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Did He Jump or Was He Pushed?

Abductive Practical Reasoning

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Abstract In this paper we present a particular role for abductive reasoning in law by applying it in the context of an argumentation scheme for practical reasoning. We present a particular scheme, based on an established scheme for practical reasoning, that can be used to reason abductively about how an agent might have acted to reach a particular scenario, and the motivations for doing so. Plausibility here depends on a satisfactory explanation of why this particular agent followed these motivations in the particular situation. The scheme is given a formal grounding in terms of Action-based Alternating Transition Systems and we illustrate the approach with a running legal example.

Keywords Argumentation Schemes · Abductive Reasoning · Practical Reasoning

1 Introduction

It is by now well-accepted that stories, or sequences of events, play an important part in theories of how people reason with the evidence in criminal cases. In legal psychology, authors such as Pennington and Hastie [13] and Wagenaar *et al.* [16] argue that judges, jurors and police investigators construct and compare stories about 'what happened' in a case using the available evidence. This approach has been adopted by researchers in AI (& Law), who model stories as causal networks that explain the evidence; Thagard [15] has applied his connectionist model of inference to the best explanation to legal cases and Bex *et al.* [7] propose an approach that combines classical abductive inference to the best explanation with defeasible argumentation.

A good story of a criminal case should not only be sufficiently supported by evidential data (e.g. testimonies, forensic data) but it should ideally also be plausible, that is, the story should conform to our beliefs about how things generally happen in the world around us. This plausibility of a story partly depends on the plausibility of the causal links between the events in the story, which give a story its coherence. For example, a story where one person died because he was shot by another person is coherent because we believe that, in general, shooting someone can cause that person to die. Many stories about crimes involve rational agents. When rational agents are concerned we need to see events not simply as the

result of the operation of physical causal laws – what Dennet [8] terms the physical stance – but also as the result of choices made by the agents – what Dennet calls the intentional stance. For the intentional stance, plausibility comes from our view of how likely it is that the agent would have made the required choice in the situation, and this in turn depends on the motivational preferences we believe the agent to have. For example, an agent may act in a certain way only if he prefers fame to fortune. If we wish to say he is motivated by fame, we need to explain why we believe this particular agent has this preference[1].

The formal framework proposed by Bex *et al.* allows for a careful analysis and critique of the causal links between the events. The validity of the causal rules can be argued about and exceptions to these rules can be given. However, the model of agent decision making as regarded from the intentional stance remains something of a 'black box'. In [7] most causal links denote a physical causal relation and while in both [7] and [15] explanations for actions can, in a sense, be given in terms of psychological states, the agents' motivations and the question of whether and how the agents act on these motivations remains implicit. For example, Thagard explains 'Claus injected Sunny with insulin' with 'Claus wanted to end his marriage to Sunny' ([15], pp. 238). Here Claus' reasoning remains implicit and therefore somewhat unbelievable, as one can argue that there are less drastic ways of ending a marriage. For real plausibility we need a more elaborate explanation of why the choice was made by Claus at the particular time.

In this paper we will attempt to allow this elaborated conception of the intentional stance by giving agents' motivations, and the priorities amongst the agents' motivations, a clear place in evidential reasoning about actions. We do this by using an argumentation scheme for abductive practical reasoning, based on the normal (non-abductive[2]) practical reasoning scheme as proposed by Atkinson *et al.* [3]. The combination of abduction and a scheme for practical reasoning has also been used by Walton and Schafer in [18]. Although they make appeal to ideas derived from computational agents built on the Belief-Desire-Intention (BDI) paradigm, they do not provide any formal framework. In contrast, our abductive scheme is formally grounded in terms of an Action-based Alternating Transition System, or AATS [21], and it allows us to explain a particular situation in terms of the choices made by the agents involved and their motivations. The resulting explanations, modelled as arguments in a Value-based Argumentation Framework [4], can then be evaluated by considering the agents' motivational priorities, or used to infer the agents' motivational priorities.

We recognise that there are legal issues relating to the notion of motive, discussed in work such as [18] and [10]. In this paper we will use "motivation" rather than "motive", and present an account which is intended to relate to the everyday notions that might be used by a juror or a detective, and leave exploration of specifically legal notions of motive to more legally qualified people. In particular we shall not address at all problems concerning the legal admissibility of motive evidence, the central concern of [10]. Never the less, we believe that the account we give here is of relevance to the legal notions, and could form a valuable basis for such exploration.

The rest of this paper is organised as follows. In section 2 we will describe the argumentation scheme for abductive practical reasoning and its associated critical questions. In section 3 we give the definitions of an AATS that we use to ground the approach, then we show how the argument scheme and critical questions can be defined in terms of an AATS. In section 4 we will apply our model to an extended example showing how explanations and

[1] When speaking of persons we might call such a preference 'character' and may attempt to explain what kind of character the person has, cf. Walton [17].

[2] We use 'non-abductive' instead of 'deductive' because deductive implies that normal practical reasoning is not presumptive/defeasible, which, of course, it is.

objections can be constructed and how conflicts between explanations may be resolved. In section 5 we discuss related work, in particular [18], and we finish by making some concluding remarks and identifying areas for future work in section 6.

2 An Argumentation Scheme for Abductive Reasoning

In this section we will define an argumentation scheme for abductive practical reasoning. This scheme is based on a well-known argumentation scheme for practical reasoning defined by Atkinson *et al.* [3]. The original scheme and its critical questions enables agents to propose, attack and defend justifications for actions: presumptive or *prima facie* justifications of actions can be presented as instantiations of the argument scheme, and then critical questions characteristic of the scheme used can be posed to challenge these justifications. The original scheme is stated as follows:

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 some value V.

This scheme is an extension of Walton's sufficient condition scheme for practical reasoning [19]. In the above scheme Walton's notion of a goal is disambiguated by separating it into three elements: the state of affairs brought about by the action; the goal (the desired features in that state of affairs); and the value (the reason why those features are desirable). For example, I may diet to lose weight, with the goal of not being overweight, to promote the value of health. 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 these differences are desired by 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.

