Reasoning about Interaction

Current Research at the Agents Group in Edinburgh

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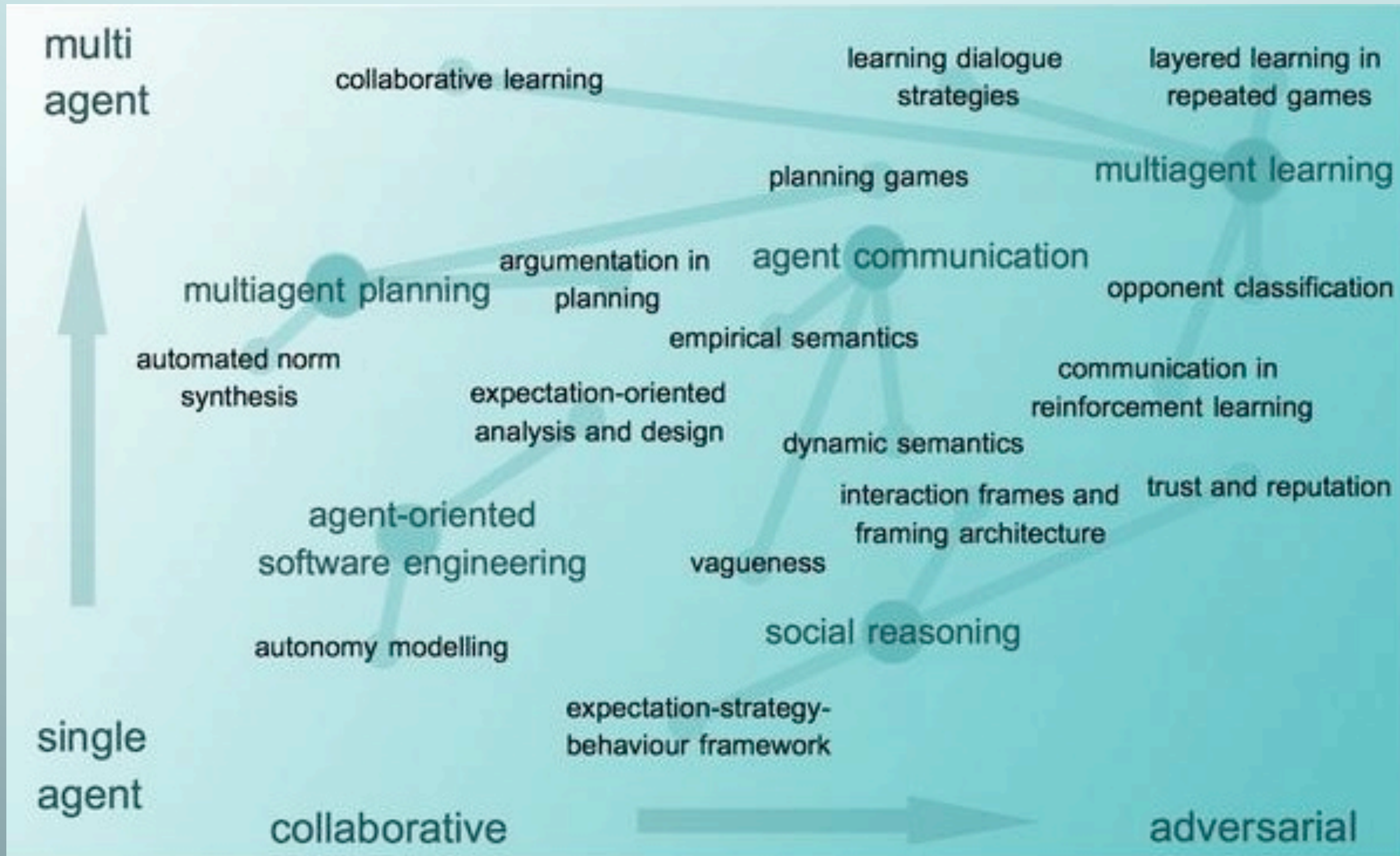
Background: Work in my group



Visit www.cisa.inf.ed.ac.uk/agents for details

Some motivation

- What is special about agents? Interaction in a common environment
- To make agents intelligent and autonomous, we need to automate such interaction
- Interested in knowledge-based reasoning about interaction
- Reasoning about interaction is by definition practical reasoning
- Vision: given a specification of the interaction problem, automatically synthesise behaviour

Practical reasoning about interaction

- We are interested in building systems, not only specifying them formally
- Rational agents need to synthesise action sequences to operate autonomously
- We want to tell them what to achieve, not how, abstraction desirable
- This suggests using knowledge represen-tation techniques
- Planning is the interface between KR methods and practical reasoning

Why not game theory?

