Action-Based Alternating Transition Systems for Arguments about Action

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Abstract

This paper presents a formalism to describe practical reasoning in terms of an Action-based Alternating Transition System (AATS). The starting point is a previously specified account of practical reasoning that treats reasoning about what action should be chosen as presumptive argumentation using argument schemes and associated critical questions. This paper describes how this account can be extended to situations where the effect of an action is partially dependent upon the choices of another agent. In this context we see practical reasoning as proceeding in three stages. The first involves determining the representation of the particular problem scenario as an AATS. Next the agent must resolve its uncertainties as to its position in the scenario. Finally, the agent moves to choosing a particular action to achieve its ends, proposing presumptive reasons for particular actions and subjecting them to a critique to establish their suitability, taking into account the choices that can be made by the other agents involved. This account thus provides a well-specified basis for addressing the problems of practical reasoning as presumptive argumentation in a multi-agent context.

Introduction

Practical reasoning has long been the focus of theories and implementations for rational interaction amongst autonomous agents. Over the last two decades there have been numerous proposals for accounts of practical reasoning, including amongst others, accounts based on agents that perform planning (Georgeff & Lansky 1987), accounts that are grounded within specific logics (Giordano, Martelli, & Schwind 2000) and those that are based upon methods of argumentation (Atkinson 2005; Rahwan & Amgoud 2006). The work we present in this paper falls under the remit of practical reasoning through argumentation. The proposal that we offer provides a formal basis for an account of practical reasoning that exploits the defeasible and subjective nature of such reasoning. In the account we present we view practical reasoning as proceeding in three distinct stages:

- *problem formulation*: deciding what facts, values, interests and aspirations are relevant in the particular situation;
- *epistemic reasoning*: determining the current situation with respect to the structure formed at the previous stage;
- *action selection*: developing the appropriate arguments and counter arguments, in terms of instantiations of an appropriate argument scheme, and evaluating the resulting set of arguments with respect to an ordering on the social values promoted by the arguments.

The contibution this paper provides draws on existing accounts of argumentation and normative systems in order to form a unified, well-specified and automatable approach to practical reasoning in agent systems.

In section 2 we describe an existing representation of normative systems developed by Wooldridge and van der Hoek (2005). In section 3 we summarise a theory of practical reasoning proposed by Atkinson (2005) upon which our formalism will be based. In section 4 we define the theory of practical reasoning in terms of the normative system described in section 2. We then discuss how, given this formalism, practical reasoning can be conducted by autonomous software agents in the three stages above. In section 5 we present a short, abstract example to illustrate the approach. Finally, section 6 offers some concluding remarks.

Action-Based Alternating Transition Systems

In this section we describe the underlying normative system that serves as the basis for our representation of arguments about action. In (Wooldridge & van der Hoek 2005) a formal description of a normative system is given, defined in terms of constraints on actions that may be performed by agents in any given state. It is this account that we will use as a basis for formalising the argument scheme and critical questions that we describe in the subsequent section. First, we briefly summarise their approach.

They present an extension to Alur et al's Alternating-time Temporal Logic (ATL) (2002), Normative ATL* (NATL*). *Action-based Alternating Transition Systems* (AATSs) provide the semantic structures which underpin NATL*. AATSs are used for modelling systems comprising multiple agents that can perform actions in order to modify and attempt to control the system in some way. An AATS is used to model the physical properties of the system in question – the actions that agents can perform in the empty normative system. We will also adopt AATSs to model the physical properties

of the systems in which our agents will carry out their practical reasoning. Based on (Wooldridge & van der Hoek 2005), we describe AATSs as follows.

Firstly the systems of interest may be in any of a finite set Q of possible *states*, with some $q_x \in Q$ designated as the *initial state*. Systems are populated by a set *Ag* of *agents*; a *coalition* of agents is simply a set $C \subseteq Ag$, and the set of all agents is known as the *grand coalition*. Here 'coalition' does not imply any common purpose or shared goal: a coalition is simply taken to be a set of agents. We will only consider the coalition of all agents, although for problems in which a group of agents deliberate to form a joint course of action, the coalition machinery is useful.

