Automated Negotiation
Principles, Approaches, and Applications

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Outline

Introduction to Negotiation

Negotiation

- A means for a group to arrive at an agreement
- Process of joint decision-making where parties with different preferences seek to reach a mutually acceptable solution
- Fundamental mechanism in multi-agent systems and human society

Negotiation Research Framework

Negotiation research deals with three topics:

1 Negotiation protocols

2 Negotiation objects

3 Agents' decision making models

Negotiation Protocols

Negotiation Protocols

A set of rules that govern the interaction:

- Includes the permitted type of participants
- Negotiation states
- Events that change states
- Actions of participants
- Rules for agreement formation
- Termination conditions

Negotiation Objects

Negotiation Objects

- Range of issues over which agreement must be reached
- Related issues:
    - Type of operations on agreements
    - Alter the structure of the negotiation

Agents' Decision Making Models

Agents' Decision Making Models

Influenced by:

- Protocol
- Nature of the negotiation object
- Range of operations

The relative importance of the components varies depending on the domain.

Domain Variation in Negotiation

- In some domains, the negotiation protocol is the dominant concern
- Example: In some auction settings, the best strategy for an agent is to bid to their true evaluation; hence no strategic analysis is really required
- In other domains the converse is true
- Given the wide range of possibilities, there is no best technique for automated negotiation

Negotiation as Distributed Search

Negotiation as Distributed Search

- Negotiation can be viewed as a distributed search through a space of potential agreements
- The dimensionality and topology of this space is determined by the structure of the negotiation object
- One could consider each attribute of the negotiation object to have a separate dimension associated with it
- As dimensions are added (or removed), the number of points of agreement may increase (or decrease)
- Similarly, if an agent changes one of the values, it is moving from one point in the agreement space to another

Participants in Negotiation

- In a negotiation, participants are the active components that determine the direction of the search
- Initially, each agent will have a portion of the space in which it will be willing to make an agreement
- Also, agents will have some means to rate the points in the space
- Negotiation involves the agents suggesting points or spaces

Minimal Negotiation Capabilities

Minimal Negotiation Capabilities

Minimal negotiation capabilities are:

- To propose some point of space as being acceptable
- To respond to such a proposal indicating whether it is acceptable

Simple setting: a Dutch auction:

- One agent (auctioneer) calls out prices
- If no signal of acceptance by an agent, then auctioneer makes a new offer which it believes will be more acceptable
- Process repeats

Limitations of Simple Accept/Reject Negotiation

- If agents can only accept/reject offers, negotiation will be very time-consuming and inefficient
- Proposer is effectively picking points in the agreement space based on what it perceives and hopes to stumble upon correct point
- For negotiation to be more efficient, the recipient needs to offer feedback

Feedback in Negotiation

Feedback

Feedback can be:

- A critique
- A counter-proposal

A critique provides two forms of feedback:

- Suggests constraints on issues
- Indicates acceptance/rejection of particular negotiation issues

The more information placed in the critique, the easier it is for the original agent to determine the boundaries of the agreement space.

Counter-proposals

- A counter-proposal is a proposal that is more favorable to the sender, made in response to a previous proposal
- Can suggest amendments or additions
- Provides implicit information about preferences
- Can significantly speed up the negotiation process

Example Negotiation Dialogue

- Agent A: I propose you provide me with X with following conditions
- Agent B: I agree with condition 1 (e.g. price), but condition 2 (e.g. delivery date) is too late
- Agent A: I propose that I will provide you with service Y if you provide me with service X
- Agent B: I don't want service Y

Example Negotiation Dialogue (continued)

- Agent A: I propose that you provide me with service X
- Agent B: I propose that I provide you with service X if you provide me with service Z
- Agent A: I propose that I provide you with service X if you provide me with service Y
- Agent B: I propose that I provide you with service X if you provide me with service Z

Limitations of Simple Proposals

Limitations of Simple Proposals

- Proposals, critiques, counter proposals are mere statements of what the agents want
- Hence the scope is confined
- Agents can't:
    - Justify their negotiation stance
    - Persuade one another to change their negotiation stance
- This leads to the idea of argumentation-based negotiation
- Allows agents to offer more information than available in proposals, critiques, and counter proposals

Approaches to Negotiation

Approaches to Reasoning in Negotiation

Approaches to reasoning in negotiation setting can be loosely categorised:

- Game-theoretic
- Heuristic
- Argumentation-based

Game-theoretic Approach

Can be applied in two manners:

- Designing appropriate protocols that will govern agents' interactions
- Design of a particular agent's strategy

Properties:

- Usually assume that rational agent will choose best strategy
- Finding best strategy can be computationally intractable
- Disadvantages include that it may be difficult to characterise agents' preferences with respect to all possible outcomes

Heuristic Approach

- Seeks to search negotiation space in a non-exhaustive fashion
- Produces good solutions rather than optimal
- Disadvantages include:
    - Sub-optimality; adopt an approximate notion of rationality and do not fully examine space
    - Models need extensive analysis through simulation
    - Usually difficult to predict behaviour

Argumentation-based Approach

- Agents aim to persuade or change opponent's ratings over agreement space
- Additional information is provided in addition to proposals etc.
- Usually take the form:
    - Threats ("If you don't accept, I'll have to...")
    - Rewards ("If you accept this offer, in the future I'll...")
    - Appeals ("This is standard practice in our industry...")

Extended Topics in Negotiation

Learning in Negotiation

- Agents can adapt strategies based on past interactions
- Types of learning:
    - Learning opponent's preferences
    - Learning effective negotiation strategies
    - Learning from past negotiation outcomes

Trust and Reputation

- Critical when agreements must be enforced over time
- Trust models help agents decide with whom to negotiate
- Reputation systems aggregate experiences across multiple agents
- Mechanisms for:
    - Preventing reneging on agreements
    - Handling deception in negotiation
    - Building long-term relationships

Applications

Applications of Automated Negotiation

- E-commerce and automated trading
- Resource allocation in distributed systems
- Supply chain management
- Smart grids and energy markets
- Autonomous vehicles (traffic management, parking)
- Meeting scheduling