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Computational Modelling of Practical Reasoning Using Transition Diagrams

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In practical reasoning an agent chooses an action based on the goals this action is expected to achieve and the values achieving the goals will promote. Argumentation schemes using transition diagrams have been proposed to support practical reasoning, but the schemes proposed previously are limited in terms of expressivity of goals and extent of look ahead. Here we explain how to overcome these limitations, using a set of linked argumentation schemes and associated critical questions, and outline how this can be formalized in ASPIC+.

KEYWORDS: argumentation schemes, diagrams, goals, practical reasoning, transition

1. INTRODUCTION

Practical reasoning is often distinguished from theoretical reasoning in terms of direction of fit (Searle, 2001). Whereas in theoretical reasoning the idea is that agents will conform their beliefs to fit the world as it is, in practical reasoning agents will choose how they wish the world to be and will seeks ways in which they can make the world fit their desires. An obvious consequence of this is that the outcome of theoretical

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reasoning is intended to be objective, but the outcome of practical reasoning will often be subjective. All agents are trying to make their beliefs fit the same world but they will differ in their aims, values and aspirations, and hence will make different choices about the way the world should be, and differ also in their abilities and preferences for actions, and so may make different choices about how they can, or can try to, realise their desires, even when these coincide.

But the current state of the world also matters for practical reasoning: the world and its current state determine what we can do, and influences the effects our actions will have. In order to perform an action, its preconditions must be satisfied, and the consequences of an action will typically depend in some way on the current state. These consequences are not, however, always determinate: sometimes the effects of an action may be better considered as a probability distribution (e.g. tossing a coin, cutting a deck of cards), and sometimes also may depend on the choices of other agents able to affect the situation.

Practical reasoning therefore needs to bring together a range of different knowledge types including:

1. the current state of the world;
2. causal relationships relating to the effects of actions;
3. what we can do in the current situation;
4. the actions of others;
5. goals we want to achieve;
6. values promoted and demoted by various actions and realisation of goals;
7. which values are preferred.

These various knowledge types have different statuses. The current state of the world, and what we can do in that state are both objective, although our beliefs may, of course, be mistaken both about what is the case, and what we are capable of doing. The effects of actions are objective in the sense that that we have beliefs about them rather than control over them, but they are often uncertain and need to be described using probabilities, or may even require an understanding of what else will happen simultaneous with our action. The actions of others can be reasoned about, and so we can arrive at more or less certain beliefs about they will do, but they are ultimately outside of our control. With goals and values we move into the realm of the subjective: we are permitted to adopt whatever goal we wish; and to declare values to be promoted or demoted by particular actions, and the realisation of particular goals, so that the acceptability of arguments becomes relative to the audience to which they are addressed (Perelman & Olbrechts-Tyteca, 1969). But others may disagree with us: whether someone

enjoys swimming or not depends on the individual: whether the value of fairness is promoted by equality of outcome or equality of opportunity is a matter for debate, and whether it is more important to promote, for example, equality or enterprise is a matter of pure choice, dependent on the preferences of individual agents.

2. MODELLING PRACTICAL REASONING

In multi-agent systems the commonest approach to modelling practical reasoning is perhaps the belief-desire-intention model based on Bratman (1987). Alternative argumentation based approaches have been explored, however, including those based on state transition diagrams (STDs) (e.g. Atkinson & Bench-Capon, 2007), in which possible states of the world are related by the actions which lead from one to another, and agents reason about which transition to follow. An argumentation scheme for practical reasoning was proposed in Atkinson *et al*. (2006), and expressed as an STD in Atkinson and Bench-Capon (2007):

> PRAS: In the current circumstances R
> I should perform action A
> Which will reach new circumstances S
> Realising goal G and
> Promoting value V.

Relating this to the different knowledge types from the previous section, we find that (1) is expressed in the first line, (3) in the second, (2) in the third, (5) in the fourth and (6) in the fifth. Moreover in Atkinson and Bench-Capon (2007) the transitions are *joint* actions, and so represent the effect of the agent's action given the set of actions performed by other relevant agents. Action A may therefore occur in several transitions, and so the particular new circumstances in the third line may rely on knowledge of what other agents will do: knowledge type (4) above. This joint action mechanism can also accommodate probabilities, through the use of a special "agent" (usually called "nature") the action of which will determine which state will be reached. Finally the "should" in the second line appeals to the particular preferences of the agent or audience concerned, which is determined by the value preferences found in knowledge of type (7). Thus PRAS brings together all seven of the knowledge types identified earlier.

