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Conflict Resolution Using the Graph Model: Strategic Interactions in Competition and Cooperation

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To Ju, Sheila, Joan and Hong

Preface

The theory and practice of key advances in the ***Graph Model for Conflict Resolution (GMCR)*** are presented for strategically investigating real-world disputes arising in any field in which conflict takes place. Since humans are inherently ***competitive***, GMCR can be utilized to ascertain what is the best a particular decision maker (DM) can achieve given the social constraints of a conflict in which the DM dynamically interacts with others in terms of moves and countermoves as he or she seeks to satisfy her goals or value system. When trying to negotiate a climate change agreement, for example, each nation may act according to its own self-interests in order to fare as well as possible in the short term, by reducing its greenhouse gas emissions as little as possible. However, a country may then attempt to find out whether it can do even better if it ***cooperates*** with other nations to reach a fair climate change deal in which each nation cuts back very significantly in its greenhouse gas emissions in order for the nations of the world to do much better in the long run and thereby avoid the extreme consequences of climate change. Accordingly, the rich range of GMCR methodologies presented in this book and elsewhere can be employed in a highly competitive situation, in which all participants are out to satisfy their own goals, to ones in which there is a high level of cooperation when it is beneficial for DMs to form coalitions.

You, our valued reader, may wish to know if this book contains information that will be useful to your understanding and capability for resolving tough disputes in your domain of interest, which may range from personal disputes within a family to international trading conflicts among corporations and nations. If you are a ***researcher*** in multiple participant decision-making who wishes to refine and expand basic GMCR methodologies or to employ the latest advances in conflict resolution for tackling complex conflicts within a domain such as stakeholder satisfaction in land use development and planning, then this book should be of high value to you. If you are a ***teacher*** in operations research, systems engineering, or an applied field of application in which conflict takes place, you may wish to use this book as a course text at the upper undergraduate or graduate levels or else as a valuable informative reference in a course. If you are a ***mentor*** of students carrying out research at the Ph.D. or Master's level, or tackling tough problems involving conflict in challenging projects, you will find this book to be highly attractive for meeting your purposes. If you are a ***student*** studying conflict resolution and would like to investigate how nations or regions can learn from their past mistakes in order to discover how to avoid similar situations ever taking place again, such as a great depression from an economical perspective or a devastating war with a rogue nation from a military viewpoint, then the contents of this text constitute essential informative conflict resolution techniques to include in your tool kit. A doctoral student may wish to expand the basic GMCR methodologies based on gaps that he finds when systematically studying conflict in fields such as energy development, environmental engineering, water resources, and legal studies. If you are a ***practitioner*** or professional like a consulting engineer, urban planner, political advisor, manager, lawyer, policy analyst, or military systems engineer, this book will be compelling for you to use in resolving challenging practical problems within your professional area of expertise. For instance, as climate change intensifies and regional wars erupt, military analysts within operations research groups in defense departments will find this book to be very useful for tackling the severe security issues involved with the mass migration of affected populations, as is occurring and intensifying right now in Europe where refugees are continually arriving in increasing numbers. If you are a professional like a computer engineer or computer scientist, you may wish to utilize the basic design for a flexible decision support system (DSS) for conflict resolution put forward in this book for programming the next generation of DSSs for employment by researchers, teachers, mentors, students, and practitioners for applying the new GMCR techniques in this book to real-life situations.

To convince you, our reader, that GMCR can be actually utilized in practice for addressing challenging ***real-world disputes***, examples are provided throughout the book to demonstrate how the various ideas can be applied. These applications clearly demonstrate why "good theory means good practice" and vice versa. Hence, in the very first chapter in the book, a highly controversial groundwater contamination dispute which occurred in the town of Elmira, Ontario, Canada, is employed to explain how the conflict can be modeled and analyzed using GMCR in order to gain a better understanding and strategic insights. This same environmental conflict along with others are utilized in the book to explain how various concepts are designed and work in practice.

The basic theoretical structure of GMCR and its expansions were purposefully designed to address conflicts which actually occur in reality. To accomplish this, the underlying axioms of GMCR were formulated to reflect the key characteristics of real-world conflict, thereby forming the solid foundations upon which the theoretical framework can be properly built and expanded. For example, in a conflict situation, DMs often think like a chess player in terms of ***moves and countermoves***. If a particular DM is contemplating moving from the current situation to a more preferred state, the DM may wish to know the consequences of this possible move.

If, for instance, a car manufacturer decides to decrease the selling price of its cars and thereby hopefully gain greater market share, will the company's competitors also decrease the cost of buying their cars and put the particular company in a worse situation? If so, the company is better off not to lower its prices. In GMCR, different ways in which people may ***behave*** under conflict can be captured mathematically by what are called solution concepts or stability definitions. Furthermore, the possible moves that a DM controls can be recorded using a graph in which the scenarios or states that could occur form the vertices (nodes) while moves that the DM can make in one step are drawn as the directed arcs connecting states. Another key feature of GMCR is that only ***relative preference information*** is required which means that you only have to know if a DM prefers one state over another or if the states are equally preferred. Hence, if someone asks you if you would like to have a cup of coffee or tea, you may respond by saying that I prefer to have coffee, thank you, or it does not matter. You would certainly not give a quantitative response by saying that for me coffee has a utility value of 6.912 while tea is worth 2.591. A key design feature of GMCR is that only relative preference information is needed, which is fairly easy to obtain in practice and mimics the way people think about their preferences.

