Universiteit Utrecht

THE UNIVERSITY OF MELBOURNE

An Empirical Study of Interest-based Negotiation

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Outline of the presentation

1. Introduction/Motivations
2. The negotiation framework:
   a) Bargaining Protocol and strategy
   b) Reframing Protocol and Strategy
   c) Meta-strategy
3. Example
4. Experimental Setting
5. Results
6. Conclusion and Future Work

Introduction / Motivation

- Automated Negotiation:
  - Negotiation is the search for an agreement on the exchange/allocation of scarce resources among self-interested agents
- Approaches to automated negotiation:
  1. Game Theoretic
  2. Heuristic

  } Position-based negotiation

  3. Argumentation-based negotiation

Introduction / Motivation

- Shortcomings of position based approaches:
  - Game theory makes strong assumptions:
    - Complete and common knowledge about the agents utility functions or goals
    - Shared knowledge (common priors) on valuations of the objects
  - Heuristic approaches limitations:
    - Counter-offer or rejection as sole feedbacks
    - Static preferences about the outcome of the negotiation that fix the preferences among offers

Introduction / Motivation

- Argument based negotiation (ABN, the idea that agents can exchange arguments about each other positions) has been proposed to go beyond position-based models.
- Interest based negotiation (IBN) has been presented as an instantiation of ABN where only the underlying interests of the agents and the different ways to achieve them are discussed.
- It has been claimed that ABN/IBN increases the likelihood and quality of agreements

Introduction / Motivation

- Our aim is to test this hypothesis:
  - To provide a formal model of IBN that overcomes the limitations (in particular by using the cognitive and social capabilities of agents that are not used by other approaches to negotiation).
  - To implement it (first implementation?)
  - To proove (through simulation) that: IBN strategy improves the outcome of the negotiation

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IBN: General picture

- IBN domain:
  - Agents: A,B
  - Agents have a goal (or several)
  - Agents know goal decomposition (in terms of sub-goals and resources)
  - Agents have non divisible consumable resources and money
  - Agents have valuation of the resources they own and estimation of the resources they don't
- But agents:
  - Do not know what is the other's goal
  - Do not know how the other evaluates the resources

Example - agent

$\mathcal{A} = \{A, B\}$ is a set of agents;

$\mathcal{G} = \{G_1, \ldots, G_{12}\}$ is a set of all possible goals;

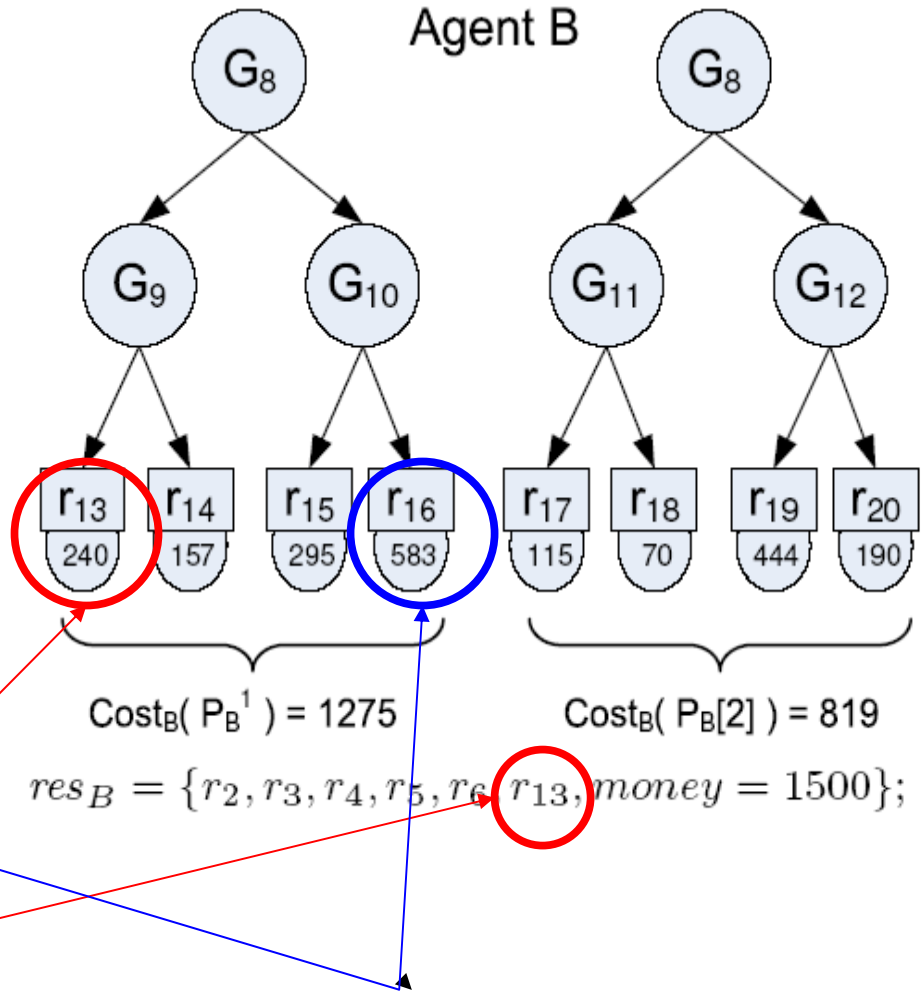
$goal_A = G_1$ and $goal_B = G_8$;

$Res = r_1, \ldots, r_{20}$;

$sub = \{(G_1, \{G_2, G_3\}), (G_1, \{G_4, G_5\}), (G_1, \{G_6, G_7\}), (G_1, \{G_8, G_9\}), (G_2, \{r_1, r_2\}), (G_3, \{r_3, r_4\}), (G_4, \{r_5, r_6\}), (G_5, \{r_7, r_8\}), (G_6, \{r_9, r_{10}\}), (G_7, \{r_{11}, r_{12}\}), (G_8, \{G_9, G_{10}\}), (G_8, \{G_{11}, G_{12}\}), (G_9, \{r_{13}, r_{14}\}), (G_{10}, \{r_{15}, r_{16}\}), (G_{11}, \{r_{17}, r_{18}\}), (G_{12}, \{r_{19}, r_{20}\})$;

The values of val_B, $prefmin_B$ and $prefmax_B$, has been generated with $error_B = 0\%$ and $var_B = 70\%$, with a potential benefit of 20%:

$[147, 174]_B^{r_1}$, $[314, 346]_B^{r_2}$, $[66, 73]_B^{r_3}$, $[445, 490]_B^{r_4}$, $[432, 475]_B^{r_5}$, $[427, 470]_B^{r_6}$, $[80, 89]_B^{r_7}$, $[222, 247]_B^{r_8}$, $[262, 328]_B^{r_9}$, $[171, 214]_B^{r_{10}}$, $[72, 90]_B^{r_{11}}$, $[323, 404]_B^{r_{12}}$, $[240, 264]_B^{r_{13}}$, $[126, 157]_B^{r_{14}}$, $[266, 295]_B^{r_{15}}$, $[524, 583]_B^{r_{16}}$, $[103, 115]_B^{r_{17}}$, $[63, 70]_B^{r_{18}}$, $[400, 444]_B^{r_{19}}$, $[171, 190]_B^{r_{20}}$



Assumptions

1. The least preferred value of an object is its estimated value
2. The potential benefit is specified as a percentage of the preferred values
3. All resources are owned
4. No resources are shared
5. Resources are consumed
6. Agents have shared knowledge of the set of possible goals, the set of resources and all possible decompositions of goals (plans)
7. There is no overlap between needed resources

IBN: General picture

- Agents will negotiate an exchange of resources for achieving their goals
  (Money will be used for utility transfer)
- Execution cycle, the agent will:
  1. Generate all the possible plans
  2. Evaluate the plans (agents usually have wrong evaluations for the resources that are missing)
  3. Pick the cheapest and negotiate to get the missing resources if any.
  4. Try the next plan if the negotiation fails.