An agent who does not accept a presumptive argument based on the above scheme may challenge elements in the instantiation through the application of critical questions and an unfavourable answer to a critical question will identify a potential flaw in the argument. For example, one of the original critical questions (CQ8) is 'Does doing the action have a side effect which demotes the value'? Through the critical questions agents can attack the validity of the various elements of the argument scheme and the connections between them, suggest alternative possible actions, and draw attention to side effects of the proposed action.

The argumentation scheme for practical reasoning has roughly the same elements as Pennington and Hastie's *episode scheme*, a basic model about intentional actions [13]. In this scheme, some *initiating states and events* cause the agent to have a set of *goals*, which give rise to *actions* that have *consequences*. In the argumentation scheme, we have the current circumstances (the initiating states) in which the value acts as a motivation for some goal, which gives rise to some action that results in the new circumstances (the consequences). An important difference, however, between an episode and an instantiation of the practical reasoning scheme is that in the argument based on the scheme the value that acts as a motivation is explicitly mentioned, whereas in an episode the motivation for the action remains implicit.

Now the argument scheme for abductive practical reasoning can be stated as follows:

The current circumstances S,

are explained by the performance of action A,
in the previous circumstances R,
with motivation M.

By combining the normal and the abductive schemes for practical reasoning this will allow us to reason about intentional actions predictively as well as explanatorily. Given this combination, two important questions need to be addressed. Firstly, is the agent reasoning about past actions or is he reasoning about possible future actions, and secondly, is the agent reasoning about his own actions or about the actions of some other agent? If he is reasoning about his own actions, then he can apply the abductive practical reasoning scheme to *justify* with what motivations he took certain actions in the past and apply the normal (non-abductive) practical reasoning scheme to *guide* his future actions according to his values. If, on the other hand, he is reasoning about some other agent, then he can apply the abductive practical reasoning scheme to *explain* why and with what motivations the other agent took certain actions in the past and apply the normal (non-abductive) practical reasoning scheme to *predict* what actions this other agent will take in the future to promote his values. The importance of the distinction is stressed in [14]. Agents can combine these different ways of practical reasoning. For example, a police investigator tracking a serial killer can be guided in his actions by predicting what the killer will do next. Similarly, a judge might be guided in his choice of action (i.e. acquit, convict) by accepting an explanation of what happened and determining what could have motivated the suspect in this particular explanation.

In [2], Atkinson and Bench-Capon argued for the necessity of a well-founded formal model underlying the generation of arguments and critical questions. They provided the required grounding in terms of an Action-based Alternating Transition System, or AATS [21]. Essentially, an AATS consists of a set of states and transitions between them, with the transitions labelled with *joint actions*, that is, actions comprising an action of each of the agents concerned. To represent the fact that the outcome of actions is sometimes uncertain, in the scenario we use in this paper we will add a third "agent" which will determine whether the actions had the desired or the undesired effect. The transitions will be labelled with motivations, corresponding to the values of [4], encouraging or discouraging movement from one state to the next. Formal definitions of the abductive argument scheme, and the associated critical questions discussed below, are given in the next section. We use a transition system which is a simplified version of the AATS used in [2] to ground the practical reasoning argumentation scheme, but this will still allow us to hypothesise the reasoning concerning the events that may have taken place.

Given an AATS and a number of arguments generated from the AATS, a story (a sequence of events) is a path through the AATS. An argument explains why that path was followed, and so gives coherence and hence plausibility to the story. For example, 'John wrote a paper, John went to Florence' is a story, but it has more coherence expressed as 'John went to Florence because he had to present the paper he had written'.

Throughout this paper, we will use a simple example to illustrate our approach. Picture two people on a bridge. The bridge is not a safe place: the footpath is narrow, the safety barriers are low, there is a long drop into a river, and a tramline with frequent traffic passing quite close to the footpath. One of the persons, call him Ishmael, is standing still, whereas the other, Ahab, is running. As Ahab reaches Ishmael, Ishmael falls into the river. Did he jump or was he pushed? To answer this we will need a story explaining either why Ahab chose to push Ishmael, or why Ishmael chose to jump to his doom. If Ahab is on trial, the story we believe will be crucial: if Ahab intended Ishmael's death it will be murder, if there is a less damning explanation for the push it may be manslaughter, and if Ishmael jumped,

Ahab is completely innocent. We illustrate the critical questions by reference to this example scenario.

Providing an explanation involves formulating the problem, generating candidate explanations, and then choosing the best explanation. As in [2] there are critical questions associated with both problem formulation and choice of explanation.

We first present the critical questions relating to the choice of explanation for the abductive scheme. Below each critical question the answer to that question which would attack the original argument is given, as well as an informal example of how such an attack would be phrased in the example situation.

Critical questions for choice of explanation:

CQ1 Are there alternative ways of explaining the current circumstances S?
a) Could the preceding state R have been different?
answer: action A was done in a different preceding state R
'You say that Ahab did not have a clear path in the previous state, but actually Ahab already had clear progress'
b) Could the action A have been different?
answer: a different action A′ was done in preceding state R
'You say that Ahab pushed Ishmael, but actually Ishmael jumped'

CQ2 Assuming the explanation, is there something which takes away the motivation?
answer: doing action A in R to reach S demotivates M
'Ahab pushing Ishmael to the ground would not provide a clear path so cannot be motivated by Ahab wanting clear progress'

CQ3 Assuming the explanation, is there another motivation which is a deterrent for doing the action?
answer: some other motivation M′ deters from doing action A in R to reach S
'Ahab is deterred from pushing Ishmael off the bridge to get progress because he does not want to bring Ishmael into danger'

CQ4 Can the current explanation be induced by some other motivation?
answer: there is another motivation M′ which motivated doing A in R to reach S
'Ahab pushing Ishmael of the bridge is not motivated by Ahab wanting clear progress, but by Ahab wanting to revenge himself on Ishmael'

CQ5 Assuming the previous circumstances R, was one of the participants in the joint action trying to reach a different state?
answer: in R, even though one agent performed his part of A with motivation M, the joint action was actually A′ which led to S′, where $A' \neq A$ and $S' \neq S$
'Ahab wanted to push Ishmael out of the way of the tram to get him out of danger, but nature did not cooperate (and Ishmael fell off the bridge)'

In the above critical questions, 'explanation' stands for 'the performance of joint action A in previous circumstances R'. With this kind of explanation we mean *physical* explanation, how performing an action in R caused the new state of affairs S, as opposed to a *mental* explanation, what motivated an agent to do a particular action. So answering CQ1 by giving an alternative cause of the current circumstances does not require committing to a particular motivation for that alternative cause. Note that it is possible to ask for an alternative mental explanation by posing CQ4. CQ2 and CQ3 ask if there are any reasons for not doing the particular action.

