On Meta-norms as Use Policies Constraining Contracts and Contract Requirements

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Abstract

In multi-agent organizations, contractual obligations and prohibitions are important for governing autonomous agents. However, agents may only wish to participate in an organization if the contracts they engage in respect and satisfy their policies specifying how the agent may be used, we call these use policies and they specify what norms may be imposed on them in a contract and what norms must be imposed on the contractual counter-parties. To address this, we propose a representation of use policies as sets of meta-norms constraining the norms that may be imposed on the agents with use policies. We then consider, given a bilateral contract formed between a client and an agent wishing to enact a role, the properties of a correct contract with respect to the use policy of the role enacting agent. This means we can analyse contract formation processes in the face of use policies.

1 Introduction

Autonomous agents, by definition, cannot be controlled directly, only influenced in their actions [18]. Thus, in order for agents to collectively perform useful tasks, norms have long been used in multi-agent systems to influence agents' decision making by imposing obligations and prohibitions on them (e.g. [4, 9, 13–15]). Meanwhile, mechanisms of compliance checking and governance have been used to ensure agents have reason to abide by norms (e.g. [10–14, 16]).

Agents may be bound to organizational roles with contracts, represented as sets of norms. Yet, agents may also have policies placed on them constraining what they may agree to in a contract, we call these use policies. We view use policies as sets of meta-norms specifying what norms ought to be and not be in a contract for contractual agreement to take place (e.g. forbidding obligations being imposed on an agent, or obligating obligations being imposed on counter-parties, such as for payment). Thus, before an agent agrees to a contract it may need to check the contractual norms with its use policy, furthermore, the contract may need to be adapted to accommodate the agent's use policy by adding, modifying or removing norms.

For a contract to be compliant with a use policy, a set of requirements must be met that ensure contractual norms do not violate meta-norms in a use policy. In this paper we contribute such a set of requirements for checking contract compliance with respect to use policies together, we also contribute representations of norms and meta-norms.

In related work, Boella et al. [2,3] propose a framework for meta-norms, arguing meta-norms are needed if there is a hierarchy of authorities, one authority guiding the other in legislation. In our case, we have a hierarchy of authorities, the authority specifying a use policy guides the authority forming the contract. Meanwhile, Brown [5] formalizes a type of norm that may act as an exception to other norms, thus somewhat getting towards the notion of use policies we aim at. Further afield, work on automated contracting (e.g. [6,7]) considers contracting as a lifecycle of negotiation and enactment. However, in none of the aforementioned work do they consider the acceptance and rejection of contracts or the application of meta-norms as use policies.

In this paper we provide a representation of norms and define role templates as an input in a role-enactment contract formation process (Section 2.1). Then, we give a representation for meta-norms over the language of norms (Section 2.2). To define the contract correctness properties, we first define the role enactment contracts (a set of norms), then a means to compare object-level norms, finally we use comparisons of norms to determine when norms in a role enactment contract are not in conflict with the meta-norms of a use policy (Section 3). In Section 4 we assess the proposed requirements with examples of correct and incorrect contracts. Finally, in Section 5 we discuss the implications of the requirements we propose and areas of future work.

2 A Language of Norms for Agent Behaviour, Role Templates and Agent Use Policies

In this section we define a language of norms needed for our definitions of role templates (the first input in contract formation), and contracts. We then give a language of meta-norms over the language of norms, to be used to construct meta-norms in agent use policies (the second input to contract formation).

2.1 Norm Specification Languages and Role Templates

In the following we assume a domain language $\mathcal{L}$ of all the propositional formulae for a given domain. We also assume the following mutually disjoint infinitely countable sets: the set of constant symbols $\mathcal{A}_{\mathcal{C}}$ denoting agents; the set of constant symbols $\mathcal{R}$ denoting roles and the set of variable symbols $\mathcal{A}_V$ denoting agent variables. We assume the domain language is used to express states of affairs and not actions, thus we respectively focus on ought-to-be and not ought-to-do.

We give a language for specifying norms N^S over an assumed domain $\mathcal{L}$ for a set of subjects S (roles and agents). The language is used to express existing norms that apply to agents in role enactment contracts or are included in templates of roles (as input for forming contracts before they are enacted). An example is introduced to give an idea of how the shortly following definition of the normative language may be used.

