Normative Practical Reasoning via Argumentation and Dialogue

Submission XXX

Abstract

In a normative environment an agent's actions are not only directed by its goals but also by the norms imposed on it. However, the potential conflicts within and between the agent's goals and norms makes decision-making in these frameworks a challenging task. The questions we address in this paper are: (i) how should an agent act in a normative environment? (ii) how can the agent explain why it acted in a certain way? We propose a solution in which a normative planning problem serves as the basis for a practical reasoning approach based on argumentation. The properties of the best plan(s) with respect to goal achievement and norm compliance are mapped to arguments that are used to explain why a plan is justified, using an existing proof dialogue game.

1 Introduction

Autonomous agents operating in a dynamic environment must be able to reason about actions in pursuit of their goals. An additional consideration for such agents are the *regulative* norms imposed on them that define what an agent is obliged or forbidden to do. To avoid punishment, agents must comply with norms while pursuing their goals. However, if complying with a norm hinders a more important goal or norm, the agent should consider violating it. In order to make a decision about what to do, an agent therefore needs to generate all possible courses of actions (i.e. plans) and weigh up the importance of goal achievement and norm compliance against the cost of goals being ignored and norms being violated, in different plans. Although practical reasoning frameworks that take norms into account exist (e.g., [Broersen *et al.*, 2001; Kollingbaum and Norman, 2003]), little attention has been paid to the explanation of the agents' decision making in such frameworks. Such explanation is important in several contexts, including human-agent teams and debugging agents. To address this shortcoming, we therefore propose conducting practical reasoning using argumentation.

Argumentation is a discipline that has dealt with issues of handling inconsistency and decision-making [Dung, 1995; Amgoud and Prade, 2009] for a long time. In addition, the dialogical aspect of argumentation makes it an appropriate tool to generate explanation for a decision made using this technique (e.g. [Fan and Toni, 2015; Caminada *et al.*, 2014b]). Although argumentation has been extensively used in practical reasoning (e.g., [Rahwan and Amgoud, 2006; Atkinson and Bench-Capon, 2007]), integrating the reasoning and dialogical aspect of argumentation for decision-making and its explanation is not addressed in existing approaches.

In this paper we propose an argumentation-based approach to normative practical reasoning that uses dialogue games to provide an intuitive overview of agent's reasoning. In achieving this aim, the following contributions are made: (i) we formalise a set of argument schemes and critical questions [Walton, 1996] that aim at checking the *justifiability* of plans with respect to goal satisfaction and norm compliance/violation; (ii) we offer a novel decision criterion that identifies the best plan(s) both in presence and absence of preferences over goals and norms; and (iii) we investigate the properties of the best plan(s) and propose a concrete application for the recently developed preferred dialogue games [Caminada *et al.*, 2014a] that uses these properties to generate an explanation for the justifiability of the best plan(s).

2 Model

This section introduces a model for normative practical reasoning based on STRIPS planning [Fikes and Nilsson, 1971].

Definition 1 (Normative Planning Problem)**.** A normative planning problem is a tuple $P = \langle FL, \Delta, A, G, N\rangle$ where FL is a set of fluents; $\Delta \subseteq FL$ is the initial state; A is a finite, non-empty set of durative actions; G is the set of agent goals; N is a set of action-based norms imposed on the agent.

Fluents FL is a set of domain fluents. A literal l is a fluent or its negation. For a set of literals L, we define $L^+ = \{fl \text{ s.t. } fl \in L\}$ and $L^- = \{fl \text{ s.t. } \neg fl \in L\}$. L is well-defined if $L^+ \cap L^- = \emptyset$. A state $s \subseteq FL$ is determined by those fluents *true* at a given time, other fluents are considered false. A state s satisfies literal fl, denoted as $s \models fl$, if $fl \in s$, and satisfies literal $\neg fl$, denoted $s \models \neg fl$, if $fl \notin s$.

Actions An action $a = \langle pr, ps, d\rangle$ is composed of well-defined sets of literals $pr(a)$, $ps(a)$ that represent a's pre- and postconditions and a number $d(a) \in \mathbb{N}$ representing the action's duration. Postconditions are divided into a set of add postconditions $ps(a)^+$ and a set of delete postconditions

$ps(a)^-$. An action a can be executed in a state s if its preconditions hold in that state. The postconditions of a durative action are applied in the state s at which the action ends, by adding the positive postconditions belonging to $ps(a)^+$ and deleting the negative postconditions belonging to $ps(a)^-$.

Goals *Achievement* goals need to instantaneously achieve a certain state of affairs. Each $g \in G$ is a well-defined set of literals $g = \{r_1, \cdots, r_n\}$, known as goal requirements (denoted as r_i), that should hold in order to satisfy the goal.

Norms An action-based norm is defined as a tuple $n = \langle d\_o, a_{con}, a_{sub}, dl \rangle$, where $d\_o \in \{o, f\}$ is the deontic operator denoting obligation or prohibition; $a_{con} \in A$ is the action that activates the norm; $a_{sub} \in A$ is the action that is the subject of the obligation or prohibition; and $dl \in \mathbb{N}$ is the norm deadline relative to the completion of the execution of the action a_{con}, that is the activation condition of the norm.