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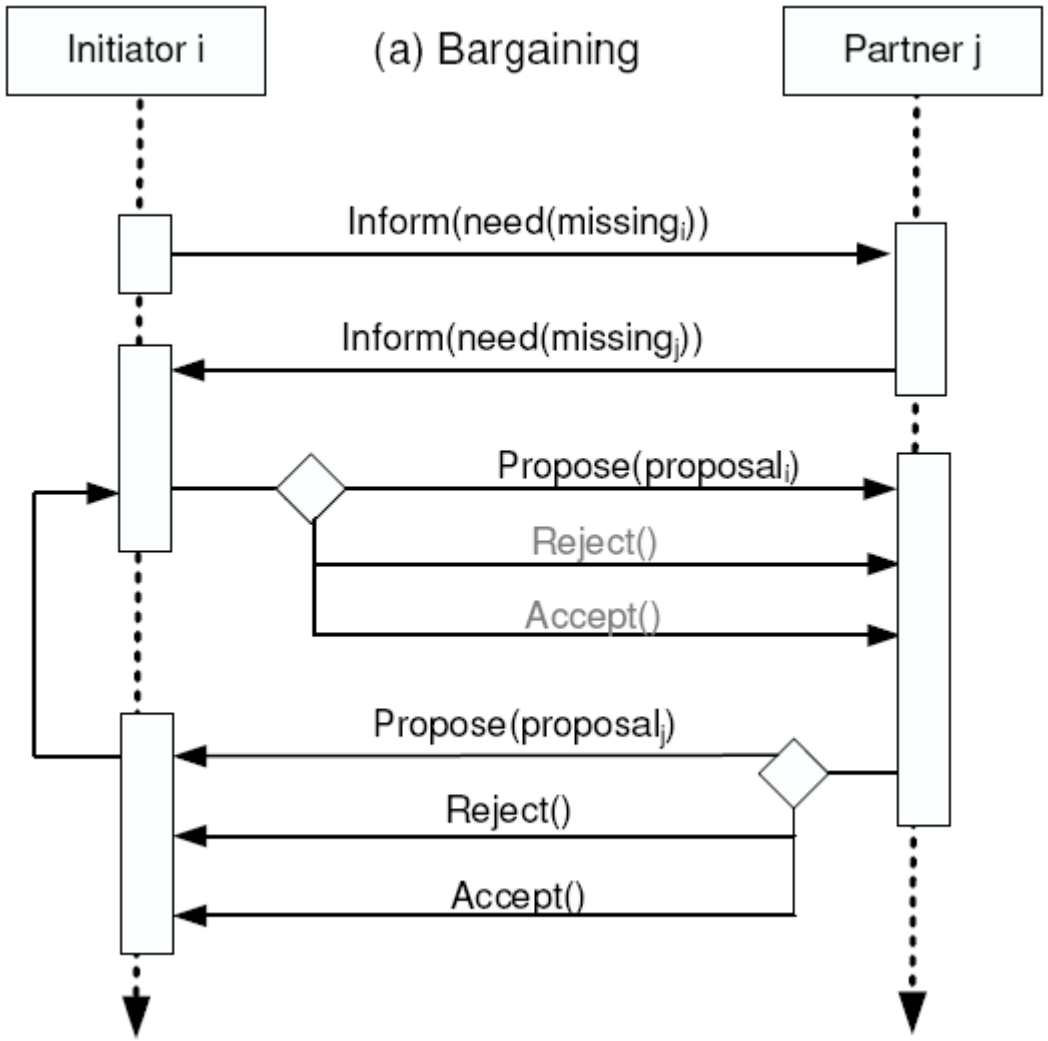
B: Bargaining Protocol and Strategy

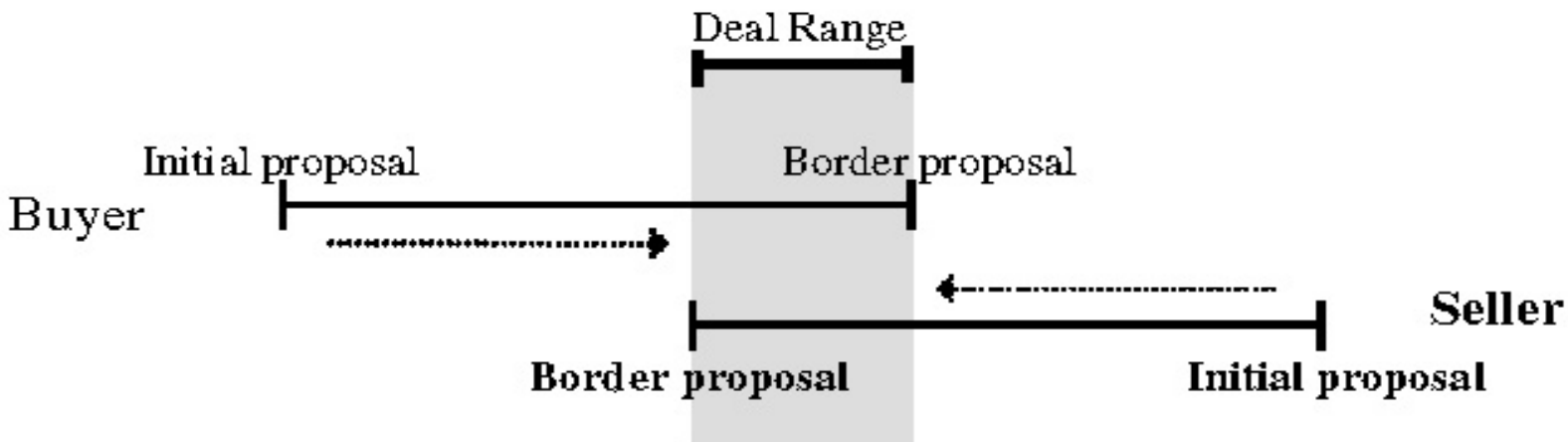
- Agents disclose the set of resources they want and start exchanging offers:

$$\langle S_{wanted}, S_{given}, Payment \rangle_{i \to j}$$



B: Bargaining Protocol and Strategy

- Agents start with their most preferred offer
- They evaluate each offer received in terms of benefits
- Alternated offers bargaining about compensatory payments with a monotonic concession strategy:
  - $X_{nextOffer} = (X_{Offer} + Y_{Offer})/2$ if within preferences boundaries
  - $X_{nextOffer} = X_{Offer}$ otherwise
  - Ending condition: the agents (both) repeat themselves



