflicts. Failure to perceive the overall picture of these interrelated conflicts may result in errors in making decisions.

Graph Model for Conflict Resolution (GMCR) is used in this book to analyze strategic conflicts effectively. The novel hierarchical graph models developed constitute significant expansions of the GMCR methodology. The hierarchical graph models can represent and solve strategic conflicts with a hierarchical structure effectively. More specifically, in a hierarchical graph model, one or more decision makers (DMs) at a higher level are involved in lower level or local disputes when a central government participates in separate disputes with different provincial governments.

Three real world conflicts with hierarchical structure are discussed in this book: controversies over the water diversions in China, the competition in the sales of aircraft between Airbus and Boeing, and the disputes between the USA and China over greenhouse gas emissions. In each conflict, the resolutions for DMs obtained by the stability calculations reflect their broader vision and their comprehensive understanding of the hierarchical conflicts.

By developing these hierarchical graph models, this book adopts a quantitative approach to analyzing interrelated conflicts for researchers. The intensive study of the three real world conflicts in the book can give new and significant insights to practitioners to mitigate, resolve, or even avoid conflicts. Mediators might also use the methodologies discussed in the book to reach agreements among belligerent parties.

Writing such a book on conflicts resolution is, for me, an arduous academic journey on which I experienced frustration and enjoyment, despair and hope, failure and success. Fortunately I got a lot of help from many people. First of all, I would like to express my sincere gratitude to my family, without whose support I could not have completed this book. I am also grateful to my former Ph.D supervisors, Dr. Keith W. Hipel and Dr. D. Marc Kilgour. The progress of hierarchical graph models could not have been constructed without their generous support and guidance.

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Notation

G	Graph model
i, N	Decision maker (DM), set of all DMs in G
s, S	State, set of states
A_i	Set of moves for DM i
$R_i(s)$	Reachable list for i from state s
$R_i^+(s)$	Unilateral improvement (UI) list for i from s
$\Pi_H(s, s')$	Set of DMs in H whose UMs are in the legal sequence from s to s'
$\Omega_{ij}(s)$	The j^{th} preference statement for i at s
$\Psi_{ij}(s)$	Score of the j^{th} preference statement for i at s
$J_i(s, s')$	Reachable matrix for i from s to s'
$J_i^+(s, s')$	UI matrix for i from s to s'
M_H	Joint movement matrix for a coalition of DMs H
M_H^+	UI matrix for a coalition of DMs H
$G^{(1)}$, $G^{(2)}$	Local graph models in hierarchical graph model G
CDM, LDM_1, LDM_2	A common decision maker (CDM) and two local decision makers (LDMs) in G
AC, AL_1	Set of moves for CDM in G, set of moves for LDM_1 in G
$S^{(1)}$	Set of states in local graph model $G^{(1)}$
$s = (s^{(1)}, s^{(2)})$	State s in hierarchical graph model G, consisting of two component states, $s^{(1)} \in S^{(1)}$ and $s^{(2)} \in S^{(2)}$
$\succsim_C$, $\succsim_{L_1}$	Preference relations for CDM, LDM_1 in G
$\succsim_C^{(1)}$, $\succsim_{L_1}^{(1)}$	Preference relations for CDM, LDM_1 in $G^{(1)}$
J_C, J_{L_1}	Reachable matrix for CDM, LDM_1, in G
$J_C^{(1)}$, $J_{L_1}^{(1)}$	Reachable matrix for CDM, LDM_1, in $G^{(1)}$
M_{N-L_1}	Joint movement matrix for all DMs except LDM_1 in G
$w^{(k)}$	Weight of local graph model $G^{(k)}$ for CDM

$\lvert S^{(1)}\rvert = m$	Number of states in $S^{(1)}$ is m
$\boldsymbol{e}_{q^{(1)}}$	m-dimension 0-1 vector with ${q^{(1)}}^{\text{th}}$ entry being 1 and others 0, where $q^{(1)} \in S^{(1)}$
N_C, $N_L^{(k)}$	Set of CDMs in G, set of LDMs, in general hierarchical graph model G
$\text{LDM}_l^{(k)}$, or short for l_k	LDM_l in local graph model $G^{(k)}$
$G^{(\tau_1)}, \cdots, G^{(\tau_K)}$	Local graph models $G^{(1)}, \cdots, G^{(K)}$ in the order from τ_1 to τ_K
$w_{C_i}^{(k)}$	Weight of local graph model $G^{(k)}$ for CDM_i

Contents

Chapter 1

Introduction

1.1 Hierarchical Conflicts

Strategic conflicts refer to the competitive or opposing actions that reflect the inconsistent interests and objectives of human beings (Hipel, 2002). Conflicts are ubiquitous in every human society, ranging from divergence of opinion among individuals to fierce antagonism between social groups. A strategic conflict is an interaction among decision makers (DMs), who can affect the courses of conflicts by their independent actions in accordance with their preferences (Kilgour and Hipel, 2005).

