# Automating Argumentation for Deliberation in Cases of Conflict of Interest

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**Abstract.** One approach to deliberation about the choice of what to do in a particular situation is to use an argument scheme based on the practical syllogism to supply a presumptive reason for the action, which is then subjected to a process of critical questioning to see if the presumption can be maintained. In this paper we describe an implemented realisation of this approach. We describe a representation which permits the instantiation of the argument scheme and the generation and consideration of critical questions to it. In order to automate the process we supply operational interpretations of the argument scheme, the critical questions and rebuttals to those questions. Our realisation is illustrated with a detailed example of a particular case.

**Keywords.** Reasoning about action with argument, decision making based on argumentation, argument schemes

## 1. Introduction

One important use of argument is in the context of rational choice of actions, what is termed "practical reasoning" in philosophy. The correctness of a choice of action typically cannot be demonstrated conclusively, since it often must be made in the face of uncertainty and incomplete information as to the current situation; the effect of the action is often unpredictable and dependent on the choices of other agents or the environment; and there is usually an element of subjectivity in that the best choice will vary from agent to agent dependent on their interests, aspirations and values. Moreover, even if the choice is a good one, it may involve rejecting better choices, or curtailing future options. Justifying an action, either prospectively in deliberation, or retrospectively when challenged to explain oneself, involves putting forward reasons for the choice, that is an argument for why it is the right choice for the person concerned in the particular situation in which it was made.

Traditionally, justifications of such arguments have taken the form of the practical syllogism (e.g. [1]), which states that the action concerned is a sufficient means to realise a goal desired by the agent concerned. This was adapted into an argument scheme by Walton in [2], the sufficient condition scheme. The essence of Walton's approach is that being able to instantiate this scheme provides a presumptive justification for an action, which is then subject to a set of critical questions characteristic of the particular scheme, and any such questions that are posed must be answered satisfactorily if the presumption is to be maintained. Walton gives four critical questions: Will alternative actions achieve the goal?; Is the action possible?; Are there other goals to consider?; and, Will the action have undesirable side effects? Walton's idea was elaborated by Atkinson and her colleagues ([3] gives the fullest description) to distinguish the goal into three elements: the state of affairs resulting from the action; the specific features of that state which are desired by the agent; and the social value or interest of the agent which makes those features desirable. This elaboration correspondingly extended the set of critical questions to sixteen.

In this paper we will provide a description of a realisation of deliberation about a choice of action based on this approach, in a situation where multiple agents have conflicting values. We will use the argument scheme proposed in [3] to generate presumptive arguments for and against actions, and then subject these arguments to critical questioning. Our critical questions will differ from those described in [3], in that some found there are inapplicable in our particular situation. We will rephrase the applicable questions in terms of our representation and supply characteristic rebuttals and counter-rebuttals of the various critical questions we use.

Throughout this paper we will illustrate our approach with a particular example, based on an ethical dilemma, also used in [4]. In section 2 we will describe the problem and our representation of this problem, together with the underlying logical formalism used, which is based on an extension of Alternating-time Temporal Logic (ATL) [5]. Section 3 will describe the argument scheme, the associated critical questions, and the ways of replying to those questions. Section 4 will describe the program which realises the approach. In section 5 we will apply the program to give an example of how agents will reason in a particular situation. Finally section 6 will offer some concluding remarks.

## 2. Representation of the Insulin Problem

We base our considerations on the representation and discussion of a specific example, a well-known problem intended to explore a particular ethical dilemma discussed by Coleman [6] and Christie [7], amongst others and also extensively discussed in [4]. The situation involves two agents, Hal and Carla, both of whom are diabetic. Hal, *through no fault of his own*, has lost his supply of insulin and urgently needs to take some to stay alive. Hal is aware that Carla has some insulin kept in her house, but does not have permission to enter Carla's house. The question is whether Hal is justified in breaking into Carla's house and taking her insulin in order to save his life. By taking Carla's insulin, Hal may be putting her life in jeopardy. One possible response is that if Hal has money, he can compensate Carla so that she can replace her insulin. Alternatively if Carla has money, she can replenish her insulin herself. There is, however, a serious problem if neither have money, since in that case Carla's life is really under threat. Coleman argued that Hal may take the insulin to save his life, but should compensate Carla.