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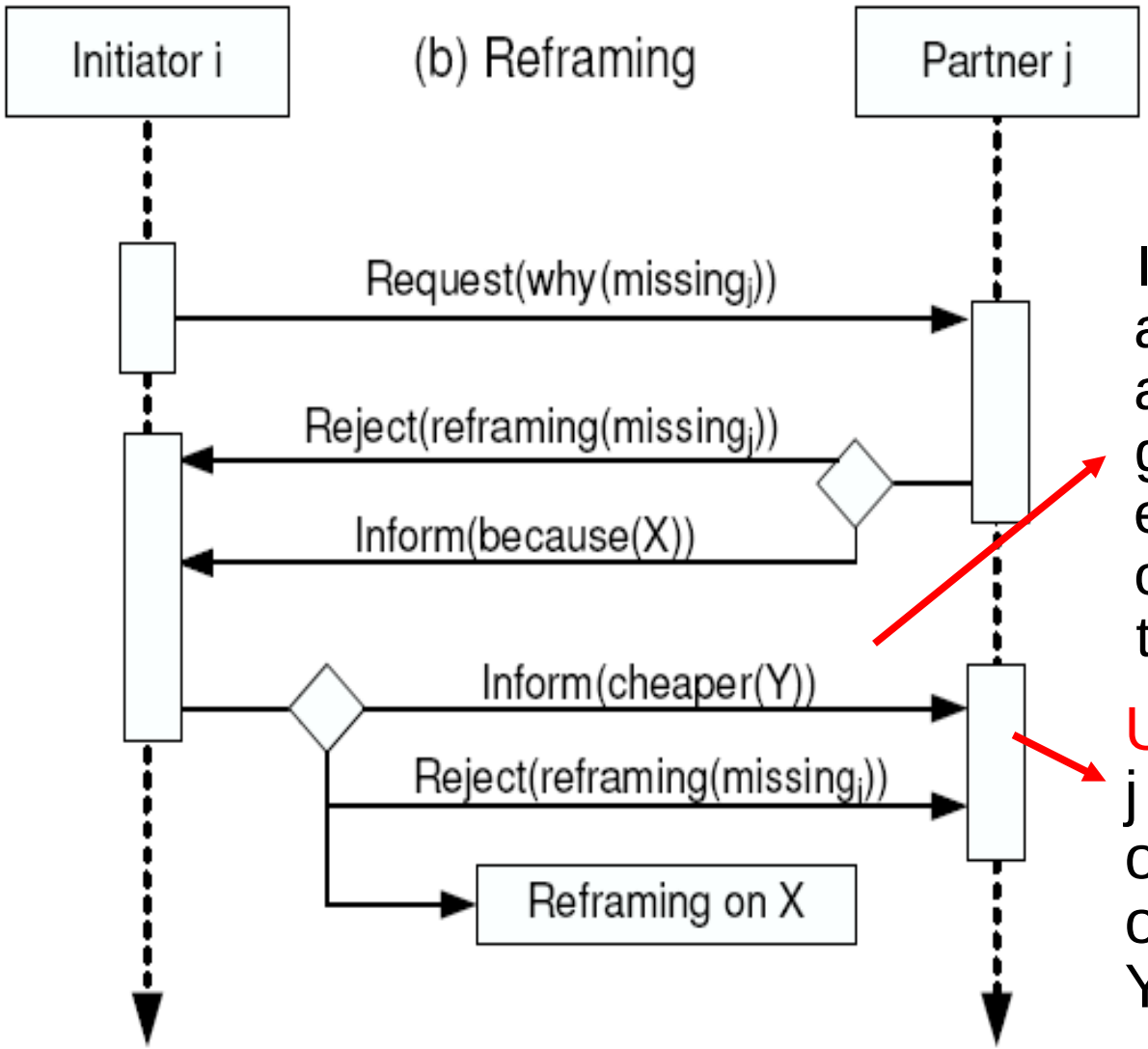
R – Reframing Strategy and Protocol

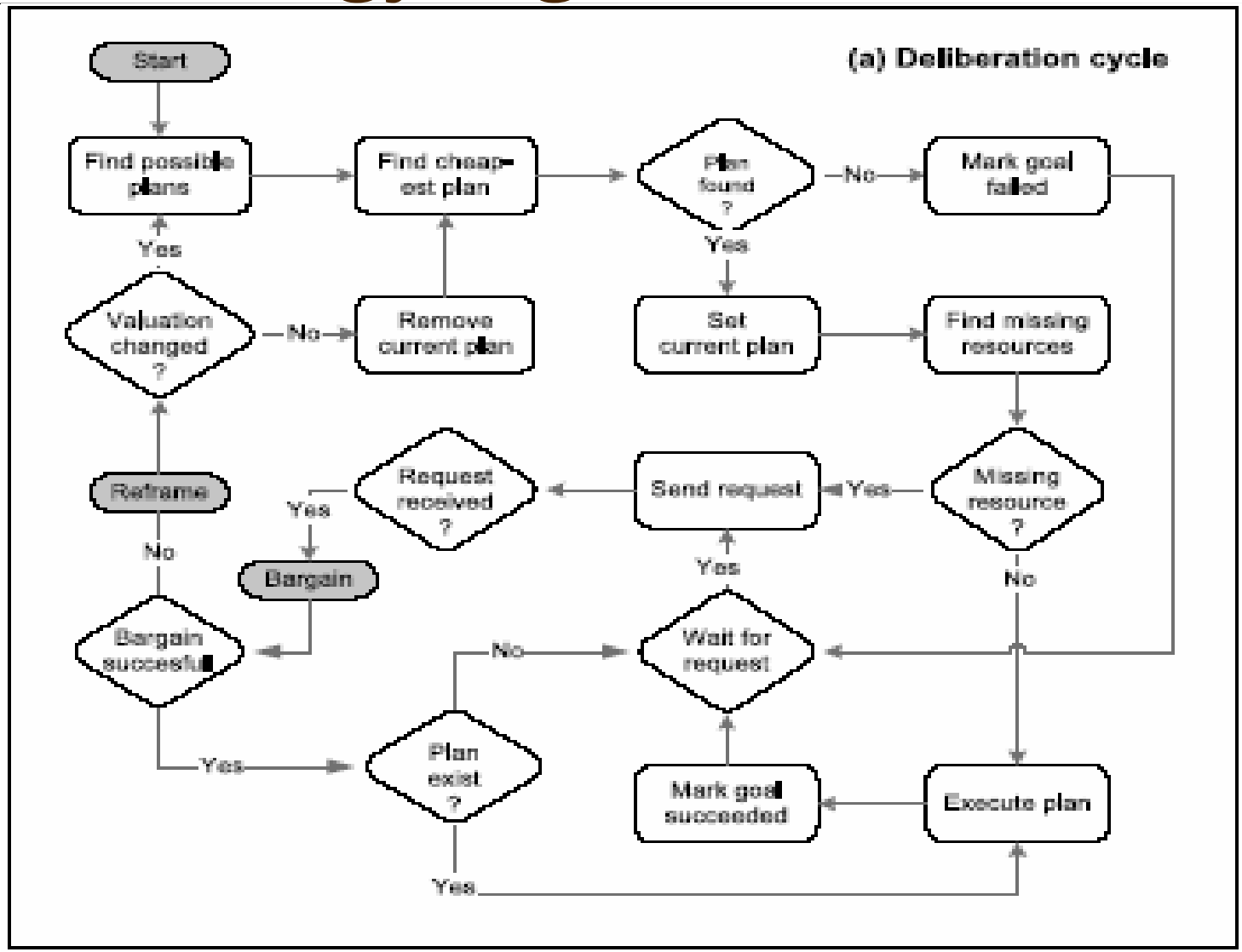


We assume that the agents are sincere and trust each other

If possible, i suggests an alternative way of achieving j's underlying goal that is subjectively evaluated to be the best option for him among the ones beneficial for j.

Update function:
j updates the valuation of the ressources not owned in order to make Y cheaper than X

Meta-strategy: agent deliberation



Meta-strategy: BO and BR agents

- BO agents: agents that can only use the bargaining protocol and strategy
- BR agents: agents that can use both bargaining and reframing.
- Meta-strategy: there are several ways to intertwine the two strategies
  - $B_1 \rightarrow R_{A\&B} \rightarrow$ Update $\rightarrow B_2 \rightarrow R_{A\&B} \rightarrow B_1 \rightarrow \ldots$
  - $B \rightarrow R_A \rightarrow$ Update $\rightarrow R_B \rightarrow B \rightarrow \ldots$
  - ...
  - $B_{1\&2} \rightarrow R_{A\&B} \rightarrow$ Update $\rightarrow B_{1\&2} \rightarrow \ldots$

