Taking the Long View: Looking Ahead in Practical Reasoning

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Abstract. In this paper we extend an argumentation scheme for practical reasoning with values based on Action-based Alternating Transition Systems. While the original scheme considers only arguments arising from the immediately next state, our proposals will enable long term considerations to be taken into account. We consider the various reasons for and against performing an action that arise from these longer term considerations, and develop a new set of argumentation schemes for practical reasoning which allows a clearer separation between facts, values and preferences, and more precise targeting of attacks.

Keywords. argumentation, practical reasoning, argumentation schemes

1. Introduction

In [1] an argumentation scheme for practical reasoning based on Action-based Alternating Transition Systems (AATS) [5] was proposed. Informally the scheme was: *In the current circumstances we should do action A to bring about a set of new circumstances which will promote a value V by realising a goal G.* An important feature was the distinction between the consequences of an action, the desired consequences (the goal) and the reason why those consequences were desirable to the agent (the value[1] promoted). That scheme had, however, some important limitations: most notably that the representation of goals was inexpressive, and that only the immediately next state was considered, meaning that agents could take no account of long term considerations. We have addressed the limitations concerning the expression of goals and fully discussed the relationship between goals and values elsewhere [2]: in this paper we will address the second limitation.

We introduce AATS with values and the associated argumentation scheme for practical reasoning in section 2. Section 3 considers look ahead, and section 4 discusses the additional justifications that this will provide for value-based practical reasoning. Section 5 offers a new view on argumentation schemes for practical reasoning and section 6 considers how such arguments can be attacked. Section 7 briefly considers the actions of others, and section 8 gives some concluding remarks and directions for future work.

[1] Values are what an agent attempts to advance; goals are goals because their achievement promotes values [2], and actions are done for the sake of values. Depending on context they may be social values, such as Liberty, Equality and Fraternity, or more personal aspirations, such as excitement and comfort.

2. Action-Based Alternating Transition Systems with Values

AATSs were originally presented in [5] as semantical structures for modelling game-like, dynamic, multi-agent systems in which the agents can perform actions in order to modify and attempt to control the system in some way. These structures are thus well suited to serve as the basis for the representation of arguments about which action to take in situations where the outcome may be affected by the actions of other agents. First we recapitulate the definition of the components of an AATS given in [5].

Definition 1: AATS 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*;
- $q_0 \in Q$ 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 $i \neq j \in Ag$;
- $\rho : Ac_{Ag} \to 2^Q$ is an *action pre-condition function*, which for each action $\alpha \in Ac_{Ag}$ defines the set of states $\rho(\alpha)$ from which α may be executed;
- $\tau : Q \times J_{Ag} \to Q$ 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
- $\pi : Q \to 2^\Phi$ 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.

AATSs are particularly concerned with the joint actions of the set of agents Ag. j_{Ag} is the joint action of the set of n agents that make up Ag, and 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 for the set of agents Ag is denoted by J_{Ag}, so $J_{Ag} = \prod_{i \in Ag} Ac_i$. Given an element j of J_{Ag} and an agent $i \in Ag$, i's action in j is denoted by j^i.

Definition 1 is taken from [5]. In that paper it is stated that every agent must have the possibility of doing nothing: that is, for all $i \in Ag$, $doNothing_i \in Ac_{Ag}$. It is also stipulated in [5] that an agent can only perform one action at a time. Together these stipulations enable us to say that every joint action contains one, and only one, action for each agent in Ag. To represent values the AATS structure must be extended. In [1] a set V of values was introduced, along with a function δ to enable every transition between two states to be labelled as either promoting, demoting, or neutral with respect to each value.

Definition 2: AATS+V

Given an AATS, an AATS+V is defined in [1] as follows:

- V is a finite, non-empty set of values.
- $\delta : Q \times Q \times V \to \{+, –, =\}$ is a *valuation function* which defines the status (promoted (+), demoted (–) or neutral (=)) of a value $v_u \in V$ ascribed 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 $v_u \in V$.

