Critical Question Formalization for an Argumentation Scheme about Plans. Technical Report

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Abstract. Planning agents that share a common goal should be able to propose, justify and share information about plans in a structured way. We present in this report the formalization of an argumentation scheme and associated critical questions to create and justify plan proposals where plans are combinations of actions requiring several agents for their execution. We believe these elements are necessary to enable agents to engage in rational debate over co-operative plan proposals.

1 Introduction

The planning literature has been focusing in recent years on overcoming strong assumptions about plan generation. The complexity of distributed systems restricts the application of single-agent planning strategies to distributed problems usually because a local agent view is not sufficient. A common assumption in AI planning is that the planner has accurate and complete knowledge of the world and the capabilities of other agents. We propose the use of an argumentation based dialogue to support some planning tasks such as the selection of the best plan.

In this report we present the formalization of an argumentation schemes for plan proposals originally presented in [9] and related critical questions [8] using Action-based Alternating Transition Systems as presented in [10]. We extend the concept of action used in [3] with action-elements taken from the PDDL 2.1 Planning Specification [1] presented in [7] such as action duration and invariant conditions. This work extends the action proposal model of [3] to more complex types of action-proposals involving several durative actions performed by several agents. An analysis over different ways to combine actions is also considered in order to create more specific critical questions.

This report is structured structured as follows: Section 2 introduces the AATS notation used to formalize the action proposal and plan proposals. Section 3 presents the formalization of the action proposal. In section 4 we present the argumentation scheme for plan proposals in AATS terms. Section 5 presents the critical questions associated to the scheme and their formalization Finally, in section 6, we conclude the report.

[1] Planning Domain Description Language (PDDL) is an attempt to standardize planning domain and problem description languages developed for the International Planning Competitions.

2 Action-based Alternating Transition Systems

We use Action-based Alternating Transition Systems (AATS) as introduced in [10] as a basis for our formalism to represent action and plan proposals. AATS models define joint-actions that may be performed by agents in a state and the effects of these actions. This makes AATSs especially suitable for situations where co-operation is important. In particular, an AATS model defines semantic structures useful to represent joint-actions for multiple agents, their preconditions and the states that will result from the transition. An *AATS* is an (n+7)-tuple of the form:

$$S = \langle Q, q_0, A_g, Ac_1, ..., Ac_n, \rho, \tau, \Phi, \pi \rangle$$

where:

- Q is a finite non-empty set of states;
- $q_0 \in Q$ is the initial state;
- $A_g = \{1, ..., n\}$ is a finite non-empty set of agents;
- Ac_i is a finite, non-empty set of actions, for each $i \in Ag$, where $Ac_i \cap Ac_j = \emptyset$ for all $i \neq j \in Ag$; Now we can say that a joint action j_{Ag} for the set of agents Ag is a tuple $(\alpha_i, .., \alpha_n)$ where for each $\alpha_j (j \leq n)$ there is some $i \in Ag$ such that $\alpha_j \in Ac_i$. We denote the set of all joint-actions J_{AG}. Given an element j of J_{AG} and an agent $i \in Ag$, $i's$ action in j is denoted by j_i .
- $\rho : Ac_{Ag} \rightarrow 2^Q$ is an action precondition function, which for each action $\alpha \in Ac_{Ag}$ defines the set of states $\rho(\alpha)$ from which α may be executed;
- $\tau : Q \times J_{Ag} \rightarrow Q$ is a partial system transition function, which defines the state $\tau(q, j)$ that would result by the performance of j from state q, note that, as this function is partial, not all joint actions are possible in all states (cf. the pre-condition function above);
- Φ is a finite, non-empty set of atomic propositions; and
- $\pi : Q \rightarrow 2^\Phi$ is an interpretation function, which gives the set of primitive propositions satisfied in each state: if $p \in \pi(q)$, then this means that the propositional variable p is satisfied (equivalently, true) in state q.

In [2] Atkinson and Bench-Capon extended this transition system to enable representation of a theory of practical reasoning related to arguments about action through which values [2] were added to the system. The extensions are:

- Av_i, is a finite, non-empty set of values $Av_i \subseteq V$, for each $i \in Ag$.
- δ: $Q \times Q \times Av_{Ag} \rightarrow \{+, -, =\}$ is a valuation function which defines the status (promoted(+), demoted(-) or neutral (=)) of a value $v_u \in Av_{Ag}$ ascribed by the agent to the transition between two states: $\delta(q_x, q_y, v_u)$ labels the transition between q_x and q_y with one of $\{+, -, =\}$ with respect to the value $v_u \in Av_{Ag}$.

[2] Our use of the term values follows [4] where values are qualitative social interests of agents.