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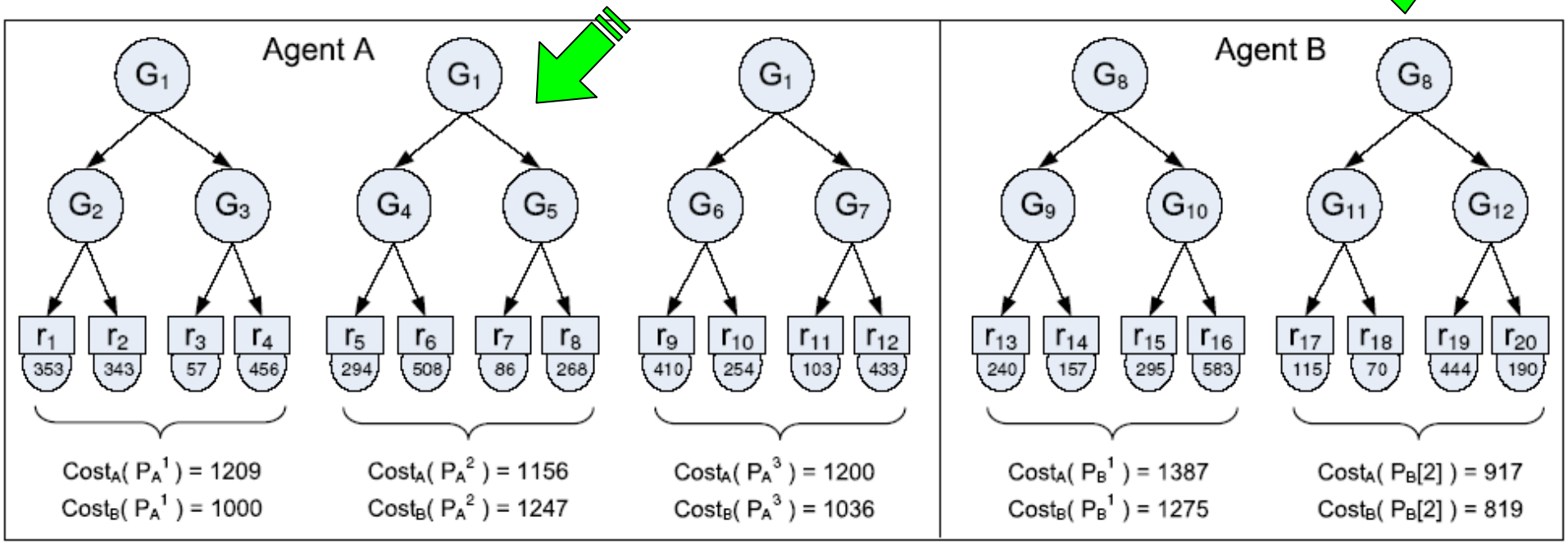
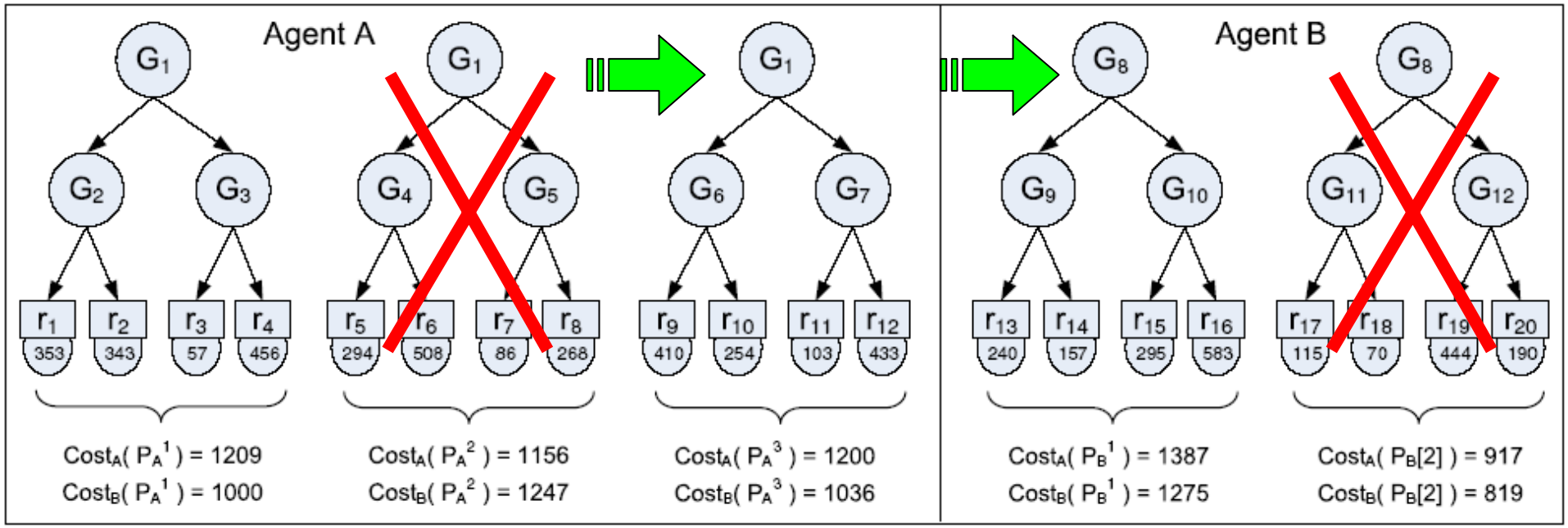
BO negotiations - example



Nb	Message	$eval_A$	$eval_B$
B^1	$\langle \{r_{17}, r_{18}, r_{19}, r_{20}\}, \{r_5, r_6\}, -208 \rangle_{B \rightarrow A}$	-177	$+168$
A^1	$\langle \{r_5, r_6\}, \{r_{17}, r_{18}, r_{19}, r_{20}\}, -195 \rangle_{A \rightarrow B}$	$+164$	-235
B^2	$\langle \{r_{17}, r_{18}, r_{19}, r_{20}\}, \{r_5, r_6\}, -208 \rangle_{B \rightarrow A}$	-177	$+168$
A^2	$reject$		

BO negotiations - example



Nb	Message	$eval_A$	$eval_B$
B^1	$\langle \{r_{17}, r_{18}, r_{19}, r_{20}\}, \{r_5, r_6\}, -208 \rangle_{B \rightarrow A}$	-177	$+168$
A^1	$\langle \{r_5, r_6\}, \{r_{17}, r_{18}, r_{19}, r_{20}\}, -195 \rangle_{A \rightarrow B}$	$+164$	-235
B^2	$\langle \{r_{17}, r_{18}, r_{19}, r_{20}\}, \{r_5, r_6\}, -208 \rangle_{B \rightarrow A}$	-177	$+168$
A^2	$reject$		