CQ5 is actually a critical question that does not apply to the abductive reasoning step from the current state S to the previous state R, but rather to normal, non-abductive reasoning performed in R. It asks if it is at all possible that in the previous state R, the agent wanted

to perform a different joint action but was somehow hindered by another agent ('nature' in the example) not cooperating. Typically, this will suggest that he was acting with a different, perhaps less culpable, motivation. This reasoning with the abductive scheme and CQ5 actually combines multiple reasoning steps into one. First, the previous circumstances are abduced using the abductive scheme. Then, assuming these previous circumstances were the case, we try to justify the action by applying the normal scheme and finally we answer critical question 17 from the original practical reasoning scheme ([2], pp. 859), 'are the other agents guaranteed to execute their part of the desired joint action?', unfavourably. For reasons of space, we have incorporated these reasoning steps into one new critical question.

We now turn to the critical questions relating to problem formulation.

Critical questions for problem formulation:

CQ6 Are the current circumstances true?
answer: the current state is not S
'Ishmael is not dead'
CQ7 Could the action have had the stated preconditions?
answer: A cannot be performed in R
'Ahab is not strong enough to push Ishmael off the bridge'
CQ8 Were the previous circumstances the same as the current circumstances?
answer: for all propositions in S and R:
if a proposition p is true in S then p_a was already true R
if a proposition p is false in S then p_a was already false R
'Ishmael was already in the water when Ahab appeared'
CQ9 Could the explanation for the current state provide the motivation?
answer: doing action A cannot be motivated by M
'Killing Ishmael would not give Ahab revenge'
CQ10 Assuming the previous circumstances, would the action have the stated consequences?
answer: doing action A in in R does not bring about S
'Ishmael could not fall from the bridge (the safety barriers are too high)'
CQ11 Assuming the previous circumstances, would the action have any consequences?
answer: doing action A in R does not get you to a new state
'Pushing Ishmael would have no effect'
CQ12 Are the current circumstances S possible?
answer: there is no state S (S is impossible)
'Suppose it was being claimed that Ishmael had flown to the moon'
CQ13 Is the joint action possible?
answer: A is not a joint action
'Ahab pushed Ishmael and Ishmael jumped'
CQ14 Are the previous circumstances R possible?
answer: there is no state R (R is impossible)
'There is no bridge'
CQ15 Is the motivation indeed a legitimate motivation?
answer: M is not a motivation
'No civilised person acts out of revenge'

3 Formal Definitions

In this section we re-capitulate the definitions of an AATS as set out in [2]. We then go on to show how the argument scheme and critical questions for abductive practical reasoning can be defined in terms of an AATS.

3.1 AATS Definitions

In order to be able to reason rigorously about actions and their effects, we need a well-defined structure in which we can represent how the actions of an agent will lead to transitions from one state to another. In particular we need to be able to contextualise these transitions so that the effects of actions can be made dependent on the action of other agents, and other events in the environment. One such structure is provided by Alternating Transition Systems (ATS), originally developed to underpin the Alternating-time Temporal Logic of [1]. These structures have also been used by van der Hoek *et al.* [21] to explore the social laws paradigm for describing coordination in multi-agent systems introduced largely through the work of Shoham, Tennenholtz and Moses (e.g. [12]). Like [21] we give the notions of actions and their pre-conditions a central role, so we adopt their version of ATS in which actions and pre-conditions are first class entities. This version is called an *Action Based Alternating Transition Systems* (AATS) in [21], and it has been used in [2] to provide formal definitions for an argument scheme and critical questions for practical reasoning. In this report we also use this structure to represent our argument scheme and critical questions for abductive practical reasoning. We first provide the definition of an AATS, as given in [21].

Assume first that the systems we wish to model may be in any of a finite set Q of possible *states*, with some $q_0 \in Q$ designated as the *initial state*. Systems contain a set Ag of *agents* and each agent $i \in Ag$ is associated with a set Ac_i of possible actions. It is assumed that these sets of actions are pairwise disjoint (i.e., actions are unique to agents).

A joint action j_C for set of agents C (termed a *coalition*) is a tuple $\langle \alpha_1,...,\alpha_k \rangle$, where for each α_j (where $j \leq k$) there is some $i \in C$ such that $\alpha_j \in Ac_i$. Moreover, there are no two different actions α_j and $\alpha_{j'}$ in j_C that belong to the same Ac_i. The set of all joint actions for coalition C is denoted by J_C, so $J_C = \prod_{i \in C} Ac_i$. Given an element j of J_C and an agent $i \in C$, i's action in j is denoted by j_i.

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 pre-condition function*, which for each action $\alpha \in Ac_{Ag}$ defines the set of states $\rho(\alpha)$ from which α may be executed;
- $\tau : Q \times J_{Ag} \rightarrow Q$ is a partial *system transition function*, which defines the state $\tau(q, j)$ that would result by the performance of j from state q - note that, as this function is partial, not all joint actions are possible in all states (cf. the pre-condition function above);
- Φ is a finite, non-empty set of *atomic propositions*; and

– $\pi : Q \rightarrow 2^{\Phi}$ is an interpretation function, which gives the set of primitive propositions satisfied in each state: if $p \in \pi(q)$, then this means that the propositional variable p is satisfied (equivalently, true) in state q.

