Dynamic Framework for Normative Relations Between Agents

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Abstract. Deontic logic – the logic of obligations, prohibitions and permissions – has been investigated in multi agent systems, because norms play an important role at the so-called social level between agents. In this paper we introduce a descriptive temporal deontic logic based on causal theories. The underlying nonmonotonic temporal logic has two distinctive properties. First, it distinguishes between observations and interventions, which among others is used to distinguish between the existence and creation of deontic states such as obligations, prohibitions and permissions. Second, its explicit causal theories lead to a descriptive or modeling perspective, that not only enables a simple and intuitive formalization of the benchmark examples of nonmonotonic temporal reasoning, but that also makes the logic a good candidate for applications of deontic logic in computer science.

1 Introduction

Deontic logic – the logic of obligations, prohibitions and permissions – and related normative formalisms such as deontic action programs [30] and commitment languages [18] have been investigated in multi agent systems, because norms play an important role at the so-called social level between agents [15]. For example, social norms can facilitate the agent’s decision-making process, an important issue for resource-bounded agents (see also the use of deontic logic in qualitative decision theory [25, 1]). Moreover, contractual obligations can be used to facilitate cooperation and teamwork, not only between cooperative agents but also between non-cooperative but rational agents (by imposing penalties on norm violations). Dynamic reasoning about norms has been formalized in dynamic deontic logic [6, 18], deontic update semantics [32] and deontic deep structure models [29], with applications in computer security (e.g. changing access rights) and electronic commerce (e.g. the transfer of rights in international trade procedures and contracts) [17, 29].

In this paper we introduce a formal framework for normative relations between agents with the following characteristic properties.

Institutional. All normative relations are relativised to institutions and agents. We represent not only the normative relations themselves, but also who is authorized or empowered to change the normative relations [7].

Dynamic. The distinction between dynamic interventions and static observations can be used to distinguish between explained and unexplained abnormalities in nonmonotonic temporal reasoning, between declarations and assertions, between creating an obligation or permission for another agent and evaluating whether such deontic states hold [32], and finally between the power and permission to create obligations and permissions [22, 7].

Computational. It is not based on a modal logic, but on a first-order one. It uses descriptive causal theories developed in planning and non-monotonic temporal reasoning. Time is represented explicitly to formalize dead-lines.

In contrast to other dynamic approaches to normative reasoning like dynamic deontic logic [6] and deontic update semantics [32], causal deontic logic is founded on the distinction between interventions and observations. The logic introduced in this paper extends Grünwald’s nonmonotonic temporal logic [10] based on Pearl’s causal theories [26] with institutions, agents, deontic facts and institutional facts. Grünwald extensively discusses that successful nonmonotonic temporal logics take a descriptive or modeling perspective, for example Sandewall’s trajectory semantics [27], Thielscher’s work on causality [28], and the work on action and change in the probabilistic community [5, 9]. The descriptive element of the logic – called causal theories – has to be introduced to solve the so-called frame and ramifications problems (based on persistence of fluen ts and indirect side-effects of actions) and their benchmark examples such as the Yale shooting problem [12] and the stolen car problem [16].

In this paper we study the descriptive deontic perspective based on causal reasoning for phenomenas such as authorization, deadlines and contrary-to-duty reasoning.

The distinction between interventions and observations in dynamic deontic reasoning can be represented by proof trees. Consider for example the institutional rule that if an agent $c_3$ owns file $x$, then he has the power to give the agent $c_4$ the power to grant permission to agent $c_5$ to read file $x$. The derivation below represents that being empowered is a precondition for a declaration to be effective: if agent $c_1$ owns the file and declares that agent $c_2$ has the power to grant the permission, and agent $c_2$ declares that agent $c_3$ has the permission to read the file, then the agent $c_4$ has the permission to read it. For simplicity we assume that all facts and actions refer to the same time moment $t$, and we leave the institution implicit. The distinction between being empowered ($P_{OU}$) and permitted ($P$) is discussed later in this paper.

\[
\frac{\text{Own}^t_{c_1} x^t}{\text{Pou}^t_{c_1} P_{OU}^t x^t} \quad \text{institutional rule} \\
\frac{\text{Pou}^t_{c_2} P_{O3}^t x^t}{\text{Pou}^t_{c_1} P_{O3}^t x^t} \quad \text{Declare}^t_{c_1} P_{OU}^t x^t \\
\frac{\text{Declar}^t_{c_2} P_{O3}^t x^t}{\text{Pou}^t_{c_2} P_{O3}^t x^t} \quad \text{Declare}^t_{c_2} P_{O3}^t x^t}
\]

The left hand side of this derivation contains the observables or institutional facts (that can be true or false), such as for example ownership of a file, and being empowered to change permissions about the file. The right hand side contains interventions or actions, such as declarations.
Another example of dynamic deontic reasoning is the transfer of deontic states called delegation, a type of norm ascription. A boss can delegate his obligation to his employee, and autonomous agents may exchange their obligations ("I will give your lecture if you referee this paper"). Task delegation is in particular important in circumstances where an agent does not know how to solve a subtask, because in such cases he also delegates a part of his planning problem. Thus, delegation and autonomy become a crucial part of problem solving. For example, consider a seller that delegates his obligation to ship goods to a shipper, because he does not know how to ship the goods. The seller cannot make a complete plan in which he fulfills his obligation to deliver goods to a buyer, he just makes a plan in which he delivers his goods on the assumption that the shipper fulfills his obligation towards him. The shipper has to decide himself how to ship the goods, and thereafter to be autonomous.