BO negotiations - example

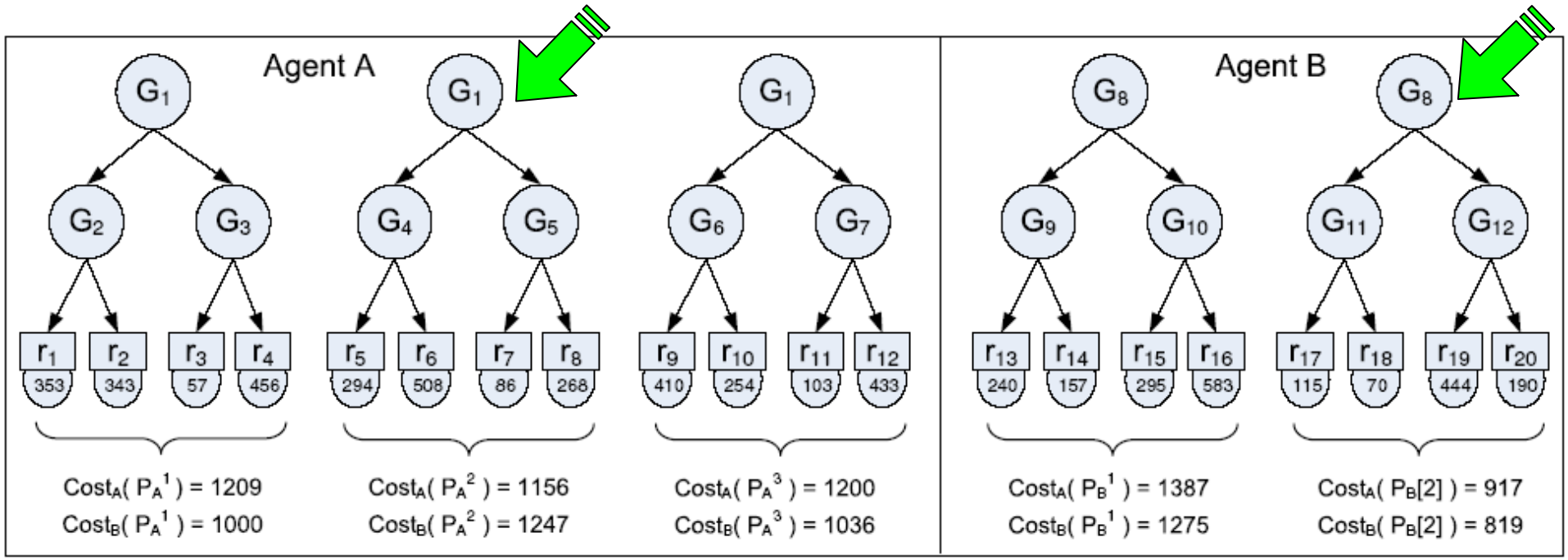
Agent A has all the resources he needs

Nb	Message	$eval_A$	$eval_B$
B^1	$\langle \{r_{14}, r_{15}, r_{16}\}, \{\}, +916 \rangle_{B \rightarrow A}$	-123	$+119$
A^1	$\langle \{\}, \{r_{14}, r_{15}, r_{16}\}, -1143 \rangle_{A \rightarrow B}$	$+104$	-108
B^2	$\langle \{r_{14}, r_{15}, r_{16}\}, \{\}, +1029.5 \rangle_{B \rightarrow A}$	-9.5	$+5.5$
...	...	...	...
A^4	$\langle \{\}, \{r_{14}, r_{15}, r_{16}\}, -1043.7 \rangle_{A \rightarrow B}$	$+4.7$	-8.7
B^5	$\langle \{r_{14}, r_{15}, r_{16}\}, \{\}, +1029.5 \rangle_{B \rightarrow A}$	-9.5	$+5.5$
A^5	$reject$		

Conclusion:

- Agent A achieves his goal with P^3 (costs 1200)
- Agent B (no more plan) does not achieve his goal

BR negotiations - example



Nb	Message	$eval_A$	$eval_B$
B^1	$\langle \{r_{17}, r_{18}, r_{19}, r_{20}\}, \{r_5, r_6\}, -208 \rangle_{B \rightarrow A}$	-177	$+168$
A^1	$\langle \{r_5, r_6\}, \{r_{17}, r_{18}, r_{19}, r_{20}\}, -195 \rangle_{A \rightarrow B}$	$+164$	-235
B^2	$\langle \{r_{17}, r_{18}, r_{19}, r_{20}\}, \{r_5, r_6\}, -208 \rangle_{B \rightarrow A}$	-177	$+168$
A^2	$reject$		

BR negotiations - example

Nb	Perf.	Message
B^1	$request$	$why\langle\{r_5, r_6\}\rangle_{B\rightarrow A}$
A^1	$request$	$why\langle\{r_{17}, r_{18}, r_{19}, r_{20}\}\rangle_{B\rightarrow A}$
B^2	$inform$	$because\langle\{G_{11}, \{r_{17}, r_{18}\}\}, \{G_{12}, \{r_{19}, r_{20}\}\}\rangle_{A\rightarrow B}$
A^2	$inform$	$because\langle\{G_4, \{r_5, r_6\}\}\rangle_{A\rightarrow B}$
B^3	$request$	$why\langle\{G_4\}\rangle_{B\rightarrow A}$
A^3	$request$	$why\langle\{G_{11}, G_{12}\}\rangle_{B\rightarrow A}$
B^4	$inform$	$because\langle\{G_8, \{r_{17}, r_{18}, r_{19}, r_{20}\}\}\rangle_{A\rightarrow B}$
A^4	$inform$	$because\langle\{G_1, \{r_5, r_6, r_7, r_8\}\}\rangle_{A\rightarrow B}$
B^5	$inform$	$cheaper\langle\{G_1, \{r_1, r_2, r_3, r_4\}\}\rangle_{B\rightarrow A}$
A^5	$request$	$why\langle\{G_8\}\rangle_{B\rightarrow A}$
B^6	$reject$	$why\langle\{G_8\}\rangle_{B\rightarrow A}$
B^6	$reject$	$reframing\langle\{r_{17}, r_{18}, r_{19}, r_{20}\}\rangle_{B\rightarrow A}$

BR negotiations - example

- Agent B drops his plan
- Agent A updates his valuation function according to this new information, i.e. so that P^1 becomes cheaper than P^2
- Valuations of the resources not owned:
  - Decrease of P1: r_2, r_3, r_4
  - Increase of P2: r_5, r_6
- A's preference relation is changing:
  - Before: $P^2 > P^3 > P^1$
  - After: $P^1 > P^2 > P^3$

BR negotiations - example

- The next bargaining succeeds:

Nb	Message	$eval_A$	$eval_B$
A^1	$\langle\{r_2, r_3, r_4\}, \{r_{14}, r_{15}, r_{16}\}, -484\rangle_{A \rightarrow B}$	$+269$	-274
B^1	$\langle\{r_{14}, r_{15}, r_{16}\}, \{r_2, r_3, r_4\}, +7\rangle_{B \rightarrow A}$	-209	$+217$
A^2	$\langle\{r_2, r_3, r_4\}, \{r_{14}, r_{15}, r_{16}\}, -245\rangle_{A \rightarrow B}$	$+30$	-35
B^2	$\langle\{r_{14}, r_{15}, r_{16}\}, \{r_2, r_3, r_4\}, +133\rangle_{B \rightarrow A}$	-82	$+90$
...	...	...	...
A^6	$\langle\{r_2, r_3, r_4\}, \{r_{14}, r_{15}, r_{16}\}, -217\rangle_{A \rightarrow B}$	$+2$	-7
B^6	$\langle\{r_{14}, r_{15}, r_{16}\}, \{r_2, r_3, r_4\}, +223\rangle_{B \rightarrow A}$	$+8$	$+0$
A^7	*accept*		

Conclusion:

- Both agents achieve their goal
- Agent A achieves his goals with a cost of 1191

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Experiments

- We have developed a negotiation simulator:
  - Allows to generate BO and BR agents: 3APL agents with goals, knowledge about the goal decomposition, knowledge of the resources they own, beliefs about the value of the resources, potential benefit, ...
    - Error made on the valuation of the resources not owned
    - Potential benefits: used to calculate [prefmin, prefmax]
  - Allows to generate synthetic IBN Domains:
    - Depth and branching factor of the plans
    - Number of alternatives for each goal
  - Allows to automatise BO and BR negotiation

Experiments

- Demonstration
- We ran simulations at the Center for High Performance Computing of the University of Melbourne.
- Alfred is a Linux Cluster system consisting of 48 computer nodes (was ranked #484 in June 2003)
- Our simulator and the 3APL environment have been modified to work in batch mode (jobs – negotiations – are distributed over the nodes)

Experiments: Parameters

- The parameters used for the experiments were:
  - Plans of depth 3, branching 2, 4 alternatives for the main goal (32 resources)
  - We assumed no overlap between the agents plans (positive or negative interactions)
  - Error was varied from -70% to +70% by step of 5%
  - 100 different configurations: initial domain and valuations
  - BO and BR for each configuration
- That is 168200 negotiations per experiment!

1 month later!