In addition to the elements of an AATS given in [21], we need to provide an extension to enable the representation of motivations from the underlying argument scheme for abductive practical reasoning. Firstly, we have a set *Am* of motivations for each agent (which are a subset of a set *M* of motivations). Every transition between two states from the set *Q* is either promoted, demoted, or is neutral, with respect to each motivation. Note that motivations are not unique to agents: individual agents may or may not have motivations in common. Whether a motivations is promoted or demoted by a given action will be determined by comparing the state reached with the state left. More formal definitions of these elements are given below:

– Am_i is a finite, non-empty set of motivations $Am_i \subseteq M$, 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 motivation $m_u \in Am_{Ag}$ ascribed by the agent to the transition between two states: $\delta(q_x, q_y, m_u)$ labels the transition between q_x and q_y with one of $\{+, -, =\}$ with respect to the motivation $m_u \in Am_{Ag}$.

We can now extend the original specification of an AATS to accommodate the notion of motivations and re-define an AATS as a $(2n + 8)$ tuple $S = \langle Q, q_0, Ag, Ac_1, \ldots, Ac_n, Am_1, \ldots, Am_n, \rho, \tau, \Phi, \pi, \delta \rangle$

3.2 Formal Definitions for the Argument Scheme and CQs for Abductive Practical Reasoning

We now present the formal definitions of the argument scheme and critical questions in terms of an AATS. The critical questions can be grouped into two categories: those concerned with choice of explanation, and those concerned with problem formulation. We present the formal definitions of the critical questions as grouped into these categories. We begin by presenting the formal version of the argument scheme:

ABS1: The current circumstances $q_0 = q_y$
are explained by agent i participating in joint action j_n where ${j_n}^i = \alpha_i$,
in the previous circumstances q_x, where $\tau(q_x, j_n)$ is q_y
and $\exists p_a \in \Phi$
such that either $p_a \in \pi(q_y)$ and $p_a \notin \pi(q_x)$, or $p_a \notin \pi(q_y)$ and $p_a \in \pi(q_x)$
such that for some $m_u \in M$, $\delta(q_x, q_y, m_u)$ is +.

We now present the formal version of the critical questions that can be used to challenge instantiations of the above argument scheme.

3.2.1 ***Critical Questions for Choice of Explanation***

CQ1a: The previous circumstances were not q_x and were actually $q_z \in Q$, in which agent $i \in Ag$ could have participated in joint action $j_n \in J_{Ag}$, such that $\tau(q_z, j_n)$ is q_y.

CQ1b: In the previous circumstances $q_x \in Q$, agent $i \in Ag$ could have participated in joint action $j_m \in J_{Ag}$, where $j_n \neq j_m$, such that $\tau(q_x, j_m)$ is q_y.

CQ2: There is a p_b, where $p_a \neq p_b$, such that either $p_b \in \pi(q_y)$ and $p_b \notin \pi(q_x)$, or $p_b \notin \pi(q_y)$ and $p_b \in \pi(q_x)$, such that $\delta(q_x, q_y, m_u)$ is –.

CQ3: There is a p_b, where $p_a \neq p_b$, such that either $p_b \in \pi(q_y)$ and $p_b \notin \pi(q_x)$, or $p_b \notin \pi(q_y)$ and $p_b \in \pi(q_x)$, such that $\delta(q_x, q_y, m_w)$ is –, where $m_u \neq m_w$.

CQ4: There is a p_b, where $p_a \neq p_b$, such that either $p_b \in \pi(q_y)$ and $p_b \notin \pi(q_x)$, or $p_b \notin \pi(q_y)$ and $p_b \in \pi(q_x)$, such that $\delta(q_x, q_y, m_w)$ is +, where $m_u \neq m_w$.

CQ5: ${j_n}^i = {j_m}^i$, $j_n \neq j_m$ and $\tau(q_x, j_n) \neq \tau(q_x, j_m)$.

3.2.2 ***Critical Questions for Problem Formulation***

CQ6: $q_0 \neq q_y$.

CQ7: $q_x \notin \rho(\alpha_i)$.

CQ8: $\forall\, p_j \in \Phi$, $p_j \in \pi(q_y)$ and $p_j \in \pi(q_x)$, or $p_j \notin \pi(q_y)$ and $p_j \notin \pi(q_x)$.

CQ9: $\delta(q_x, q_y, m_u)$ is not +.

CQ10: $\tau(\mathrm{q}_x, \mathrm{j}_n)$ is not q_y.

CQ11: $\tau(\mathrm{q}_x, \mathrm{j}_n)$ is q_x.

CQ12: $q_y \notin Q$.

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

CQ14: $q_x \notin Q$.

CQ15: $m_u \notin Am_i$.

The above formalism can be used by agents in scenarios where reasoning takes place to generate arguments to explain how an agent may have acted to find itself in a particular situation and its motivations for doing so. A worked example demonstrating such a scenario is presented in the next section.

4 Representation of the Example

The first stage of our approach is to produce a transition diagram representing the scenario. The objective is to include all that is relevant, but only what is relevant, so as to avoid complicating the problem beyond what is necessary. Recall that the footpath is narrow, and that Ahab is running. He may be assumed to desire a clear path, and so our first proposition is “Ahab’s path is clear” (C). Recall also that the bridge is a dangerous place: a person on the bridge may be in danger by falling into the river (R), or by being hit by a tram (T). We also introduce a proposition “Ishmael’s life is in danger” (D), which is true whenever either R or T is true, since this will be useful when we construct our arguments. In our example we consider only the states which are of interest to us, and for simplicity’s sake omit the other possible states from the diagram. For example, the state in which both T and C are true is of no interest to us, since no one claims that it was the case, nor that anyone tried to reach it.

q1: CRTD = 0000 – Ahab’s path is not clear and Ishmael is not in danger from either the river or the tram. This is the presumed situation before the incident.

q2: CRTD =1101 – Ahab's path is clear and Ishmael is in danger from the river. This is the situation immediately after the incident, which we wish to explain.

q3: CRTD = 1000 – Ahab's path is clear and Ishmael is not in danger from either the river or the tram.

q4: CRTD = 0011 – Ahab's path is not clear and Ishmael is in danger from the tram. This situation would hold if Ishmael was too close to the tramline and a tram was approaching.