- Game-theoretic methods very popular currently and address the problem of reasoning about interaction
- Information in real-world domains available in relational terms (e.g. on the Web), not enumerated state actions as assumed in game theory
- Non-incremental: unable to express how a game changes when we incrementally change background knowledge
- Knowledge-based methods might be useful in lifting overly restrictive assumptions (full rationality, perfect knowledge, etc)
- Intuition: many large-scale games might be actually "easier" than we think *(this is speculative)*

Current work

- Three examples of our current work in this area:
  - Macro-level: Automated norm synthesis
  - Meso-level: Argumentation-based conflict resolution
  - Micro-level: Practical social reasoning architectures
- Address general multiagent systems problems :
  - Setting up social laws to avoid undesirable states
  - Exchanging information to align divergent views
  - Reasoning about others from an agent’s point of view
- From a general computer science point of view:
  - Designer-level specification of system constraints
  - Integration of distributed sources of data
  - Process-level view of environment behaviour

Automated norm synthesis in a planning environment

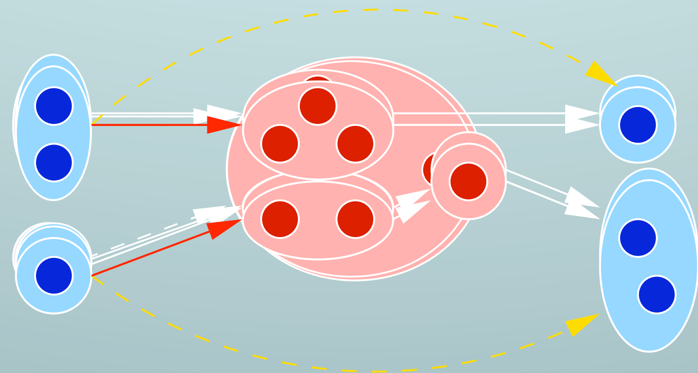
- Norms ensure global conflict states are never entered by prohibiting actions in certain states
- At the same time agents' private goals should remain achievable
- Automated synthesis of such norms is NP-hard in enumerated state systems
- Existing methods don't exploit abstractions of propositional/first-order domain theories
- Our method: find "detours" around conflict states by local search in generalised state spaces

The norm synthesis problem

- Assume a system with states S and some set of conflict states S_c
- Agents execute actions from a set A that change the global state
- Norm synthesis problem: compute a set of prohibitions (s,a) such that
  - S_c is never entered
  - any state in S that was reachable before is still reachable
  - not assuming specific initial states or knowledge about goals for the agents
- We assume that the norms will be adhered to, but could also look at automated synthesis of sanctions
- Traditional methods operating on enumerated state/ action spaces result in large sets of prohibitions, and don't scale well, so we attempt a relational approach

Automated norm synthesis

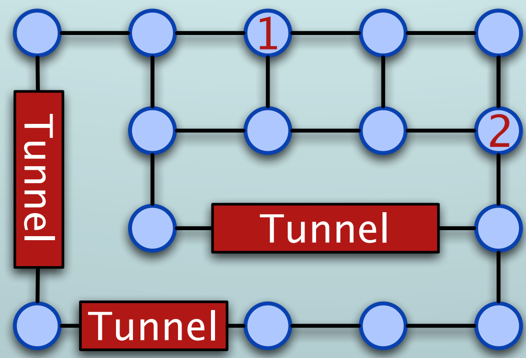
Iterated process of forward-backward search around conflict state specification:



- **Not better than full state-space search in the worst case but often get lucky**
- **With simple additional pruning techniques search can often be cut down drastically**
- **Currently working on synthesising sanctions**