2.1 Semantics

Let $P = \langle FL, \Delta, A, G, N \rangle$ be a normative planning problem as described previously. Also let $\pi = \langle (a_0, 0), \cdots, (a_n, t_{a_n}) \rangle$ with $a_i \in A$ and $t_{a_i} \in \mathbb{Z}^+$ be a sequence of actions a_i executed at time t_{a_i} s.t. $\forall i < j, t_{a_i} < t_{a_j}$. The total duration of a sequence of actions is calculated as follows: $\mathit{Makespan}(\pi) = max(t_{a_i} + d(a_i))$. The execution of a sequence of actions from a given starting state $s_0 = \Delta$ brings about a sequence of states $S(\pi) = \langle s_0, \cdots s_m \rangle$ for every discrete time interval from 0 to m, where $m = \mathit{Makespan}(\pi)$. The transition relation between two states is given in Equation (1) below. If an action a_i ends at time k, state s_k results from removing all delete postconditions and adding all add postconditions of action a_i to state s_{k-1}. Thus, $\forall\ 0 < k \leq m$:

$$s_k = \begin{cases} (s_{k-1} \setminus ps(a_i)^-) \cup ps(a_i)^+ & k = t_{a_i} + d(a_i) \\ s_{k-1} & \text{otherwise} \end{cases} \quad (1)$$

***π* satisfies a goal:** if there is a state that satisfies the goal: $\pi \models g$ iff $\exists\ s_k \in S(\pi)$ s.t. $s_k \models g$. The set of satisfied goals by π is denoted as G_π.

***π* complies with an obligation:** if the action that is the subject of the obligation, a_{sub}, occurs during the compliance period (i.e. between when the condition holds and when the deadline expires):

$$\pi \models n \text{ iff } (a_{con}, t_{a_{con}}), (a_{sub}, t_{a_{sub}}) \in \pi \text{ s.t.}$$
$$t_{a_{sub}} \in [t_{a_{con}} + d(a_{con}), dl + t_{a_{con}} + d(a_{con}))$$

If a_{sub} does not occur during the compliance period, the obligation is violated: $\pi \not\models n$.

***π* complies with a prohibition:** if the prohibition's subject action a_{sub} does not occur during the compliance period:

$$\pi \models n \text{ iff } (a_{con}, t_{a_{con}}) \in \pi,\ \nexists (a_{sub}, t_{a_{sub}}) \in \pi \text{ s.t.}$$
$$t_{a_{sub}} \in [t_{a_{con}} + d(a_{con}), dl + t_{a_{con}} + d(a_{con}))$$

If a_{sub} occurs during the compliance period, the prohibition norm is violated: $\pi \not\models n$.

We assume that the norm deadlines end before $m = \mathit{Makespan}(\pi)$. Therefore, all the activated norms in π, denoted as N_π, are either complied with or violated by time m.

2.2 Conflict

In this section different types of conflicts are discussed; and it is defined which sequence of actions are identified as a plan w.r.t these conflicts. We consider a running example where an agent has the goals of going on strike, submitting a report and getting a certificate of some sort. However, if the agent goes on maternity leave, it cannot go to the office and submit the report. Moreover, if the agent goes on strike, it cannot go to office or attend any meeting.

Definition 2 (Conflicting Actions)**.** Actions a_i and a_j have a concurrency conflict iff the preconditions or postconditions of a_i contradict the preconditions or postconditions of a_j.

$$cf_{action} = \{(a_i, a_j) \text{ s.t. } \exists r \in pr(a_i) \cup ps(a_i),$$
$$\neg r \in pr(a_j) \cup ps(a_j)\}$$

Definition 3 (Conflicting Goals)**.** Goal g_i and g_j are trivially in conflict iff satisfying them requires bringing about conflicting state of affairs.

$$cf_{goal} = \{(g_i, g_j) \text{ s.t. } \exists r \in g_i, \neg r \in g_j\}$$

Example 1. $\mathit{strike} = \{\mathit{union\_member}, \neg \mathit{at\_office}, \neg \mathit{meeting\_attended}\}$ and $\mathit{submission} = \{\mathit{at\_office}, \mathit{report\_finalised}\}$ are conflicting.

Definition 4 (Conflicting Obligations and Goals)**.** $n = \langle o, a_{con}, a_{sub}, dl \rangle$ and g are trivially in conflict, if executing action a_{sub} that is the subject of the obligation, brings about postconditions that are in conflict with the requirements of g.

$$cf_{goalobl} = \{(g, n) \text{ s.t. } \exists r \in g, \neg r \in ps(a_{sub})\}$$

Example 2. strike and $n_1 = \langle o, \mathit{get\_company\_funding}, \mathit{attend\_meeting}, 2 \rangle$, where the agent is obliged to attend a meeting on behalf of the company if it uses the company funding, are in conflict, since the postconditions of $\mathit{attend\_meeting}$ prevents the agent from going on strike.