The foregoing fashion of directly thinking about a conflict in terms of moves and countermoves coupled with relative preferences is called the ***logical form*** of the game. A person can intuitively understand how a conflict can evolve and be resolved by logically explaining what can happen using moves and countermoves as DMs attempt to do the best they can in a dispute. If, for instance, from a state all of the ways in which a DM could unilaterally improve can be sanctioned by others, then this state is said to be stable for that DM according to a certain ***type of behavior***. If it is not advantageous for any of the DMs to move, the state is a possible resolution or equilibrium if it is reached during the evolution of the dispute under study. For a specific conflict, providing a logical explanation of what can happen is highly appealing. However, the information contained in a graph keeping track of moves or preferences can be stored in a matrix for computational purposes. In fact, the logical interpretation of GMCR both in terms of modeling and stability calculations can be equivalently formulated using a ***matrix representation***, which is also called algebraic form. When programming the engine for calculating the stability results, the matrix form is much more efficient than its logical counterpart in terms of the number of required calculations. Moreover, for theoretical purposes, it is much easier to expand GMCR when the matrix form is utilized. Therefore, throughout the book, both the logical and matrix representations of GMCR are provided for all of the advancements that are presented, which makes this book truly unique.

To appreciate the uniqueness and innate capabilities of GMCR, the connections and differences of GMCR with respect to other game theory methods are discussed in the second chapter. Moreover, the relationships of GMCR to other formal decision-making techniques developed in the fields of Operations Research, Systems Engineering and elsewhere are clearly explained. If a decision-making methodology like GMCR is programmed as a DSS so it can be readily applied to actual disputes, the methodology becomes an ***operational decision technology***. In practice, one may use a toolbox of decision technologies for addressing a complex problem like urban expansion for which GMCR could be used for investigating the strategic and controversial aspects of the project.

In actuality, everything affects everything else within and among societal and physical systems of systems. For instance, the utilization of fossil fuels in society's industrial, transportation and electricity generation systems in nations around the world releases massive quantities of carbon dioxide into the atmosphere, which is one of a number of deadly greenhouse gases causing average temperatures around the globe to increase significantly over time. This, in turn, alters the earth's climate system, creates extreme weather conditions, shrinks the area and thickness of sea ice, melts glaciers, makes ocean levels rise, and increases the acidity of oceans. These and other negative consequences of climate change on the earth's natural systems can adversely impact societal systems such as agriculture, industry and the economy as a whole, as well as the stakeholders who are part of these systems. Accordingly, it is highly intuitive and informative to envision any problem from a ***system of systems perspective***. Within this vision of reality, a useful tool like GMCR can be employed to investigate the myriads of conflicts that will arise among affected parties, which for the case of climate change will surely increase in number and intensity as the climate continues to deteriorate, perhaps irreversibly.

To responsibly handle complex problems connected to climate change, the Elmira groundwater contamination problem, and other tough issues facing society, an ***integrative and adaptive approach to management and governance*** can be followed in a participatory fashion with stakeholders whose interests or values must be taken into account in policy design and decision-making. In this way, solutions to problems can be found which adhere to desirable systems characteristics like sustainability, fairness, and robustness. A flexible tool like GMCR can be employed to handle disputes that may arise for which the stakeholders value systems are always considered.

After putting decision-making into perspective in Chap. 2 and explaining the vital role that GMCR has to play, various conflict models are defined in Chap. 3. As explained in Chap. 3, what is called the ***option form*** of the game is particularly powerful as a notation for keeping track of the options or courses of actions available to each DM in a dispute and recording the possible feasible states or scenarios that could occur in the conflict. These states are then used in both the ***logical form*** and ***matrix representation*** of GMCR presented in Sects. 3.2 and 3.3, respectively. Because they reflect the underlying value system of a DM, a crucial input to a conflict model is the relative preference of the DM among the feasible states that could occur.

Subsequent to modeling a given conflict in terms of DMs, states, state transitions, and relative preferences, a stability analysis is carried out in terms of investigating moves and countermoves that could occur according to four ***solution concepts*** reflecting ***human behavior*** under conflict when determining if a state is stable or not: Nash stability, general metarationality, symmetric metarationality, and sequential stability. Depending on the type of preference information that is available, these solution concepts are appropriately defined for both the logical and matrix representations of GMCR. Hence, the next four chapters in the book provide the stability definitions for the following types of preference information:

Chapter 4: ***Simple preference*** in which a given state can be more preferred, equally preferred, or less preferred to another state by a DM.

Chapter 5: ***Unknown preference*** in which a DM does not know the preference relationship for some pairs of states. This type of preference uncertainty is uniquely defined for employment with GMCR since it does arise in practice. In the last chapter in this book, it is mentioned that fuzzy sets, grey numbers, and probabilistic approaches to preference uncertainty have also been developed for employment with GMCR.