Each agent $i \in Ag$ is associated with a set Ac_i of possible actions, and it is assumed that these sets of actions are pairwise disjoint (i.e., actions are unique to agents). A joint action j_{Ag} for the grand coalition is a tuple $\langle \alpha_1,...,\alpha_n \rangle$, where for each α_j (where $j \leq n$) there is some $i \in Ag$ such that $\alpha_j \in Ac_i$. Moreover, there are no two different actions α_j and $\alpha_{j'}$ in J_{Ag} that belong to the same Ac_i. The set of all joint actions is denoted by J_{Ag}, so $J_{Ag} = \prod_{i \in Ag} Ac_i$. Given an element j_n of J_{Ag} and an agent $i \in Ag$, i's action in j_n is denoted by ${j_n}^i$.

An *Action-based Alternating Transition System* (AATS) is an $(n + 7)$-tuple $S = \langle Q, q_0, Ag, Ac_1, \ldots, Ac_n, \rho, \tau, \Phi, \pi \rangle$, where:

- Q is a finite, non-empty set of *states*;
- $q_0 = q_x \in Q$ is the *initial state*;
- $Ag = \{1,...,n\}$ 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 $i \neq j \in Ag$;
- $\rho : Ac_{Ag} \rightarrow 2^Q$ 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 precondition 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 section 4 we extend this account to enable us to deal with the more subjective elements of our theory of practical reasoning, the agents' interests/values. Before we articulate this extension we first provide an overview of the account of practical argument upon which our formalism is based.

Background Theory of Practical Reasoning

In (Atkinson 2005) an argument scheme and associated critical questions are presented to enable agents to propose, attack and defend justifications for action. This argument scheme follows Walton (1996) in viewing reasoning about action (practical reasoning) as presumptive justification — *prima facie* justifications of actions can be presented as instantiations of an appropriate argument scheme, and then critical questions characteristic of the scheme can be used to identify challenges to these justifications. The argument scheme AS1 developed by Atkinson is an extension of Walton's *sufficient condition scheme for practical reasoning* (Walton 1996). AS1 is stated as follows:

AS1 In the current circumstances R
We should perform action A
Which will result in new circumstances S
Which will realise goal G
Which will promote value V.

In this scheme Walton's notion of a goal has been made more precise by distinguishing three elements it encompasses: the state of affairs brought about by the action; the goal proper (the desired features in that state of affairs); and the value (the reason why those features are desirable). Atkinson states that the underlying idea in making this distinction is that the agent performs an action to move from one state of affairs to another. The new state of affairs may have many differences from the current state of affairs, and it may be that only some of them are significant to the agent. The significance of these differences is that they make the new state of affairs better with respect to some good valued by the agent and typically the new state of affairs will be better through improving the lot of some *particular* agent.

Instantiations of argument scheme AS1 provide *prima facie* justifications of proposals for action. Associated with this scheme are sixteen different critical questions that can challenge the presumptions in instantiations of AS1. These critical questions are:

CQ1: Are the believed circumstances true?
CQ2: Assuming the circumstances, does the action have the stated consequences?
CQ3: Assuming the circumstances and that the action has the stated consequences, will the action bring about the desired goal?
CQ4: Does the goal realise the value stated?
CQ5: Are there alternative ways of realising the same consequences?
CQ6: Are there alternative ways of realising the same goal?
CQ7: Are there alternative ways of promoting the same value?
CQ8: Does doing the action have a side effect which demotes the value?
CQ9: Does doing the action have a side effect which demotes some other value?
CQ10: Does doing the action promote some other value?
CQ11: Does doing the action preclude some other action which would promote some other value?
CQ12: Are the circumstances as described possible?
CQ13: Is the action possible?
CQ14: Are the consequences as described possible?
CQ15: Can the desired goal be realised?
CQ16: Is the value indeed a legitimate value?

As described in (Atkinson 2005), each of the above critical questions can identify a source of disagreement about a particular element of the argument scheme AS1. In posing a critical question an opponent is making an attack on the element of the position in question and this attack may be stated with varying degrees of force. This leads to a number of variants that can be associated with particular critical questions. For example, with CQ1 an attacker may simply disagree with the description of the circumstances, i.e., deny that R is the current state of the world. Beyond this minimalist attack, an attacker may also state an alternative position to that proposed, for example, expressing not only that R is not the current state of the world, but instead that T is the current state. A full list and description of the attacks and their variants are given in (Atkinson 2005) and although we will not address all variants of attacks in our formalisation, we will provide an example to illustrate the point.