3 Action Proposals

Argumentation schemes are stereotypical patterns of defeasible reasoning used in everyday conversational argumentation. In an argumentation scheme, arguments are presented as general inference rules where under a given set of premises a conclusion can be presumptively drawn [11]. Artificial Intelligence has become increasingly interested in argumentation schemes due to their potential for making significant improvements in the reasoning capabilities of artificial agents [6] and for automation of agent interactions.

The action proposal presented in [3] is as follows: In the current circumstances R, we should perform action A to achieve new circumstances S which will realize some goal G which will promote some value v. Furthermore, in [2] the authors re-stated the argumentation scheme in terms of the extended AATS. So, we can extend the action proposal from [3] with elements from the PDDL 2.1 specification. The extended action proposal and AATS representation are presented in Tables 1 and 2.

Table 1. Argumentation scheme for actions

In the current circumstances R
we should perform action A at time t with duration d
to achieve start effects from point t
given invariant conditions
action finishing by termination conditions
to achieve new circumstances S
which will realize some goal G
which will promote some value v

Table 2. Argumentation scheme for actions in AATS terms

In the initial state $q_0 = q_x \in Q$
agent $i \in Ag$ should participate in joint action $j_n \in J_{Ag}$
where $j_{n^i} = \alpha_i$
such that $\tau(q_x, j_n)$ is q_y
such that $p_a \in \pi(q_y)$ and $p_a \notin \pi(q_x)$
or $p_a \notin \pi(q_y)$ and $p_a \in \pi(q_x)$
such that for some $v_u \in Av_i$, $\delta(q_x, q_y, v_u)$ is +.

4 Plan Proposals

We now present our argumentation scheme in terms of the action elements presented above. Our plan proposal ASP is as follows:

Given a social context X, in the current circumstances q_0 holding preconditions $\pi(q_0)$, the plan PL should be performed to achieve new circumstances q_x , that will hold postconditions $\pi(q_x)$ which will realize the plan-goal G which will promote value(s) V_G.

The valid instantiation of the scheme pre-supposes the existence of a regulatory environment or a social context X in which the proponent has some rights to engage in a dialogue with the co-operating agent. The "social context" was an extension to the argumentation scheme presented in [5] where agents use a social structure to issue valid commands between them. Current circumstances are represented by the initial state q_0. An agent could instantiate the scheme to propose plan PL as a finite set of linked action-combinations. The plan leads to a state in which post-conditions $\pi(q_x)$ hold and the plan-goal G is achieved (where G is an assignment of truth values to a set of propositions $p \subseteq \Phi$) and a non-empty set of values is promoted/demoted.

Our objective specifying a set of values V_G rather than a single value, comes from the idea that a plan (and the set of actions of which is conformed) might include different preferences for different actions. In other words, a value may be promoted by the first action of a plan and a different value promoted in the second action. So, the set of values promoted by the plan is just the set of values promoted by all the actions that comprise the plan. Indeed, this feature could be extended to allow a more complex value representation for the set of actions, this representation is out of the scope of this paper. Table 3 presents the plan proposal and Table 4 the proposal with AATS elements.

Table 3. Plan Proposal ASP

Given a social context X,
in the current circumstances q_x
holding preconditions $\pi(q_x)$
plan PL should be performed
to achieve new circumstances q_y
that will hold postconditions $\pi(q_y)$
which will realize the plan-goal G
which will promote value(s) V_G.

Table 4. *AATS* representation of the Argumentation Scheme for Plan Proposals *ASP*.

Given social context X,
in the initial state q_0 = $q_s \in Q$
with preconditions $\pi(q_0)$ and $\overline{\pi}(q_0)$,
agents $i, j \in Ag$ should execute plan PL
starting at time t_s with duration d, such that $t_s + d = t_f$
where PL is a finite set of joint-actions j_{PL}
with transition $\lambda_{j_{PL}}[t] = \{q_s, ..., q_f\}$
such that $PL = \{j_0, .., j_n\}$
and for each $j_{PL} \in PL$, $j_{PL} \in J_{AG}$
and $j_{PL^i} = \alpha_i$ and $j_{PL^j} = \alpha_j$
with transition given by $\tau(q_s, PL)$ is q_f
where $\tau(q_0, \{j_1, .., j_n\}) = \tau(\tau(q_0, j_1), (j_2, ..j_n))$
(and $\tau(q_s, \{\}) = q_s$)
such that $p_G \in \pi(q_s)$ and $p_G \notin \pi(q_f)$ where $G = p$
$V_{PL} \subseteq V$ and $V_{PL} \neq \emptyset$

5 Critical Questions for Plan Proposals

In [12], Walton explains: "*...arguments need to be examined within the context of an ongoing investigation in dialogue in which questions are being asked and answered*". Critical questions are a way to examine the acceptability of arguments instantiating schemes. Depending on the nature of the critical question, they can be used to critique several aspects of the argument. Usually, critical questions provide pointers which would make the argumentation scheme inapplicable or could lead to a valid way to attack the argument, either defeating the argument on one of its premises or on its presumptive conclusion.