Christie's argument against this was that even if Hal had no money and was unable to compensate Carla he would still be justified in taking the insulin by his immediate necessity, since no one should die because of poverty. Christie then argues he cannot be *obliged* to compensate Carla even when he is able to.

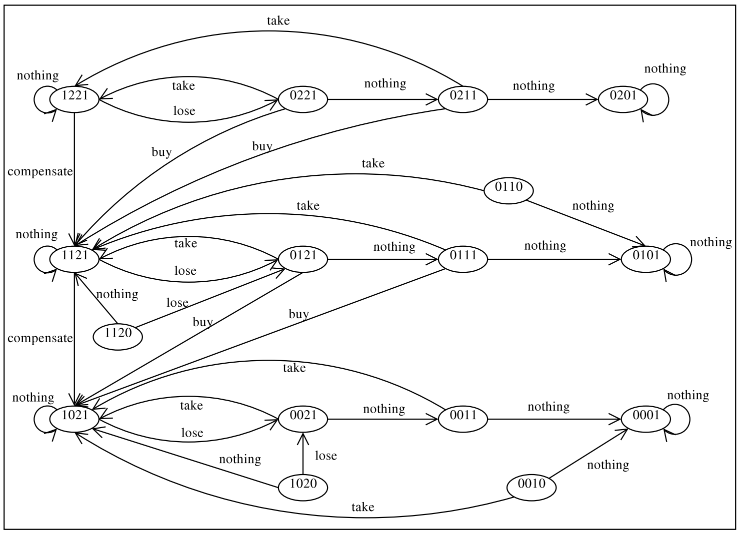


**Figure 1.** State Transition diagram for each agent.

We need to extend the representation given in [4] in order to make explicit the implicit information used there to block fruitless arguments. For the purposes of our representation four attributes of agents are important: whether they have insulin ($I$), whether they have money ($M$), whether they are alive ($A$) and the time in the world ($W$). The world attribute represents the fact that the shops are shut when Hal loses his insulin and so he cannot buy insulin and has to take Carla's, whereas later the shops are open so Carla is able to buy insulin if she can afford it. The state of an agent may thus be represented as a vector of four digits, $IMAW$, with $I$ and $W$ equal to 1 if the agent has insulin and the shops are open and 0 if these things are false. $M$ and $A$ can have three values each with $M$ equal to 0 if the agent has no money, 1 for enough money to buy insulin and 2 if they have more than enough money. $A$ is equal to 0 if the agent is dead, 1 if the agent is in a critical state (which Hal is because he urgently needs insulin) and 2 if the agent is healthy (which Carla is initially). Since $I$ cannot be true and $A$ zero or one (the agent will be in good health if he or she has insulin), an agent may be in any one of sixteen possible states shown in Figure 1. Because there are two agents, the system has 16x16=256 possible states. We may now represent the actions available to the agents by depicting them as automata, as shown in Figure 1. An agent with insulin may lose its insulin; an agent with money and insulin may compensate another agent; an agent with no insulin may take another's insulin, or, with money, buy insulin provided the shops are open. In any situation when it is alive, an agent may choose to do nothing; if dead it can only do nothing. The nodes representing distinct world-states are labelled with the values of the vector $IMAW$. Arcs are labelled with actions.

To represent the interaction between the agents we draw upon the approach of Wooldridge and van der Hoek [5] which formally describes a normative system in terms of constraints on actions that may be performed by agents in any given state. The semantic structures used in [5] are known as Action-based Alternating Transition Systems (AATSs) and were developed for modelling game-like, dynamic, multi-agent systems.