Strategic conflicts often take place when DMs attempt to seize natural and social resources. Because of the scarcity of natural resources and the significant impacts of human activities on the natural environment, environmental issues have become an origin of conflicts in the modern world. An environmental conflict involves a clash of interests between individuals or social groups seeking profits by exploiting natural resources, and stakeholders whose well-being may be at risk. Major environmental conflicts include disputes over water usage among nations or parties, the negotiations on reducing greenhouse gas emissions among countries, and the connection between the economic growth and the deteriorating air quality in the developing world.

The struggle over social resources, such as wealth and power, is also at the root of many conflicts. In business competition, enterprises contest over selling goods to gain more profits or market share. The terminology of business competition has been well defined in economics (Stigler, 1988; Blaug, 2008; Fleisher and Bensoussan, 2003): it can be regarded as conflict when competitors strive for the same resources, such as market share, and interact with each other. For example, in a duopoly market, each company uses business strategies to grab more market share and thereby put its opponents at a disadvantage.

In the real world, a dispute often includes smaller conflicts that are connected spatially or logically. These connected conflicts are called hierarchical conflicts. Failure to perceive these connections may lead to inaccurate predictions about the outcome of the conflicts and irrational solutions for DMs. For example, a large-scale construction project initiated by a national government can evoke disputes during the implementation at different locations. The government cannot properly resolve these disputes without considering the conflicts at all locations.

A historical example is the global rivalry between Britain and France during the Seven Years' War. The military contest which occurred in three major theatres, comprising the European continent, North America, and India, ended in a victory for the British and their allies. With its strong navy, Britain carried out several successful military operations in overseas colonies, while the strategy for France with its overwhelming army was to concentrate on continental Europe, hoping that losses overseas could be traded for victories in Europe through treaty negotiation. Victory for Britain was the result of its vision over all continents, and the effective deployment of troops in all theatres.

The word "hierarchy" originated from the Greek word "hierarchia", meaning "rule of a high priest" or "leader of sacred rites" (Liddell et al., 1940). Hierarchy refers to the arrangement of a particular set of ranks or levels (Dawkins, 1976; Simon, 1991). The hierarchical structure of conflicts has been widely discussed within the Game Theory paradigm. Hierarchical games denote interrelated games with different ranks or multiple levels. Weights and thresholds may be assigned to define the seniority of players in a hierarchical game (Beimel et al., 2008). The weight structure in hierarchical games was investigated by Gvozdeva et al. (2013). The hierarchical game was used for allocating resources among players (Gilles, 2010; Beimel et al., 2008; Farras and Padro, 2010), while the solutions to this game are complex. Markov models have been utilized to analyze hierarchical games within the game of tennis. The mathematical models describe players as attempting to win in tennis by optimizing their energy available (Gale, 1971; George, 1973; Gillman, 1985; Walker and Wooders, 2001; Brimberg et al., 2004). The results obtained for tennis have also been applied to other real world conflicts, such as defence strategy, which can be modelled by a hierarchical scoring system (Epstein, 2012). Theoretical contributions to hierarchical scoring include calculations of the parameters in a hierarchical model using probabilistic functions (Morris, 1977).

Stackelberg games also constitute hierarchical conflicts, because players are divided into a leader and several followers (Von Stackelberg, 1934; Simaan and Cruz, 1973). Different from other models in game theory, players in a Stackelberg game move sequentially and have asymmetric information about the game.

This brief literature review shows that models have been constructed to analyze hierarchical conflicts. However, these models require a large amount of input information, thereby forfeiting flexibility and simplicity. For example, in game theory, utility values that describe the preferences of DMs, and threshold values to define levels in a hierarchical game, are needed. The Markov model used to analyze tennis games requires computations using probabilities. However, these probabilities are difficult to calibrate (Lichtenstein et al., 1982). Therefore, a formal methodology to model hierarchical conflicts using a flexible structure and simpler model input is required to provide better predictions and resolutions (Howard, 1971; Kilgour and Hipel, 2005).

1.2 Classical Approaches to Conflict Analysis

The ubiquitousness of strategic conflicts in the real world and the importance of conflict support the call for comprehensive methodologies to understand conflicts and produce positive resolutions for DMs to take reasonable and beneficial actions (Kilgour and Hipel, 2005). The conflict methods can also help mediators propose resolutions.

Various approaches have been developed to analyze decision behaviour. The study of decision making processes of human beings is a psychological science (Marshall, 1920). Among the descriptive approaches used to model decision making behaviour in reality is Prospect Theory, developed by Kahneman and Tversky (1979), which states that the decisions of mankind are based on relative gains and losses, and that losses are more significant than gains. In Satisficing Theory (Simon, 1978;

1990), a decision maker will search for a reasonable outcome that reflects the information the decision makers have, the constraints of time and other resources, and the decision makers' cognitive limitations (Simon, 1991).