In Walton [13] the notion of Argumentation Schemes is associated with a set of characteristic critical questions so that each argumentation scheme has its own set of critical questions. These critical questions are designed to ensure that there is no reason

to reject the presumptive conclusion of the Argumentation Scheme, and so each question can be seen as a potential attack on the argument made using the Argumentation Scheme.

Critical questions provide examination patterns where a question could be seen as a passive attack on the argument: passive in that they do not present counter-arguments, but can provide reasons to reject the argument they critique. Specifically, critical questions represent a way to evaluate arguments constructed using an argumentation scheme and provide pointers to factors which could potentially make the argumentation scheme inapplicable. The set of critical questions (presented in the following subsections) is classified into seven layers:

Layer 1: An action and its elements (Lowest level): Questions about the action and its elements.
Layer 2: The timing of an action: Questions about the duration and timing of the action.
Layer 3: The way actions are combined: Questions about the combination of two actions in terms of concurrency and periodicity.
Layer 4: The plan proposal: Questions about the plan proposal in general.
Layer 5: The timing of the plan proposal: Questions about the timing of the plan.
Layer 6: Side effects of actions or the plan: A *side effect* is an unintended outcome of an action, and could in principle, promote or demote a value in contradiction to an agent's interest.
Layer 7: Alternative paths (Highest Level): Questions about alternative, possibly better, actions or plans.

The layers are derived from the different categories of critical questions that relate to the different elements of the argumentation scheme. Each layer groups questions according to the level of detail on which they focus. At the plan proposal level, for example, the critical questions are all those that are independent of the way in which actions are composed inside the plan *e.g.* the way in which actions are combined. This classification allows us to consider questions at each layer separately.

The analysis of critical questions is formalised and structured in the following subsections.

5.1 Layer 1. Critical Questions for an Action.

This layer comprises fourteen critical questions that consider different ways to attack a single action. I extended the list of critical questions for action proposals in [4] considering the characteristics of a durative action.

CQA-01. Is the action valid (possible in some state)?
- $[j_n \notin J_{AG}]$
- Another agent could question/attack the validity of an action if the action is not in its local representation of the world.

CQA-02. Is the action possible in the current state?

- $\neg\exists\tau$ s.t. $\tau((q_s, j_n))$
- Another agent could question/attack the possibility to execute an action in the current state. This critical question is the basis for the next questions that focus on more finer details.

CQA-03. Are the action preconditions valid?

- $\forall q \in Q$, $pc \notin \pi(q) \vee pc \notin \overline{\pi}(q)$ where pc is a precondition.
- Another agent could question/attack the validity of an action preconditions if it is never satisfied (for this question and the remaining when referring to a condition or an effect it is assumed that the instantiation of the question refers to a specific condition or effect).

CQA-04. Are the action preconditions satisfied in the current state?

- $pc \notin \pi(q_0) \vee \overline{pc} \notin \pi(\overline{q_0})$
- The preconditions of an action could be valid but not possible in the current state.

CQA-05. Are the action start effects valid?

- $[\forall q \in \lambda[t]$ s.t. $se \notin SE(\pi(q))]$
- If the start effects are not valid for all the states a start effect can be challenged over its validity.
- A start effect does not hold in the transition of any joint action.

CQA-06. Are the action start effects satisfied in the current state?

- $se \notin \pi(SE(q_{s+1}))$
- A start effect of an action may not be achieved given the current circumstances.

CQA-07. Are the action invariants conditions valid?

- $[\forall q \in \lambda[t]$ s.t. $ic \notin IC(\pi(q))]$
- An invariant condition does not hold in the transition of any joint action.

CQA-08. Are the action invariants conditions currently possible?

- $ic \notin \pi(IC(q_{s+1}))$
- An invariant condition of an action is not possible in the current circumstances (state).

CQA-09. Are the action end effects valid?

- $[\forall q \in \lambda(t)$ s.t. $ic \notin EE(\pi(q))]$
- End effect missing in action specification leads to discard action j_n or assert end effect.
- An end effect does not hold in the final state of any joint action.

CQA-10. Are the action end effects possible?

- $[ee \notin EE(q_f)]$
- An end effects is not possible from the current state.

CQA-11. Does the new circumstances already pertain?