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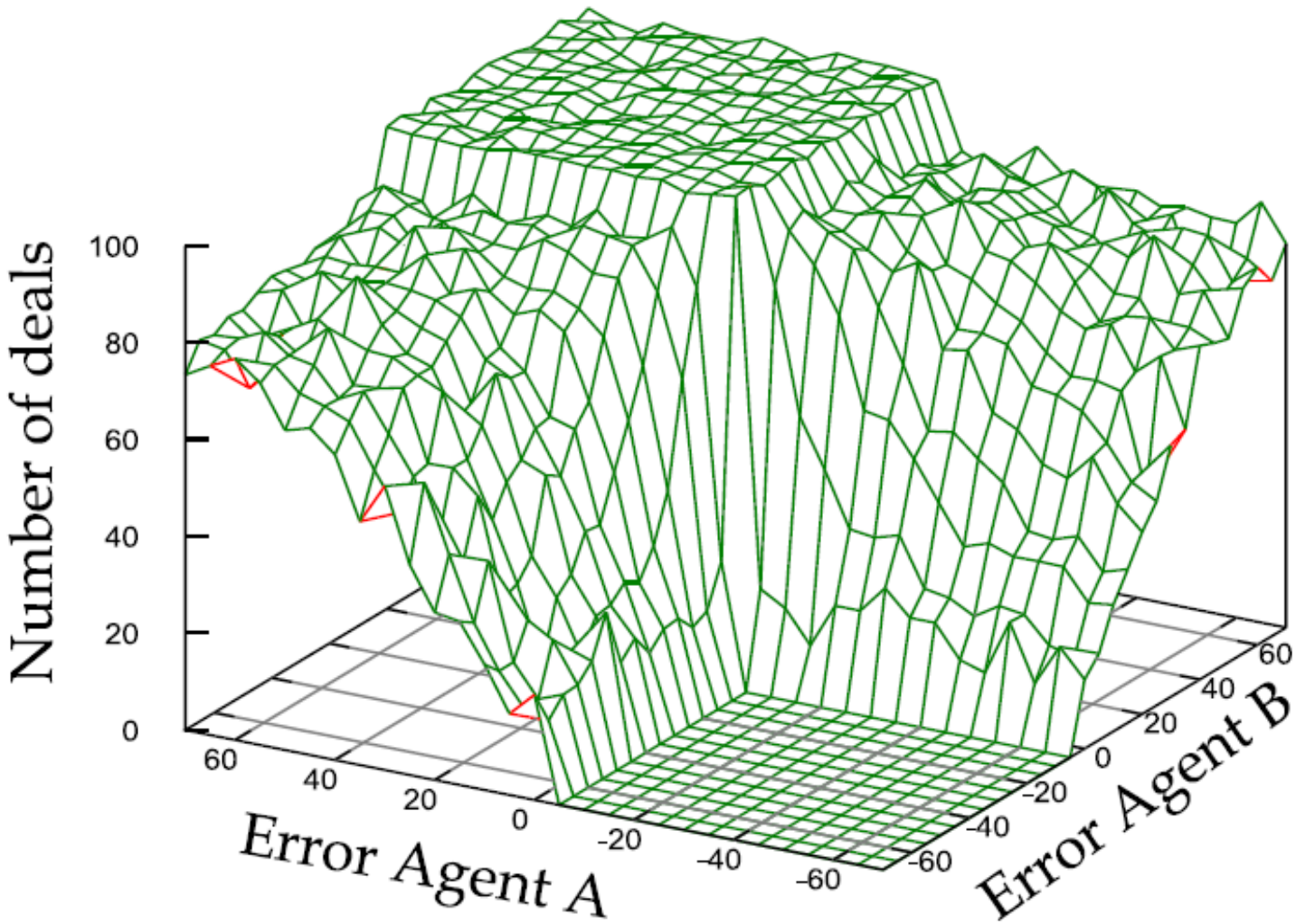
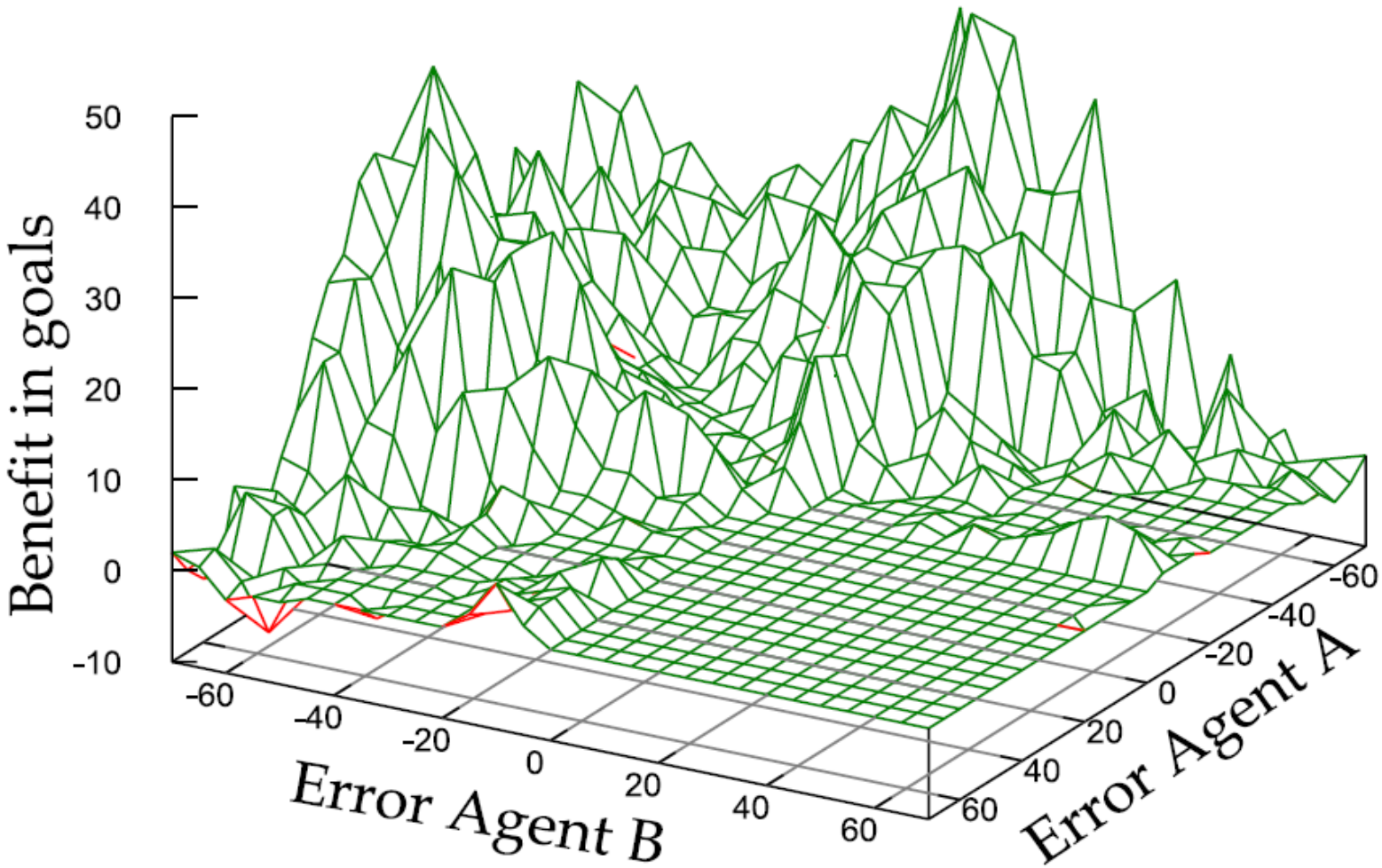
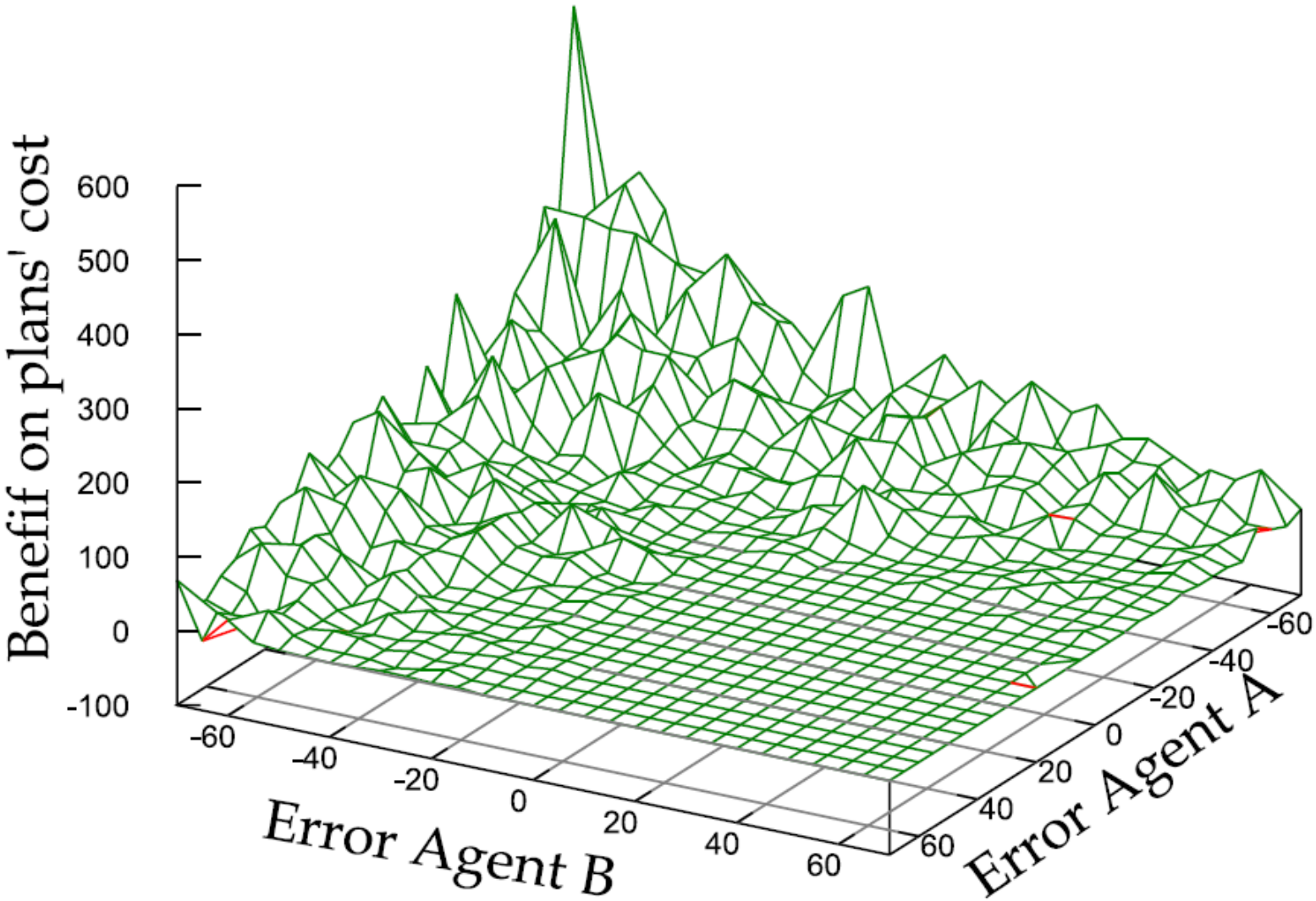
Qualitative result for Bargaining