Definition 2 is taken from [1]. There δ was defined in terms of the source and destination states. It may, however, be that the performance of an action *in itself* promotes or demotes a value. Suppose Tom enjoys fishing while Dick does not. Now both the joint action where Tom fishes and Dick does nothing and the joint action where Dick fishes and Tom does nothing will result in the pair having fish. But only the first will promote pleasure, since only Tom enjoys the activity of fishing in itself. Thus there will be two different transitions, one for each of the joint actions, and only one of them should return "+" with respect to the value pleasure. Thus we need to associate values promoted and demoted with the actions in the various Ac_i. We use a function ϵ:

- $\epsilon : J \times V \rightarrow \{+, –, =\}$ is a *valuation function* which defines the status (promoted (+), demoted (–) or neutral (=)) of a value $v_u \in V$ ascribed to a joint action: $\epsilon(j_{Ag}, v_u)$ labels the joint action j_{Ag} with one of $\{+, –, =\}$ with respect to the value $v_u \in V$.

An *Action-based Alternating Transition System with Values* (AATS+V) is thus defined as a (n + 10) tuple $S = \langle Q, q_0, Ag, Ac_1, ..., Ac_n, \rho, \tau, \Phi, \pi, V, \delta, \epsilon\rangle$[2]. This formalism was used in [1] as the basis of an argumentation scheme for Practical Reasoning (PRAS).

Definition 3: PRAS

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 ${j_n}^i = \alpha_i$,
and $\tau(q_x, j_n)$ is q_y,
and $p_a \in \pi(q_y)$ and $p_a \notin \pi(q_x)$, or $p_a \notin \pi(q_y)$ and $p_a \in \pi(q_x)$,
and for some $v_u \in V$, $\delta(q_x, q_y, v_u)$ or $\epsilon(j_n, q_x)$ is +.

In [1], seventeen potential ways to attack arguments formed by instantiating PRAS were identified and divided into three groups:

- *problem formulation*: decisions as to what the propositions and values relevant to the particular situation are, and constructing the AATS. There are eight attacks on these choices. These concern the propositions used in the state descriptions, the actions available and their effects, which values exist and which transitions promote and demote them.
- *epistemic reasoning* to determine the initial state and which joint action will be performed. There are two such attacks: one challenging the current circumstances and one questioning the anticipated behaviour of the other agents involved in joint actions.
- *choice of action*: These are the remaining seven attacks, which involve consideration of alternative ways of achieving goals and values; side effects that will demote values, and passing up an opportunity to promote some other value. Essentially these will be resolved according to the value preferences of the individual(s) acting as the audience for the argument.

[2]Both δ and ϵ could, if desired, be adapted to return a specific number, allowing for degrees of promotion and demotion.

3. Looking Ahead

As mentioned in the introduction, there were two important limitations with the scheme proposed in [1]. One concerned the limited nature of goals: since we have addressed this elsewhere[3] we do not look at this here; indeed we will restrict goals to propositions $\phi \in \Phi$. Since we can illustrate reasoning about the future with simple propositions, we do not need more complex goals in this paper, and the restriction simplifies the discussion. Our focus will be on the second limitation: that [1] considers only circumstances that can be brought about with a single action, that is, states immediately following q_0.

Consider a transition from q_1 to q_2: there are four situations with respect to a given proposition ϕ.

E1 ϕ is true in q_1 and true in q_2: in q_1, j maintains ϕ.
E2 ϕ is true in q_1 and false in q_2: in q_1, j removes ϕ.
E3 ϕ is false in q_1 and true in q_2: in q_1, j achieves ϕ.
E4 ϕ is false in q_1 and false in q_2: in q_1, j avoids ϕ.

In order to enable our thinking to go beyond the next state, we need to be able to consider the future. In a state q a proposition ϕ may be:

Always/never true, written ($\mathcal{G}\phi$/$\mathcal{G}\neg\phi$): true/false in q and every subsequent state.
Contingent, written ($\neg\mathcal{G}\phi \wedge \neg\mathcal{G}\neg\phi$): neither always true nor never true.
True/false in the next state, written $\mathcal{X}\phi$/$\mathcal{X}\neg\phi$
True/false at some point in every future, written $\mathcal{F}\phi/\mathcal{F}\neg\phi$

Now consider a transition from q_1 to q_2:

E5 ϕ is contingent in q_1 and becomes always true from q_2. We say that in q_1, j *ensures* ϕ. Iterating the modalities can provide variants e.g. ϕ could become true in q_1 and every subsequent state ($\mathcal{X}\mathcal{G}\phi$); ϕ could be true on every path from the next state, but might cease to be true ($\mathcal{X}\mathcal{F}\phi$); ϕ could be true on every path from the next state, and then remain true ($\mathcal{X}\mathcal{F}\mathcal{G}\phi$), etc. Any of these could be intended by in q_1, j *ensures* ϕ.
E6 ϕ is contingent in q_1 and becomes always false from q_2. We say that in q_1, j *prevents* ϕ. There are similar variants for prevents as ensures.
E7 ϕ is false in q_1 and q_2 and $\mathcal{X}\phi$ is true in q_2. We say that in q_1, j *enables* ϕ.
E8 ϕ is true in q_1 and q_2 and $\mathcal{X}\neg\phi$ is true in q_2. We say that in q_1, j *risks* $\neg\phi$.

E7 and E8 allow one step of look ahead: recursive application would give additional steps of look ahead: e.g. it could be that in q_1, j *risks risking* $\neg\phi$.

4. Values and Reasons

In [1] the promotion and demotion of values is normally through achieving propositions desired to be true, and the removal of propositions desired to be false. Values are promoted by *transitions*, so promotion and demotion will relate to their effect on the status

[3] In [2], where the key idea is to take goals as intensionally defined in terms of elements of Φ. That paper also provides a comparison of our model with some other approaches.

of a proposition (E1-E8) or to the transition itself. The labels returned by δ and ϵ are determined as in [2]. The scheme of [1] relates only to E2, E3 and values promoted by the action. We now have a fuller a set of reasons to participate or not to participate in a given joint action j. Reasons are labelled with the corresponding E-number and an "N" if they are reasons not to participate. In some cases we can have reasons both for and against participation. A useful set of reasons when the goal is that ϕ be true are:

R1 We should participate in j in q in which ϕ holds to maintain ϕ and so promote v.
R2N We should not participate in j in q in which ϕ holds since it would remove ϕ and so demote v.
R3 We should participate in j in q in which $\neg\phi$ holds to achieve ϕ and so promote v.
R4N We should not participate in j in q in which $\neg\phi$ holds which since it would avoid ϕ and so fail to promote v.
R5 We should participate in j in q to ensure ϕ and so promote v. Note that ϕ may be contingently realised or unrealised in q and that, in some variants, the promotion of v might not be immediate, or permanent. This also applies to R5N and R6.
R5N We should not participate in j in q which would ensure $\neg\phi$ and so demote v.
R6 We should participate in j in q to prevent $\neg\phi$ and so promote v. Note that $\neg\phi$ may be contingently realised or unrealised in q.
R6N We should not participate in j in q which would prevent ϕ and so fail to promote v. Here we suggest that to make the reason worth consideration we should only use variants which do prevent ϕ immediately and permanently.
R7 We should participate in j in q in which $\neg\phi$ to enable ϕ to be achieved and v to be promoted on the next move.
R8N We should not participate in j in q in which ϕ which will risk ϕ being removed on the next move which would demote v.
R9 We should participate in j in q because participation in j^{ag} promotes v.
R9N We should not participate in j in q because participation in j^{ag} demotes v.

Some of these reasons are perhaps relatively weak, since they do not themselves demote v but only forgo (in the case of R6N permanently forgo) an opportunity to promote v. R8N is perhaps weakest, since it presents only a risk that v will be demoted, which we may be able to avoid when we move on from that state, whereas R5N makes the demotion inevitable, and, in some variants, permanent. Note that such differences in the strength of reasons depend on the way in which a value is affected, suggesting a way of ordering arguments which does not depend on value orderings, but on the nature of the reason. This might be especially useful when conflicting arguments promote the same value. We will explore this further in future work.