- $[q_s = q_f$ where q_s is the initial state and q_f is the final state]
- In continually evolving contexts, new circumstances could be true before or during the execution of the plan. This critical question presents the case where an action may already have been executed or another action may have caused the new circumstances to be true.

CQA-12. Can the desired sub-goal be realized?

- $g \notin \pi(q)$ for all $q \in Q$ or $g \notin \pi(q_f)$ where $\delta(q_s, j_n)$ is q_f for all $j_n \in J_{Ag}$
- The action goal cannot to be achieved with any available action .

CQA-13. Is the value a legitimate one?

- $v \in V_{PL}$ but $v \notin V$
- A value may be part of the values promoted by the action but not legitimate or valid.

CQA-14. Is the value promoted/demoted by the execution of the action?

- $\delta(q_s, q_f, v_u)$ is not $+$ where (q_s, j_n) is q_f.
- This question assumes the value is legitimate but is not promoted/demoted by the execution of the action.

5.2 Layer 2. Critical Questions for the Timing of an Action

This layer comprises nine questions and focuses on the timing of the action abstracting from details on how the action is represented. The questions aim to challenge or change the start-time, end-time and duration of the action. Given joint action j_s with transition $\lambda[t] = \{q_s, q_{s+1}, q_f\}$ at $\{t_s, t_{s+1}, t_f\}$ respectively. That is, j_s is performed with duration two since we say that all actions has duration one this is the same as performing j_s twice.

CQAT-01. Is the joint action possible with the specified duration?
- $\tau(\tau(q_s, j_s))$ is not q_f) where $j_s(t_f - t_s)$
- This question is about the possibility of the action in specific relation to the duration. The question is similar to question *CQA-02* but more specific and inquires directly the action duration A conflict in the action duration between agents can lead to discard the action.

CQAT-02. Is the action possible at the specified start-time?
- $\tau(q_s, j_s)$ is not q_f) with $j_s(t_s)$
- The possibility of an action at a specific time is challenged with this question. The action may be possible with the specified duration but not at the specified start-time.

CQAT-03. Is the action possible to finish at the specified time?
- $\tau(\tau(q_s, j_s))$ is not q_f) where $j_s(t_f)$
- A conflict in the time the action finishes can lead to modify the action duration or discard the action.

CQAT-04. Could the action start-time point be earlier?
- $\rho(j_n) \in q_s$ and $\rho(j_n) \in q_{s-1}$
  such that $\tau(q_{s-1}) \equiv \tau(q_s, j_n)$
  where $q_{s-1}(t_s) < q_s(t_s)$
- That is, the preconditions of j_s hold in $\pi(q_s)$ and $\pi(q_{s-1})$ such that performing j_s from q_{s-1} has the same effect as performing it from q_s.
- This question that aims to change the start-time of the action.

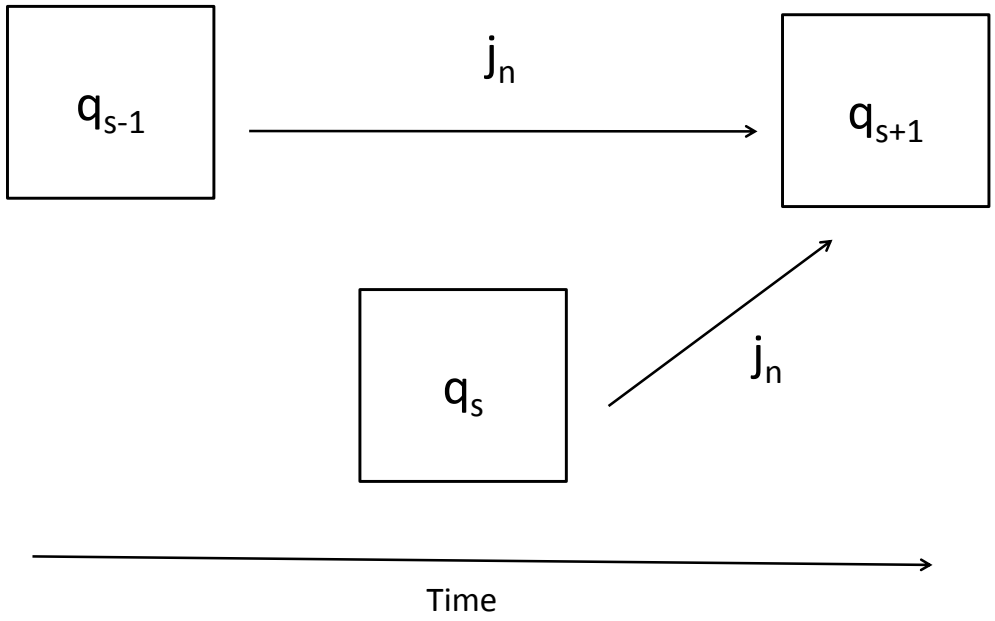

Fig. 1. Action j_n can start from state q_{s-1} with the same result state.