Example 1. *(Precipitation) Suppose an agent, `client`, wishes to establish a contract where an agent playing an organizational role Precip_Role must provide it with data on the local precipitation ($precipitation\_data$) before one time interval has passed (interval(1)). The client wishes to establish a contract with norms that appropriately guide an agent, `sensor_resource`, playing the role of precipitation gatherer into fulfilling this task.*

In our representation language a norm specifies who it applies to, the deontic type (obligation or prohibition), the aim of the norm that is obligated/prohibited, when the norm is detached (the condition) and a deadline of the norm. There are many other possible representations of norms which we do not discuss here but instead refer to the following literature survey [1].

Definition 1. *(Language of Norms). We define the language of norms $\mathcal{N}^S$ parametrised with the set of agent and role symbols $S \subseteq \mathcal{A}_{\mathcal{C}} \cup \mathcal{R}$, as the set of norms of the form $\mathrm{d}_{de:cr}(\rho, \alpha, \delta)$ denoting that if the state ρ holds the debtor de is obligated/prohibited (given by d) towards the creditor cr to ensure the obligated/prohibited state α holds before the deadline state δ holds. Where:*

- $d \in \{O, F\}$ *specifies a deontic type of either obligation (O) or prohibition (F).*
- $de, cr \in S$ *denote the agent or role enacted by an agent to which the norm is directed and to which the norm serves, respectively, s.t. $de \neq cr$.*
- $\rho \in \mathcal{L} \cup \{\top\}$ *is the condition.*
- $\alpha, \delta \in \mathcal{L} \cup \{\bot\}$ *are the states the agent/role de is obligated or prohibited to see to and the deadline of the norm, respectively.*

Taking the previous example, the following norm expresses an obligation with no condition, for gathering precipitation data before a temporal deadline:

$$O_{\textit{Precip\_Role:Client\_Role}}(\top, \textit{precipitation\_data}, \textit{interval(1)})$$

We define role templates as input for forming contracts. These specify the set of norms an agent enacting the role, the debtor, would commit to and the creditor the role serves. In the case of the debtor, the symbol identifying the agent that will play the role is unknown *a priori*, so in the role template's norms the name of the role is used as a place holder for the debtor agent.

Definition 2. *(Role Template). A role template is a tuple* (r, a, N) *where:*

- $r \in \mathcal{R}$ *is a label of the role.*
- $a \in \mathcal{A}_{\mathcal{C}}$ *is the creditor to which the agent enacting the role serves.*
- $N \subseteq \mathcal{N}^{\{r,a\}}$ *is a set of norms that apply to the role s.t.* $\forall d_{\textit{de:cr}}\varphi \in N : \textit{de} = r \wedge \textit{cr} = a$.

For example, the role template $T = (\texttt{Precip\_Role}, \texttt{client}, N_{pr})$ describes a role for gathering precipitation data on behalf of a client agent.

$$\begin{aligned} N_{pr} = \{&O_{\textit{Precip\_Role}:\texttt{client}}(\top, \textit{precipitation\_data}, \textit{interval(1)})), \\ &F_{\textit{Precip\_Role}:\texttt{client}}(\top, \textit{turn\_device\_off}, \textit{fulfilled(obj1)} \vee \textit{violated(obj1)}), \\ &O_{\textit{Precip\_Role}:\texttt{client}}(\textit{violated(obj1)} \vee \textit{violated}(pro1), \textit{paid}, \textit{interval(1)}))\} \end{aligned}$$

2.2 Meta-norms and Agent Use Policies

Meta-norms allow use policies to be defined for agents, specifying what is required in a contract for a contractual agreement to take place. Meta-norms are appropriate for this task because they can be used to describe what norms are obligated and prohibited from being in a contract. We define a meta-norm language first and then the notion of the use policy as a set of meta-norms.

Unlike object-level norms and for simplicity meta-norms have no deadlines. Meta-norms constrain the single action of forming a contract. Thus, the implicit deadline of a meta-norm is the formation of the contract and no explicit deadline is required.

There are two different concepts that may be expressed in the language of meta-norms:

- **Obligatory obligations and prohibitions** defining those norms that must be imposed by the organization. For example, an agent's use policy may stipulate that if the agent is obliged to perform some work, another agent must be obliged to pay it.
- **Prohibited obligations and prohibitions** specifying what may not be imposed on the agent. These guide the legislator (in this case the authority forming the contract) in what they may prohibit or obligate.

All meta-norms may have an object-level norm acting as a condition, that is, the meta-norm is only in effect if a particular object-level norm is in the contract.