One further point to note regarding the argument scheme and critical questions is that AS1 can be stated in the negative: given a particular set of circumstances, an action *should not be performed*, as it would lead to a particular state of affairs that entails some 'goal' which demotes a value. This negative version of AS1 can thus be used in scenarios where the onus is on avoiding some undesirable outcome rather than achieving some positive outcome.

The usefulness of the approach of (Atkinson 2005) for the analysis of practical reasoning situations has been shown for a range of areas including law (Bench-Capon, Atkinson, & Chorley 2005), e-democracy (Atkinson, Bench-Capon, & McBurney 2006) and reasoning about the morally correct course of action (Atkinson & Bench-Capon 2006; Chorley, Bench-Capon, & McBurney 2006). Thus far, however, the generation of arguments and critical questions has been rather *ad hoc*. In order to provide rigour to the approach, it is necessary to make explicit the relation between the arguments and questions and some well-founded underlying formal model. The chief objective of this paper is to provide just such a grounding in terms of AATSs, as we show in the next section.

Formalising Practical Reasoning as an AATS

In addition to the elements of an AATS given in section 2, we need to extend this structure to enable the representation of values from the underlying theory of practical reasoning. Firstly, we have a set *Av* of values for each agent (which are a subset of a set *V* of values). Every transition between two states from the set *Q* is either promoted, demoted, or is neutral, with respect to each value. Note that values are not unique to agents: individual agents may or may not have values in common. More formal definitions of these elements are given below:

- Av_i is a finite, non-empty set of values $Av_i \subseteq V$, for each $i \in Ag$.
- $\delta : Q \times Q \times Av_{Ag} \rightarrow \{+, -, =\}$ 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 $v_u \in Av_{Ag}$.

We have extended the original specification of an AATS to accommodate the notion of values and we thus re-define an AATS as a $(2n + 8)$ tuple $S = \langle Q, q_0, Ag, Ac_1, \ldots, Ac_n, Av_1, \ldots, Av_n, \rho, \tau, \Phi, \pi, \delta \rangle$

Given these above definitions, we can now re-state argument scheme AS1 in these terms. This gives us:

AS2 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 $p_a \notin \pi(q_x)$,
Such that for some $v_u \in Av_i$, $\delta(q_x, q_y, v_u)$ is +.

Furthermore, we can now describe each of the critical questions associated with the argument scheme in terms of our extended definition of an AATS[1]. However, before we present these descriptions, we will first make some remarks about the different categories that each of the critical questions fall under and state how these relate to the three stages of the practical reasoning process that we identified in section 1.

Firstly, eight of the critical questions represent differences uncovered between the agents' AATS representations. CQ2 accepts that the pre-conditions for the performance of the action hold, but disputes the resultant state attained through execution of the action. CQ3 does not dispute the state reached through execution of the action but instead disputes the truth of some proposition (the goal) within this state. CQ4 reveals a difference between how individual agents value states of affairs; CQ12, CQ13, CQ14 and CQ15 all represent differences in language between individual agents (resulting, for example, in dispute over descriptions of the state of the world); and, CQ16 represents disagreement as to what counts as a value. Resolution of these eight critical questions falls under the remit of the *problem formulation* stage of the practical reasoning process. In this stage agents may disagree about what is relevant.

In the *epistemic reasoning* stage of the process the agent determines which state of affairs it finds itself in within the structure, and so CQ1 is the only critical question in the list that can be asked at this stage. CQ1 relates to the pre-conditions required to be satisfied for the performance of the action. Later on in this section we will make a further comment about the epistemic reasoning involved in this stage when discussing the implications of joint actions. In this stage agents may disagree about the facts of the situation.

The remaining critical questions comprise CQ5 – CQ11 and these are all pertinent to the final stage of the practical reasoning process, the *action selection* stage. CQ5, CQ6 and CQ7 all consider possible alternatives to the original action

[1]The AATS provides a public structure so that we do not need to rely on notions such as beliefs and desires, which are private to the agent. The agent's beliefs will, of course, determine the AATS it constructs.

proposed with each of these critical questions considering the effects of any such alternative actions upon the the consequences, goal and value, respectively. CQ8, CQ9 and CQ10 are all concerned with the side effects of the proposed action. CQ8 and CQ9 draw attention to possible negative side effects, whilst CQ10 can be seen as more of a supporting argument that identifies positive side effects of the action that endorse rather than dispute the performance of the action. It is used to question the justification, not the action. There now remains only one critical question, CQ11, which identifies a clash between the action proposed and some other desirable action. CQ11 arises when the goal state achieved by the proposed action is incompatible with the goal state of some other action that promotes a desirable value, so that only one of the actions can be executed. All of the critical questions discussed in this final stage propose alternative arguments of one type or another and so they can be viewed as arguments that are to be compared as part of the action selection process. Here agents may disagree as to how values are ranked, and to which arguments should be accepted.