Now consider the actions. Ishmael can jump or do nothing. Ahab can push Ishmael or do nothing. Pushing and jumping are not simultaneously possible. Since, however, the effect of a push is uncertain, we add a notional third agent ("nature") to determine whether the push sends Ishmael into the river, or simply out of Ahab's way. Nature is irrelevant here when Ishmael jumps.

There are thus three joint actions which can be performed in states q1 and q4 (see Figure 1):

j1: Ishmael jumps and Ahab does nothing.

j2: Ishmael does nothing, Ahab pushes Ishmael and Ishmael falls off the bridge into the river.

j3: Ishmael does nothing, Ahab pushed Ishmael and Ishmael is out of Ahab's way but still on the bridge.

We must next label the transitions with motivations. Moving from q1 to both q2 and q3 is motivated by Ahab's progress: in q1 the path was not clear and in q2 and q3 it is clear. Equally the transitions from q1 to q2 demote Ishmael's safety: in q1 he is in no danger and in q2 he is. But suppose also Ahab has a reason to seek revenge of Ishmael: this will apply only if q2 is reached from q1 by Ahab pushing Ishmael. Finally suppose Ishmael wishes to kill himself, then, for him, oblivion will motivate moving from q1 to q2. Turning to the transitions from q4, we can see that moving from q4 to q3 promotes both Ahab's progress and Ishmael's safety. Moving from q4 by j1, where Ishmael jumps, promotes Ahab's progress, but does not affect Ishmael's safety or his chance of oblivion, since he dies in either case. Finally the transition from q4 to q2 by j2 can be motivated either by Ahab's progress or by Ahab's revenge, since it is important to satisfy this motivation that Ishmael is killed by Ahab rather than by the tram.

Our final transition diagram is shown in Figure 1. Of course, there are further transitions such as those between q1 and q4, and those where both do nothing, which leave the state unchanged, but those play no role in our considerations, and so are omitted.

This model could be challenged using the critical questions relating to problem formulation given in the previous section. For example, someone might claim that any push would send Ishmael into the river, so denying that j3 is possible, which would remove the transitions into q3. For reasons of space, however, let us take our formulation as accepted, and not consider these questions further here.

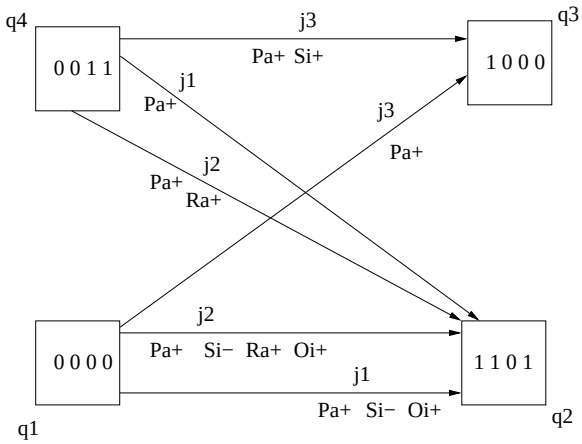

Figure 1. State transition diagram for the scenario

We now turn to the arguments that can be produced on the basis of Figure 1. Recall that we are trying to explain how we reached q2 and say that first we assume that the previous state is q1. There are two transitions from q1 to q2, one promoting three values and one promoting two. We therefore have five possible instantiations of our abductive argument scheme.

A1: q2 is explained by Ahab pushing Ishmael in q1 to reach q2 motivated by progress.
A2: q2 is explained by Ahab pushing Ishmael in q1 to reach q2 motivated by revenge.
A3: q2 is explained by Ahab pushing Ishmael in q1 to reach q2 motivated by oblivion.
A4: q2 is explained by Ishmael jumping in q1 to reach q2 motivated by progress.
A5: q2 is explained by Ishmael jumping in q1 to reach q2 motivated by oblivion.

These arguments can be now be the subject of critical questioning. CQ1 applies, attacking all five of the above arguments. Answering CQ1a, we can say that it is possible that the preceding state was q4 rather than q1. Thus we have:

Obj1a: The preceding state was q4, not q1.

This objection can be met with the following rebuttal:

Reb1: The preceding state was indeed q1.

Notice that here, we label the answer to the critical question as an objection. It is also possible to answer critical questions that ask for another explanation (CQs 1, 4 and 5) by providing an instantiation of the argument scheme, an alternative explanation. If we take, for example, A1 as the current explanation, A4 and A5 are answers to CQ1b and if we take A4 as our explanation, A1 – A3 are answers to CQ1b. So in virtue of CQ1b we can see that A1 – A3 attack A4 – A5 and vice versa.

CQ2 does not apply because none of the transitions has a motivation which both encourages and discourages it at the same time.

CQ3 is important: the threat to Ishmael's safety could be sufficient to deter Ahab from pushing and Ishmael from jumping. Thus we have Obj3a attacking A1 – A3 and Obj3b attacking A4 and A5.

Obj3a: In q1 Ahab should not push Ishmael to reach q2 since it demotes Ishmael's safety.
Obj3b: In q1 Ishmael should not jump to reach q2 since it demotes Ishmael's safety.

CQ4 applies in that if we take, for example, A1 as the current explanation, A2 and A3 are answers to CQ4. So in virtue of CQ4 we can see that A1 – A3 all attack one another and A4 and A5 mutually attack.

CQ5 also can be posed. If, for example, the critical question is targeted at A1, the answer to this question could be an argument that Ahab did indeed push Ishmael motivated by progress, but hoped he would not fall off the bridge.

Obj5a: Ahab pushed Ishmael in q1 to reach q3 motivated by progress, but nature did not cooperate.

Obj5a attacks (and is attacked by) A1 – A5 because, even though it does not directly explain q2, it does provide us with a reason for believing things went differently than is postulated in A1 – A5.

We have one final objection to consider, which can be made if we accept Obj1a, rather than taking it to be refuted by Reb1. Suppose that Ahab saw the situation as q4 rather than q1, perhaps because he thought a tram was about to hit Ishmael. He therefore might have pushed Ishmael out of the way, hoping to reach q3, but unfortunately Ishmael went off the bridge. Now Ahab's claim would be:

Obj5b: Ahab pushed Ishmael in q4 to reach q3 motivated by safety, but nature did not cooperate.

