On the Construction of Joint Plans through Argumentation Schemes

(Extended Abstract)

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1. INTRODUCTION

The term Multi-Agent Planning (MAP) refers to any kind of planning in domains in which several independent entities (agents) plan and act together. Recently, a number of attempts have used argumentation to handle the issue of selecting the best actions for an agent to do in a given situation [4]. Particularly, there have been proposals to apply argumentation theory to planning, for dealing with conflicting plans or goals. Most notably, the work in [3] represents a step ahead towards the resolution of a planning problem through argumentation by modeling a planner agent able to reason defeasibly. None of these works, however, apply to a multi-agent scenario except the work in [2] which presents an argumentation-based approach for cooperative agents who discuss plan proposals.

MAP is regarded here as devising a mental process (plan) among several heterogeneous agents which have different capabilities, different (and possibly conflicting) views of the world, and different rationalities. In this paper we present an argumentation-based partial-order planning model that allows agents to solve MAP problems by proposing partial solutions, giving out opinions on the adequacy of these proposals and modifying them to the benefit of the overall process. We adapt the instantiation of an argument scheme and the associated critical questions to a MAP context by following the computational representation of practical argumentation presented in [1].

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2. THE MAP FRAMEWORK

A **MAP task** is a tuple $\mathcal{T} = \langle \mathcal{AG}, \mathcal{P}, \mathcal{A}, \mathcal{I}, \mathcal{G}, \mathcal{F} \rangle$, where $\mathcal{AG}$ is the set of planning agents, $\mathcal{P}$ is a finite set of propositional variables, $\mathcal{A}$ is the set of deterministic actions of the agents' models, $\mathcal{I}$ is the initial state of the planning task, $\mathcal{G}$ is the set of problem goals and $\mathcal{F}$ is the utility function.

In our model agents interact to design a plan that none of them could have generated individually in most cases. An agent in $\mathcal{AG}$ is equipped with three bases $\langle \mathcal{B}, \Theta, \mathcal{PG} \rangle$ such that $\mathcal{B}$ is the agents' belief base, Θ is the agents' base of actions (planning rules), and $\mathcal{PG}$ is a (possibly empty) set of private goals. A literal is a proposition p or a negated proposition $\sim p$. Two literals are contradictory if they are complementary. Agents discuss on the truth value of belief literals and when they reach a consensus the literal becomes an indisputable statement, a fact that is stored in the set *commitment store* CS. An action a is a tuple $\langle PRE, EFF \rangle$ where PRE is a set of literals representing the preconditions of a, and EFF is a consistent set of literals representing the consequences of executing a. PRE denotes the set of literals that must hold in a world state S for that a be applicable in this state. Additionally, actions have an associated cost; $cost(a) \in \mathbb{R}_0^+$ is the cost of a in terms of the global utility function $\mathcal{F}$. Finally, the problem's initial state $\mathcal{I}$ is computed as the union of the beliefs of the agents so $\mathcal{I}$ might initially comprise contradictory beliefs.

A **partial plan** is a triple $\Pi = \langle \Delta, \mathcal{OR}, \mathcal{CL} \rangle$, where $\Delta \subseteq \mathcal{A}$ is the set of actions in the plan, $\mathcal{OR}$ is a set of ordering constraints ($\prec$) on Δ, and $\mathcal{CL}$ is a set of causal links over Δ. A partial plan Π is a **consistent multi-agent plan** if for every pair of unequal and unordered actions a_i and a_j that belong to different agents, then a_i and a_j are not conflicting (mutex) actions. An **open goal** in a partial plan $\Pi = \langle \Delta, \mathcal{OR}, \mathcal{CL} \rangle$ is defined as a literal p such that $a_j \in \Delta$, $p \in PRE(a_j)$, and it does not exist a causal link in $\mathcal{CL}$ which enforces p. $openGoals(\Pi)$ denotes the set of open goals in Π. A partial plan Π_j is a **refinement** of another partial plan Π_i if and only if $\Delta_i \subseteq \Delta_j$, $\mathcal{OR}_i \subseteq \mathcal{OR}_j$, $\mathcal{CL}_i \subseteq \mathcal{CL}_j$ and $\exists p \in openGoals(\Pi_i)/p \notin openGoals(\Pi_j)$.

3. THE ARGUMENTATION PROCESS

We propose here an adaptation of the computational representation of practical argumentation presented in [1] for solving a MAP task. Agents present refinements on the current base plan Π_b, which initially is the empty plan Π_0, in the form of an argument scheme to solve one or more of the open goals in Π_b:

AS In the current circumstances given by Π_b, $\mathcal{G}$, and CS
We should proceed with the partial plan Π_s
Which will result in a new valid base plan $\Pi_r = \Pi_b \circ \Pi_s$

During this evaluation process, if agents do not agree with the presumptive argument, they may challenge some of its elements by presenting *critical questions*. A critical question identifies a potential flaw in the argument, so they are used to attack the argument scheme. Five critical questions in [1] are adapted to our model to assess the acceptability of the argument.