CQAT-05. Could the action start-time point be later?

- $\rho(j_n) \in q_s^{'}$ and $\rho(j_n) \in q_s$
  such that $\tau(q_s^{'}) \equiv \tau(\tau(q_s, j_n))$
  where $q_s^{'}(t_s) > q_s(t_s)$ and $q_s^{'}(t_s) < q_{s+1}(t_s)$
- That is, the preconditions of j_s hold in q_s and $q^{'}s$ such that performing j_s from $q^{'}s$ has the same effect as performing it from q_s.
- This question that aims to change the start-time of the action. Figure 2 presents the states and transitions considered in this question.

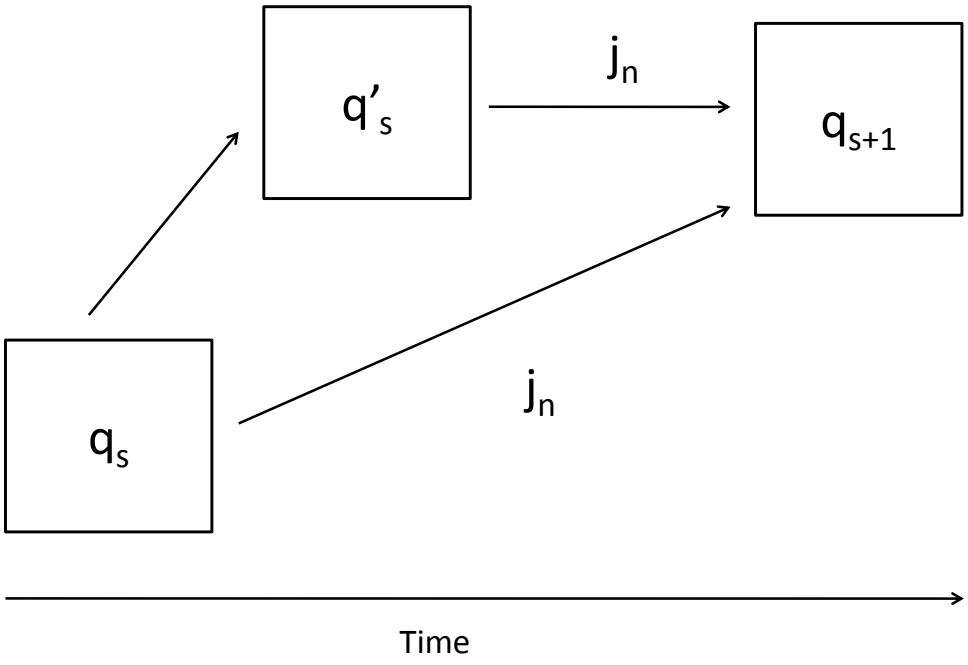

Fig. 2. Action j_n can start from state $q_s^{'}$ with the same result state.

CQAT-06. Could the action duration be less?

- $\rho(j_n) \subseteq \pi(q_s)$ and $\rho(j_n) \subseteq \pi(q_{s+1})$
  such that $\tau(q_s, k(j_n))$ is q_{s+1}
  for $k = 1$ or $\tau(q_s, j_n) \equiv \tau(\tau(q_s, j_n), j_n)$
- That is, the transition from q_s to q_{s+1} could be performed with duration $k = 1$ with the same result (q_{s+1}) where $k = 2$. Figure **??** presents an example where this question could be used.
- This question aims to change the duration of the action by reducing the duration.

CQAT-07. Could the action duration be longer?

- $\rho(j_n) \subseteq \pi(q_s)$ and $\rho(j_n) \subseteq \pi(q_{s+1})$
  such that $\tau(q_s, k(j_n))$ is q_{s+1} for $k = 2$
  or $\tau(q_s, j_n) \equiv \tau(\tau(q_s, j_n), j_n)$
- That is, the transition from q_s to q_{s+1} could be performed with duration $k = 1$ with the same result (q_{s+1}) where $k = 2$. Figure **??** presents an example where this question could be used.
- This question aims to change the duration of the action by extending the duration.

CQAT-08. Could the end-time point be sooner?

- $\exists j_s^{'}$ such that $j_s^{'}((t_f^{'}) < j_s(t_f)$ for which $\tau(q_s, j_s^{'})$ is q_f.
- This question aims to change the end-time of the action to an earliest time by either changing the duration or the start time.

CQAT-09. Could end-time point be later?