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

- $Q$ is a finite, non-empty set of *states*;
- $q_0 \in Q$ is the *initial state*;
- $Ag = \{1, ..., n\}$ 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 $\alpha$ may be executed;
- $J_{Ag}$ is the set of *Joint Actions* such that every $j \in J_{Ag}$ is a tuple $\langle \alpha_1, \alpha_2, ..., \alpha_k \rangle$ where for each $\alpha_i$ $(i \leq k)$ there is some $i \in Ag$ such that $\alpha_i \in Ac_i$.
- $\tau : Q$ x $J_{Ag} \rightarrow Q$ 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);
- $\phi$ 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 $q$.

We have extended the AATS to include a set of values $(V_n)$ and a set of functions which determine whether these values are promoted or demoted by a transition between states.

We now turn to representing the Hal and Carla scenario as an AATS. As noted above, we have 256 possible states for the two agents, $q_1..q_{256}$. Normally both agents will have insulin, but we are specifically interested in the situations that arise when one of them (Hal) loses his insulin and is in critical health. For reasons of space we will consider only the initial state of the scenario where both agents have money, $q_0 = q_{253}$. The initial state is thus the one in which $I_H = 0$, $M_H = 1$, $A_H = 1$ and $W_H = 0$ and $I_C = 1$, $M_C = 1$, $A_C = 2$ and $W_C = 0$. As the shops are closed in the initial state, represented by $W_H = 0$, Hal's only option is to take Carla's insulin or do nothing. If Hal does nothing, neither agent can act further because Hal dies. If Hal takes Carla's insulin then Hal can then compensate Carla or do nothing. Similarly, after Hal takes the insulin, Carla can buy insulin or do nothing. The possible developments from the initial state are shown in Figure 2. States are labelled with the two vectors $I_H M_H A_H W_H$(on the top row) representing Hal's state of the world and $I_C M_C A_C W_C$ (on the bottom row) representing Carla's state of the world, and the arcs are labelled with the joint actions and with the value promoted or demoted by the joint action. The instantiation of the problem as an AATS is summarised in Table 1.

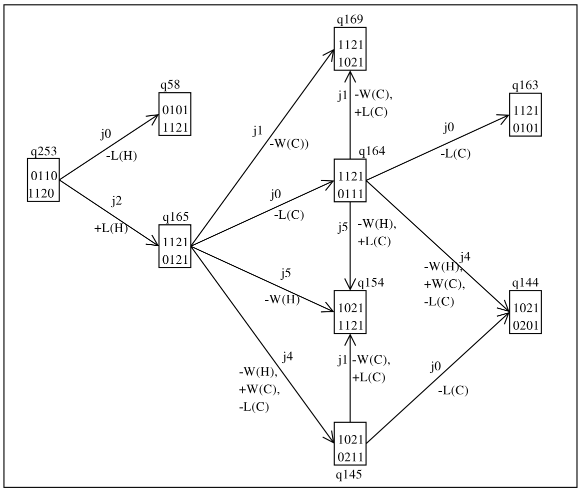


**Figure 2.** Part of the State Space when Both Agents have money at the initial state.

## 3. Constructing Arguments and Attacks

The argument scheme proposed in [3] is:

> In the current situation R action A should be performed to bring about a new situation S which realises Goal G which promotes value V.

### *3.1. Refining the Argument Scheme*

In our formalism the agent is in some particular state, $Q_n$. From that state there are a number of transitions available to reach new states. Each transition is achieved through some joint action $J_n$, which requires the agent to play its part by performing some action $Ac_n$. Each resulting state can be compared with $Q_n$ to see how it changes the situation with respect to the values of the agent. We can then label the transitions with $V_n+$ or $V_n-$ as appropriate to indicate that the value $V_n$ is promoted or demoted, respectively.

Now for each transition with a positive label $V_n+$ we can produce the argument scheme:

**PA1:** In $Q_n$ action $Ac_n$ should be performed by $Ag_i$ to reach $Q_m$ which realises $\phi$ which promotes $V_n$.

Where the label is negative the argument scheme is slightly different:

**PA2:** In $Q_n$ action $Ac_n$ should not be performed by $Ag_i$ to avoid $Q_m$ which realises $\phi$ which demotes $V_n$.