The normative approaches to analyzing decision process were developed to investigate how a better decision should be made. Analysis of human conflicts is a multidisciplinary domain of research, combining knowledge in economics, sociology, philosophy, and mathematics (Hipel, 2009). Among various conflict analysis methods in different disciplines, game theory is a formal methodology to investigate strategic conflicts using mathematical tools. Not until the mid 1940s did game theory rapidly develop. The book written by Von Neumann and Morgenstern (1944), called *Theory of Games and Economic Behavior*, is widely considered as the start of modern game theory. In this book, the rationality of players is discussed and their choices are formally analyzed (Kilgour and Hipel, 2005). Decision makers in game theory are assumed rational, because it is important for policy makers or mediators to know how a better outcome can be achieved. Besides, although individuals may not be rational, the actions for large organizations are close to being rational. It is strategically important to know what an organization should do for its managers or policy makers. To describe rationality in a game, Nash (1950) defined a solution concept of a non-cooperative game, called Nash equilibrium, to describe a situation for two DMs, at which both of them cannot make a better choice.

The game theoretical models can be classified as being quantitive or non-quantitive. The genealogy of these models is depicted in Fig. 1.1. In quantitive models, preference relations for DMs are expressed using utility values (Von Neumann and Morgenstern, 1944) to represent a DM's gains or losses in making a choice. Strategies for a DM can be classified as pure strategies, which mean definite actions for the DM, and mixed strategies, denoted by the probabilistic mixture of actions. In comparison, non-quantitive models were designed for use with relative preferences, in which a DM may prefer one state to another or consider the two states to be equally preferred. Normal and extensive form models are two representative quantitive models. In a normal form model, each DM can only move once by changing his choices. Extensive games were developed to describe the sequence of moves for DMs. Cooperative games, which describe conflicts among DMs in allocating limited resources, can also be analyzed by using quantitive approaches. In quantitive models, the use of utility values has drawbacks because they are usually hard to measure. The determination of utility is usually intuitive and lacks statistics to validate the value. In addition, the probabilities underlying mixed strategies may be difficult to estimate in practice.

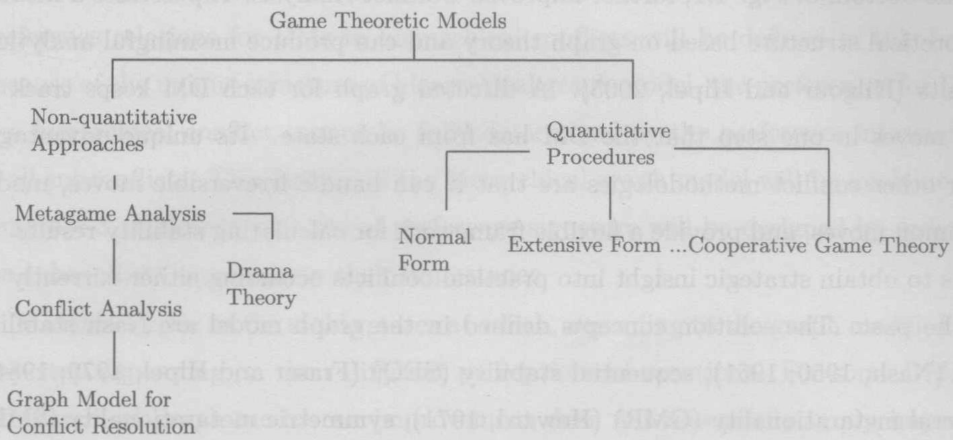

Figure 1.1 Genealogy of conflict analysis methodologies (Hipel and Fang, 2005)

Non-quantitive models, in comparison, can overcome the aforementioned drawbacks. Howard (1971) developed the Metagame Analysis methodology to mitigate these shortcomings. In a metagame, DMs can move in any order and at any time. Relative preference for a DM is represented by a comparison of each pair of possible outcomes. An outcome, formally called a state, can be more preferred, less preferred, or equal in preference. Drama theory is an extension of metagame theory by considering emotions for DMs (Howard, 1999). In a drama theoretical model, emotional interactions among DMs and possible scenarios are investigated.

Conflict Analysis, devised by Fraser and Hipel (1984), is an important extension of the metagame methodology by introducing sequential stability (SEQ) and symmetric stability (SMR), as additional new solution concepts for capturing human behaviour under conflict (Kilgour and Hipel, 2005). In general, a DM will consider a state to be stable if other DMs can somehow block possible improvements. Stability analyses can be carried out by investigating the stability of each feasible state for each DM under a given solution concept. An equilibrium is a state that is stable under a given solution concept for all DMs. Conflict analysis can be used