Definition 5 (Conflicting Prohibitions and Goals)**.** A prohibition norm $n = \langle f, a_{con}, a_{sub}, dl \rangle$ and a goal g are trivially in conflict, if the postconditions of a_{sub} contribute to satisfying g, but executing action a_{sub} is prohibited by norm n.

$$cf_{goalpro} = \{(g, n) \text{ s.t. } \exists r \in g, r \in ps(a_{sub})\}$$

Example 3. $\mathit{submission} = \{\mathit{at\_office}, \mathit{report\_finalised}\}$ and $n_2 = \langle f, \mathit{take\_maternity\_leave}, \mathit{go\_to\_office}, 6 \rangle$ are in conflict since taking maternity leave prevents the agent from going to the office and hence prevents fulfilling the goal of submission: $(\mathit{submission}, n_2) \in cf_{goalnorm}$.

The entire set of conflicting goals and norms is defined as: $cf_{goalnorm} = cf_{goalobl} \cup cf_{goalpro}$.

Definition 6 (Conflicting Obligations)**.** $n_1 = \langle o, a_{con}, a_{sub}, dl \rangle$ and $n_2 = \langle o, b_{con}, b_{sub}, dl' \rangle$ are in conflict in the context of π if the obliged actions in n_1, i.e. a_{sub}, and n_2, i.e. b_{sub} have a concurrency conflict; and action a_{sub} is in progress during the entire period over which the agent is obliged to execute action b_{sub}.

$$cf^{\pi}_{oblobl} = \{(n_1, n_2) \text{ s.t. } (a_{con}, t_{a_{con}}), (b_{con}, t_{b_{con}}) \in \pi;$$
$$(a_{con}, b_{sub}) \in cf_{action};$$
$$t_{a_{sub}} \in [t_{a_{con}} + d(a_{con}), t_{a_{con}} + d(a_{con}) + dl);$$
$$[t_{b_{con}} + d(b_{con}), t_{b_{con}} + d(b_{con}) + dl') \subseteq [t_{a_{sub}}, t_{a_{sub}} + d(a_{sub}))\}$$

Example 4. Due to the concurrency conflict between actions $\mathit{attend\_meeting}$ and $\mathit{attend\_interview}$, in $n_1 = \langle o, \mathit{get\_company\_funding}, \mathit{attend\_meeting}, 2 \rangle$ and $n_4 =$

$\langle o, take\_theory\_test,\ attend\_interview, 2\rangle$ and depending on the way actions are sequenced in a plan, it is possible that in some π: $(n_1, n_4) \in cf^{\pi}_{oblobl}$.

Definition 7 (Conflicting Obligations and Prohibitions)**.** An obligation $n_1 = \langle o, a_{con}, a_{sub}, dl\rangle$ and a prohibition $n_2 = \langle f, b_{con}, a_{sub}, dl'\rangle$ are in conflict in the context of π if n_2 forbids the agent to execute action a_{sub} during the entire period over which obligation n_1 obliges the agent to take a_{sub}.

$$\begin{aligned} cf^{\pi}_{oblpro} = \{&(n_1, n_2) \text{ s.t. } (a_{con}, t_{a_{con}}), (b_{con}, t_{b_{con}}) \in \pi; \\ &[t_{a_{con}} + d(a_{con}), t_{a_{con}} + d(a_{con}) + dl) \subseteq \\ &\qquad [t_{b_{con}} + d(b_{con}), t_{b_{con}} + d(b_{con}) + dl')\} \end{aligned}$$

Example 5. The obligation to, and a prohibition from $attend\_meeting$ in $n_1 = \langle o, get\_company\_funding,\ attend\_meeting, 2\rangle$ and $n_3 = \langle f, take\_maternity\_leave, attend\_meeting, 6\rangle$ can cause a normative conflict in some π: $(n_1, n_3) \in cf^{\pi}_{oblpro}$.

All together, two sets cf^{π}_{oblobl} and cf^{π}_{oblpro} constitute the set of conflicting norms: $cf^{\pi}_{norm} = cf^{\pi}_{oblobl} \cup cf^{\pi}_{oblpro}$.

Definition 8 (Plan)**.** A sequence of actions $\pi = \langle(a_0, 0), \cdots, (a_n, t_{a_n})\rangle$ is a plan for the normative planning problem $P = (FL, \Delta, A, G, N)$ iff the following conditions hold:

- The fluents in Δ (and nothing else) hold in the initial state: $s_0 = \Delta$
- the preconditions of action a_i holds at time t_{a_i} and throughout the execution of a_i:
  $$\forall k \in [t_{a_i}, t_{a_i} + d(a_i)), s_k \models pr(a_i)$$
- the set of goals satisfied by plan π is a non-empty ($G_\pi \neq \emptyset$) consistent subset of goals:
  $$G_\pi \subseteq G \text{ and } \nexists g_i, g_j \in G_\pi \text{ s.t. } (g_i, g_j) \in cf_{goal}$$
- there is no concurrency conflict between actions that are executed concurrently:
  $$\nexists (a_i, t_{a_i}), (a_j, t_{a_j}) \in \pi \text{ s.t. } t_{a_i} \leq t_{a_j} < t_{a_i} + d(a_i), (a_i, a_j) \in cf_{action}$$
- there is no conflict between norms complied with.
  $$\nexists n_i, n_j \in N_{cmp(\pi)} \text{ s.t. } (n_i, n_j) \in cf^{\pi}_{norm}$$
- there is no conflict between goals satisfied and norms complied with:
  $$\nexists g \in G_\pi \text{ and } n \in N_{cmp(\pi)} \text{ s.t. } (g, n) \in cf_{goalnorm}$$

Having defined the set of plans, Π, in the next section we deal with the issue of choosing the best plan.