**Table 1.** Instantiation of the Insulin Problem

States and Initial States

$Q = \{q_0, ..., q_{256}\}$

Initial State $q_{253}$

Agents, Actions and Joint Actions

Ag = {H, C} $Ac_H = \{take_H, compensate_H, doNothing_H\}$

$Ac_C = \{buy_C, doNothing_C\}$

$J_{Ag} = \{j_0, j_1, j_2, j_3, j_4, j_5\}$, where $j_0 = \langle doNothing_H, doNothing_C \rangle$,
$j_1 = \langle doNothing_H, buy_C \rangle$, $j_2 = \langle take_H, doNothing_C \rangle$, $j_3 = \langle take_H, buy_C \rangle$,
$j_4 = \langle compensate_H, doNothing_C \rangle$, $j_5 = \langle compensate_H, buy_C \rangle$

Propositional Variables

$\phi = \{hasInsulin_H, hasMoney_H, isAlive_H, world_H,$
$hasInsulin_C, hasMoney_C, isAlive_C, world_C\}$

Values

$V_n = \{L_H, L_C, W_H, W_C\}$

Transitions/Pre-Conditions/Interpretation

| $q \backslash j$ | $j_0$ | $j_1$ | $j_2$ | $j_3$ | $j_4$ | $j_5$ | $\pi(q)$ |
|---|---|---|---|---|---|---|---|
| $q_{253}$ | $q_{58}$ | - | $q_{165}$ | - | - | - | $\{0_H, 1_H, 1_H, 0_H, 1_C, 1_C, 2_C, 0_C\}$ |
| $q_{58}$ | - | - | - | - | - | - | $\{0_H, 1_H, 0_H, 1_H, 1_C, 1_C, 2_C, 1_C\}$ |
| $q_{144}$ | - | - | - | - | - | - | $\{1_H, 0_H, 2_H, 1_H, 0_C, 2_C, 0_C, 1_C\}$ |
| $q_{145}$ | $q_{144}$ | $q_{154}$ | - | - | - | - | $\{1_H, 0_H, 2_H, 1_H, 0_C, 2_C, 1_C, 1_C\}$ |
| $q_{154}$ | - | - | - | - | - | - | $\{1_H, 0_H, 2_H, 1_H, 1_C, 1_C, 2_C, 1_C\}$ |
| $q_{163}$ | - | - | - | - | - | - | $\{1_H, 1_H, 2_H, 1_H, 0_C, 1_C, 0_C, 1_C\}$ |
| $q_{164}$ | $q_{163}$ | $q_{169}$ | - | - | $q_{144}$ | $q_{154}$ | $\{1_H, 1_H, 2_H, 1_H, 0_C, 1_C, 1_C, 1_C\}$ |
| $q_{165}$ | $q_{164}$ | $q_{169}$ | - | - | $q_{145}$ | $q_{154}$ | $\{1_H, 1_H, 2_H, 1_H, 0_C, 1_C, 2_C, 1_C\}$ |
| $q_{169}$ | - | - | - | - | - | - | $\{1_H, 1_H, 2_H, 1_H, 1_C, 0_C, 2_C, 1_C\}$ |

This bipolarity of arguments, depending on whether they provide a reason to act or refrain has been noted in [8], although the treatment there differs from that described below, as we use such arguments as critical questions to arguments of the form PA1. Finally, it may be that nothing good can be done, in which case we may wish to perform an action which will avoid harm. Thus, if the transition neither promotes nor demotes any value, the argument scheme is:

**PA3:** In $Q_n$ action $Ac_n$ should be performed by $Ag_i$ to reach $Q_m$ which is neutral with respect to all values.

From the schemes PA1, PA2 and PA3 the agent can instantiate a set of arguments, one or more per transition, depending on how many values are affected by a transition. The agent can now order these arguments, beginning with the argument promoting its most favoured value down to that promoting its least favoured value, through any neutral arguments to the argument demoting its least favoured value and finally to the argument demoting its most favoured value. Each argument will be considered in turn, as providing the currently best presumptive justification.