Given the above stages under which each of the critical questions falls, we now present the formal definitions of all the critical questions, grouped according to these categories. We begin with those from the *problem formulation* stage of the practical reasoning process. The critical questions are directed against the instantiation given as AS2.

CQ2: $\tau(q_x, j_n)$ is not q_y.

CQ3: $p_a \notin \pi(q_y)$.

CQ4: $\delta(q_x, q_y, v_u)$ is not +.

CQ12: $q_x \notin Q$.

CQ13: $j_n \notin J_{Ag}$.

CQ14: $\tau(q_x, j_n) \notin Q$.

CQ15: $p_a \notin \pi(q)$ for any $q \in Q$.

CQ16: $v_u \notin V$.

Next we define the critical question relevant to the second stage of the process, the *epistemic reasoning*:

CQ1: $q_0 \neq q_x$ and $q_0 \notin \rho(\alpha_i)$.

Finally, we define the critical questions pertinent to the *action selection* stage of the process:

CQ5: Agent $i \in Ag$ can participate in joint action $j_m \in J_{Ag}$, where $j_n \neq j_m$, such that $\tau(q_x, j_m)$ is q_y.

CQ6: Agent $i \in Ag$ can participate in joint action $j_m \in J_{Ag}$, where $j_n \neq j_m$, such that $\tau(q_x, j_m)$ 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 $p_a \in \pi(q_x)$.

CQ7: Agent $i \in Ag$ can participate in joint action $j_m \in J_{Ag}$, where $j_n \neq j_m$, such that $\tau(q_x, j_m)$ is q_z, such that $\delta(q_x, q_z, v_u)$ is +.

CQ8: In the initial state $q_x \in Q$, if agent $i \in Ag$ participates in joint action $j_n \in J_{Ag}$, then $\tau(q_x, j_n)$ is q_y, such that $p_b \in \pi(q_y)$, where $p_a \neq p_b$, such that $\delta(q_x, q_y, v_u)$ is –.

CQ9: In the initial state $q_x \in Q$, if agent $i \in Ag$ participates in joint action $j_n \in J_{Ag}$, then $\tau(q_x, j_n)$ is q_y, such that $\delta(q_x, q_y, v_w)$ is –, where $v_u \neq v_w$.

CQ10: In the initial state $q_x \in Q$, if agent $i \in Ag$ participates in joint action $j_n \in J_{Ag}$, then $\tau(q_x, j_n)$ is q_y, such that $\delta(q_x, q_y, v_w)$ is +, where $v_u \neq v_w$.

CQ11: In the initial state $q_x \in Q$, if agent $i \in Ag$ participates in joint action $j_n \in J_{Ag}$, then $\tau(q_x, j_n)$ is q_y and $\delta(q_x, q_y, v_u)$ is +. There is some other joint action $j_m \in J_{Ag}$, where $j_n \neq j_m$, such that $\tau(q_x, j_m)$ is q_z, such that $\delta(q_x, q_z, v_w)$ is +, where $v_u \neq v_w$.

Before we conclude our definitions, we return briefly to the issue of variants of critical questions, as discussed in section 2. Recall that variants arise from the strength of the argument put forward: simply denying that an element of AS1 is as stated by a proponent is a weaker form of argument than the additional proposal of an alternative to the element denied. To illustrate this point we now provide a couple of definitions of such variant arguments. Consider first CQ2. The definition shows the minimalist attack that can be made by simply denying that the consequences of the action entail the goal state. If the purveyor of the attack were to offer a stronger attack, making use of CQ2 to both deny the consequences are as stated and suggest they are otherwise, then we would define this as follows:

CQ2b[2]: $\tau(q_x, j_n)$ is not q_y and $\tau(q_x, j_n)$ is q_z, where $q_y \neq q_z$.

