Negotiation Frames

Michael Rovatsos

Lehrstuhl für Theoretische Informatik und Grundlagen der Künstlichen Intelligenz
Fakultät für Informatik, Technische Universität München

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Overview

Application Scenario

Simple negotiation frames in m²infra

Advanced negotiation frames

Conclusion
Overview

Motivation

Outline

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Conclusion
Frame learning and generalisation techniques provide foundation for frame-based strategic communication management.

Combination of
- (hierarchical) reinforcement learning
- case-based reasoning and cluster validation techniques
- deliberative, knowledge-based reasoning
- content-rich agent communication

But how can it be used in practice?
Outline of this talk

- Application scenario: Link Exchange Simulation
- Simple negotiation frames with m^2infra
- Advanced negotiation frames
- Conclusion
Overview

Application Scenario

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LIESON system overview

- LIESON – Link Exchange Simulation System
- System objective: increase linkage transparency on the WWW using automated link exchange
- Link ratings express approval/disapproval of target site
- Web surfer behaviour (i.e. site popularity) rating-dependent
- Includes implementation of BDI-like agents with m²infra engine
  - Entirely self-interested agents
  - Maximisation of dissemination of own opinion
  - Highly boundedly rational agents
- BDI reasoning = goal selection according to projected utility (planning process trivial)
- BDI choices overruled by m²infra
Outline
Overview
Application Scenario
Simple negotiation frames
Advanced negotiation frames
Conclusion

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Negotiation Frames
<table>
<thead>
<tr>
<th>Action</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>addLink(0, agent2, g0 agent1, -1)</td>
<td>0.5034</td>
</tr>
<tr>
<td>addLink(0, g0 agent7, g0 agent2, 0)</td>
<td>0.5</td>
</tr>
<tr>
<td>addLink(0, g0 agent7, g0 agent2, 1)</td>
<td>0.5</td>
</tr>
<tr>
<td>addLink(0, agent7, g0 agent2, -1)</td>
<td>0.5</td>
</tr>
<tr>
<td>modLink(0, g0 agent2, g0 agent7, 1)</td>
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<tr>
<td>modLink(0, g0 agent7, g0 agent2, 2)</td>
<td>0.4906</td>
</tr>
<tr>
<td>addLink(0, agent1, g0 agent2, 0)</td>
<td>0.4727</td>
</tr>
</tbody>
</table>

**Goal description**

- existsLink(0, agent2, g0 agent7, 2), existsLink(0, agent2, g0 agent7, 2)

**Own action branching**

- 10

**Peers considered**

- 4

**Peer action branching**

- 2

**Maximal queue length**

- 10

**Requests to process**

- 5
Overview

Application Scenario

Simple negotiation frames in $m^2$infra

Proposal-based frames
Experimental setup
Results

Advanced negotiation frames

Conclusion
Proposal-based negotiation frames

First series of experiments as proof-of-concept implementation

Simple frames allowed for making proposals, counter-proposals, and compromise offers:

- \( \langle \text{request}(A, B, X) \rightarrow \text{accept}(B, A, X) \rightarrow \text{confirm}(A, B, X) \rightarrow \text{do}(B, X) \rangle \)
- \( \langle \text{request}(A, B, X) \rightarrow \text{reject}(B, A, X) \rangle \)
- \( \langle \text{request}(A, B, X) \rightarrow \text{propose}(B, A, Y) \rightarrow \text{accept}(A, B, Y) \rightarrow \text{do}(B, Y) \rangle \)
- \( \langle \text{request}(A, B, X) \rightarrow \text{propose} - \text{also}(B, A, Y) \rightarrow \text{accept}(A, B, Y) \rightarrow \text{do}(B, X) \rightarrow \text{do}(A, Y) \rangle \)

State abstractions of the form
\( \{\uparrow|\downarrow\}\{\{I, R\}, \{I, R, T\}, \{+, -, ?\}\} \)

Example: \( a_1 \) and \( a_2 \) talk about \( \text{do}(a_1, \text{deleteLink}(a_1, a_3)) \), \( a_2 \) is the responder, \( a_2 \) likes \( a_3 \)'s site \( \Rightarrow \) add \( \downarrow(I, T, +) \) to state
Experimental setup

- Compared utility performance of m²inffra to
  - BDI agents with simple communication
  - BDI agents without communication
  - random agents

- Utility function with interesting properties:
  - Empty/fully connected linkage networks yield highly suboptimal utility distribution
  - Interesting utilities range between rating-based and “politically correct” linkage

- Fixed rating profile
  - two antagonistic “groups” (in-ward cohesion, out-group distinction)
  - agents with higher index are more popular within their group
  - “bridge” between the two groups
Utility comparison: random agents
Utility comparison: BDI agents with communication

![Graph showing agent performance over reasoning cycles]

- Average
- Minimum
- Maximum
- Rating-based average
- Positive rating-based average
Utility comparison: BDI agents without communication
Utility comparison: $m^2$infra agents
Overview

Application Scenario

Simple negotiation frames in m²infra

Advanced negotiation frames
  Argumentation-based negotiation
  Interest-based negotiation (IBN)
  IBN frames in m²infra

Conclusion
Why negotiation?