Example

- **Tunnel world example:**



- **Agents entering tunnels have to leave them out the opposite end immediately (so on entering tunnel, future crash not avoidable)**
- **Our algorithm solves this by computing a general norm ({at_1(N), at_2(N'), tunnel(T), conn(N,T), conn(T,N')}, $move_1$(N,T))**
- **Note that we ignore extra cost caused to agent that has to take a detour to reach her goal when adhering to the norm**

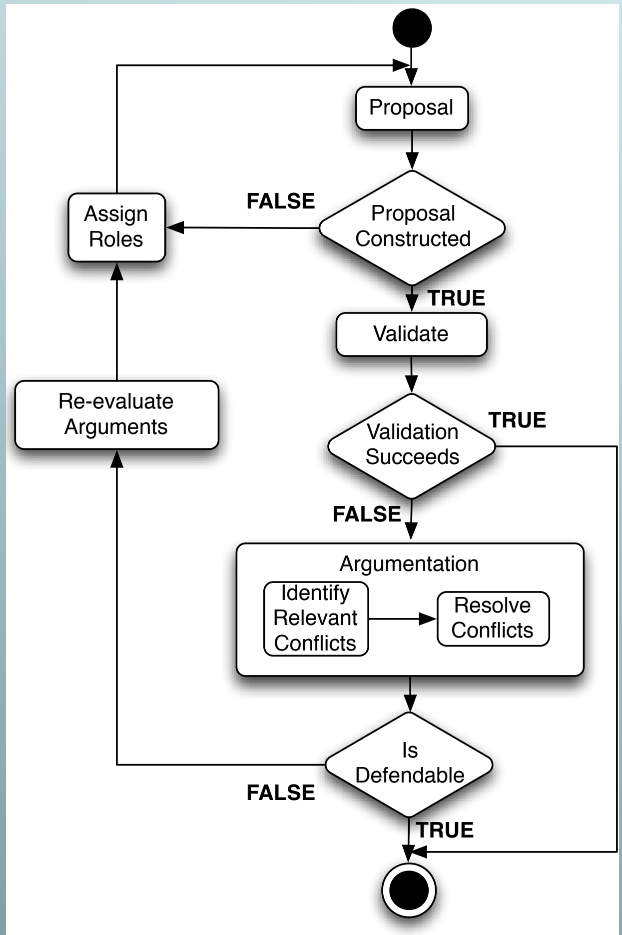
Argumentation-based conflict resolution in planning

- **Argumentation** is a method for determining the status of propositions in the presence of conflicting information
- Different acceptability-based semantics and protocols that implement these
- Rarely used for reasoning about action, our intuition is that this can be done more efficiently due to domain structure
- Suggest framework for **acceptable** planning:

  A plan P is acceptable wrt (potentially conflicting) knowledge bases KB_1 and KB_2