4.1. Chess Example

For our example we will consider a situation in chess. Suppose a player can force a draw immediately by repetition. Alternatively he may play a safe variation: if the opponent plays correctly the draw by repetition is still available, but if the opponent makes an error, there is a simple win. Finally the player may play adventurously, unbalancing the position. Then the result will depend on who plays best thereafter. Winning will increase

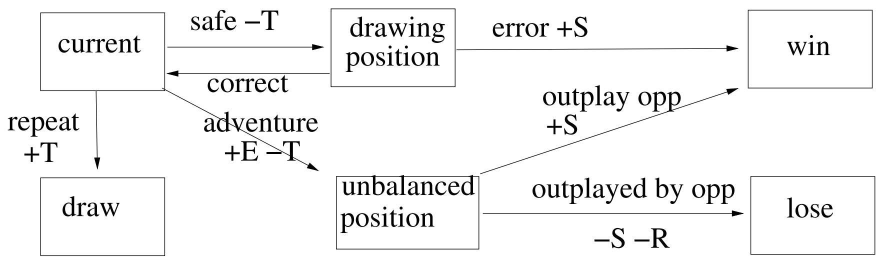

Figure 1. Chess Example

satisfaction, but losing from a drawn position will not only lead to dissatisfaction, but also inspire regret. Playing the unclear position will offer excitement, but will take time. The situation is shown in Figure 1.

Considering only the immediately next states available, it seems that the player must choose between time and excitement: *repeat* promotes time (R9), while *safe* demotes time (R9N) and *adventure* promotes excitement (R9) at the expense of time (R9N). In particular there is no reason to choose the safe move which appears to waste time with no compensating gain. But if we extend the look ahead, we see that the safe move offers the possibility of a win without risk (R7). So if satisfaction is more important than time, the safe variation is worth trying. Turning to the adventurous move, we again have the possibility of a satisfying win (R7), but now we also risk demoting satisfaction (R8N) and feeling regret (R6N). Note the difference between satisfaction and regret: we are dissatisfied because we lose, while we regret passing up the opportunity of a draw. The choice will depend on how confident the player is that the opponent will be outplayed, and the relative preferences for satisfaction, regret and time. To represent this example properly, look ahead (as in chess itself) is essential: the time question is unlikely to be important to a chess player, whereas winning versus not losing will matter, and chess players do vary in their attitudes to these two values, as do they also in their confidence in their own ability to win from an unclear position.

5. Argumentation Schemes

Our original scheme, PRAS was expressed in natural language as: in the current situation R agent ag should do α to reach S to realise γ and promote v. In AATS terms:

PRAS1 $q_0 \equiv q_1$: $R \equiv \pi(q_1)$
PRASC Agent ag should perform α: $j^{ag} = \alpha$
PRAS2 $\tau(q_1, j) = q_2$: $S \equiv \pi(q_2)$
PRAS3 $q_2 \Longrightarrow \gamma$
PRAS4 $\delta(q_1, q_2, v) = +$ or $\epsilon(j, v) = +$

We now introduce a **New Practical Reasoning Scheme** argumentation scheme **NPR**. Informally, this scheme is that where R is the case, agent ag can perform α, and so participate in j which will promote v. So ag should perform α so as to participate in j.

New Practical Reasoning Scheme

NPR1 **Circumstances premise.** The current circumstances include R (the current state q_1 is such that $R \subseteq \pi(q_1)$)
NPR2 **Action Premise.** Action α belonging to Agent ag is possible ($q_1 \in \rho(\alpha)$)
NPR3 **Promotion Premise.** There is a j such that $j^{ag} = \alpha$ and performing j promotes v
NPRC **Conclusion**. Agent ag should perform α and so participate in j

Note that whereas PRAS used complete states in its premises, NPR commits to a conjunction R which may be only a partial state description. The three premises need to be justified in turn. First we establish NPR1. We need to show that every state in which we (epistemically) might be contains R

Partial State Scheme Facts:

PSF1 **Current State Premise:** $q_1 \in PQ$, where $PQ \subseteq Q$.
PSF2 **Facts Hold Premise:** For all $pq \in PQ$, $R \subseteq \pi(pq)$.
PSFC **Conclusion**: NPR1 holds

Next we establish NPR2. Every state in which we (epistemically) might be satisfies the preconditions for α.

Partial State Scheme Action:

PSA1 **Current State Premise:** $q_1 \in PQ$, where $PQ \subseteq Q$.
PSA2 **Action Possible Premise:** For all $pq \in PQ$, $pq \in \rho(\alpha)$.
PSAC **Conclusion**: NPR2 holds

We then establish NPR3. Every state in which we (epistemically) might be contains a transition in which ag performs α which promotes v.