Negotiation is a form of interaction in which a group of agents with conflicting interests and a desire to cooperate, try to come to a mutually acceptable agreement on the division of scarce resources. (Rahwan et al. 2004)

- LIeson experiments show that agent really only exchange proposals
- limited strategic options if no information about reasons is available
- ideal for domain in which “Web traffic” is a scarce resource
Different types of Automated Negotiation

- Game-theoretic approaches (formulation of games, quest for optimal strategies and equilibria)
- Heuristic-based approaches (use “good enough” rules of thumb rather than optimality criteria)

All based on direct exchange of proposals, i.e. all information is available in advance

- preferences are proper and fixed
- no influence on mental attitudes during negotiation
General negotiation agent design

Diagram showing the flow of negotiation processes, including:

- Proposal Database
- Proposal Evaluation/Generation
- Opponent/Environment Model & Mental Attitudes
- Locution Interpretation
- Incoming Locutions
- Outgoing Locutions
- Locution Generation

Processes involve:
- proposal
- content
- query
- update
Argumentation-based negotiation (ABN)

- ABN approaches are based on the idea of exchanging information (arguments) *during* negotiation

- External elements:
  - Agent communication language and domain language
  - Negotiation protocols (rules for admission, termination, withdrawal, proposal validity, commitment rules, outcome determination)
  - Information stores (in particular: commitment stores)

- Elements of ABN agents:
  - locution interpretation and generation
  - proposal evaluation/generation
  - argument interpretation, generation, selection
ABN agent design
Interest-based negotiation (IBN)

- Special form of ABN (Rahwan, Sonenberg and Dignum 2003)
- Main idea: acquiring and use information about other’s goals, beliefs and goals
- Process characterised by iterations of
  - *challenge*: a request for reasons behind other’s proposal/refusal
  - *justification*: providing the rationale for previous standpoint
  - *attack*: refutation of other’s beliefs/presentation of alternatives

- Operational model (our contribution):
  - If attack successful, the other agent will make a concession regarding previous rejection
  - If set of “open rejected issues” is empty, acceptance is likely
    ⇒ set of agreed terms is new proposal
Proposal-based negotiation process

- Proposal
- Rejection
- Agreement
- Execution
Repeated proposal-based negotiation process
Interest-based negotiation process

- Proposal
- Concession
- Attack
- Challenge
- Justification
- Rejection
- Agreement
- Execution
Objective: utilise IBN theory in m²infra

Case study in development of InFFrA architectures

Requirements:
- Develop a meta-model of the entire IBN process
- Add interest-based reasoning to sub-social inference processes
- Capture negotiation moves in the form of frames
- Ensure they are linked through conditions
- Develop online frame construction mechanism
- Adapt Q-update rule to suit negotiation moves
Adapting reasoning mechanisms

- Formal apparatus to talk about goals and ways of achieving them
- Based on relation \( \text{achieves}(V, V') \) where \( V, V' \) sets of logical facts and actions
- Can be used to derive: \( \text{achieved}(V) \), \( \text{achievable}(V) \), \( \text{threat}(\varphi, V) \), \( \text{instr}(v, v') \) (if \( \text{achieves}(V, V'), v \in V, v' \in V' \))
- Basic idea: a proposal is accepted if it is instrumental for a goal, rejected if it is a threat to a goal
- Assumption: only goals that are achievable and have not yet been achieved can be pursued
- NOTE: these are communicative conventions, need not reflect agents’ internal beliefs or desires
Goal graphs

- enemyPopularity
- +friendPopularity
- ownPopularity
- −ratingDiffFriend
- −ratingDiffEnemy
- +score
- {X=Y}
- {existsLink(A,B,Y)}
- modifyRating(A,B,X)
- addLink(A,B,X) {existsLink(A,B,X)}
- deleteLink(A,B) {−existsLink(A,B,X)}
- {other(A), self(B)}
- {self(C), rating(C,B)>0}
- {self(A), rating(A,C)>0}
- {self(C), rating(C,A)>0}
- {self(C), rating(C,A)<0}
- {self(A), rating(A,C)<0}
- {existsLink(C,B,Y), existsLink(A,C,Z)}
- |Y−Z|>|Y−X| |Y−Z|<|Y−X|
- {existingLink(C,B,Y), existingLink(A,C,Z)}
- {existsLink(C,B,Y), existsLink(A,C,Z)}