*3.2. Critical Questions*

Consideration of the arguments involves posing critical questions. Our approach will not use all the critical questions of [3] because the aim there was to generate arguments that could arise amongst a group of agents with different views as to what is the case and/or different values and interests, whereas here we have a single agent, with a particular view of the situation, posing critical questions to itself, although in a context where other agents may influence the outcome of its actions. This is of course applicable to a range of problem scenarios.

For the purposes of this paper we will assume that the agent knows which state it is in. As [4] shows, uncertainty as to the current situation has an important role to play in determining how acceptable a given justification is, but for purposes of deliberation the agent must act as if a state held, and must choose one state consistent with its beliefs on which to base its reasoning. We also consider that the agent is aware of its possible actions, and which state they will bring about for a given action of the other agent. Critical questions pertaining to verifying that the agent is aware of the consequences of its choice are therefore obviated. Since we are concerned with the deliberations of a single agent, questions as to the validity of its values cannot arise. Finally the ordering of the arguments discussed in Section 3.1 ensures that there is no better alternative to the argument under current consideration.

This leaves us with three critical questions: Whether the action will demote a more important value; Whether performing the action will realise the desired goal; and whether the action will preclude some more desirable future actions. In terms of our representation, we may state these questions as:

**PCQ1** Might the action lead to states that the agent will wish to avoid?

**PCQ2** Might the other agent fail to act so as to perform the desired joint action?

**PCQ3** Is the desired state in fact a local optimum, so that all subsequent states will result in a state worse than the current one?

PCQ1 relates to whether we have a stronger argument against performing the action. This argument may be from an unfortunate side effect of the target state itself, in that it demotes a value we prefer to the one it promotes. Remember, however, that the state we reach from performing an action may not be the one we wish to reach, since the chosen action only determines a set of joint actions. Thus the choice of the other agent may mean that performing this action will take us to an unfavourable state: this risk can only be avoided by refraining from the action. In either case there will be present in the set of arguments an argument or arguments of the form PA2, which may point wither to demote values in the target state, or the risk of demoted values if other agents behave unexpectedly. Each of these poses a critical question of form PCQ1.

The rebuttal to PCQ1 involves considering the arguments available to the other agent. On the assumption that the other agent is rational, it will be reasoning in a similar fashion. And if the other agent also has a reason to avoid the undesired state, we can discount the risk. Thus if the other agent has available an argument of the form PA2 instructing it to avoid the undesired state, we may consider rejecting PCQ1. PCQ1, however, may be re-instated if the other agent has a counter-rebuttal: that is if the other agent has a better reason (in terms of its own value ordering) to reach the undesired state. That is, an argument of the form PA1 in favour of reaching the state to promote a value that agent prefers. In this case we must consider PCQ1 unanswered and reject the argument it attacks.

PCQ2 also involves the other agent. In this case the other agent may have a reason for avoiding the state we wish to reach, that is, have an argument of form PA2 recommending that it avoids the state we wish to reach. In this case, there is no point in acting to reach the state since we will expect the other agent to frustrate our attempt. The rebuttal to PCQ2 is that the other agent has a stronger reason to reach the state we desire, namely an argument of the form of PA1 relating to a value preferred (on its own value ordering). Given such an argument we may expect it to cooperate and participate in the joint action which will reach this state.

PCQ3 arises from the possibility that the state we are trying to reach may be initially promising, but ultimately lead to unfortunate consequences. Thus we have a reason to avoid a state, even if it promotes a value, if all subsequent choices that can be made in that state will result in us being worse off than we were in the initial state. This involves looking ahead to some final state. In the case where paths do not terminate, some cut-off to keep within resource bounds must be applied. Again the rebuttal of this question involves the other agent having a compelling argument to avoid the state with this property, and no stronger argument to reach it.