Value Promotion Scheme:

PSV1 **Current State Premise:** $q_1 \in PQ$, where $PQ \subseteq Q$.
PSV2 **Transition Premise:** For all $pq \in PQ$, there is a a joint action j such that j^{ag} is α.
PSV3 **Value Promotion Premise**. In q_1 the transition associated with j promotes v
PSVC **Conclusion**: NPR3 holds.

5.1. Ways of Promoting a Value

PSV3 can be established using any of the reasons R1-R9N given above, each giving rise to a separate scheme. For reasons of space we can discuss only one example here: we choose promotion by R3 to facilitate comparison with the scheme of [1]. Reason R3 treats ϕ as an achievement goal. The goal ϕ is not true in the current state. The transition resulting from j leads to a state in which ϕ is true, and this promotes v.

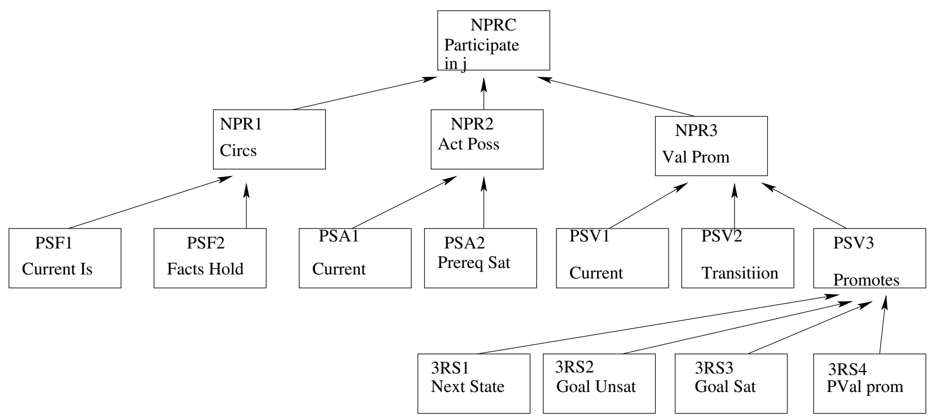

Figure 2. Tree of Argumentation Schemes

Reason 3 scheme

3RS1 **Next State Premise**: j moves to q_2.
3RS2 **Goal Currently Unsatisfied Premise**: ϕ is not true in q_1
3RS3 **Achievement Premise**: ϕ is true in q_2
3RS4 **Promotion Premise:** $\delta(q_1, q_2, v)$ is $+$.
3RSC **Conclusion:** PSV3 holds.

We can now relate this to PRAS. PRASC is NPRC. Once the transition has been identified, PRAS2 is 3RS1, PRAS3 is 3RS3 and PRAS4 is 3RS4. We can see from this that PRAS is a special case of NPR, with a specified reason R3, and the need to *fully* specify the initial state. A diagrammatic version of the new schemes is shown in Figure 2.

6. Challenging NPR

It is generally accepted that an argument can be attacked in three different ways, undermining, undercutting and rebuttal (e.g. [4]).

Rebuttal. The conclusion of NPR is that ag should perform α in order to participate in a joint action j which will promote a particular value. A rebuttal is therefore an argument that ag should not participate in j. This can be shown in two ways.

- Directly: By giving a reason not to participate in j. This can be done using one of the reasons RnN not to participate in j.
- Indirectly: By giving a reason to participate in a joint action other than j, say j_2, on the assumption that j and j_2 cannot both be performed together. This will require an argument based on NPR to participate in j_2.

Both these methods will result in an argument, justified by reference to a value, and so may be resolved according to the value preferences of the audience.

Undercut. Can we undercut NPR? That is, are there ever cases where an action can be performed to promote a value, but this does not provide a *prima facie* reason to perform that action? One possibility is that the action would be morally (or legally, or socially) unacceptable to the agent. Previously such considerations have been handled using values. But this allows the dictates of, for example, morality to be ignored by preferring some other value: e.g. money may be preferred to respect for moral law. It may, however, be thought desirable to remove morality from the sphere of preference, and using an undercutter for NPR concluding that the action was morally wrong would enable this, since undercutters cannot be defended against using preferences [4]. Then we would need to defeat (rather than simply choose to ignore) the moral argument, in order to reinstate the argument.