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Negotiation Frames
Goal graphs and challenges

- Assumptions:
  - all agents have the same goal graph structure (but concrete actions and facts depend on knowledge base!)
  - internal ratings are identical to displayed ratings (“suspension of disbelief”)
  - if no justification can be given for rejection, the agent must accept a proposal

- During negotiation agents seek to identify each other’s goals and beliefs

- Two types of challenges can be used: asking for the **purpose** of a proposal (or a rejection), and asking for the **justification** for pursuing a goal

- These correspond to tracing **instr**- and **threat**-edges **forwards** and **backwards** in the goal graph
Goal graphs and attacks

- Let $\phi$ is the issue talked about (a fact or a plan/action)
- An attack to a purpose $g$ claimed for $\phi$ can be any of the following assertions from the counter-party:
  - $achieved(g)$
  - $threat(\phi, g)$
  - $\neg achievable(g)$
  - $\neg achievable(\phi)$
  - $threat(\phi, g'), achievable(g')$
  - $instr(\phi, g'), achievable(g)$

- An attack to a justification $\phi$ claimed for $g$ can be any of the following:
  - $\neg achieved(\phi)$
  - $threat(\phi, g)$
Online frame construction

- Idea: equip agents only with \(\langle \text{propose}(A, B, X) \rightarrow \text{accept}(B, A, X) \rangle\) as a “real” frame and with additional negotiation frames that consist of
  - challenge, attack, concession
  - challenge, attack, counter-attack, concession

- Each of this moves also comes with a reject prefix which causes the content to be negated before being challenged (e.g. \(\text{propose}(a_1, a_2, \text{addLink}(a_2, a_1)) \rightarrow \text{reject}(a_2, a_1, \text{addLink}(a_2, a_1)) \rightarrow \text{request} - \text{purpose}(a_1, a_2, \neg \text{addLink}(a_2, a_1)))\)

- “Admissible” proposals must contain achievable and not yet achieved goals (or the respective plans)
Online frame construction (II)

- Rejection or unsolicited challenge causes a framing problem
- Concession effects deletion from “open issues” list
- Line of reasoning: if “open issues” list is empty, proposal will be accepted
- Attack/justification generation according to knowledge of other’s goal graph (model only used within a single conversation)
  - select least defeasible arguments (goal graph search)
  - remain truthful (i.e. arguments do only contain facts that can be derived from one’s own knowledge base)
  - step between attack and concession/counter-attack (only performed once) mediated by belief revision (perception)
- Useful frame can be constructed by concatenating moves until accept/reject ⇒ desirability criterion need not be changed
Example

- propose\((a, b, \text{modifyRating}(b, c, 3)) \rightarrow\) reject\((b, a, \text{modifyRating}(b, c, 3))\)

- \(a\) knows existLink\((b, c, 1)\), infers instr\((\text{modifyRating}(b, c, 3), +\text{friendPopularity})\), attacks with request-purpose\((\neg \text{modifyRating}(b, c, 3))\)

- \(b\) justifies with provide-purpose\((\text{instr}(\neg \text{modifyRating}(b, c, 3), -\text{ratingDiffFriend}))\)

- \(a\) verifies that existLink\((a, c, 1)\) and existLink\((b, c, 1)\) through observation actions

- \(a\) says concede\((a, b, \neg \text{modifyRating}(b, a, 3))\)

- \(b\) says propose\((b, a, \{\text{modifyRating}(b, c, 3), \text{modifyRating}(a, c, 3)\})\)

- \(a\) cannot find a suitable reason to reject and sends accept
Adaptations to Q-learning mechanism

- Instead of learning framing utility, now learn use of negotiation moves
- Re-framing procedure spawned everytime a new issue is discussed (through rejection or an unsolicited challenge)
- Update rule for Q-learning has to be modified, since entire frames will only be generated temporarily
- Open question: *What should the state abstraction during negotiations be?*
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Conclusions

- Discussed simple proposal-based and complex interest-based negotiation frames
- Reassuring results regarding learning algorithms with proposal-based frames
- Advancing into more complex forms of negotiation to explore wider range of communication strategies
- InFFrA approach combines design of protocols, information stores, and agent strategies
- Next step: implementation of IBN frames and experimental validation