Following Walton (1996), in Atkinson and Bench-Capon (2007) challenges to arguments take the form of so-called critical questions. Seventeen critical questions were identified and divided according to

three stages of the reasoning: problem formulation, epistemological reasoning and option selection. Much of the knowledge (types 2, 3 and 6) is hard-coded into the transition diagram, and this has to be critiqued at the problem formulation stage. Once an appropriate transition diagram has been agreed, in the epistemic stage assumptions are made to capture beliefs about the current state and what the other agents will do, i.e. knowledge of types (1) and (4). Most of the argument in Atkinson and Bench-Capon (2007) centres on disagreement as to preferences between the values, knowledge of type (7), representing different audiences (Perelman & Olbrechts-Tyteca, 1969). Arguments are generated by instantiating PRAS and its critical questions from the transition diagram and the status of these arguments is evaluated separately according to the preferences of particular audiences using a value-based argumentation framework (Bench-Capon, 2003). Although this model has proved useful in a variety of applications including law (Atkinson & Bench-Capon, 2005), medicine (Atkinson *et al.,* 2006) and e-participation (Bench-Capon *et al.,* 2015), it has some distinct limitations. First, much of the potentially questionable information is implicit in the transition diagram and so argument about what form the transition diagram should take precedes the generation of arguments and so is beyond dispute during the practical reasoning itself. A second limitation is that the goals of Atkinson and Bench-Capon (2007) are very inexpressive – essentially only subsets of states, restricting the representation of type (5) knowledge. A third limitation of Atkinson and Bench-Capon (2007) is that it allows only the immediately next state to be considered.

To address the first of these limitations we have to provide a way of justifying (i.e. arguing for) various elements of the transition diagram, while the second limitation requires a richer notion of goal, and the third a notion of the future. The first two of these problems were addressed in Atkinson and Bench-Capon (2014). In that paper the transition diagram was augmented by several logic programs. The first of these was *GProg* which intensionally defined a set of goals in terms of the basic propositions forming the states of the diagram. These goal propositions either do, or do not, hold, in a given state according to whether they or not they can be derived from the program using the basic propositions of the state as facts. This gives rise to four varieties of goal:

- achievement goals: desirable things which do not hold in the current state, but will be realised by the action;
- remedy goals: undesirable things which hold in the current state, but will be terminated by the action;

- maintenance goals: desirable things which hold in the current state, but which would cease to do so unless the action were taken;
- avoidance goals: undesirable things which do not hold in the current state, but which would occur unless prevented by some action.

Note that the above means that goals depend both on the current state and the next state. A second logic program (*VProg*) maps these goals to the promotion and demotion of values. Together these programs are able to justify claims about which goals will be achieved by a transition, and which values will be promoted by realising these goals. Similarly knowledge of type (2) can be encapsulated in a third logic program (*CProg*) which, given an assignment of truth values to the set of basic propositions representing a state, and a set of actions, one per relevant agent, will determine the assignment of truth values in the next state. Thus this causal model allows explanation of which aspects of the current state and which actions of which agents led to particular aspects of the new state, and so can form the basis of argumentation about these issues.

The third limitation, concerning the extent of look ahead, was addressed in Atkinson and Bench-Capon (2014b). In that paper consideration was extended beyond the next state, to the subsequent states. This gives rise to a further four types of goal:

- enabling goals: desirable things which do not hold in the current state, cannot be realised from the current state, but can be realised from the target state.
- risks: undesirable things which do not hold in the current state, and cannot occur in the next state but which may occur subsequently if a particular action is taken:
- assurance goals: desirable things which hold in the current state, and which will continue to do so if the action is taken;
- prevention goals: undesirable things which do not hold in the current state, and which can never occur if the action is performed.

That paper also recognised that the performance of an action may in itself promote of demote a value (e.g. we may swim for the pleasure of swimming, not to get anywhere). This gives a ninth kind of goal:

- performance goal: the action is in itself desirable and performed for its own sake.

These additional goal types allow the specification of nine kinds of reason in Atkinson and Bench-Capon (2014b), some of which have both positive and negative (arguing for the non-performance of an action) variants.