Thus undercutters represent reasons for not performing an action which override value preference considerations. It may be doubted whether this is always (or even if it is ever) desirable, but there may be particular situations in which individual preferences need to be subject to some set of objective obligations. If we do need to reason within some set of inviolable normative constraints, undercutters of NPR can provide a way to represent such constraints.

Underminding. Finally NPR may be undermined by defeating any one of PSF, PSA or PSV. Obviously, each of these can also be rebutted, undercut or undermined.

6.1. Attacking PSF

We can establish NPR1 by showing that we are currently in a particular state and that some set of propositions $R \subseteq \Phi$ hold in that state. But to show that we are in a particular state q (i.e. q_0 is q), we need to show that for all $\phi \in \Phi$, ϕ has the required value, while to establish NPR1, we need only establish that for all $r \in R$, r is the case. We can therefore replace PSF with $|R|$ premises, one for each $r \in R$. Now PSF becomes a strict argument, incapable of being rebutted or undercut: establishing every $r \in R$ as true will compel acceptance of NPR1.

So now we must turn to how an element $r \in R$ is shown to be true. This is an epistemological question, and requires us to say what will count as an argument for something to be the case. For example, we may have some list of argumentation schemes which rely on *Credible Sources* [6], such as witness testimony, expert opinion, direct observation, and authoritative work of reference. Each of these will have their own characteristic rebutters, undercutters and underminers, appropriate to the particular scheme, and these will need to be considered when assigning a status to each $r \in R$ in turn. Alternatively if we take $q = q_0$ as a given (or can simply assume that it is so), we can take PSF1 as satisfied without further argument: then all we need do to satisfy PSF2 is to show that for $R \subseteq \pi(q)$.

6.2. Attacking PSA

If we have established NPR1, we can assume that we know that the current state is q and that $R \subseteq \pi(q)$, so there can be no dispute about PSA1. Now to show that the action cannot be performed in q we would need to show either:

- One of the preconditions of α is unsatisfied. That is, there is some precondition of α, c, such that $c \notin R$: which rebuts PSA2. But given α, ρ and R, it is a straightforward matter to determine strictly whether $R \subseteq \pi(q) \rightarrow q \in \rho(\alpha)$, and so this question is easily settled.

- There is a precondition of α not specified by ρ in the AATS. But this would challenge our formulation of the AATS, and to be resolved would require us to have a way of justifying an AATS, or at least particular elements such as ρ.

If we ignore challenges to the AATS itself, we can be confident that PSA can be shown satisfied without the need for choice or resort to defeasible arguments.

6.3. Attacking PSV

As with PSA, we can take it as known (from NPR1) which state we are currently in, and so take PSV1 as satisfied. PSV2 is solely about τ: as with ρ above, questioning this would call the AATS into question, and we do not wish to allow that at this stage. Thus an attack on PSV requires an attack on the argument used to establish PSV3. PSV3 can be justified using any of the reasons R1-R9N: in this paper we have only considered R3 and so we will only discuss attacks on arguments which use the scheme 3RS here.

6.4. Attacking 3RS

To rebut an argument based on 3RS, it is necessary to find an argument that v is demoted. Such an argument can be based on any of the reasons RnN above. While these reasons also can give rise to a rebuttal of NPR when they concern a value other that v, rebutting 3RS uses v itself, thus undermining NPR. Whereas the rebuttal of NPR is resolved by a choice based on preferences, the decision here concerns conflicting arguments based on a single value, and so is not resolved by value preferences, but requires some additional way of distinguishing strengths.

Undercutters of 3RS do not arise: if 3RS1-3RS4 are satisfied, we can conclude that v is indeed promoted. We must, however, consider each of the premises to see how arguments based on 3RS can be undermined. 3RS1 does no more than assert that there is a transition which reaches a particular state. This can only be denied by challenging τ claiming that there is a state in which the circumstances hold but which does not have a transition to the required new state (q_2). But this was exactly what was established in PSV2. Similarly 3RS2 and 3RS3 concern π, applied to q_1 and q_2 respectively, while 3RS4 asserts that realising ϕ when it was previously unrealsised promotes v, which is implicit in the way the transition has been labelled. All the premises of 3RS can be considered givens in the AATS, unless we open them to dispute by making explicit the relation between goals and the values they promote, using the machinery of [2].