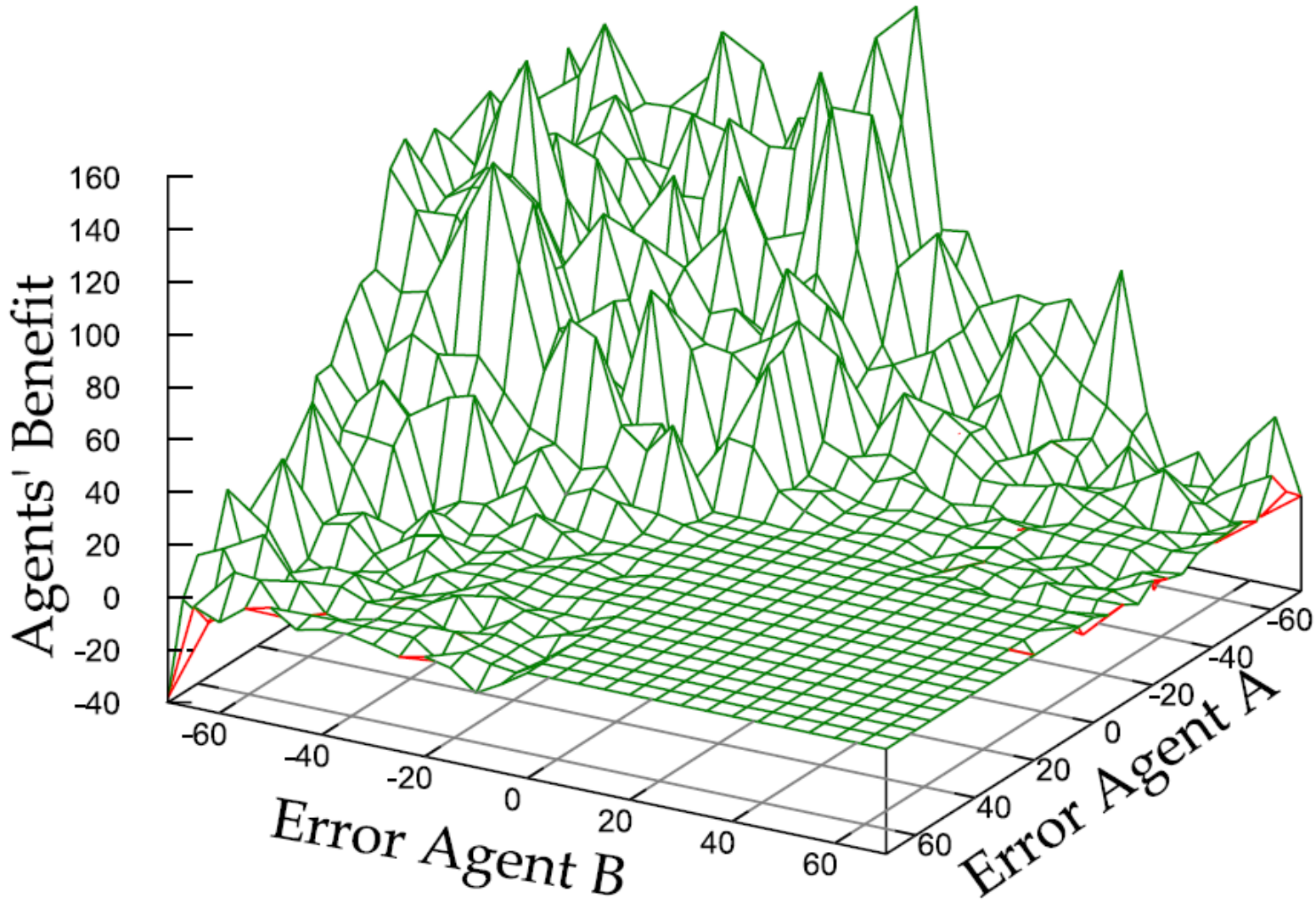
Qualitative benefits of IBN



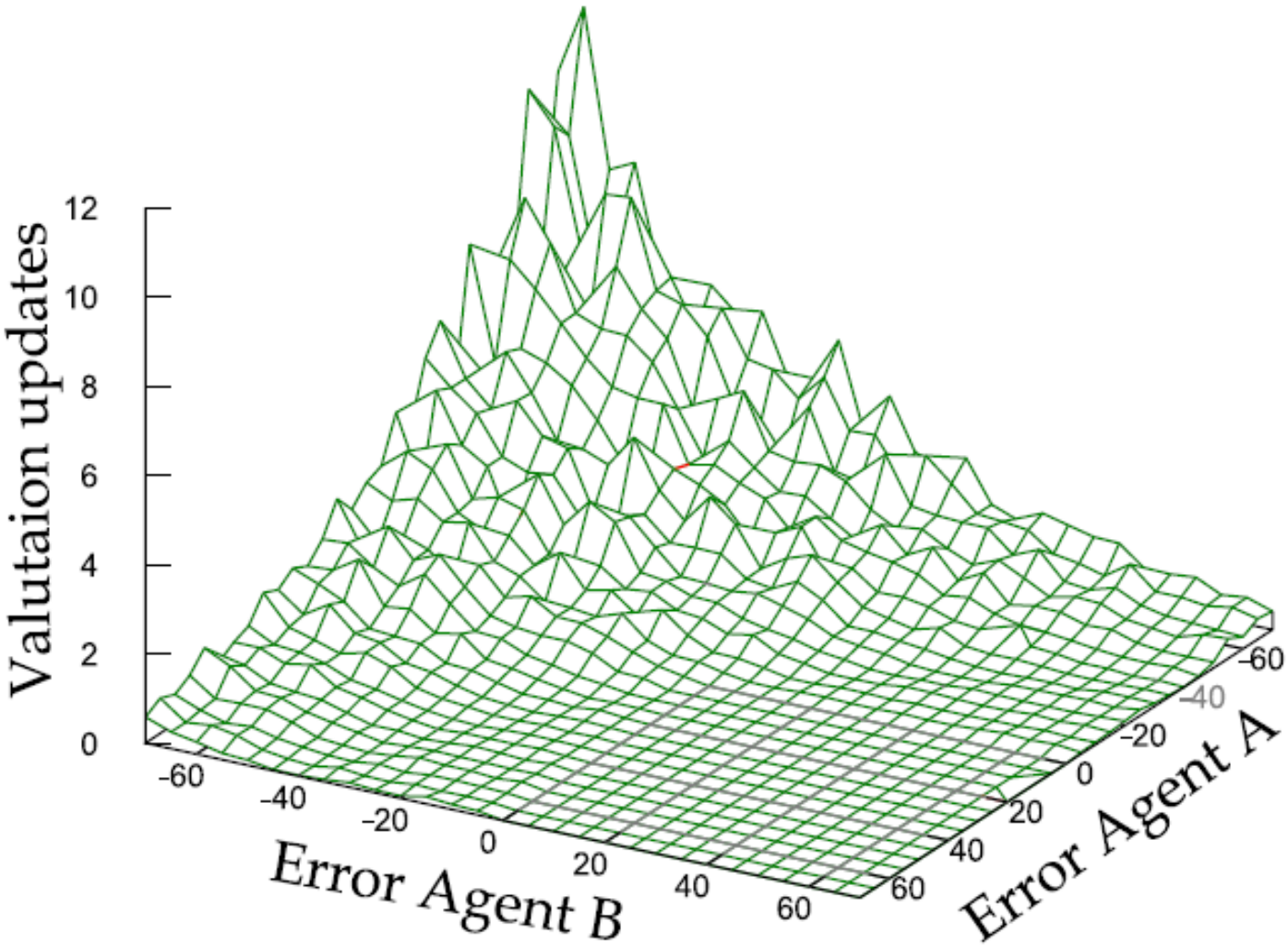
Quantitative benefits of using IBN



Quantitative benefits of using IBN



Qualitative dimension of IBN



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Conclusion - Results

- In this work, we demonstrate (through simulation) that IBN (the BR strategy) increases the likelihood and the quality of deals:
  - Increases the number of agreements
  - When both BO and BR allow for a deal: less expensive plan(s) and/or more (subjective) benefits are made in the BR deals
- However, these qualitative and quantitative advantages are not of analytical nature but empirical results that hold in general rather than in all cases.

Conclusion - results

- The proposed model gets rid of the four limitations mentioned in the introduction:

- Agents do not have a priori knowledge of the others' utility function or goal
- Agents have imperfect evaluation of the resources not owned

} Incomplete and imperfect knowledge

- Feedbacks are not restricted to an exchange of offers
- The agents' valuation functions and preferences about plans are dynamic

} Takes advantage of the cognitive and social capabilities (communication) of cognitive agents

Future and Related Work