3 Identifying the Best Plan

The conflict between agent's goals and norms often makes it impossible for the agent to satisfy all its goals while complying with all norms triggered in a plan. In this section we show how to treat each plan as a proposal of actions and how to use argumentation schemes to check the justifiability of a plan proposal with respect to conflicts and preferences, as a step toward identifying the best plan(s) in Section 3.2.

3.1 Argumentation Framework

An argumentation framework (AF) consists of a set of arguments and attacks between them [Dung, 1995]: $AF = \langle Arg, Att\rangle, Att \subseteq Arg \times Arg$. In scheme-based approaches [Walton, 1996] arguments are expressed in natural language and a set of critical questions is associated with each scheme, identifying how the scheme can be attacked. Below, we introduce a set of argument schemes and critical questions to reason about a plan proposal w.r.t. goals it satisfies and norms it complies with or violates.

Definition 9 (Plan Argument Arg_π)**.** A plan argument claims that the agent should execute a proposed sequence of actions because that leads to satisfying a set of goals, and complying with a set of norms, although it violates some norms:

- In the initial state Δ
- The agent should execute sequence of actions π
- Which will satisfy set of goals G_π and complies with set of norms $N_{cmp(\pi)}$ and violates set of norms $N_{vol(\pi)}$

Definition 10 (Goal Argument Arg_g)**.** A goal argument claims that a feasible goal should be satisfied:

- Goal g is a feasible [1] goal of the agent
- Therefore, satisfying g is required

The set of goal argument is denoted as Arg_G.

Definition 11 (Norm Argument Arg_n)**.** A norm argument claims that an activated norm should be complied with:

- n is an activated norm imposed on the agent in plan π
- Therefore, complying with n is required in π

The set of norm argument for a plan is denoted as Arg_{N_π}.

Critical Questions Associated with Plan Scheme

CQ1: Is there any attack from a goal argument to Arg_π? This CQ results in an undercut attack (asymmetric by nature) from a goal argument to a plan argument, when the goal is not satisfied in the plan:

$$\forall Arg_g \in Arg_G \text{ if } \pi \not\models g \text{ then } (Arg_g, Arg_\pi) \in Att$$

CQ2: Is there any attack from a norm argument to Arg_π? This CQ results in an undercut from a norm argument to a plan argument, when the norm is violated in the plan:

$$\forall Arg_n \in Arg_{N_\pi} \text{ if } \pi \not\models n \text{ then } (Arg_n, Arg_\pi) \in Att$$

Critical Questions Associated with Goal Scheme

CQ3: What goal arguments might attack Arg_g? This CQ results in a rebut attack (symmetric by definition) between arguments for conflicting goals:

$$\begin{aligned} &\forall Arg_g, Arg_{g'} \in Arg_G \\ &\qquad \text{if } (g, g') \in cf_{goal} \text{ then } (Arg_g, Arg_{g'}) \in Att \end{aligned}$$

CQ4: What norm arguments might attack Arg_g? This CQ results in a rebut attack between arguments for a goal and a norm that are in conflict:

$$\begin{aligned} &\forall Arg_g \in Arg_G, Arg_n \in Arg_{N_\pi} \\ &\qquad \text{if } (g, n) \in cf_{goalnorm} \text{ then } (Arg_g, Arg_n) \in Att \end{aligned}$$

Critical Questions Associated with Norm Scheme

CQ4: What goal arguments might attack the norm presented by Arg_n? The previous critical question, is associated with argument schemes for norms as well as goals, hence the repetition of the number of critical question.

$$\begin{aligned} &\forall Arg_g \in Arg_G, Arg_n \in Arg_{N_\pi} \\ &\qquad \text{if } (n, g) \in cf_{goalnorm} \text{ then } (Arg_n, Arg_g) \in Att \end{aligned}$$

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[1] A goal is feasible if there is at least one plan that satisfies it.

CQ5: What norm arguments might attack the norm presented by Arg_n? Conflict between two norms is defined as a contextual conflict that depends upon the context of the plan in which the norms are activated.

$$\forall Arg_n, Arg_{n'} \in Arg_{N_\pi}$$

$$\text{if } (n, n') \in cf^{\pi}_{norm} \text{ then } (Arg_n, Arg_{n'}) \in Att$$

Preferences between arguments distinguish an attack from a *defeat* (i.e., a successful attack [Amgoud and Cayrol, 2002]). The attack from one argument to another is a defeat if the latter argument is not preferred over the former. However, as discussed in [Prakken, 2012], rebuttal attacks are preference-dependent, whereas undercuts are preference-independent. Thus, attacks due to CQ3, CQ4 and CQ5 need preferences to be resolved, while attacks caused by CQ1 and CQ2 are preference independent, always resulting in defeat.