- $\exists j_s^{'}$ such that $j_s^{'}((t_f^{'}) > j_s(t_f)$ for which $\tau(q_s, j_s^{'})$ is q_f.
- This question that aims to change the end-time of the action to a later time by either changing the action duration or the start time.

5.3 Layer 3. Critical Questions for the Way Actions are Combined

The questions challenge the way two actions are combined and differentiating between sequential actions and concurrent actions.

Lets suppose we have arbitrary joint-actions j_m and j_n and transition $\lambda\{q_s, q_{s+1}, q_{s+2}, q_{s+3}, q_f\}$ that start at times $\{t_s, t_{s+1}, t_{s+2}, t_{s+3}, t_{s+4}\}$ where j_m starts at q_{s+1} and ends at q_{s+2} and j_n starts at q_{s+2} and ends at q_{s+3}.

CQAC-01. Could sequential actions j_m and j_n be performed concurrently at some point?

- for joint-actions j_m and j_n, $\rho(j_n) \subseteq IC(j_m)$
- That is, the preconditions of action j_n are part of the invariant conditions of j_m such that actions could be performed concurrently at some point.
- This questions aims to modify the start time of the actions such that actions are executed concurrently at some point.

CQAC-02. Could the order of the sequential actions j_m and j_n be changed?

- $\rho(j_m) \subseteq \pi(q_{s+1})$ and $\rho(j_m) \subseteq \pi(q_{s+2})$
  and $\rho(j_n) \subseteq \pi(q_{s+1})$ and $\rho(j_n) \subseteq \pi(q_{s+2})$
  but $\rho(j_n) \not\subseteq IC(j_m)$
  such that $\tau(q_{s+1}, j_m)$ is q_{s+2} and $\tau(q_{s+2}, j_n)$ is q_{s+3}
- That is, the preconditions of action j_n and action j_m hold in q_s but the preconditions of J_n are not part of the invariant conditions of j_m such that the order of sequential actions can be changed. Figure **??** presents the states and transitions considered in this question.
- This question leads to change the order of two actions in favour of some agent's interest.

CQAC-03. Is there a conflict in any of the preconditions of the concurrent actions?

- A conflict in the preconditions of the actions leads to dismiss an action or perform actions sequentially.

CQAC-06. Is there a conflict in the start effects of the concurrent actions?

- $\exists se \in SE(q_{s+1})$ and $\exists se_1 \in SE(q_{s+1})$
  such that $se \rightarrow \neg se_1$ or $se_1 \rightarrow \neg se$
  where $\tau(q_s, j_2)$ is q_{s+1}
- A conflict in the start effects of the actions leads to dismiss an action or perform actions sequentially.

CQAC-07. Is there a conflict in the end effects of the concurrent actions?

- $\exists ee \in EE(q_f)$ and $\exists ee_1 \in EE(q_f)$
  such that $ee \rightarrow \neg ee_1$ or $ee_1 \rightarrow \neg ee$
  where $\tau(q_s, j_2)$ is q_f
- A conflict in the effects of the actions could leads to dismiss an action or perform actions sequentially.

CQAC-08. Is there a maximum duration for actions to perform concurrently?

- $max(\lambda(j_n)[t] \cap \lambda(j_m)[t]$
- The max function could be defined as critical question CQAT-06 (could the action duration be less?).
- This question aims to change the time in which actions are performed concurrently by changing the start time of the actions or inquire for an allowed range.

CQAC-09. Is there a minimum duration for actions to perform concurrently?
- $min(\lambda(j_n)[t] \cap \lambda(j_m)[t])$
- The max function could be defined as critical question CQAT-07 (Could the action duration be less?).
- This question aims to change the time in which actions are performed concurrently by changing the start time of the actions or inquire for an allowed range.

5.4 Layer 4. Critical Questions for the Plan Proposal

This layer presents eleven questions that consider the plan as a single entity with no regard to the actions that comprise the plan.

CQPP-01. Is the plan possible?
- $[\{j_m, j_n\} \notin PL]$
- Conflicts could be at several levels. This question leads to argue at different plan levels.

CQPP-02. Is the current social context valid?
- $\exists n \in X)$, $x \notin \Phi$ where n is a norm and Φ is a finite, no-empty set of atomic propositions.
- Conflict in social context or domain constraints could lead to dismiss proposal. With this question I aim to provide a way to consider questions about norms or social constraints regarding the proposal. In [5], for example, questions regarding the social authority to issue commands are specified for a command dialogue.

CQPP-03. Is the initial state valid?
- $q_0 \neq q_s$ and $q_s \in Q$
- Different initial state representations in the agents can lead to dismiss proposal or align initial state.
- The initial state is not part of the valid states.