The syntax of meta-norms is given below, capturing the aforementioned concepts by nesting a norm acting as a condition and a norm acting as an aim within an obligation or a prohibition. For simplicity, the language limits meta-norms to just one level of nesting:

Definition 3. *(Language of Meta-Norms). The language of meta-norms* $\mathcal{MN}^S$ *is defined as a set of meta-norms over a language of norms* $\mathcal{N}^S$. *A meta-norm mn* $\in \mathcal{MN}^S$ *is defined as:*

$$\textit{mn} ::= d(n, n')$$

Where:

- $n \in \mathcal{N}^S \cup \{\varepsilon\}$ *is either a norm or empty and* $n' \in \mathcal{N}^S$ *is a norm.*
- $d \in \{O, F\}$ *is the deontic type.*
- $d(n, n')$ *indicates that on the condition either norm* n *is imposed or* n *is empty, then it is obligatory/prohibitory for norm* n' *to be imposed.*

Finally, we define an agent's use policy as a a set of meta-norms:

Definition 4. *(Agent Use Policy). Let* $a \in \mathcal{A}_{\mathcal{C}}$ *identify the agent with the use policy,* $MN \subseteq \mathcal{MN}^{\{a\} \cup \mathcal{A}_{\mathcal{C}} \cup \mathcal{A}_{\mathcal{V}}}$ *be the set of meta-norms constraining what should and should not be in a contract for the agent* a *to agree to it, an agent use policy is a tuple* (a, MN).

3 Role Enactment Contracts and Correctness

A role enactment contract is a set of norms given in a role template and possibly further norms as demanded by a use policy. If in the role template used to construct the contract the subject of a norm was the role name, in the contract this becomes the agent enacting the role.

Definition 5. *(Role Enactment Contract). Given a role template* $T = (r, a, N)$*, a symbol denoting the agent enacting the role* $a' \subseteq \mathcal{A}_{\mathcal{C}}$*, a role enactment contract rec(*a', T*)* $\subseteq \mathcal{N}^{\{a, a'\}}$ *is a contract binding an agent to the role. The role identifier in the template's norms is replaced with the identifier of the role enacting agent:*

$$\forall d_{de:cr}\varphi \in N, \exists d_{de':cr}\varphi \in rec(a', T) : de' = a'$$

For example, for some role template *pr_templ* the role enactment contract $C = rec($`sensor_resource`$, pr\_templ)$ may be described as:

$$C = \{O_{\texttt{sensor\_resource:client}}(\top, precipitation\_data, interval(1))),$$
$$F_{\texttt{sensor\_resource:client}}(\top, turn\_device\_off, fulfilled(obj1) \vee violated(obj1))$$

3.1 Norm Entailment

Use policies state what norms ought and ought not be in a contract. To analyse a contractual norm's compliance with a meta-norm, a comparison with the norms acting as antecedents and consequences of meta-norms and the contractual norm is needed. The comparison needs to determine whether when the duties of a norm n are detached the same duties are also detached from the norm n' for the same agents. If it is the case that the same duties are detached and the norm n is the consequence of an obligatory meta-norm, then the norm $n\prime$ can be said to be compliant with the meta-norm. On the other hand, if the norm n is the consequence of a prohibitive meta-norm (and the antecedent holds), the norm n' is said to be non-compliant with the meta-norm.

When making such comparisons, we are not interested in whether norms are identical (i.e. that *only* the same duties are detached by two norms in *only* the same contexts). To illustrate why, take a meta-norm in a use policy stating there must be an obligation for the agent receiving services to pay the agent supplying the services. This norm is satisfied by any object-level norm in a contract that obligates payment in return for services. However, the meta-norm is also satisfied by any non-identical norm that obligates further duties, for example both payment and gratitude for services. Furthermore, the meta-norm is satisfied by an object level-norm that obligates the same duties in additional contexts, for example obligating payment when services are provided or when it is Wednesday. We thus define the notion of norm *entailment*, where one norm n entails another norm n' if *at least* all the duties of n are detached by n' in *at least* the same contexts.

A further consideration in norm entailment is its negation. If, for example, it is prohibited for an agent to be prohibited from turning its device off when it is in Rotterdam, then the existence of a norm where the

agent is prohibited from turning the device off when it is Wednesday will mean that the agent is prohibited from turning its device off when it is in Rotterdam if it is also Wednesday. This is undesirable even though the detachment of the prohibition was not *caused* by it being in Rotterdam. Thus, we also introduce a stronger version of negated norm entailment.