3. PRACTICAL REASONING AS PROCESS

It was further argued in Atkinson and Bench-Capon (2014b) that practical reasoning is best seen as a *process* (cf. Prakken, 2010b), as suggested by the three stages identified in Atkinson and Bench-Capon (2007). PRAS should thus be viewed as a highly compressed version of this process and its various parts can be fruitfully separated and encapsulated as a cascade of argumentation schemes each with its own characteristic critical questions. The process is shown in Figure 1.

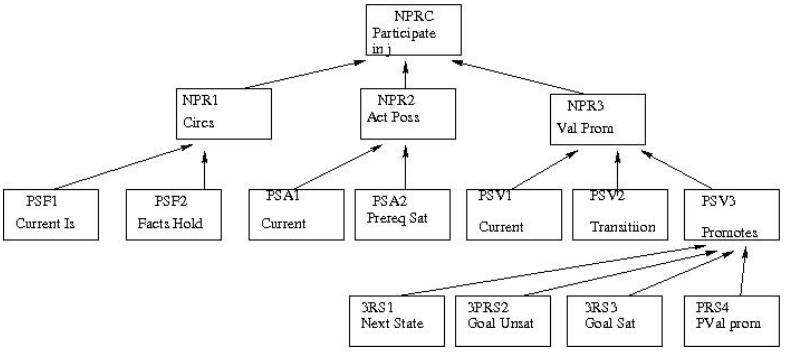

Figure1: Argumentation Schemes from Atkinson and Bench-Capon (2014b)

Thus the New Practical Reasoning Scheme (NPR) concludes that a particular joint action should be participated in on the basis of three premises: NPR1, which states the current circumstances, NPR2 which states that the action required of the agent is possible, and NPR3 which indicates the value that will be promoted by participating.

NPR1 is established on the basis that the circumstances are true of the current state, which can be established using whatever form of theoretical reasoning is appropriate to the particular propositions being questioned.

NPR2 is established by showing that the preconditions for the required action are satisfied by the circumstances.

NPR3 is established by showing the value will be promoted by moving from the current state to the state that will result from participation in the advocated action. Note that this relies on both CProg to determine the transition and its effect and VProg to demonstrate that the value is indeed promoted. The promotion of the value is itself can be established in a number of ways (using GProg) corresponding to the nine goal types listed above (one of which, the simple achievement of a

goal in the immediately next state) is shown in the third layer in Figure 1.

> NPR can be challenged in several ways:
> - It can be **rebutted**, either by offering an argument not to participate in the action, based on one of the negative variants mentioned above, or by offering an argument to participate in some other action, itself based on NPR. In either case the rebutting argument will also be based on a particular value, and acceptability will be decided by the audience according to its value preferences (Bench-Capon, 2003).
> - In some situations it may be **undercut**. As Prakken (2010a) argues, undercutters cannot be simply disregarded on the basis of value preferences: if an argument is shown to be inapplicable, then it cannot be used. Thus for undercutters, the undercutting argument must be defeated or the undercut argument withdrawn. This provides a mechanism, if desired, for some values to be given priority, so that all audiences must rank them more highly than other values. In many cases there will be no such values and so undercutters will not be used.
> - Finally the argument may be **undermined**, by showing that one of its premises is false. Thus for example an argument based on some proposition *P* being currently true, would be undermined by an argument showing that *–P*. Such arguments are not themselves based on practical reasoning and values, and so must be resolved as appropriate for the argument of the type used in the particular case. Very often such arguments will also not rely on value preferences, but will represent constraints coming from the way the world is. More detail on particular ways of undermining the various different premises is given in Atkinson and Bench-Capon (2014b).

We have presented extensions to the simple argumentation scheme of Atkinson and Bench-Capon (2007). These extensions have then been presented as a process involving several argumentation schemes, which has the effect of separating out the various types of knowledge identified in the introduction. This more complete and better articulated view allows us to choose what will be considered in the argumentation and what will be taken as agreed according to the current dialectical setting. It also enables richer and deeper disagreements, going beyond differences in preferences and priorities to fundamental conceptualisations; it enables the source of disagreement to be located quite precisely, and allows attacking arguments to be expressed more clearly using appropriate argumentation schemes.