We define $\succeq^{gn}$ as a partial preorder on $G \cup N$. Symbol $\succ^{gn}$ denotes the strict relation corresponding to $\succeq^{gn}$. Also, $(\alpha, \beta) \in \sim^{gn}$ iff $(\alpha, \beta) \in \succeq^{gn}$ and $(\beta, \alpha) \in \succeq^{gn}$. The preferences between the goal and norm arguments result from the preference relation between these entities: $(Arg_\alpha, Arg_\beta) \in \succeq$ iff $(\alpha, \beta) \in \succeq^{gn}$.

An AF for a plan proposal consists of the argument for the plan itself, a set of arguments for goals and arguments for norms that are activated in that plan. Although the set of goal arguments in AFs for plan proposals remain the same across the AFs, the set of norm arguments differs from one to another depending on the norms that are activated in each.

Definition 12 (Plan Proposal AF)**.** The AF for plan proposal π is $AF_\pi = \langle Arg, Def \rangle$, where $Arg = Arg_\pi \cup Arg_G \cup Arg_{N_\pi}$ and Def is defined as: $\forall Arg_\alpha, Arg_\beta \in Arg, (Arg_\alpha, Arg_\beta) \in Def$ iff $(Arg_\alpha, Arg_\beta) \in Att_{CQ1-5}$ and $(Arg_\beta, Arg_\alpha) \notin \succ$.

The next section explains how an AF for a plan proposal is evaluated and used toward identifying the best plan(s).

3.2 Evaluating the Argumentation Framework

Argumentation semantics are a means for evaluating arguments in an AF and various semantics have been introduced since the proposal of Dung's AF [Dung, 1995]. Among these semantics credulous *preferred* is repeatedly proposed [Caminada, 2006; Prakken, 2006; Oren, 2013] to reason about and toward actions. Caminada [2006] provides an intuitive way to identify the status of arguments w.r.t. various semantics through labellings. Here, an argument is respectively, labelled in, out and $undec$, if it is acceptable, rejected and undecided under a certain semantics. In a complete labelling, an argument is labelled in iff all its attackers are labelled out, and the argument is labelled out iff there exists an attacker for it that is labelled in. A complete labelling in which the set of arguments labelled in are maximal (w.r.t. set inclusion) is a preferred labelling. Intuitively, an argument is credulously accepted under preferred semantics if it is labelled in by at least one preferred labelling.

Definition 13 (Justified Plans)**.** Plan π is justified if Arg_π is labelled in by at least one preferred labelling for AF_π: $\exists\, \mathcal{L}_{pr}$ s.t. $Arg_\pi \in in(\mathcal{L})$.

Although all justified plans are internally consistent, they can still be disagreed with externally for different reasons. That is, there might be further criteria to take into account when identifying the best plan among justified plans. We define the criteria for the best plan(s) using an established set ordering principle in argumentation, the *Democratic* principle: $(S_i, S_j) \in \trianglerighteq$ iff $\forall \beta \in S_j \setminus S_i, \exists \alpha \in S_i \setminus S_j$ s.t. $(\alpha, \beta) \in \succ$. Since the preferences over goals and norms is partial, comparing two plans based on the set of goals and norms is not always possible. Therefore, absent such preference information, the best plan(s) satisfies most goals while violating fewest norms. We start by defining the *goal-dominant* and *norm-dominant* plans, based on which a *better than* relation between plans is defined.

Definition 14 (Goal-dominance)**.** Plan π_i goal-dominates π_j denoted as $(\pi_i, \pi_j) \in \geq_G$ if:

1. $(G_{\pi_i}, G_{\pi_j}) \in \triangleright_G$; else:
2. $|G_{\pi_i}| \geq |G_{\pi_j}|$.

Definition 15 (Norm-dominance)**.** Plan π_i norm-dominates π_j denoted as $(\pi_i, \pi_j) \in \geq_N$ if:

1. $(N_{vol(\pi_i)}, N_{vol(\pi_j)}) \in \triangleright_N$; else:
2. $|N_{vol(\pi_i)}| \geq |N_{vol(\pi_j)}|$.

It is straightforward to show that $\geq_G$ and $\geq_N$ are total preorders on a set of plans Π.

Definition 16 (Plan Comparison)**.** Plan π_i is better than π_j, denoted $(\pi_i, \pi_j) \in >_\pi$, iff:

1. π_i is justified and π_j is not; or
2. π_i and π_j are both justified and $(\pi_i, \pi_j) \in >_G$; or
3. π_i and π_j are both justified and and $(\pi_i, \pi_j) \in \sim_G$ but $(\pi_j, \pi_i) \in >_N$.

Plan π_i is as good as π_j, denoted $(\pi_i, \pi_j) \in \sim_\pi$, iff $(\pi_i, \pi_j) \notin >_\pi$ and $(\pi_j, \pi_i) \notin >_\pi$.

The relation $>_\pi$ is irreflexive, asymmetric and transitive, while $\sim_\pi$ is an equivalence relation on Π.

Definition 17 (Equivalence Classes)**.** Given $\pi \in \Pi$, let $[\pi_i]$ denote the equivalence class to which π_i belongs. $([\pi_i], [\pi_j]) \in \geq$ iff $(\pi_i, \pi_j) \in >_\pi$ or $(\pi_i, \pi_j) \in \sim_\pi$.