Looking at a second example, consider CQ4. Its minimalist attack states that a value is not promoted by a transition between two states. A variant on CQ4 would be the statement that not only does the transition not promote the value, but it actually demotes it:

CQ4b: $\delta(q_x, q_y, v_u)$ is not + and $\delta(q_x, q_y, v_u)$ is –.

The above examples give a flavour of how variants of the critical questions can affect the strength of the attack put forward and though it is not a difficult task to fully specify the full set of variants associated with the appropriate critical questions, due to space restrictions, we will not provide all the definitions here.

One final point to be made regarding the critical questions concerns an additional question that arises through defining

[2]The first conjunct in CQ2b and CQ4b though redundant is included to show explicitly that it subsumes CQ2 and CQ4.

the background theory in terms of an AATS, needed to recognise that the effects of an action may depend upon the *choice* of another agent. In an AATS actions are seen as *joint actions* that two (or more) agents may participate in. This means that the choice of one agent may not determine which joint action is performed: the other agent(s) may make choices which lead to other joint actions. Given that we have defined all the critical questions in terms of such joint actions, this introduces the need for a further critical question: is the other agent guaranteed to execute its part of the desired joint action? We shall call this additional critical question CQ17. Such a critical question falls under the remit of the *epistemic reasoning* stage of the practical reasoning process and we formally define it as follows:

CQ17: ${j_n}^i = {j_m}^i, j_n \neq j_m$ and $\tau(q_x, j_n) \neq \tau(q_x, j_m)$.

This concludes our definition of the critical questions associated with AS2. In the next section we provide a short example to demonstrate how these definitions can be used to represent and reason about practical problems.

Example

In this section we use a small, artificial example able to illustrate the use of all seventeen critical questions. A concrete, more elaborate example can be found in (Atkinson & Bench-Capon 2006). Our example makes reference to an agent scenario represented as example AATSs. In Figure 1 the state labelled q_5 is designated as the initial state. The possible developments from this initial state are denoted by the joint actions that label the arcs. Additionally, the arcs are also labelled with the value promoted or demoted by a transition for agent *i* (with neutral values being omitted from the arcs). States are labelled with a vector to denote the propositions that are true in each state. For agent *i* there are three propositions that are relevant, with 1 denoting the proposition as being true and 0 as false.

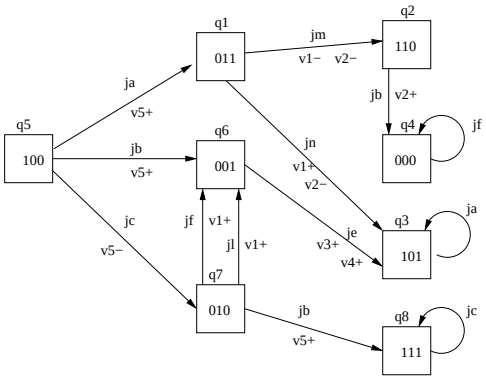

Figure 1. Example AATS for agent *i*.

Given agent *i*'s representation of the scenario as shown above, we can see that this state transition diagram allows for several instantiations of AS2. For example, in q_5 agent *i* can perform its component of j_a to reach q_1, promoting v_5. In q_1 agent *i* can perform its component of j_n to reach q_3, promoting v_1, and so on.

Now, in order to be able to pose the critical questions relating to problem formulation, some other agent, agent *k*, must have a different representation of the scenario, such as the example diagram shown in Figure 2.

As we can see from Figure 2, there are numerous differences between the two agents' views of the scenario, resulting from agent *i* recognising an additional proposition as relevant. So, for example, *i* can discriminate between q_1 and q_7, whereas agent *k* cannot. Thus the states in Figure 2 are a subset of the more detailed AATS featuring in Figure 1. Furthermore, agent *i*'s representation also includes more actions and values due its richer representation of the scenario. Given the two agents' views of the situation, we now describe, in relation to both Figure 1 and Figure 2, how the critical questions can be posed. We begin with the critical questions from the problem formulation stage.