The notions are formalized in terms of obligations, so we define equality between an obligation and a prohibition. The definition of equality is based on the following intuitions: compliance with an active obligation requires either the aim being *achieved* or the deadline being *maintained* to the contrary. Conversely, for an active prohibition compliance requires either the aim being *maintained* to the contrary or the deadline being *achieved*. This means that, for example, a prohibition to turn a sensor off until the sensor has collected data is equivalent to an obligation to collect data before the sensor is turned off.

Thus, we define equality between prohibitions and obligations as the switching of the aim and the deadline. This differs from Von Wright's [17] definition, where a prohibition is equivalent to an obligation to the contrary. The discrepancy is due to our norms having deadlines. A prohibition of an aim before a deadline is not equivalent to the obligation of the negation of the same aim before the same deadline. Otherwise, we would also expect an obligation to achieve a state before a deadline to be contradictory to an obligation to achieve the negation of the same state, before the same deadline. Yet, for example, in the Logic for Contract Representation formalism of the OperA framework [8], there is no such contradiction.

Before formalizing norm entailment, we illustrate the intuitions with some examples, where $\vdash_D$ denotes a norm entails another norm. An obligation to pay a fine when a particular norm has been violated entails a norm with the same aim but which may also be detached under other conditions.

$$O_{\texttt{Precip\_Role:client}}(\textit{violated}(\textit{obj1}), paid, \textit{interval(1)}) \vdash_D$$
$$O_{\texttt{Precip\_Role:client}}(\textit{violated}(\textit{obj1}) \vee \textit{violated}(\textit{pro1}), paid, \textit{interval(1)})$$

A norm obligating the payment of a fine before one time interval entails a norm that obligates the payment of the fine and apologising (i.e. further duties) with a deadline of one time interval passing or leaving the jurisdiction (i.e. stricter deadlines).

$$O_{\texttt{Precip\_Role:client}}(\textit{violated}(\textit{obj1}), paid, \textit{interval(1)}) \vdash_D$$
$$O_{\texttt{Precip\_Role:client}}(\textit{violated}(\textit{obj1}), \textit{paid} \wedge \textit{apologise}, \textit{interval(1)} \vee \textit{left\_jurisdiction})$$

We formalize norm entailment and equality between obligations and prohibitions ($\equiv_D$) with a proof system using propositional logic's syntactic consequence $\vdash$. The following intuitions are for two norms n_1 and n_2. $(E1)$ states n_1 entails n_2 so long as the subjects are not different and n_2 is detached in at least the same contexts, has at least the same duties and has at least the same deadline. $(E2)$ states that n_1 does not entail n_2 in the strong sense if the subjects are different, or the same aims and deadlines are never detached in the same context (i.e. they are different or the conditions are contradictory). $(E3)$ is equality between prohibitions and obligations. $(E4)$ specifies a pair of a debtor and creditor entails another such pair so long as the subjects have the same symbols or are variables.

Definition 6. *(Norm Entailment and Equivalence). Let $n, n' \in \mathcal{N}^S_{\mathcal{L}}$, be two norms, $de, de', cr, cr' \in \mathcal{A}_{\mathcal{C}} \cap \mathcal{A}_{\mathcal{V}} \cap \mathcal{R}$ be subjects, the definitions of norm entailment, equivalence and subject entailment, respectively denoted with $n \vdash_D n'$, $n \equiv_D n'$ and (de, cr) $\vdash_S (de', cr')$, are defined as below:*

$$(E1)\quad O_{de:cr}(\rho, \alpha, \delta) \vdash_D O_{de':cr'}(\rho', \alpha', \delta') \quad \Leftrightarrow \quad \textit{(de, cr)} \vdash_S (de', cr') \textit{ and } \rho \vdash \rho' \textit{ and } \alpha' \vdash \alpha \textit{ and } \delta \vdash \delta'$$

$$(E2)\quad \textit{not}(O_{de:cr}(\rho, \alpha, \delta) \vdash_D O_{de':cr'}(\rho', \alpha', \delta')) \quad \Leftrightarrow \quad (de, cr) \nvdash_S (de', cr') \textit{ or } \rho' \vdash \neg\rho \textit{ or } \alpha' \nvdash \alpha \textit{ or } \delta \nvdash \delta'$$