Definition 18 (Best Plan(s))**.** Plan π_i is (one of) the best plan(s) for the agent to execute iff

- π_i is justified, and
- $\nexists \pi_j$ such that $([\pi_j], [\pi_i]) \in \geq$.

Example 6. Assume an agent with three goals $strike, submission$ (Example 1), and $\mathit{certificate} = \{\mathit{course\_fee\_paid}, \mathit{theory\_test\_done}, \mathit{interviewed}\}$ and four norms n_1, n_2, n_3, and n_4 (Examples 2, 3, 4, and 5). The agent prefers satisfying goal $submission$ to complying with norm n_2: $submission \succeq n_2$, also it prefers complying with n_4 rather than n_1: $n_4 \succeq n_1$. Let $\pi_1, \pi_2, \pi_3, \pi_4 \in \Pi$:

- $\pi_1 \models submission, N_{active(\pi_1)} = \{n_1\}, \pi_1 \models n_1$
- $\pi_2 \models submission, \mathit{certificate}, N_{active(\pi_2)} = \{n_1, n_4\}, \pi_2 \models n_4, \pi_2 \not\models n_1$
- $\pi_3 \models submission, \mathit{certificate}, N_{active(\pi_3)} = \{n_1, n_2, n_3, n_4\}, \pi_3 \models n_3, n_4, \pi_3 \not\models n_1, n_2$
- $\pi_4 \models strike, \mathit{certificate}, N_{active(\pi_4)} = \{n_1, n_2, n_3, n_4\}, \pi_4 \models n_2, n_3, n_4, \pi_4 \not\models n_1$.

Figure 1 displays the argumentation graph associated with each of these plans [2]. Plan π_1 is not justified, whereas π_2, π_3 and π_4 all are. Thus, the first condition in Definition 18 holds for the last three plans. Since the preferences provided over goals and norms is minimal, in this example the number of goals satisfied and norms violated determines the best plans as follows: although $|G_{\pi_2}| = |G_{\pi_3}| = |G_{\pi_4}|$, $|N_{vol(\pi_2)}| = |N_{vol(\pi_4)}| < |N_{vol(\pi_3)}|$. Therefore, $\pi_2 \succ \pi_3$, $\pi_4 \succ \pi_3$, and $\pi_2 \sim \pi_4$, which makes π_2 and π_4 the best plans.

3.3 Properties

First, we confirm the satisfaction of rationality postulates [Caminada and Amgoud, 2007]. Second, we investigate the properties of the best plan(s) and the preferred extensions that include it.

Property 1. *Closure: The conclusions of any extension (in labelled arguments) are closed under strict rules.*

Proof. Plan, goal and norm arguments are built based on defeasible rules (schemes). With no strict rules the property follows immediately.

Property 2. *Direct Consistency: The conclusions of any extension are consistent.*

Proof. Suppose the conclusions of the extension E are inconsistent, i.e., there are arguments $Arg_\alpha, Arg_\beta \in E$ such that:
- Arg_α's conclusion requires executing plan π and Arg_β's conclusion requires satisfying goal g/complying with norm n, while g is not satisfied/n is violated in π. Thus, Arg_β defeats Arg_α; E is not conflict-free and cannot be an extension.
- Arg_α's conclusion requires satisfying goal g/complying with norm n and Arg_β's conclusion requires satisfying goal g/complying with norm n', while g/n and g'/n' are inconsistent. Thus, Arg_α attacks Arg_β and vice versa. Due to the preferences, at least one of these attacks is identified as defeat and therefore E is not conflict-free and not an extension.

Property 3. *Indirect Consistency: The closure under strict rules of the conclusions of any extension is consistent.*

Proof. With no strict rules the property follows immediately.

Property 4. *If a plan argument is labelled in by preferred labelling $\mathcal{L}$, the arguments representing all the goals that it does not satisfy and norms it violates are labelled out by $\mathcal{L}$ and vice versa:*
$Arg_\pi \in in(\mathcal{L}) \Leftrightarrow Arg_{g \in G \setminus G_\pi} \cup Arg_{n \in N_{vol(\pi)}} \subseteq out(\mathcal{L})$.

Proof. Every preferred labelling is a complete labelling. An argument is labelled in by a complete labelling iff all its attackers are labelled out. Therefore, a plan argument is labelled in by a preferred labelling iff all its attackers, namely the arguments for goals that it does not satisfy and norms that it violates, are labelled out by that labelling.

Property 5. *If a plan argument is labelled in by preferred labelling $\mathcal{L}$, the arguments representing all the goals that it satisfies and norms it complies with are also labelled in:*
$Arg_\pi \in in(\mathcal{L}) \Rightarrow Arg_{g \in G_\pi} \cup Arg_{N_{cmp(\pi)}} \subseteq in(\mathcal{L})$.