  iff $KB_1 \models P$ and $KB_2 \models P$

Argumentation-based conflict resolution



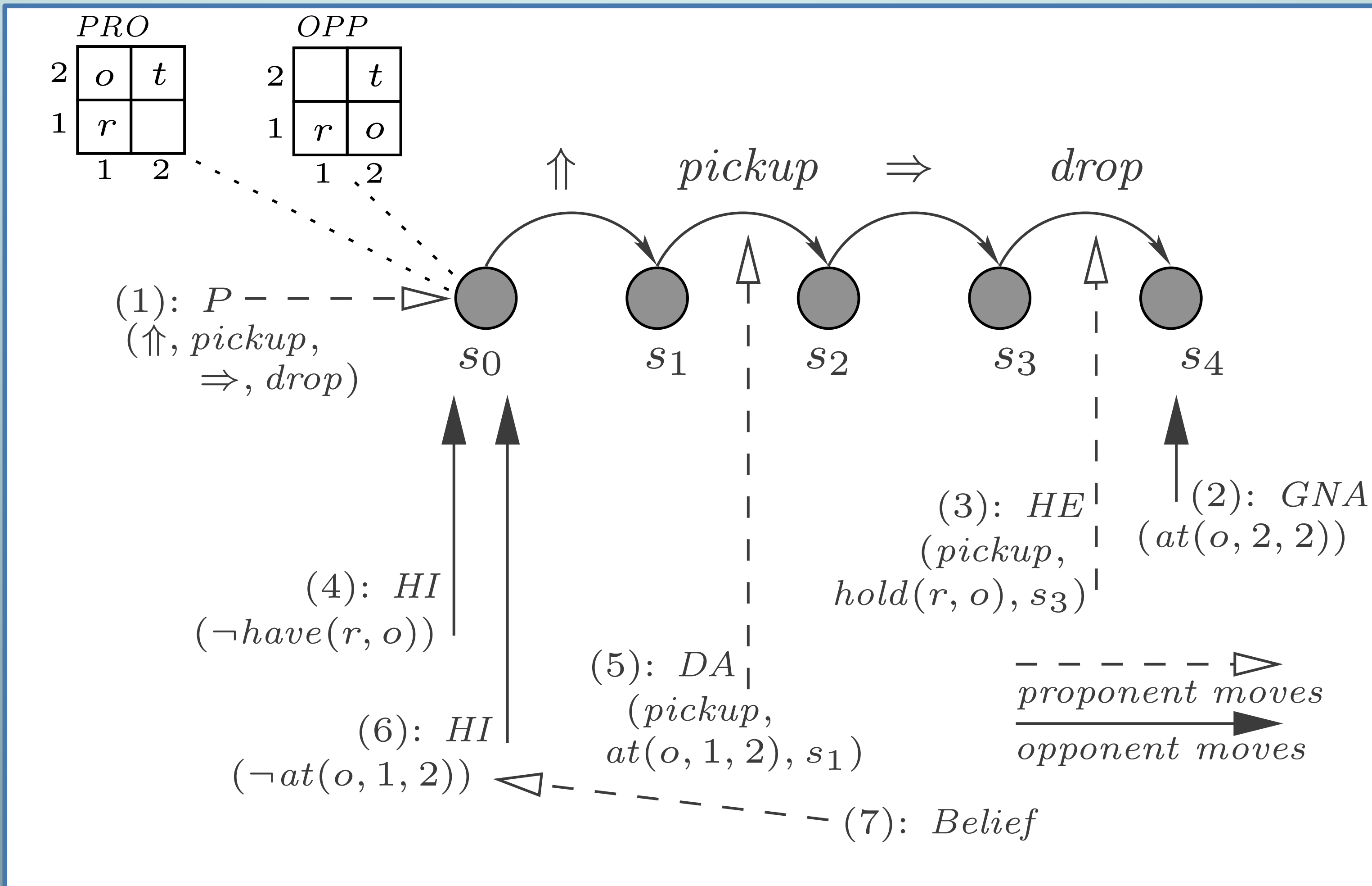
- Plan proposal generated by single agent (with any planner)
- Validation based on simple plan projection
- Dispute in case of disagree-ment, argumentation follows
- Ends in successful defence of initial proposal or rejection
- An alternative to generating one *P* that works under both *KBs*

Argumentation-based conflict resolution

- Planning domain represented in Situation Calculus
- Disagreement may exist regarding
  - initial state (including background knowledge)
  - planning operators (agreement on goal)
- Application of TPI-dispute protocol, but argument generation guided by plan structure
- Currently trying to extend method by updating local planning knowledge
- Also trying to extend method to planning with a defeasible planning theory
- Open problem: how to efficiently find plans that are possible using the combined knowledge of agents

Example

- **Robot gridworld domain**



Practical social reasoning architectures

- Practical reasoning architectures like BDI do not specifically consider social interaction
- Social reasoning = reasoning about other agents and social mechanisms governing the system (i.e. hidden system properties)
- Assumption:

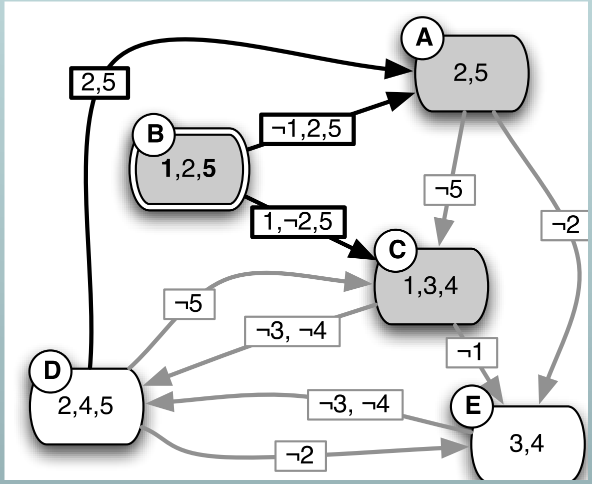
  any social reasoning mechanism can be formalised as a set of update rules regarding constraints concering hidden system properties
- Expectation-Strategy-Behaviour (ESB) architecture as a general computational framework