Critical questions **CQ1: Are the believed circumstances true?** and **CQ12: Are the circumstances as described possible?** are put forward by an attacker agent if the beliefs used by the proponent agent of Π_s get in contradiction with his own beliefs. The critical question **CQ13: Is the action possible?** is used as an attack against the refinement step Π_s if $a \in \Delta_s$, $p \in PRE(a)$, $p \in openGoals(\Pi_r)$, and, according to the knowledge of the attacker agent, the literal p is an unreachable precondition. The critical question **CQ14: Are the consequences as described possible?** is articulated when, according to the beliefs of an agent, there exist two mutex actions in Π_r. Finally, the attack **CQ15: Can the desired goal be realised?** occurs when a problem goal, $g \in \mathcal{G}$, is still unsupported in Π_r, i.e. $g \in openGoals(\Pi_r)$, and the attacker says g is unreachable because there is not a refinement upon Π_r for solving g.

The undefeated refinements, i.e. the ones which do not receive an attack or the attack is counterattacked by another agent, are considered as accepted arguments and thus as ***valid refinements***. If there are no valid refinements for the current base plan, then a backtracking step is carried out. A backtracking step implies to return to the previous base plan to evaluate and select a different backup refinement. If the current base plan is Π_0, backtracking leads to an unsolvable MAP task. If Π_r is a valid refinement, then the beliefs used in Π_r become facts and are stored in CS as they turn out not to be defeated during the argumentation.

Once the argumentation process is finished, we have a set VR of valid refinements. In the next step, agents select the refinement through which to proceed towards the plan construction. In this case, the argument scheme used is:

AS Given the current base plan Π_b and the set VR
We should proceed with the partial plan Π_s
Which will result in a new valid base plan Π_r
Which realize some subgoals, SG, of Π_b
Which will promote some values V

An agent suggests to proceed with the refinement Π_r from the set of valid refinements VR, emphasizing the open goals of the base plan that Π_r solves, $SG = openGoals(\Pi_b) \setminus openGoals(\Pi_r)$, as well as the values V that Π_r promotes. V represents the agent's preferences like ***Uniqueness***, number of enforced subgoals in Π_b which have just one way of being solved; promoting this value decreases the possibility of selecting a wrong refinement; ***Selfishness***, number of private goals solved by Π_r; ***Reliability***, number of contradictory beliefs discussed during the argumentation along with the number of received attacks; in general, the lower number of attacks, the more reliable Π_r; ***Cost***, cost of the refinement according to the utility function $\mathcal{F}$, plus an estimate of the cost of solving the pending open goals; the lower the cost, the better the solution; and ***Participation***, promotes a more balanced distribution of the plan actions among the agents.

The values V of one same refinement are differently regarded (estimated) by the agents due to their different abilities and knowledge. These differences emphasize the importance of arguing about the advantages and limitations of selecting a particular refinement. Given a refinement Π_r from VR proposed by an agent, the rest of agents express their opinion on Π_r by articulating some of the following critical questions, and then run a voting process to select the refinement which will be adopted as the next base plan.

Questions **CQ5: Are there alternative ways of realising the same consequences?**, **CQ6: Are there alternative ways of realizing the same goal?** and **CQ7: Are there alternative ways of promoting the same value?** state there is an alternative refinement $\Pi'_r \in VR$ with the same degree of accomplishment than Π_r, and that Π'_r is a better choice to reach a solution. Questions **CQ8: Does doing the action (refinement) have a side effect which demotes the value?**, **CQ9: Does doing the action (refinement) have a side effect which demotes some other value?** and **CQ11: Does doing the action (refinement) preclude some other action which would promote some other value?** state a negative opinion on Π_r as it is considered it would prevent the plan construction from progressing. **CQ10: Does doing the action (refinement) promote some other value?** states that Π_r also promotes other important values V', $V \cap V' = \emptyset$ (this CQ actually represents an additional support to Π_r). **CQ16: Is the value indeed a legitimate value?** states the promoted values V are not relevant.

4. CONCLUSIONS

In our proposal agents argue over plan refinements and try to reach an agreement on the presumptively best plan composition for the joint plan. Novelties in our model are the instantiation of the argument scheme to a set of elements rather than to a single action, goal or value, and a sophisticated evaluation of attacking situations able to envisage the future consequences of the agents' decisions.

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