CQPP-04. Is the initial state possible?
- $q_s \in Q$
- The initial state is different from the current state.

CQPP-05. Do the new circumstances already pertain?

- $q_s = q_f$ where q_s is the initial state and q_f is the final state.
- This question inquires if the actual state is the same as the desired state.

CQPP-06. Assuming initial state is valid, will the plan bring about the desired state?

- $\tau(q_s, PL)$ is not q_f.
- Agents with different planners may not obtain the same result state when the plan is applied in the same circumstances. Specific action questions may help to tease out the problem with the plan.

CQPP-07. Assuming the initial state is possible and valid, will the plan PL bring about the desired goal G?

- $G \notin \pi(q_f)$
- The question challenges that the plan does not bring about the goal.

CQPP-08. Can the desired goal G be realized?

- $G \notin \Phi(q_f)$
- This question challenges the fact that the goal cannot be realized in any state.

CQPP-09. Are the values in V_{PL} legitimate values?

- $\exists v_n \in V_{PL}$ but $v_n \notin V$
- Values that are not legitimate can lead to dismiss the plan proposal.

CQPP-10. Is the value v_n promoted by the execution of the plan?

- $\delta(q_s, q_f, v_n)$ is not $+$
- This question reveal differences on how agents use the values to promote the plan.

CQPP-11. Can the value v_n be promoted?

- $\forall v_n \delta(q_s, q_f, v_n)$ is =
- This question challenges the fact that a value cannot be promoted by any plan.

5.5 Layer 5. Critical Questions for the Timing of the Plan

In this layer the plan proposal is questioned/challenged in the same way the action was questioned in Layer 2. Questions include pointers to suggest a change in the time the plan should start or finish. Let's assume $\tau(q_s, PL)$ is q_f where $\lambda_{PL} = \{q_s, q_{s+1}, q_f\}$ at $\{t_s, t_{s+1}, t_f\}$. A $range$ function is defined as the difference between two interval points $\lambda\{q_s\}[t_s] - \lambda\{q_f\}[t_f]$.

CQPPT-01. Is the start time-point for the plan fixed?
- $\neg\exists q_s^{'} \in Q$ such that $\tau(q_s^{'}, PL)$ is q_f and $\lambda\{q_s\}[t_s] \neq \lambda\{q_s^{'}\}[t_s^{'}]$
- Question aims to change the start time of the plan.

CQPPT-02. If the starting point is not fixed, what is the range allowed?
- if $\exists q_s^{'} \in Q$ at t_s such that $\tau(q_s^{'}, PL)$ is q_f and $\rho(q_s^{'})$ and $\lambda\{q_s\} \neq \lambda\{q_s^{'}\}$ the range $\lambda\{q_s\} - \lambda\{q_s^{'}\}$
- That is, given that there exists a state $q_s^{'}$ the range is the difference between the original state q_s and the new state $q_s^{'}$
- If the start time is not fixed the questions inquires for the range of time allowed. The question leads to change the start-time of the plan.

CQPPT-03. What is the range allowed in the plan duration?
- $(\lambda\{q_s\} - \lambda\{q_s^{'}\}) + (\lambda\{q_f\} - \lambda\{q_f^{'}\})$
- That is, the range of the plan duration is the sum of the differences between valid states $q_s^{'}$ and $q_f^{'}$.
- This question aims to modify the plan duration inquiring for a range.

CQPPT-04. Is the plan possible with the specified duration?
- The possibility of the plan with the specified duration is given by the duration of the actions that comprise the plan specified in question *CQAT-01*. The question challenges the possibility of the plan with the specified duration.

CQPPT-05. Can the plan duration be less?
- A change in the duration of the plan is given by a change in the duration of the actions that comprise the plan, so this question is a generalization of question *CQAT-06. Can the action duration be less?*. The question inquires for a change in the duration of the plan.

CQPPT-06. Can the duration be longer?

– A change in the duration of the plan is given by a change in the duration of the actions that comprise the plan, so this question is a generalization of question *CQAT-07. Can the action duration be longer?*. The question inquires for a change in the duration of the plan.

CQPPT-07. Is the plan possible at the specified time?

– A change in the start time of the plan is given by a change in the start time of the initial(s) joint actions that comprise the plan, so this question is a generalization of question *CQAT-02. Is the action possible at the specified start time?*. The question inquires for a change in the start time of the plan. The question challenges the possibility of the plan with the specified start point in time.

CQPPT-08. Is the plan possible to finish at the specified time?

– A change in the end time of the plan is given by a change in the end time of the initial(s) joint actions that comprise the plan, so this question is a generalization of question *CQAT-03. Is the action possible to finish at the specified time?*. The question inquires for a change in the start time of the plan. The question challenges the possibility of the plan with the specified end-time.