The ESB framework

- Expectations express assumptions about other agents' mental states or behaviours
- Their specification includes rules for how to update beliefs with relevant observations
- Strategies restrict the way potential future expectations are projected (think of a restricted expectation graph)
- Behaviours condition own behaviour (e.g. belief change at BDI level) on constraints verified against expectation graph
- Formal semantics, easily combined with state-of-the-art model-checkers
- An ESB engine can be easily combined with a normal BDI interpreter (in our implementation, Jason/ AgentSpeak

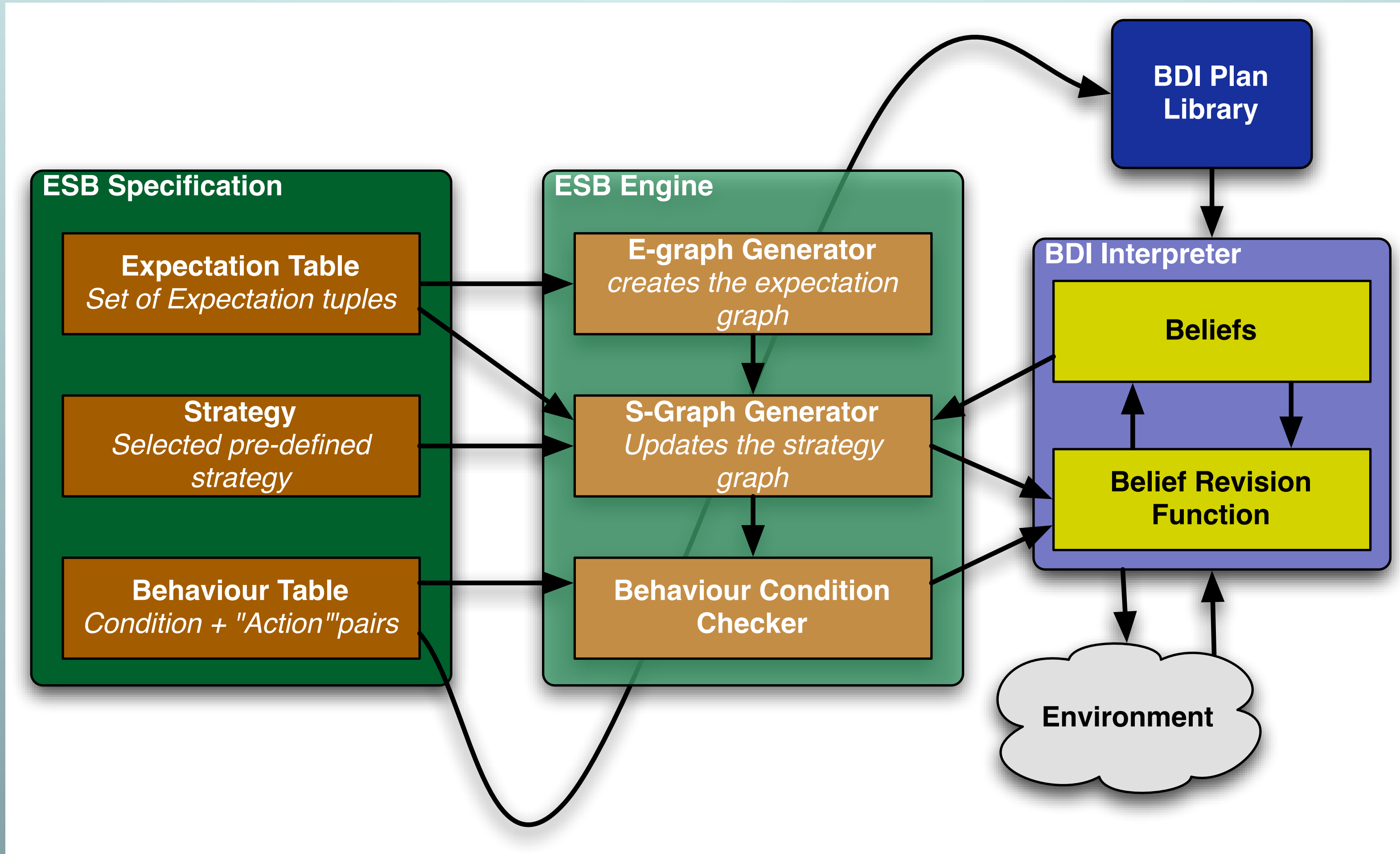
Reasoning in ESB

- Designer specifies expectations, strategies and behaviours in a declarative, modular way
- ESB engine constructs state transition system, restricted by strategy



- Model-checker verifies conditions on behaviour rules, and modifies BDI beliefs when behaviour rules fire

ESB reasoning engine



So what?

- Our current work addresses specific problems of reasoning about interaction
- But fragmented and very specific, would like solutions for more general problems
- Strongest contribution of agents to general AI is consideration of multiple (potentially conflicting) goals
- With “practical reasoning” glasses on, this suggests looking at strategic planning problems
- Very little work in this area, will discuss most recent approach

Brafman/Domshlak/Engel/ Tennenholtz (IJCAI 2009)

- Introduce notion of coalition-planning game (reward for goal, cost for plan, no action = 0)
- Solution stable if no set of agents can increase utility by jointly adopting other plan
- Formally: plan π *stable* for iff no plan π exists for any subset Φ' of agents Φ such that $u_\phi(\pi') > u_\phi(\pi)$ for all ϕ in Φ'
- Present an algorithm for computing stable plans, but complexity issues (enumeration of strategies necessary)

Interesting problems

Three general problems seem interesting:

- How to compute acceptable plan given a solution criterion (in particular adapting existing planning heuristics)
- How to search plan space incrementally for generating proposals during negotiation
- How to use background knowledge to guide plan recognition and optimal response generation

Evaluation