This objection is a combination of CQ1 and CQ5, where first CQ1 is answered positively and then CQ5 is also answered positively. Similar to Obj5a, Obj5b attacks A1 – A5, and also attacks Obj5a.

We have identified a set of arguments and attacks between them, with each argument associated with a motivating value. We now need to evaluate the status of the arguments. To do this we form the arguments into a Value-based Argumentation Framework (VAF), introduced in [4]. A VAF is an extension of the argumentation frameworks (AFs) of Dung [9]. In an AF an argument is admissible with respect to a set of arguments S if all of its attackers are attacked by some argument in S, and no argument in S attacks an argument in S. In a VAF an argument succeeds in defeating an argument it attacks only if its value is ranked as high as, or higher than, the value of the argument attacked. In VAFs *audiences* are characterised by their ordering of the values. Arguments in a VAF are admissible with respect to an audience A and a set of arguments S if they are admissible with respect to S in the AF which results from removing all the attacks which do not succeed with respect to the ordering on values associated with audience A. A maximal admissible set of a VAF is known as a Preferred Extension (PE). The VAF for our example is given below in Figure 2.

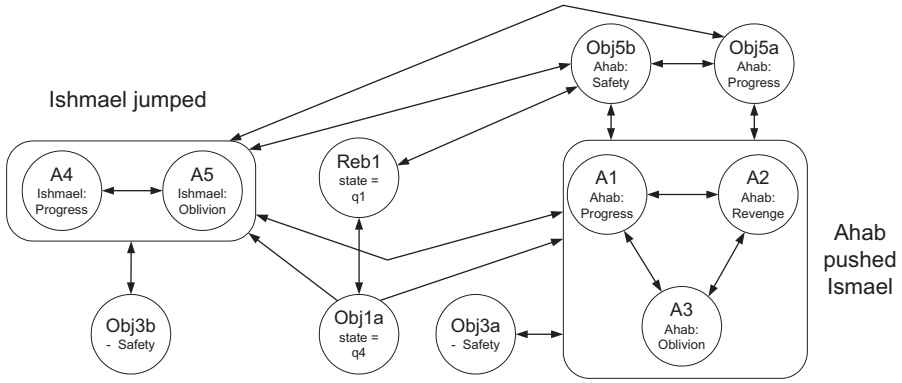

Figure 2. VAF showing arguments, objections and rebuttals

Arrows between nodes denote attack relations. To improve readability, the 'jumping' (A4 – A5) and 'pushing' (A1 – A3) explanations have been grouped together. This is represented by a rounded box around the respective arguments; the arrow between, for example, Obj5a and the box surrounding A4 – A5, means that Obj5a attacks both A4 and A5 and vice versa.

Since we have a number of different orderings on values that yield different PEs, we have a number of competing explanations which we must choose between. In order to determine which of the arguments A1 – A5 is in the preferred extension, we must first provide an ordering on the motivations of Ahab and Ishmael which will allow one of our arguments to resist the others. In this case, only the most preferred value is important. We thus have the following possibilities[3]:

1. *ahab* $\in$ {R $>$ {S, P, O}} (murder)
2. *ahab* $\in$ {P $>$ {S, R, O}} (manslaughter (arguably))
3. *ahab* $\in$ {S $>$ {P, R, O}} (he did not push)
4. *ahab* $\in$ {O $>$ {P, R, S}} (mercy killing)
5. *ishmael* $\in$ {O $>$ {S, P,}} (suicide)
6. *ishmael* $\in$ {P $>$ {S, O}} (sacrifice to let *ahab* pass)
7. *ishmael* $\in$ {S $>$ {P, O}} (he did not jump)

If we commit to such an ordering of motivating values, the arguments or objections associated with the stronger motivation defeat the arguments and objections that rely on one of the other motivations. This commitment to motivational orderings is important in different ways, depending on the phase of the case. In the investigation phase of a case, the assumed motivations of the actors will direct the search for evidence; in the decision-making phase, the assumed motivations can influence the decision of the judge or jury. Examples of both these ways of using motivational orderings will be given below.

We may well think that the normal priority is 3 and 7. Normally people would not endanger the life of another to make progress, have no strong feelings of revenge and see oblivion as something to be avoided rather than sought. If we indeed assume that S is the most important motivation for both actors, the only possible acceptable argument is Obj5b, because Obj3a and Obj3b would defeat A1 – A3 and A4 – A5, respectively. For Obj5b to be in the preferred extension, however, we have to suppose that the preceding state was q4 and that Obj1a defeats Reb1. In other words, if there is evidence that Ishmael's life was indeed threatened by a rapidly approaching tram, we might believe that Ahab accidentally pushed him in the river in an effort to save him. This would be a reasonable explanation, since it needs no unusual preference, but it does require evidence for the tram, and it is unlikely that this would have been overlooked when the case was prepared. A variant on Obj5b is saying that Ahab had a false belief: no tram was approaching but Ahab *thought* that Ishmael's life was threatened by a rapidly approaching tram. This requires evidence that supplies reasons for why Ahab had the false belief, or very convincing testimony from Ahab. It does not, however, require further explanation of Ahab's ordering of values.

If, however, we assume the situation was indeed q1 and that Ahab was not justified in believing the situation was any different from q1, we have to say that either Ahab or Ishmael had an abnormal ordering of motivations[4]. The question then is which of the these

[3] Determining the audience given a VAF and an admissible set is computable in polynomial time [5], so there are no complexity issues, even in large examples.

[4] The point that crimes invariably involve an abnormal or deviant motivation is made in [18], which we will discuss further in section 5.

abnormal orderings is the most plausible, and the role of the story is to explain why the agent concerned can be thought to have this particular abnormal ordering.