Thus the attacks on 3RS require some fundamental questions to be asked of the problem formulation, directed either at the transition function, or the way in which goals are linked to facts, or the way in which values are linked to goals. None of this, however, is up for debate in the current context, since it requires the limitations discussed in [2] to be addressed.

7. Defending Attacks Based on the Behaviour of Others

John Paul Sartre famously observed "*L'enfer, c'est les autres*", and certainly the need to consider how others will behave greatly complicates the practical reasoning task. The problem centres on PSV2. The condition imposed by PSV2 is rather weak: it requires only that some transition in which ag performs α realises the goal. If there is only one agent this is indeed the situation: each action available to the agent in a given state gives rise to a single transition. But this is rarely suitable to model a problem: at a minimum it is likely that some actions will not have entirely predictable effects, and this is usually dealt with by including a second agent (*Nature*). The normal situation is that there will be several agents, and this quickly expands the number of transitions from a state: given n agents each with two actions independently available, we potentially have 2^n joint actions.

An argumentation approach is to insist that the question is posed as a particular alternative which challenges PSV. Thus we need to find a joint action j_2 which can be performed in the current state q_1, in which ag performs α and which leads to a state q_2 in which v is demoted. At least one agent, ag_2 must perform an action β such that $\beta \neq j^{ag_2}$ and β = $j_2^{ag_2}$ and $\tau(q_1, j_2) = q_2$. We can now argue against PSV by saying that if ag_2 performs β, the transition accomplished by j is not available, and so PSV2 is undermined. Moreover, if $\delta(q_1, q_2, v)$ is $-$, the value is demoted and PSV3 is rebutted, and PSV undermined on that premise also. This, however, is not enough: it is not sufficient to argue that ag_2 *could* perform β: rather we need to offer reasons why ag_2 might be *expected* to perform β. In other words we need to provide an argument using NPR to justify a conclusion that ag_2 should perform β to participate in j_2. If such an argument is advanced, defending against an attack based on alternative behaviour of other agents will involve defeating this new argument: note that the focus is switched from what ag should do in q_1 to what ag_2 should do in q_1, and the relevant value preferences are those of ag_2, not those of ag.

Sometimes also the actions of other agents may be beneficial: it could be there are several agents who could realise a goal, so that it is desirable that one of them does so, but each may have some other action that is individually preferable. Here anticipating whether an agent needs to realise the goal itself, or whether it can rely on another agent to do so is a rather subtle matter which deserves careful consideration in future work.

8. Concluding Remarks and Future Work

In this paper we have addressed one of the two key limitations of the argumentation scheme for practical reasoning proposed in [1], namely the restriction to a single step of look ahead. We have also presented practical reasoning not as a single scheme, but as a tree representing a cascade of linked argumentation schemes. This clarifies the reasoning by articulating it into smaller units, which in turn allows attacks on such arguments to be specified with greater precision. We can now see that the *problem formulation* attacks require justification of elements of the AATS itself: these were taken as givens in [1], but ways of enabling these matters to be debated were offered in [2]. These attacks appear as underminers in our new set of schemes. The *epistemic* attacks of [1] concern which state we are in, or which joint action will result from ag performing a particular action α. These require their own justifying arguments, using schemes appropriate to facts and actions respectively. These epistemic arguments also appear as underminers of arguments in Figure 2. The *choice of action* attacks typically result from the availability of an argument based on NPR, justifying a different action, or the non-performance of the advocated action. These appear as rebuttals, to be resolved according to individual value preferences. Finally undercutters can be used should we want to prevent value preferences from being exercised.

For future work, we need to represent the argumentation schemes formally, using a formalism for structured argumentation (e.g. ASPIC+ [4]), so that we can better structure the attacks on arguments and establish properties of the proposed reasoning, such as the satisfaction of various rationality postulates [3]. We also wish to explore degrees of promotion, both via a finer grained interpretation of the δ and ϵ functions, and through the idea that different reasons give different strengths to arguments: e.g. that it may be better to achieve a goal now, rather than later, or perhaps better to ensure that it will always be true in future even if it takes longer to accomplish this.

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