CQPPT-09. What is the earliest time the plan can end?

– A change in the end time of the plan is given by a change in the end time of the initial(s) joint actions that comprise the plan, so this question is a generalization of question *CQAT-08. Is the action possible to end earlier?*. The question inquires for a change in the end time of the plan. The question inquires for a change in the end point time of the plan.

CQPPT-10. What is the latest time the plan can end?

– A change in the end time of the plan is given by a change in the end time of the initial(s) joint actions that comprise the plan, so this question is a generalization of question *CQAT-09. Is the action possible to end later?*. The question inquires for a change in the end time of the plan. The question inquires for a change in the end point time of the plan.

5.6 Layer 6. Critical Questions for the Side Effects of the Plan.

A side effect is an outcome of the action that was unintended, and could in principle promote or demote a value.

CQSE-01. Does the plan have a side effect which demotes the value v_n?
- $[\tau(q_s, PL)$ s.t. $p_b \in \pi(q_f)$ s. t. $\delta(q_s, q_f, v_n)$ is $-]$
- Side effects of the plan may interfere with agents' preferences over values. Question leads to dismiss the plan based on a different set of priorities

CQSE-02. Does performing the plan have a side effect which demotes some other value v_n?
- $[\tau(q_s, PL)$ is q_f s.t. $\delta(q_s, q_f, v_n)$ is $-$ and $v_n \in V_{PL}]$
- Side effects may interfere with agents' local value specification. Question leads to dismiss the plan.

CQSE-03. Does performing the plan promote some other value?
- $[\delta(q_s, q_f, v_w)$ is + and $v_w \notin V_{PL}]$
- Side effects may promote other not necessarily desired values.

CQSE-04. Does performing the plan preclude doing some other action which would promote some other value v_u?
- $[\exists PL_x$ s.t. $\tau(q_s, PL_x)$ is q_f s.t. $\delta(q_s, q_f, v_u)$ is $+$, where $v_u \neq V_{PL}]$
- Side effects may interfere with agents' local value specification; answer leads to dismiss current plan.

5.7 Layer 7. Critical Questions inquiring Alternative Options.

Questions in this layer consider other possibly better alternatives. Lets suppose PL_x is an alternative plan

CQAO-01. Is there an alternative plan PL_x to promote the same value v_n?
- $[\exists PL_x$ such that $\tau(q_s, PL)$ is q_f
  such that $\delta(q_s, q_f, v_n)$ is $+$ = $\tau(q_s, PL_x)$ is q_f
  such that $\delta(q_s, q_f, v_n)$ is $+]$
- A possibly more efficient plan promoting the same value is available.

CQAO-02. Is there an alternative plan to realize the same new circumstances?
- [$\exists PL_x$ such that $\tau(q_s, PL)$ is q_f = $\tau(q_s, PL_x)$ is q_f]
- Another plan is available to reach the same final state.

CQAO-03. Is there an alternative plan to realize the same goal ?
- [$\exists PL_x$ such that $\tau(q_s, PL)$ is q_f
  such that $G \in \pi(q_f)$ = $\tau(q_s, PL_x)$ is q_f such that $G \in \pi(q_f)$]
- Another plan is available to reach the same goal.

CQAO-04. Is there another agent that could perform a particular action?
- [$\exists x$ such that $\tau(q_s, \{j_m, j_n)\})$ is q_f= $\tau(q_s, \{j_m, j_x)\})$ is q_f
  such that $x \in Ag$ and $\alpha_x \in Ac_x$ and $\alpha \in j_x$
- Another agent can perform the action.

- *CQAO-05. Is there another joint-action that could be performed with the same result?*
- [$\exists j_x$ such that $\tau(q_s, \{j_m, j_n\})$ is q_f = $\tau(q_s, \{j_m, j_x\})$ is q_f]
- Another action can be performed leads to change action specification in the plan.

6 Conclusion

Our research aims at contributing to solving problems related to multi-agent planning, where agents need to agree on plans given different views of the world and of other agents' capabilities. The contribution of this report is that it presents a list of critical questions related to an argumentation scheme for plan proposals formalized in terms of an AATS including different combination of actions and temporal aspects. The critical questions address each element of a proposed plan and so they are comprehensive with respect to the representation we have chosen for plan proposals. We believe every component and every interaction of components in our representation of a proposal for plan is subject to a possible critical question The importance of this work is that it enables a proposal for plan execution to be considered rationally and automatically by software agents engaged in deliberation over the plan of action. The critical questions enable the proposed plan to be questioned/challenged in a comprehensive and organized manner, and to be clarified or defended in response, as appropriate.

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