- No good benchmarks for MAP exist because research is fragmented
- Too many different potential problems to be accommodated
- Single-agent planning benchmarks can be adapted but is this useful?
- Multiagent systems people also interested a lot in continuous planning
- But performance metrics domain-dependent in this case

A good application?

- **Dialogue planning metaphor** covers synthesis, negotiation, and execution aspect
  - If communication actions are interpreted in a planning-based way, we should be able to plan them just like physical actions
  - But hard to decide about communication strategy before having synthesised collaborative plans
  - Actions planned for deception detection ahead of execution may affect suggested deals

Examples

BUYER-SELLER

B: I would like an art history book.

S: Good art history books range from $35-$55.

B: I would like something cheaper.

S: There's "Art for Kids" at $15.

B: I want a book for adults.

S: There's "Art History for Dummies" at $25.

B: Great, I'll take that.

(execution follows, including payment, delivery, etc)

PEER-TO-PEER

P: I'd like to stream a music concert in high quality tomorrow night.

Q: Who will be performing?

P: It's a "best-of" transmission from a festival.

Q: I don't like watching concerts unless I know what bands are playing.

P: Could I still borrow your bandwidth?

Q: OK, if you grant me prioritised access to yours for seven days after that.

(*execution follows, including settings to preference in P2P system, actual streaming actions, etc)*

Conclusions

- Reasoning about interaction crucial to multiagent systems
- Must involve planning one way or another, but no standard simple frameworks for multiagent case
- Some of our own work shows that planning formalisms are useful
- To develop more generic problems need convincing, simple examples
- Looking at multiple goals is (in my opinion) the strongest thing that multiagent perspective can add to single-agent planning
- Current solution concept proposals lead overly complex, more approximate methods needed

Thank you. Questions?

Material based on
Christelis & MR @ AAMAS 2009
Belesiotis, MR & Rahwan @ ArgMAS 2009
Wallace & MR @ AAMAS 2009

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http://www.cisa.inf.ed.ac.uk/agents