In the example, it could have been the case that Ishmael preferred O to S or P to S. The latter is implausible in the extreme: it is difficult to think of a story which would explain why Ishmael would risk his own life in order to expedite Ahab's progress. But we are familiar with the fact that, in some exceptional circumstances, people are suicidal and this does indeed lead them to prefer O to S. So a possible explanation is that Ishmael preferred O to S and therefore jumped to his death (A5). While this is not an implausible explanation, we would also want the story to be supported by evidence. So we will investigate further. We might find witnesses who heard Ishmael say that life was not worth living since his wife left him, or we might find other circumstances, for example, that Ishmael was bankrupt or terminally ill. Assuming that no such evidence can be found, however, this explanation must be abandoned: we cannot accept A5 with no evidence for Ishmael's suicidal state. So if the motivational orderings for Ishmael are not 5 and 6 then he must have the normal ordering 7. A4 and A5, the explanations in which Ishmael jumped, are now defeated by Obj3b, which means that Ishmael did not jump, since he valued his own safety.

If Ishmael did not jump, one of the explanations that Ahab pushed Ishmael must be true. The question is now with which motivation Ahab did push Ishmael? One explanation assumes that both Ahab and Ishmael preferred O to S; so Ishmael wanted to die but could not bring himself to jump so Ahab pushed him to facilitate his death. The problem with this explanation – apart from the intrinsic implausibility that anyone would agree to such a scheme – is that it would need substantiation for Ishmael's suicidal state. But this has already been looked for and not found in connection with A5.

We next consider the ordering for Ahab in which R is preferred to S, that Ahab pushed Ishmael because he wanted revenge (A2). This explanation is not implausible: feelings of revenge, although normally of little impact, have been known to increase sufficiently to dominate a person's thinking. The explanation will, however, have to be supported by evidence: for example, witness testimonies of people who heard Ahab threaten Ishmael, or evidence that Ahab had been ruined by Ishmael. If no such evidence can be found, we should reject A2 and thus also reject a verdict of murder, which requires Ahab to have killed Ishmael with murderous intent.

Another option is that Ahab preferred P to S: Ahab cared only about his own progress and so he pushed Ishmael to his death to clear his way (A1). Again, however, we need to justify the context. For example, assume that Ahab was in a rush to get to work; his boss told him he would be fired if he was late for work. Ishmael was a co-worker of Ahab's who for some reason had a score to settle with Ahab. Ishmael then decided to hinder Ahab's progress so that Ahab would be fired and Ahab pushed Ishmael to his death because he did not want to lose his job. Here, Ahab's culpability depends on the risk he took: if, as in A1, it was virtually certain that Ishmael would die, Ahab could still be prosecuted for murder, even though he did not explicitly wish for Ishmael to die.

It is also possible, however, that Ahab was merely reckless and that he pushed Ishmael to clear his way, not realising that Ishmael would fall from the bridge (Obj5a). While Obj3a *should* have been sufficient to defeat Obj5a, it is not entirely implausible to suggest that Ahab miscalculated the risk, and so this attack failed in practice to influence his reasoning. There were, after all, safety barriers, although these proved too low to be effective. Ahab is clearly at fault in that he did not take due account of the risk to Ishmael. It could now be considered whether the charge should be one of manslaughter rather than murder, but we will not delve further into these legal niceties.

5 Related Work

The most relevant related work is a paper by Walton and Schafer [18]. They distinguish motive from intent on the one hand and character on the other, but argue that identification of a motive can be important evidence of who committed a particular crime. They give an example, taken from [10], in which five nurses had the opportunity to steal some Dermatol, but only one had the motive of having been addicted to the drug. The motive was important evidence because Dermatol is not something that anyone would normally want, and there was no reason to think that it had been stolen for resale.

Walton and Schafer state that motives "are immediate goals to which an agent is strongly committed". They use a scheme for practical reasoning in which an action is justified for an agent if that agent has a goal and the action will realise the goal. They also give a scheme for value based practical reasoning in which the goal is required to be supported by the agent's set of values, but even there the action is performed for the sake of the *goal* rather than the *value* as in our scheme. The role of values in their scheme is to provide support for the claim that the agent has the particular goal, rather than as the mainspring of the action as in [3] which is the scheme on which the work in this paper is based. Although Walton and Schafer claim to follow Wigmore [20], who defined a motive as "a specific emotion or passion that is likely to lead to a specific act", our notion of motivation used above seems closer to Wigmore's definition than their notion of an immediate goal. Wigmore does recognise that "motive" can be ambiguous, but the ambiguity is between the emotion and the event that gave rise to the emotion, not the goal designed to satisfy the emotion. In our example, Ahab's motivation might be revenge or the event for which he wants revenge, such as Ishmael's ruining Ahab, but not Ishmael's death, which is the immediate goal. In a second (hypothetical) example, also taken from [10], where a car thief murders someone to prevent him informing the police, the motivating goal identified by Walton and Schafer is to avoid punishment. Here, because the motivating goal is different from the event to be explained, there is more plausibility in calling it the motive, but we would still prefer to see the motivation as something like *freedom* which would be demoted by states in which the thief was punished. Committing murder is only one way to avoid imprisonment: paying the potential informant or fleeing the country would be alternative actions with the same motivation.

Walton and Schafer's account of the reasoning in [18] is as follows. They proceed in two steps, a forward reasoning step based on their practical reasoning argument scheme, and then an abductive step to establish that this provides the best explanation. The first step is based on [10], which gives the structure of the reasoning in the car theft example as:

- EVIDENCE: D stole a car, V was aware of the fact, and V threatened to inform the police.
- INFERENCE: D had a motive to prevent V from revealing the theft to the police.
- CONCLUSION: D purposely killed V to prevent V from revealing the theft to the police.

Looking at our example in this structure would give:

- EVIDENCE: Ishmael's financial dealings bankrupted Ahab
- INFERENCE: Ahab had a motive to harm Ishmael
- CONCLUSION: Ahab purposely killed Ishmael to get revenge

Here the role of the evidence is to support the claim that D had V's silence as a goal. It plays the same role as the value in Walton and Schafer's value based practical reasoning scheme. The problem is, however, that the conclusion does not follow in any real sense

from these premises: while we can say that D had an argument to kill V, it says nothing about why D should have found this argument to be acceptable. At this point Walton and Schafer appeal to abductive reasoning to establish that this is indeed the best explanation. Unfortunately their informal presentation gives little clue as to how this is done: while they have a premise that it is the best explanation, no support for it being the best, as opposed to one plausible, explanation is given unless there is no motive at all for any of the alternatives.