4. FORMALISING PRACTICAL REASONING

In the work so far, the approach has been described only in semi-formal terms. Although the transition diagram itself is formally represented, and permits formal statements of argumentation schemes and critical questions, there is a need to represent the machinery uniformly in a formal framework, which will allow the formal proof of properties of the practical reasoning process advocated, such as rationality postulates (Caminada & Amgoud, 2007). A sensible choice of framework would be ASPIC+ (Modgil & Prakken, 2013), a main objective of which is "to identify conditions under which instantiations of the framework satisfy logical consistency and closure properties." (Modgil & Prakken, 2014).

There are a number of similarities between ASPIC+ and our presentation of practical reasoning which make it a good choice as our formal framework. ASPIC+ structures arguments using an argument-subargument structure which corresponds readily to the process of practical reasoning shown in Figure 1. ASPIC+ uses strict and defeasible rules of inference, and these rules correspond to the argumentation schemes sketched here and described in detail in Atkinson and Bench-Capon (2014b). ASPIC+ generates arguments from a set of knowledge bases: our programs GProg, VProg and CProg, together with the facts taken from the current state, will readily instantiate these knowledge bases.

Formally representing the process of practical reasoning in ASPIC+ will allow the demonstration that it satisfies desirable properties and will be an invaluable step towards a full implementation.

5. FUTURE WORK

In the compendium of argumentation schemes presented in Walton *et al.* (2008), there are a number of schemes which are used in practical reasoning, including a scheme from values, a scheme from positive consequences, a scheme from negative consequences, argument from goals, and argument from ends and means. These argumentation schemes are presented individually, and so it is difficult to discern their relationships to one another. Each of these schemes can be related to parts of the process we describe: We thus are able to bring together the piecemeal presentation of Walton *et al.* (2008) into a coherent whole, and better explain why particular schemes appear in various different situations. In real dialogues, there will be a measure of agreement between the parties and so the argumentation will focus on the areas of disagreement. Thus, for example, if the emphasis of the disagreement is on the causal model, we would expect to see means-ends reasoning used, whereas if the disagreement were about subjective preferences, we would expect to see some form of argument from value. By

representing our account in a formal framework, we will also be able to put the informal schemes of Walton *et al* (2008) on a formal basis.

Once the practical reasoning process has been formalisised and its properties demonstrated, we will evaluate it by reworking applications previously tackled using PRAS in these terms. Examples that can be used are:

- Law: The property law line of cases stating with Pierson v Post were represented using PRAS in Atkinson and Bench-Capon (2005). This will allow direct comparison of the effectiveness of the new schemes. Moreover this set of cases has become a de facto benchmark in AI and Law (see, e.g. Atkinson, 2012), so that comparison may also be made with other approaches.
- Medicine: A problem concerning a choice between several different drugs to medicate a heart attack was tackled using PRAS in Atkinson et al. (2006). Again this particular scenario has also been addressed in other approaches (e.g. Modgil & Fox, 2006), allowing wider comparison.
- E-Participation: PRAS was used as the basis for the two e-participation tools described in Bench-Capon et al (2015), one of which allows the user to critique a policy proposal and the other which elicits a policy proposal from the user and then supplies a critique. Both of these tools can be re-implemented to evaluate the new schemes.

This series of projects will give a firm basis for determining the value added by addressing the limitations of PRAS which formed the basis for the original implementation.

6. CONCLUDING REMARKS

Practical reasoning plays a central role in most areas of human activity. The need to choose between actions so as to further one's aims constantly arises. Law, medicine and e-participation are three areas of AI where particular attention has been paid to the topic, although it is a pervasive concern of argument and dialogue systems in general. Even where the focus is apparently on theoretical reasoning, this is often being performed in order to inform practical decision making. While approaching practical reasoning with argumentation schemes has proved fruitful, current schemes have limitations: for example the scheme of Atkinson and Bench-Capon (2007) imposes limits of expressiveness and coverage, and the schemes of Walton *et al.* (2008) are presented as a compendium of individual schemes. In this paper we have proposed ways in which the limitations of Atkinson and Bench-Capon (2007) can be removed, so as to provide a structure which can

relate the various different schemes of Walton *et al.* (2008) so as to allow a coherent account of the practical reasoning seen as a whole. Additionally, our proposal lends itself to a formal representation in a framework such as ASPIC+ (Prakken, 2010; Modgil & Prakken, 2013), which will allow formal demonstration of its properties.

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