

Article

Non-Commutative Logic for Collective Decision-Making with Perception Bias

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Abstract: In the paper we suggest an implementation of the non-commutative logic and apply its operators for decision-making in the group of autonomous agents. The suggested operators extend the uninorm and absorbing norm aggregators and use an additional asymmetry parameter that defines the “level of non-commutativity”. The value of this parameter is specified using the perception bias of humans measured in the experiments. The suggested operators and decision-making method are illustrated by simulated behavior of mobile robots in the group.

Keywords: mobile robots; swarm dynamics; multivalued logic; non-commutative algebra; decision-making; uncertainty; irrational decisions

1. Introduction

Starting from “An Investigation of the Laws of Thought” by Boole [1], data analysis and decision-making are considered using the methods of formal logic and probability theory involving rational principles of judgement and reasoning. Logic formalizes the rules for deriving truthiness of the statements, and probability theory provides rigorous methods for handling uncertainty in the knowledge about the statements and events.

Combination of the concepts of uncertainty and truthiness gave a rise for the development of multivalued logic; the first version of such logic – the three valued logic – was suggested by Lukasiewicz [2]. Later Lukasiewicz and Tarski [3] extended this logic to the K_n -valued logic.

Further development of the multivalued logic resulted in probabilistic logic [4] and fuzzy logic [5]. After formulation of the uninorm [6] and absorbing norm [7], fuzzy logic forms a basis for the development of non-Bayesian decision-making and of non-probabilistic methods of handling uncertainty [8].

In parallel to the development of multivalued logics, Lambek [9] initiated the studies of non-commutative logics. At the beginning, these logics were developed for representation of the syntactical and grammatical structures of natural languages, and then were adopted for modeling preference relations in the decision-making processes [10, 11]. Theoretical studies in these directions resulted in the invention of multivalued non-commutative operators [12] and multivalued non-commutative logics algebras [13] that allow direct consideration of the situations where truthiness depends on the order of the statements.

The attempts to use the multivalued non-commutative logics in decision-making gave a rise to two main problems: how to implement the non-commutative logical operators, and how to define the correct “level of non-commutativity” of these operators.

In the paper, we suggest the implementation of non-commutative logical operators based on the extension of the uninorm and absorbing norm [14]. In addition to the neutral and absorbing elements, these norms are equipped with the asymmetry parameter which controls the “level of non-commutativity”. To define the value of this parameter we utilize

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Table of Contents Probability Models Of Collective Decision Making Merrill Political Science Series

1. Understanding the eBook Probability Models Of Collective Decision Making Merrill Political Science Series
 - The Rise of Digital Reading Probability Models Of Collective Decision Making Merrill Political Science Series
 - Advantages of eBooks Over Traditional Books
2. Identifying Probability Models Of Collective Decision Making Merrill Political Science Series
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Probability Models Of Collective Decision Making Merrill Political Science Series
 - User-Friendly Interface
4. Exploring eBook Recommendations from Probability Models Of Collective Decision Making Merrill Political Science Series
 - Personalized Recommendations

- Probability Models Of Collective Decision Making Merrill Political Science Series User Reviews and Ratings
- Probability Models Of Collective Decision Making Merrill Political Science Series and Bestseller Lists
- 5. Accessing Probability Models Of Collective Decision Making Merrill Political Science Series Free and Paid eBooks
 - Probability Models Of Collective Decision Making Merrill Political Science Series Public Domain eBooks
 - Probability Models Of Collective Decision Making Merrill Political Science Series eBook Subscription Services
 - Probability Models Of Collective Decision Making Merrill Political Science Series Budget-Friendly Options
- 6. Navigating Probability Models Of Collective Decision Making Merrill Political Science Series eBook Formats
 - ePub, PDF, MOBI, and More
 - Probability Models Of Collective Decision Making Merrill Political Science Series Compatibility with Devices
 - Probability Models Of Collective Decision Making Merrill Political Science Series Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Probability Models Of Collective Decision Making Merrill Political Science Series
 - Highlighting and Note-Taking Probability Models Of Collective Decision Making Merrill Political Science Series
 - Interactive Elements Probability Models Of Collective Decision Making Merrill Political Science Series
- 8. Staying Engaged with Probability Models Of Collective Decision Making Merrill Political Science Series
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Probability Models Of Collective Decision Making Merrill Political Science Series
- 9. Balancing eBooks and Physical Books Probability Models Of Collective Decision Making Merrill Political Science Series
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Probability Models Of Collective Decision Making Merrill Political Science Series
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Probability Models Of Collective Decision Making Merrill Political Science Series
 - Setting Reading Goals Probability Models Of Collective Decision Making Merrill Political Science Series

- Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Probability Models Of Collective Decision Making Merrill Political Science Series
 - Fact-Checking eBook Content of Probability Models Of Collective Decision Making Merrill Political Science Series
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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