### *3.3. Damage Limitation*

Note that the arguments so far considered all supply a reason to act, so as to reach a particular state which promotes a value. Arguments to refrain from an action to avoid a state demoting a value have appeared only in the critical questions. This is as it should be, since in our formalism we can only refrain from an action by choosing to perform a different one, and we need to justify this choice against alternative ways of refraining. If we have no positive arguments able to withstand the critical questions, we need choose the least damaging action. We pick the argument which demotes the least favoured value and perform the action despite these bad consequences. Even though the argument is demoting a value, that value is only the one that is the least preferred value for the agent. We can therefore rewrite the arguments of the form PA2 as an argument of the form PA4.

**PA4:** In $Q_n$ action $Ac_n$ should be performed by $Ag_i$ to reach $Q_m$ even though it realises $\phi$ which only demotes $V_n$.

PA4 can now be subjected to critical questions of the form PCQ1 if $Ac_n$ reaches a state demoting a value preferred to $V_n$. PCQ2 does not arise in the situation when the target state is already not desirable. PCQ3 can be used because the state may still be only locally the least bad; it may be that subsequent moves will eventually result in a much worse state, which could have been avoided by choosing an initially less attractive option.

In the next section we will briefly describe a program which instantiates these argument schemes and critical questions, so as to deliberate on the best choice of action for an agent with given value preferences.

## 4. Program

We have implemented the above in Java to produce a program which takes the description of the problem given in Table 1 and generates the transition matrix, also given in Table 1, for the initial state of interest, represented by Figure 2. The program then calculates the values that are promoted or demoted by each action when the agents move from state to state shown as the labels on the arcs of these figures. It then generates the arguments for making or not making a particular action from each state depending on the values promoted or demoted by instantiating the argument schemes PA1-4. Using the arguments, the program attacks the arguments using the three critical questions so as to select the justified action. This operation will be illustrated by the example in the next section.

## 5. Example

What an agent should do will vary according to the ordering the agent places on values. Agents can make different choices depending on whether they are selfish or act in a selfless manner. In [4], the authors described five different value orderings: Morally Correct, Selfish, Self-Interested, Noble and Sacrificial. For all agents life is preferred to wealth. For a Selfish agent, each agent prefers its own interests to any interests of the other agent. For Hal, $L_H > W_H > L_C > W_C$ and for Carla, $L_C > W_C > L_H > W_H$. We will consider the case where both agents are selfish.

From the initial state, $q_{253}$, four arguments are produced, two for Hal and two for Carla. The best argument for Hal is A3 and the best argument for Carla is A4:

**A3:** In $q_{253}$ $take_H$ should be performed by Hal, to reach $q_{165}$ which realises $isAlive_H = 2$ which promotes $L_H$

**A4:** In $q_{253}$ $doNothing_C$ should be performed by Carla, to reach $q_{165}$ which realises $isAlive_H = 2$ which promotes $L_H$

There are no critical questions posed for A3 so Hal performs the $take_H$ action, and there are no critical questions posed for A4 so Carla performs the $doNothing_C$ action. This produces the joint action $\langle take_H, doNothing_C\rangle$ and the agents reach $q_{165}$.

For $q_{165}$ there are twelve arguments produced, six for Hal and six for Carla. Each agent has one PA1 argument and five PA2 arguments. The arguments are listed below.

**A1:** In $q_{165}$ $doNothing_H$ should not be performed by Hal, to avoid $q_{164}$ which realises $isAlive_C = 1$ which demotes $L_C$

**A2:** In $q_{165}$ $doNothing_C$ should not be performed by Carla, to avoid $q_{164}$ which realises $isAlive_C = 1$ which demotes $L_C$

**A3:** In $q_{165}$ $doNothing_H$ should not be performed by Hal, to avoid $q_{169}$ which realises $hasMoney_C = 0$ which demotes $W_C$

**A4:** In $q_{165}$ $buy_C$ should not be performed by Carla, to avoid $q_{169}$ which realises $hasMoney_C = 0$ which demotes $W_C$

**A5:** In $q_{165}$ $compensate_H$ should not be performed by Hal, to avoid $q_{145}$ which realises $hasMoney_H = 0$ which demotes $W_H$