Proof. Since $Arg_\pi \in in(\mathcal{L})$, from Property 4 we know that $Arg_{g \in G \setminus G_\pi} \cup Arg_{n \in N_{vol(\pi)}} \subseteq out(\mathcal{L})$. We also know from the definition of a plan that $Arg_{g \in G_\pi} \cup Arg_{n \in N_{cmp(\pi)}}$ is conflict free. Since all possible attackers of $Arg_{g \in G_\pi} \cup Arg_{n \in N_{cmp(\pi)}}$ belong to $Arg_{g \in G \setminus G_\pi} \cup Arg_{n \in N_{vol(\pi)}}$ and $Arg_{g \in G \setminus G_\pi} \cup Arg_{n \in N_{vol(\pi)}}$ are all labelled out, we conclude that $Arg_{g \in G_\pi} \cup Arg_{n \in N_{cmp(\pi)}} \subseteq in(\mathcal{L})$.

Note that from $Arg_{g \in G_\pi} \cup Arg_{n \in N_{cmp(\pi)}} \subseteq in(\mathcal{L})$ one cannot conclude that $Arg_\pi \in in(\mathcal{L})$, as there might be justified goals or norms not satisfied/complied with in the plan.

Property 6. *There is no more than one preferred labelling in which $Arg_\pi \in in(\mathcal{L})$.*

Proof. From Property 4 and 5 we know that if $Arg_\pi \in in(\mathcal{L})$ then $Arg_{g \in G \setminus G_\pi} \cup Arg_{n \in N_{vol(\pi)}} \subseteq out(\mathcal{L})$ and $Arg_{g \in G_\pi} \cup Arg_{n \in N_{cmp(\pi)}} \subseteq in(\mathcal{L})$. Since every preferred labelling is a complete labelling and the following property holds for complete labellings: if $out(\mathcal{L}_{cmp1}) = out(\mathcal{L}_{cmp2})$ then $\mathcal{L}_{cmp1} = \mathcal{L}_{cmp2}$; we conclude that there is no more than one preferred labelling in which $Arg_\pi \in in(\mathcal{L})$.

Property 7. *If $Arg_\pi \in in(\mathcal{L})$, $\mathcal{L}$ is a stable labelling.*

Proof. In Property 4 we showed that if $Arg_\pi \in in(\mathcal{L})$ then $Arg_{g \in G \setminus G_\pi} \cup Arg_{n \in N_{vol(\pi)}} \subseteq out(\mathcal{L})$ and $Arg_{g \in G_\pi} \cup Arg_{n \in N_{cmp(\pi)}} \subseteq in(\mathcal{L})$, which makes the $undec(\mathcal{L}) = \emptyset$. A preferred labelling with $undec(\mathcal{L}) = \emptyset$ is a stable labelling. Therefore, $\mathcal{L}$ is a stable labelling.

Property 8. *Let $\succeq^{gn}$ be a total preorder on $G \cup N$ and therefore $\succeq$ be a total preorder on goal and norm arguments. If $Arg_\pi \in in(\mathcal{L})$, and the set of arguments for the most preferred goals and norms, $Pref(Arg)$, is conflict free, all arguments belong to $Pref(Arg)$ are labelled in by $\mathcal{L}$.*

Proof. Elements of set $Pref(Arg)$ cannot be defeated, since the set itself is conflict-free and the rest of arguments belong to $Arg \setminus Pref(Arg)$ cannot defeat elements of $Pref(Arg)$, since that implies an attack from a less preferred argument to a more preferred one has resulted in a defeat, which is contrary to assumption. Assume that $\exists Arg_\alpha \in Pref(Arg)$ such that $Arg_\alpha \notin in(\mathcal{L})$. If $\nexists Arg_\beta \in in(\mathcal{L})$ s.t. $(Arg_\alpha, Arg_\beta) \in Def$ then Arg_α should have been labelled in by $\mathcal{L}$ otherwise it is contrary to the assumption of maximality of preferred labellings. If $\exists Arg_\beta \in in(\mathcal{L})$ s.t. $(Arg_\alpha, Arg_\beta) \in Def$ then $\exists Arg_\gamma \in in(\mathcal{L})$ s.t. $(Arg_\gamma, Arg_\alpha) \in Def$, which is contradictory to the fact that Arg_α cannot be defeated. Therefore, all elements of $Pref(Arg)$ are labelled in by $in(\mathcal{L})$.

4 Explaining the Justifiability of the Best Plan

In this section we exploit an existing dialogue for preferred semantics known as *Socratic Discussion* [Caminada *et al.*, 2014a] to provide an explanation for the justifiability of the best plan(s). Deciding if an argument is in at least one preferred extension amounts to deciding if it is at least in one admissible extension (i.e. it is labelled in by at least one admissible labelling). In an admissible labelling if an argument is labelled in, all attackers are labelled out, and if an argument is labelled out, it has an attacker that is labelled in.

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[2] st, sub and cer in these figures stand for $strike$, $submission$ and $certificate$, respectively.