In contrast we reason backwards from the outset to identify the actions which could have given rise to the current state, and the motivations that might have led an agent to perform them. The resulting argument is then subject to critical questioning: in the car theft example, having identified that V might have been killed by a person wishing to avoid punishment we would consider critical questions such as CQ10 (it appears that the police found out about the theft anyway), and CQ3 (killing someone provides another possibility of punishment), and better ways of achieving the goal such as paying V to keep silent, or leaving the country. We then use a VAF to determine what kind of audience would choose act on the original argument. In this case D would have to be a person who could not afford to pay V, who held life cheaply, accepted the risk of getting caught for murder, and who preferred to kill V to leaving the country. At this point we will look for the evidence which tells a story to explain why D is that sort of person. This where character and past actions become relevant: we can infer that D has the required value order either from past actions suggesting that he has used these preferences before, or from a particular character manifest in such past actions.

It is this need to explain what is particular about the person that made him act upon the motive that is lacking from the account presented in [18], even though in their motivation the points showing the importance of this aspect are well made. For example in discussing an example where a person kills his daughter for financial gain they write “only a very few people kill their children, or step children, for financial gain. Almost all of them can sleep soundly in their beds, even if the financial burden on their parents is very heavy”. But the argument that *X needed money and would inherit on his daughter’s death, so that X had a motive for his daughter’s death, so we can conclude that X killed his daughter for her money* is of precisely the same form as that proposed for the car theft in [10] and endorsed by Walton and Schafer. Another interesting example in [18] is taken from the Sherlock Holmes story, *The Mystery of the Noble Bachelor*, in which a bride disappears before her wedding reception. There the explanation turns not on an unusual value ordering (the bride’s previous husband, presumed dead, appears and she leaves with him motivated by love, the desire to avoid scandal and fear of a charge of bigamy, all of which seem quite normal). In that case, before the discovery of the *deus ex machina* in the form of the long lost husband there was simply no justification acceptable to any reasonable audience, which led Holmes to look for some additional features in the situation which could give a reasonable explanation. We believe that our account provides a much better way of recognising that crimes are, as stated in [18], “by definition deviant behaviour, what people do not normally do”.

Our use of the AATS also allows us to clarify the notion of *intent*. Because the argument only motivates the particular agent’s component of a *joint* action, the state reached may not be the state that the agent wished to reach. For example the car thief may have hit V intending to intimidate him into silence, but through some misfortune the blow proved fatal. Note that in Leonard’s formulation of the example followed in [18], the same evidence and inference would equally license the conclusion *D unintentionally killed V while attempting to intimidate V to prevent V from revealing the theft to the police*.

Finally we should note that the primary concern of [10], also touched on in [18], is the legal admissibility of motive evidence. We do not want to go into these legal issues here:

our aim is only to provide a mechanism for rationally explaining actions in terms of their motivation.

Other relevant works in AI and Law are other accounts of justification through a causal story such as Bex *et al* [6], [7] and Thagard [15]. In the next section we will discuss how we see our account as extending and developing the work of Bex *et al*. Similar remarks could also be made about [15].

6 Concluding Remarks

In this paper we have shown how we can use an argument scheme for practical reasoning abductively in order to generate a set of explanations for a given state of affairs in terms of the motivations of the agents who brought it about. Typically we will have competing explanations which we can resolve by considering the priorities amongst motivations of the agents concerned. If the normal default priorities do not explain the situation, we must find an ordering which does, and then justify this by means of a story which explains how the agent came to have this ordering. This will in turn guide search for further evidence to anchor this explanatory "back story". Explanation in terms of motivations is important, both to make our chosen story plausible and, in some cases, to determine the degree of culpability of the agents. We have thus given motivations a clear and separate place in evidential reasoning about actions. This distinction has been recognised in other work such as [11], where a formal treatment is proposed. There Modgil defines a framework in which conflicts over value orderings are reasoned about at a separate meta-level. This means that conflicts between arguments may be resolved through reasoning about preference orderings at a different level, resulting in a hierarchical argumentation framework. For a rule based treatment in the style of [7], the need for meta-level reasoning will require rules of an additional kind which allows us to conclude that an agent has a particular value preference, such as *if Ishmael ruined Ahab then Ahab prefers Revenge to Safety*.

Our approach is firmly grounded on a formal structure provided by an AATS. The AATS makes the underlying model of the stories less *ad hoc* than in previous approaches which rely on a set of rules. In addition, when compared to [7] the problem formulation critical questions stated formally in section 3 give us a better opportunity to reason about the causal model underlying the story. A disadvantage is perhaps that the causal rules are not as explicit as in [7], since the causal relations are now implicit in the transition system. We believe, however, that the possibilities for richer reasoning about motivation more than compensate for this.

For future work we intend to apply the above analysis to provide a rule based representation so as to facilitate computation. Taking as a starting point the rules found in [7], we will need three kinds of rules: rules describing physical causation, such as "If q1 and Ahab pushes Ishmael then Ishmael is in the river"; rules to describe motivation "If q1 and Ahab pushes Ishmael revenge is promoted"; and rules to determine value preferences such as that mentioned above to explain why Ahab prefers revenge to safety. The first kind can be straightforwardly derived from the AATS: each transition represents one such rule. The second kind can also be extracted from the AATS: each label on a transition represents one such rule. The third kind of rule is not present in the AATS, since these rules belong to the meta-level reasoning associated with the VAF: these rules will require the kind of analysis we used in determining the appropriate audience to use for Ahab and Ishmael. An excellent case to which these ideas can be applied is the Claus von Bülow case which is described by Thagard in [15]. There Thagard gives a full description of the case as well as representations

of the cases presented at both the initial trial and the appeal. Using this example will allow direct comparisons with the Explanatory Coherence and Bayesian Network approaches used by Thagard, as well as the approach of [7].

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