Chapter 6: In some situations, a DM may greatly prefer one state over another such as when environmentalists greatly prefer that an industrialist does not allow his company to significantly pollute the surrounding environment by releasing untreated wastes. This is referred to as ***degree of preference*** for which the degree can be taken to any level for specified pairs of states.

Chapter 7: ***Hybrid preference*** in which unknown and degree of preference can occur as well as simple preference.

As mentioned earlier, in addition to determining how well a given DM may fare when behaving independently, one should also determine if a DM can do even better by cooperating with others. Hence, in Chap. 8 ***coalitional stabilities*** are defined for the aforementioned four types of preference situations for both the logical and matrix forms of GMCR. As an important type of follow-up analysis, the possible ***evolution of a conflict*** from a specified starting or status quo state to a particular final state is presented for both the logical and matrix representations of GMCR in Chap. 9. In practice, one may wish to know whether a desirable state, such as a win/win resolution, can actually be reached by DMs who have under their control unilateral moves that they can select to levy.

The book concludes with the presentation of a ***universal design*** of future generations of DSSs for GMCR based on an internal matrix representation structure for handling the current and future expansions of GMCR in Chap. 10. These ***future opportunities*** include the capability of having systems engineering investigations in which inverse engineering and behavioral engine specification can be fully studied. Inverse engineering or inverse GMCR means ascertaining the preferences needed by DMs for a desirable final state to be an equilibrium. The behavioral engine problem is given the input and output to determine the type of behavior exhibited by the DMs.

So, our cherished readers, we trust that you will enjoy the exciting journey through our comprehensive book. But hang on to your hats: there will be a lot more to come in the future both in terms of ***new operational methodologies*** for expanding the capabilities of GMCR and also the wealth of ***pressing conflicts*** that have to be properly addressed right now, as well as challenging conflicts that may arise in the future as the earth becomes a smaller and smaller place for all of us to live and prosper.

We warmly wish you, our readers, a most revealing and exciting journey through our book.

Bon voyage!

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Although the solid foundations for the leading-edge ideas of the Graph Model for Conflict Resolution (GMCR) contained in this text were cleverly designed and carefully constructed over three decades ago, this book focuses on advances in GMCR achieved during the past ten years, including some material appearing in print here for the first time. Research ideas from journals or other publications are of course properly referenced. Moreover, for material that comes directly from another publication, permission of the copyright holder has been obtained.

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Acronyms

CCA	Council of Canadian Academies
CDO	Canadian Opposition
CIUM	Coalition Improvement or Uncertain Move
CWAM	Cooperative Water Allocation Model
DBMS	Database Management System
DGMS	Dialog Generation and Management System
DM	Decision Maker
DSS	Decision Support System
GCGMR	General Coalitional General Metarationality
GCGS	General Coalitional Graph Model Stability
GCNash	General Coalitional Nash Stability
GCSEQ	General Coalitional Sequential Stability
GCSMR	General Coalitional Symmetric Metarationality
GDU	Garrison Diversion Unit
GGMR	General General Metarationality
GGS	General Graph Model Stability
GHG	Greenhouse Gases
GMCR	Graph Model for Conflict Resolution
GMCR II	GMCR (Graph Model for Conflict Resolution) II
GMR	General Metarationality
GNash	General Nash Stability
GS	Graph Model Stability
GSEQ	General Sequential Stability
GSMR	General Symmetric Metarationality
GWP	Global Water Partnership
IG	Integrated Graph
INBO	International Network of Basin Organizations
INFOR	Information Systems and Operational Research
MBMS	Model-base Management System
MCDA	Multiple Criteria Decision Analysis

MRCR	Matrix Representation for Conflict Resolution
MRSC	Matrix Representation of Solution Concepts
MRSCU	Matrix Representation of Solution Concepts with Preference Uncertainty
MSUI	Mild or Strong Unilateral Improvement
MSUIUM	Mild or Strong Unilateral Improvement or Uncertain Move
OR	Operations Research
SCGS	Strong Coalitional Graph Model Stability
SCGMR	Strong Coalitional General Metarationality
SCSEQ	Strong Coalitional Sequential Stability
SCSMR	Strong Coalitional Symmetric Metarationality
SEQ	Sequential Stability
SGMR	Strong General Metarationality
SGS	Strong Graph Model Stability
SMR	Symmetric Metarationality
SoS	System of Systems
SSEQ	Strong Sequential Stability
SSMR	Strong Symmetric Metarationality
UI	Unilateral Improvement
UIUM	Unilateral Improvement or Uncertain Move
UM	Unilateral Move
USS	United States Support
UUM	Unilateral Uncertain Move
WCGMR	Weak Coalitional General Metarationality
WCGS	Weak Coalitional Graph Model Stability
WCSEQ	Weak Coalitional Sequential Stability
WCSMR	Weak Coalitional Symmetric Metarationality
WGMR	Weak General Metarationality
WGS	Weak Graph Model Stability
WSEQ	Weak Sequential Stability
WSMR	Weak Symmetric Metarationality
WWI	World War I
WWII	World War II

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