- There are many perspectives on this work:
  - Other experiments:
    - Asymmetric reframing (only one agent)
    - Variants of the type and structure of the domain (ready for that)
    - Different update functions
    - Different meta-strategies
  - Refining the current protocols (looping, …)
  - Malicious/insincere agents
  - Positive/negative interactions between goals and conflicting needs for resources

Future and Related Work

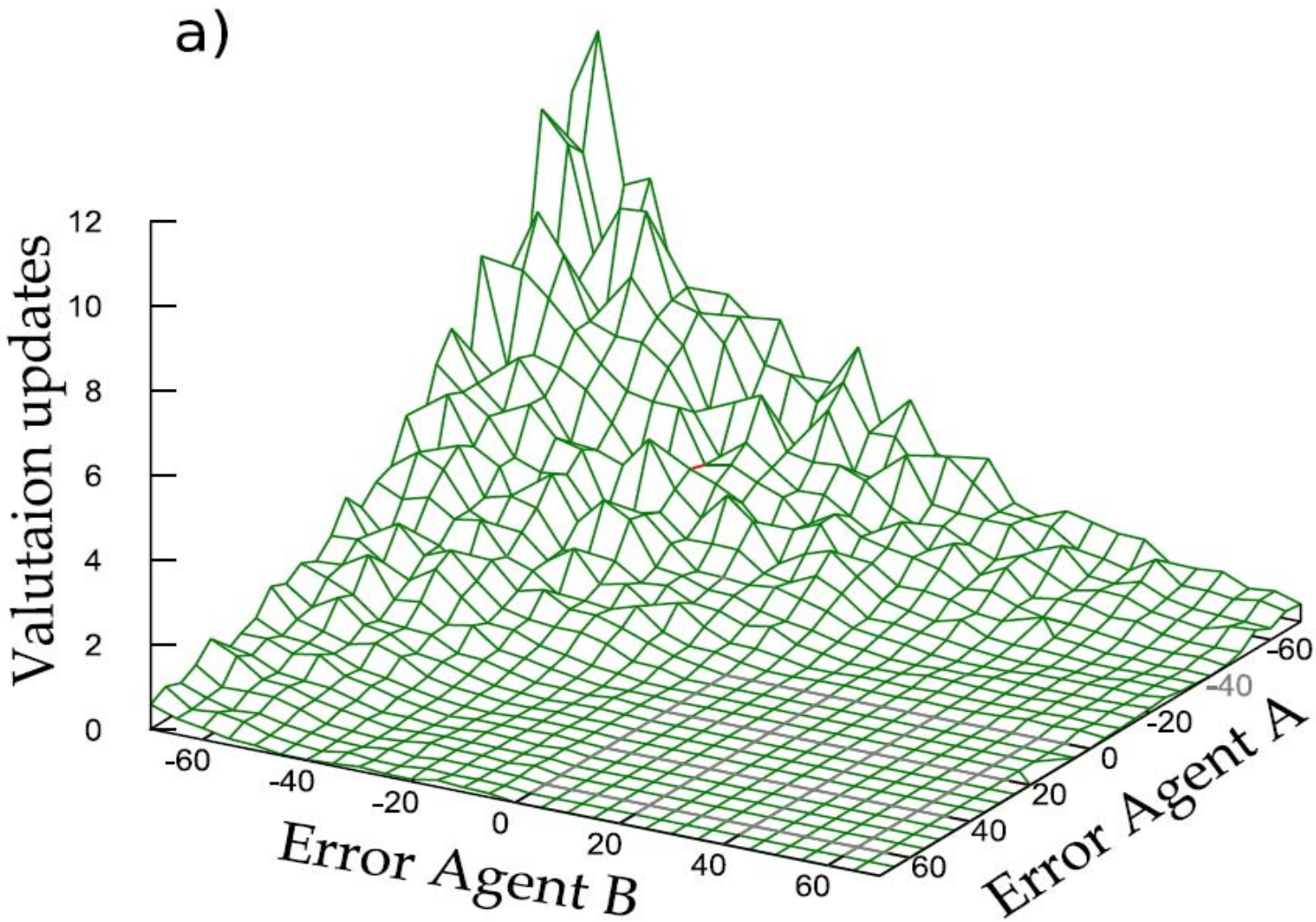
- Extending/refining the model:
  - Uncertainty about the validity of plans
  - Incomplete knowledge about plan decomposition
  - Extend the reframing protocol with more argumentation
  - Propose other ABN protocols
  - ABN/IBN strategies other than reframing
- In a related paper (submitted to JAAMAS we present similar model (simpler) with analytical results about positive interactions

Questions and Discussion

Example of loop

Preferences of agent A (subjective costs)
$P_1^A(400) \succ^c P_2^A(500) \succ^c P_3^A(550)$
$P_3^A(475) \succ^c P_1^A(476) \succ^c P_2^A(500)$
$P_1^A(476) \succ^c P_2^A(487.5) \succ^c P_3^A(488.5)$
$P_3^A(481) \succ^c P_1^A(483) \succ^c P_2^A(487.5)$
...

Complexity


a)
Valutaion updates
0
2
4
6
8
10
12
-60
-40
-20
0
20
40
60
Error Agent B
Error Agent A