$$(E3)\quad F_{de:cr}(\rho, \alpha, \delta) \equiv_D O_{de':cr'}(\rho', \alpha', \delta') \quad \Leftrightarrow \quad de = de' \textit{ and } cr = cr' \textit{ and } \rho \equiv \rho' \textit{ and } \alpha \equiv \delta' \textit{ and } \delta \equiv \alpha'$$

$$(E4)\quad \textit{(de, cr)} \vdash_S (de', cr') \quad \Leftrightarrow \quad (de = de' \textit{ or } de \in \mathcal{A}_{\mathcal{V}} \textit{ or } de' \in \mathcal{A}_{\mathcal{V}}) \textit{ and } (cr = cr' \textit{ or } cr \in \mathcal{A}_{\mathcal{V}} \textit{ or } cr' \in \mathcal{A}_{\mathcal{V}})$$

We now define the correctness of the contract with respect to the definition of norm entailment. The property *MObl(C, UP)* asserts that all the obligatory obligations specified in the use policy must be respected in the contract. The property *WMPro(C, UP)* asserts that the prohibition of norms must be weakly respected such that for any prohibited norm in the use policy and a norm in the contract with at least the same duties and deadlines, they must not have the same conditions. The property *SMPro(C, UP)* is the strong version of the previous property. It states that for any prohibited norm in the use policy and a norm in the contract with the same duties and deadlines, the conditions must be contradictory.

The consequent of a meta-norm may be *collectively* entailed by several norms in a contract. For example, an obligatory obligation to be paid and thanked for services is collectively satisfied by one norm that obliges payment and another that obliges thanking for services. Thus, to make pair-wise comparisons we ensure previously independently defined norms are represented as single norms by introducing the closure of the set of contractual norms.

Definition 7. *(Role Enactment Contract Correctness). Let T be a role template (r, a, N), UP be a use policy (a, MN), C a role enactment contract rec(a', T) and the set C' be the closure of the set C under logical equivalence, the relation $\equiv_D$ previously introduced and the following rules*

$$\frac{O_{de:cr}(\rho, \alpha, \delta) \quad O_{de':cr'}(\rho', \alpha, \delta) \quad (de,\ cr) \vdash_S (de', cr')}{O_{de:cr}(\rho \vee \rho', \alpha, \delta)}\ \textit{Disjoined Conditions}$$

$$\frac{O_{de:cr}(\rho, \alpha, \delta) \quad O_{de':cr'}(\rho, \alpha', \delta) \quad (de,\ cr) \vdash_S (de', cr')}{O_{de:cr}(\rho, \alpha \wedge \alpha', \delta)}\ \textit{Conjoined Aims}$$

$$\frac{O_{de:cr}(\rho, \alpha, \delta) \quad O_{de':cr'}(\rho, \alpha, \delta') \quad (de,\ cr) \vdash_S (de', cr')}{O_{de:cr}(\rho, \alpha, \delta \vee \delta')}\ \textit{Disjoined Deadlines}$$

The properties MObl(C, UP), WMPro(C, UP) and SMPro(C, UP) for contract correctness are:

$$\begin{aligned}
\textit{MObl(C, UP)} &\Leftrightarrow \forall O(n, n') \in MN, \exists n'' \in C'(n = \varepsilon \vee n \vdash_D n'') \rightarrow \exists n''' \in C'(n' \vdash_D n''') \\
\textit{WMPro(C, UP)} &\Leftrightarrow \forall F(n, n') \in MN, \exists n'' \in C'(n = \varepsilon \vee n \vdash_D n'') \rightarrow \forall n''' \in C'(n' \nvdash_D n''') \\
\textit{SMPro(C, UP)} &\Leftrightarrow \forall F(n, n') \in MN, \exists n'' \in C'(n = \varepsilon \vee n \vdash_D n'') \rightarrow \forall n''' \in C'[\textit{not}(n' \vdash_D n''')]
\end{aligned}$$