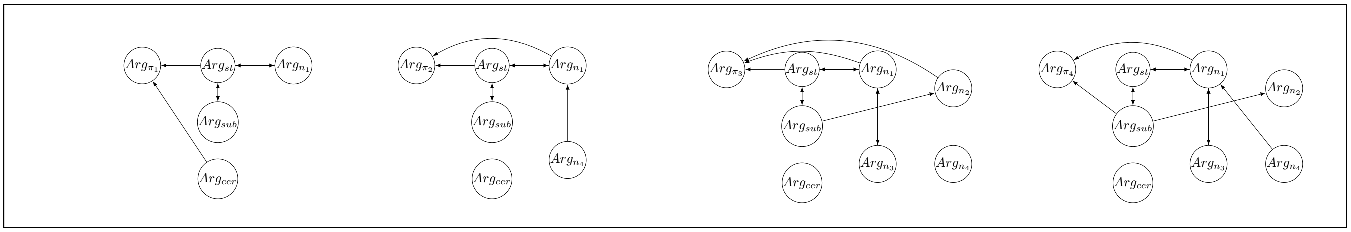

Figure 1: Argumentation Graph for Plans $\pi_1, \pi_2, \pi_3, \pi_4$

Definition 19 (Socratic Discussion [Caminada *et al.*, 2014a])**.** Let $AF = \langle Arg, Def \rangle$. The sequence of moves $[\Delta_1, \Delta_2, \cdots, \Delta_n]$ $(n \geq 1)$ is a Socratic discussion iff: (i) each odd move (M-move) is an argument labelled in; (ii) each even move (S-move) is an argument labelled out; (iii) each argument moved by S attacks an argument moved by M earlier in the dialogue; (iv) each argument moved by M attacks an argument moved by S in the previous step; (v) S-moves cannot be repeated. Player S wins the discussion if there is an M-move and an S-move containing the same argument. Otherwise, the winner is the player that makes the last move.

Given that the agent's best plans(s) π is labelled in by at least one preferred labelling, player M is guaranteed a winning strategy in a Socratic discussion with $\Delta_1 = in(Arg_\pi)$. The even moves in the rest of dialogue are arguments labelled out, which according to Property 4 are goals not satisfied or norms violated in π. On the other hand, the rest of odd moves in the dialogue are arguments labelled in, which according to Property 5 are goals satisfied or norms complied with in π. Since each odd move attacks the even move in the previous step, during a dialogue the agent is able dialectically to explain why it did not satisfy a goal or violate a norm, which are the two causes of attacks to the plan proposals.

Example 7. This example shows a Socratic discussion $\Delta = [in(Arg_{\pi_4}), out(Arg_{sub}), in(Arg_{st}), out(Arg_{n_1}), in(Arg_{n_4})]$ for plan π_4.
- M: Plan π_4 is (one of) the best plan(s) and is justifiable.
- S: Why does the plan not satisfy goal $submission$?
- M: Because the plan satisfies goal $strike$ that attacks goal $submission$.
- S: Why does the plan violate norm n_1?
- M: Because the plan satisfies norm n_4 that attacks norm n_1.

5 Related Work

One of the most well-known scheme-based approach in practical reasoning is [Atkinson and Bench-Capon, 2007]. Recently, [Oren, 2013] has proposed a similar scheme-based approach for normative practical reasoning, but unlike [Atkinson and Bench-Capon, 2007] arguments are constructed for a sequence of actions rather than every single action. As a result the schemes are simpler. Similar to the latter approach, in this paper, arguments are constructed for plans rather than actions. [Oren, 2013] assumes that the conflicts within and between goals and norms are inferred from paths, rather than being formulated at the formal model level. Thus, although it is possible to explain why a path is more preferred over another one, it is not possible to underpin why a path does not satisfy a goal or violate a norm. In contrast, we explicitly concern ourselves with why the agent does not satisfy a goal or violate a norm. In addition, in this work the explanation of justifiability of why a plan is (one of) the best plan(s) for the agent to execute is formulated using a dialogue game for preferred semantics.

There are few applications of dialogue games that use the dialogues for explanation purposes [Zhong *et al.*, 2014; Fan and Toni, 2015; Caminada *et al.*, 2014b]. In [Zhong *et al.*, 2014] and [Fan and Toni, 2015] admissible dispute trees developed for Assumption-based Argumentation [Dung *et al.*, 2009] are used to provide explanation for why a certain decision is better than another one. In [Caminada *et al.*, 2014b] a dialogical proof procedure based on the grounded semantics dialogue game [Caminada and Podlaszewski, 2012] is created to justify the actions executed in a plan. Despite the popularity of the preferred semantics, they have not been used in applications in the past. Our work proposes a concrete application of preferred dialogue games in a practical reasoning domain.

6 Conclusion and Future Work

Argumentation has been used to study practical reasoning and decision-making in the past [Zhong *et al.*, 2014; Rahwan and Amgoud, 2006; Amgoud and Prade, 2009; Oren, 2013]. In contrast to existing approaches, we propose a framework that integrates the reasoning and dialogical aspects of argumentation to undertake normative practical reasoning. The question of how should an agent act in a normative environment while it has conflicting goals and norm is answered using argumentation-based reasoning. Moreover, the question of how can the agent can generate explanation for why it acted a certain way, is answered using an argumentation-based dialogue.

In the current approach the conflict within goals and between goals and norms is addressed trivially. Similar to conflicts between norms, these two types of conflicts can be addressed temporally, hence enriching the conflict detection. This is left for future work. Another interesting direction of future work is testing empirically if providing explanation, in particular in natural language, in practical reasoning domain raises the likelihood of human users accepting the recommendation of the system regarding the best plan(s).

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