- CQ2: Agent *k* can pose this question to state that in q_1 action j_n actually leads to q_2, not q_3 as it does in *i*'s representation.
- CQ3: In (Atkinson 2005) CQ3 was intended to express differences between the agents as to what can be inferred on the basis of primitive propositions. Since in the AATS all propositions are primitive, this reduces to CQ2.
- CQ4: Agent *k* can pose this question against *i*'s statement that the transition between q_2 and q_4 promotes v_2: in *k*'s representation this transition demotes v_2.
- CQ12: Agent *k* can pose this question to show that the state agent *i* designated as the initial state does not feature in the particular scenario (because agent *k* does not recognise the third proposition).
- CQ13: Agent *k* can pose this question to state that an action does not feature in this scenario (because agent *i* includes actions not recognised by *k*).
- CQ14: Agent *k* can pose this question when the action affects the third proposition that *k* does not recognise.
- CQ15: Agent *k* can pose this question to state that the third proposition does not feature in any state in the scenario, as it does in *i*'s representation.
- CQ16: Agent *k* can pose this question to state that value v_5 does not label any of the arcs in its scenario, as it does in *i*'s representation.

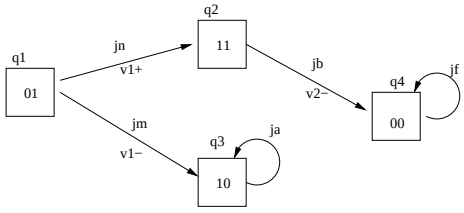

Figure 2. Example AATS for agent *k*.

Moving on to the epistemic reasoning, the agent determines where it is in the scenario by designating some state as q_0. The critical questions relevant here are:

- CQ1: Agent *k* can pose this question when, for example, it believes itself to be in q_1 and agent *i* believes itself to be in q_7.

- CQ17: Agent *k* can pose this question against *i* in state q_1, where there are two actions available for performance, j_n and j_m. If the action that agent *k* performs as part of these joint actions is the same for both cases (i.e., ${j_n}^k = {j_m}^k$) then it is agent *i*'s part of the joint action that determines which state results from executing the joint action, thus *k* can question whether *i* will carry out its part of the action.

After the epistemic reasoning stage, an initial set of arguments can be produced from the AATS by instantiating AS2. In the third stage, the action selection, we produce further arguments by instantiating the appropriate critical questions.

- CQ5: In q_7 if action j_f is proposed in order to reach q_6, then j_l can be proposed as this will also reach q_6.
- CQ6: In q_7 if action j_f is proposed in order to realise the goal of the third proposition being true, then j_b will offer an alternative way of realising this same goal.
- CQ7: In q_5 if action j_a is proposed to promote v_5 then j_b offers an alternative way to promote v_5.
- CQ8: In q_1 agent *k* can argue that j_n should be performed to reach q_2 and so promote v_1, but for agent *i* reaching q_2 will demote v_1 due to the falsity of the third proposition.
- CQ9: In q_1 agent *i* has an argument for performing j_n since it promotes v_1, but also an argument against j_n because it demotes v_2.
- CQ10: In q_6 the justification for performing j_e could be either that it promotes v_3 or that it promotes v_4.
- CQ11: In q_7 there is an argument to perform j_f to reach q_6 and so promote v_1. However, if q_6 is reached, it is subsequently impossible to promote v_5, which would be promoted were j_b to be performed instead.

This concludes our example demonstrating the use of each critical question.

Concluding Remarks

In this paper we have presented an account of practical reasoning based upon presumptive argumentation using argument schemes and critical questions. We have used Action-based Alternating Transition Systems to provide the structures from which to generate our arguments. This work is intended to supply a rigorous basis for the investigations of practical reasoning required in several domains such as law, e-democracy and moral reasoning. Moreover, the machinery we have provided will facilitate implementations of presumptive practical reasoning, such as that provided in (Chorley, Bench-Capon, & McBurney 2006).

The division into three stages is important as it identifies different aspects on which agents must come to agreement in a deliberation. First they need to agree on what is relevant. Next they must agree on what the facts are. Given agreement on these parts, the arguments generated will be the same for both agents. They may still, however, disagree as to how these are evaluated, if they rank values differently[3]. We can compare this with, for example, legal decision making: first evidence is taken and accepted or rejected as irrelevant or inadmissible. Conflicts in the evidence are next resolved to provide an agreed set of facts. Finally, points of law are agreed to come to a decision.

The approach to practical reasoning advocated here contrasts with most existing accounts in that it is based upon a theory of argumentation that enables the different perspectives and interests of the agents involved in the reasoning to be taken into account and evaluated accordingly. We believe this account provides an effective means to represent and handle the subjective and defeasible nature of practical reasoning.

[3]How value orders are used to select between alternatives is described in (Atkinson 2005).

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