4 Examples of Correctness

We give the idea of how meta-norms constrain contracts and the definitions of correctness with an example of an incorrect contract, followed by a correct version. We recall a contract may be produced from a role template by way of Definition 5, where its set closure may be produced by way of Definition 7. The contract $C \supseteq$ *rec(*`sensor_resource`$, pr\_templ)$ is the closed set of the role template contract, described as:

$$\begin{aligned}
C = \{&O_{\texttt{sensor_resource:client}}(\top, \textit{precipitation_data}, \textit{interval(1)})), \\
&F_{\texttt{sensor_resource:client}}(\top, \textit{turn_device_off}, \textit{fulfilled(obj1)} \vee \textit{violated(obj1)}), \\
&O_{\texttt{sensor_resource:client}}(\textit{violated(obj1)}, \textit{paid}, \textit{interval(1)})), \\
&O_{\texttt{sensor_resource:client}}(\textit{violated(pro1)}, \textit{paid}, \textit{interval(1)})), \\
&O_{\texttt{sensor_resource:client}}(\textit{violated(obj1)} \vee \textit{violated(pro1)}, \textit{paid}, \textit{interval(1)}))\}
\end{aligned}$$

The agent's use policy stipulates the agent demands to be paid for providing data (a meta-obligation), may not be prohibited to turn the device off at any point (a prohibition on a prohibition) and may not be obligated to pay another agent (a prohibition on an obligation). The use policy $UP_{res} =$ (`sensor_resource`, MN_{res}) is described as:

$$\begin{aligned}
MN_{res} = \{&O(O_{\texttt{sensor_resource:X}}(\top, \textit{precipitation_data}, \textit{interval(1)})), \\
&O_{\texttt{Y:sensor_resource}}(\textit{fulfilled(obj1)}, \textit{paid}, \textit{interval(2)})), \\
&F(\varepsilon, F_{\texttt{sensor_resource:X}}(\top, \textit{turn_device_off}, \bot))\}
\end{aligned}$$

The property *MObl(C*, UP_{res}) does not hold, there is no norm obligating an agent to make a payment in return for services. The strong property for meta-prohibitions, *SMPro(C*, UP_{res}) also does not hold, as we can see with a counter-example where the agent's meta-norm specifies it may not be prohibited from turning its device off, whilst the contract does the opposite (n.b. these are prohibitions and so the equality with obligations must be used to show the following):

$$\neg[\textit{not}(F_{\texttt{sensor\_resource:}X}(\top, \textit{turn\_device\_off}, \bot)) \vdash_D \\ F_{\texttt{sensor\_resource:client}}(\top, \textit{turn\_device\_off}, \textit{fulfilled(obj1)} \vee \textit{violated(obj1)}))]$$

We might be led to believe that there is a second counter-example, where *WMPro(C*, UP_{res}) does not hold. This would appear to be due to the use policy specifying the prohibition of an obligation for the resource agent to make a payment and the obligation in the contract for it to make a payment. However, *WMPro(C*, UP_{res}) does hold in this case because the resource agent's use policy states that it is only in the general case the agent must not be obliged to pay another agent (denoted with $\top$), meanwhile, the contract actually specifies the obligation to pay another agent is in the specific case that a norm is violated:

$$O_{\texttt{sensor\_resource:}X}(\top, \textit{paid}, \bot)) \nvdash_D O_{\texttt{sensor\_resource:client}}(\textit{violated(obj1)}, \textit{paid}, \textit{interval(1)}))$$

We conclude with a contract that is correct with respect to the use policy:

$$C' = \{O_{\texttt{sensor\_resource:client}}(\top, \textit{precipitation\_data}, \textit{interval(1)})), \\ O_{\texttt{sensor\_resource:client}}(\textit{violated(obj1)} \vee \textit{violated(pro1)}, \textit{paid}, \textit{interval(1)})) \\ O_{\texttt{client:sensor\_resource}}(\textit{fulfilled(obj1)}, \textit{paid}, \textit{interval(2)}))\}$$

MObl(C', *UP*) holds, the obligation for the sensor resource to be paid is now included. *SMPro*(C', *UP*) holds, the previously prohibited prohibition has been removed and consequently *WMPro*(C', *UP*) also holds.

5 Conclusions

In this paper we have presented a way to check if the contracts required by organizations match the requirements of the parties in the contracts as specified in their use policies. We have done this by characterising contracts as sets of norms and use policies as sets of meta-norms. Thus, directions for future work include solutions to forming contracts that comply with use policies and an assessment of any such solutions based on the requirements specified in this paper.

Although the choice of propositional logic is adequate for presenting the problem, future work may also extend the requirements to cover frameworks defined over first order logic. Other obvious extensions include incorporating sanctions and describing when a sanction is acceptable with regard to a use policy. Finally, thus far we have considered bilateral contracts, but in multi-agent organizations role dependencies are commonplace and so it may not suffice to just consider direct agreements between agents.

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