**A6:** In $q_{165}$ $doNothing_C$ should not be performed by Carla, to avoid $q_{145}$ which realises $hasMoney_H = 0$ which demotes $W_H$

**A7:** In $q_{165}$ $compensate_H$ should be performed by Hal, to reach $q_{145}$ which realises $hasMoney_C = 2$ which promotes $W_C$

**A8:** In $q_{165}$ $doNothing_C$ should be performed by Carla, to reach $q_{145}$ which realises $hasMoney_C = 2$ which promotes $W_C$

**A9:** In $q_{165}$ $compensate_H$ should not be performed by Hal, to avoid $q_{145}$ which realises $isAlive_C = 1$ which demotes $L_C$

**A10:** In $q_{165}$ $doNothing_C$ should not be performed by Carla, to avoid $q_{145}$ which realises $isAlive_C = 1$ which demotes $L_C$

**A11:** In $q_{165}$ $compensate_H$ should not be performed by Hal, to avoid $q_{154}$ which realises $hasMoney_H = 0$ which demotes $W_H$

**A12:** In $q_{165}$ $buy_C$ should not be performed by Carla, to avoid $q_{154}$ which realises $hasMoney_H = 0$ which demotes $W_H$

Hal starts with his PA1 argument, A7. A7 is attacked by PCQ1 using the PA2 argument A5 because the action $compensate_H$ could reach the state $q_{145}$ where the value $W_H$ is demoted which Hal prefers to the value $W_C$ being promoted by A7. A5 is in turn attacked by the PCQ1 rebuttal using A6 because Carla also does not want to reach $q_{145}$ because of the demoted value $W_H$. A6 is then attacked and defeated by the PCQ1 counter-rebuttal using A8 because Carla has a better reason to reach $q_{145}$ than to avoid it. This is because $q_{145}$ promotes $W_C$ which Carla prefers over $W_H$. A5 is then attacked and defeated by the PCQ1 rebuttal using A10 because Carla has a reason to avoid $q_{145}$ and does not have a better reason to reach it. This is because $q_{145}$ demotes $L_C$ which is the most important value for Carla. A7 thus survives this line of questioning.

A7 is then attacked by PCQ1 using A9 because Hal does not want to use the action $compensate_H$ because he may reach $q_{145}$ which demotes the value $L_C$ which Hal prefers to the value $W_C$ promoted by A7. A9 is attacked by the PCQ1 rebuttal using A6 which is then attacked and defeated by the PCQ1 counter-rebuttal using A8. A9 is finally attacked and defeated by the PCQ1 rebuttal using A10.

A7 is then attacked by PCQ1 using A11 because Hal does not want to perform the action $compensate_H$ and reach the state $q_{154}$ because the value $W_H$ would be demoted. A11 is attacked and defeated by the PCQ1 rebuttal using A12 because Carla has a reason to avoid $q_{154}$ and does not have a better reason to reach it. A7 is finally attacked and defeated by PCQ2 using A10 because Carla has a reason not to want to reach $q_{145}$ and no rebuttal argument to want to reach it.

Now Hal has exhausted his supply of PA1 arguments so he must now use his PA2 arguments. These are ordered in reverse order of his value preferences so that the order Hal uses is $(W_C = \text{A3}) > (L_C = (\text{A1, A9})) > (W_H = (\text{A5, A11}))$. Hal takes the PA2 argument with the least favoured value, A3, and rewrites it in the form of PA4.

**A3'** In $q_{165}$ $doNothing_H$ should be performed by Hal, to reach $q_{169}$ even though it realises $hasMoney_C = 0$ which only demotes $W_C$

A3' is attacked by PCQ1 using A1 because the action $doNothing_H$ can reach the state $q_{164}$ where the value $L_C$ is demoted which Hal prefers to the value $W_C$ demoted in A3'. A1 is attacked and defeated by the PCQ1 rebuttal using A2 because Carla has a reason to avoid $q_{164}$ and no better reason to reach it.

A3' is not attacked by PCQ3 because not all of the states reachable from $q_{169}$ are bad states. This means that A3' is not defeated so Hal will perform the $doNothing_H$ action even though it demotes the value $W_C$.

Carla first starts with her PA1 argument, A8. A8 is attacked by PCQ1 using A2 because Carla does not want to do the action $doNothing_C$ to avoid $q_{164}$ where the more preferred value of $L_C$ is demoted. A2 is then attacked and defeated by the PCQ1 rebuttal using A1 because Hal also does not want to reach $q_{164}$ and does not have a better reason to reach it. A8 is then attacked by PCQ1 using A10 because Carla does not want to do the action $doNothing_C$ to avoid $q_{145}$ where the more preferred value of $L_C$ is demoted. A10 is then attacked and defeated by the PCQ1 rebuttal using A5 because Hal also does not want to reach $q_{145}$. Finally A8 is attacked and defeated by PCQ2 using A5 because Hal does not want to reach $q_{145}$ because the value of $W_H$ is demoted.

Carla has now used all of her PA1 arguments and now must use the set of PA2 arguments. These are ordered in reverse to her value preferences and the order Carla uses is ($W_H$ = (A6, A12)) > ($W_C$ = A4) > ($L_C$ = (A2, A10)). Carla takes the first of these arguments, A6, and rewrites it in the form of PA4.

**A6'** In $q_{165}$ $doNothing_C$ should be performed by Carla, to reach $q_{145}$ even though it realises $hasMoney_H = 0$ which only demotes $W_H$

A6' is attacked by PCQ1 using A2 because Carla does not want to do the action $doNothing_C$ to avoid $q_{164}$ where the more preferred value, $L_C$, is demoted. A2 is then attacked and defeated by the PCQ1 rebuttal using A1 because Hal also does not want to reach $q_{164}$, since he prefers $L_C$ to $W_C$. A6' is then attacked by PCQ1 using A10 because Carla does not want to do the action $doNothing_C$ and risk $q_{145}$ where the more preferred value $L_C$ is again demoted. A10 is then attacked and defeated by the PCQ1 rebuttal using A5 because Hal also does not want to reach $q_{145}$. Finally A6' is attacked by PCQ3 because all of the end states reachable from $q_{145}$ are worse than $q_{145}$. However this argument is attacked and defeated by the PCQ3 rebuttal using A5 because Hal does not want to reach $q_{145}$ either. This means that A6' is not defeated and so Carla will perform the action $doNothing_C$. Based of this joint action the agents reach $q_{164}$. Note that the effect is for both agents to wait since neither wishes to spend their money if they can avoid it.

From the state, $q_{164}$, sixteen arguments are produced, eight for Hal and eight for Carla. The best argument for Hal is A5 and the best argument for Carla is A6:

**A5:** In $q_{164}$ $doNothing_H$ should be performed by Hal, to reach $q_{169}$ which realises $isAlive_C = 2$ which promotes $L_C$

**A6:** In $q_{164}$ $buy_C$ should be performed by Carla, to reach $q_{169}$ which realises $isAlive_C = 2$ which promotes $L_C$

There are no critical questions posed for either argument so the joint action $\langle doNothing_H, buy_C \rangle$ is performed and the agents reach $q_{169}$. This means the agents both have insulin. Note that here, because Hal is selfish, Carla is forced by the threat to her life which is now immediate to buy her own insulin. Different value preferences for the different agents produce different outcomes, as described in [4].

## 6. Concluding Remarks

In this paper we have described an implemented realisation of the approach to deliberation using presumptive argumentation and associated critical questions. The program is built on a representation of the problem domain as an Alternating Time Transition System with agents represented as automata. The program instantiates the arguments scheme and then subjects it to critical questioning. We have explored automation of argumentation for practical reasoning by a single agent in a multi-agent context, where agents may have conflicting values. Traditionally, reasoning about actions between potentially self-interested agents in a multi-agent context has used Game Theory. Game Theory, however, has not been concerned with rational justification or explanation of action, which is a key focus of work in argumentation.[1]

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