After delegating an obligation the agent may still be responsible. For example, when a seller delegates his obligation to ship goods to a shipper and the shipper violates his obligation, then the buyer will take the seller to court. It is only afterwards the seller takes the shipper to court. In other cases of delegation, such as the following one, the agent not only transfers his obligation but also his responsibility; after the transfer the agent \( a_1 \) no longer has an obligation (\( O \)).

\[
\frac{O_{a_1}^{t+2} \text{Pou}_{a_2}^{t+1} p^{t+2}}{O_{a_2}^{t+1} p^{t+2} \rightarrow O_{a_1}^{t+1} p^{t+2}} \quad \text{Declare}_{a_1}^{t+1} p^{t+2}
\]

Causal deontic logic is not only well suited for applications, it also clarifies old philosophical problems. For example, consider the well-known problem of deontic logic how to proceed once a norm is violated, called the contrary-to-duty problem [3]. In static frameworks, a contrary-to-duty obligation is an obligation that is only in force in a sub-ideal situation. In the causal framework we can formalize that a violation causes a new obligation.

\[
\frac{O_{a_1}^{t} \rightarrow p^{t}}{O_{a_1}^{t+1} \rightarrow p^{t+1}} \quad \text{Cld}(O_{a_1}^{t+1} \mid O_{a_1}^{t} p^{t})
\]

This paper is organized as follows. In Section 2 we discuss the role of dynamic deontic reasoning in multi agent systems. In Section 3 we introduce institutions, agents, deontic facts and institutional facts in Grünwald’s nonmonotonic temporal logic and in Section 4 we discuss an example of normative reasoning. The distinction between observations and interventions (i.e. left and right hand side of the proof trees) is represented by respectively a \( H_0 \) and \( D_0 \) predicate.

2. The Social Level

Our long term objective is to formalize the social level between agents [15], and in this paper we introduce a formalism which may be used to represent normative relations between agents. What is the role of deontic logic in multi agent systems? Deontic logic only formalizes the logical relations between norms, and other aspects of normative reasoning such as diagnosis (the search for violations), decision-making (planning as in contract negotiation, task delegation and more generally norm ascription) and game-theoretic notions (strategies, cooperation, protocols) therfore have to be formalized in addition [31]. The addition of these principles is context dependent, as shown by the following discussion on the so-called causal assumption: the agent fulfills as much of his obligations as possible.

1. When an agent is reasoning about another agent.

- He sometimes assumes that the other agent fulfills his obligation to facilitate his planning process. For example, when approaching a green light most people assume that people approaching from the left or right will stop. He thus predicts which actions will occur by reasoning about the actions that ought to occur; he derives is from ought. Moreover, agents also assume that other agents fulfill their norms when there is a so-called preventative control system [8], as in the metro in Paris, in which the other agents cannot violate their norms.

- He sometimes assumes that the other agent does not fulfill his norm. For example, in electronic commerce careful agents do not trust other agents. Consequently agents build expensive detective control systems [8] based on electronic signatures, trusted third parties etc.

2. When the agent is reasoning about itself.

- He sometimes considers his obligations as a kind of constraints (so-called soft constraints) on his behavior and accepts the additional causal assumption [23, 30].

- Autonomous agents can violate their obligations. As noticed by Dignum [6, 4, 2], agents that cannot violate their obligations are in a sense not really autonomous.

In this paper we focus on the deontic logic needed in agent applications. One desirable property is the ability to deal with dynamic deontic reasoning together with norm ascriptions, for example to be able to formally reason about the transfer of rights and obligations [29]. For example, it is a crucial notion in international trade procedures and contracts, where so-called bills of lading as titlement and claim documents are negotiable documents that can be sold to other agents. In the oil trade it happens quite frequently that a shipment of oil is traded several times during the transport, and each time the right to claim the oil is thus transferred from the previous owner to the new owner. In [29] it is argued that in the case of (re)design of procedures (such as the ‘electronification’ of a procedure in electronic commerce) it is essential to understand the underlying functionality of the procedure in terms of transfer of obligations and permissions.

The distinction between interventions and observations represents the fundamental difference in groups of agents between an agent creating an obligation or permission for another agent and an agent evaluating whether such deontic states hold [32]. The former is an act whereas the latter is an assessment. For example, a purchase contract creates an obligation for the buyer to pay the seller for the goods, when buying a CD via the Internet the buyer can grant permission to the merchant to charge his credit card by sending his card number, and the city counsel can grant a permission to a person to build a house. Usually deontic states are created by performing certain actions like the actual signing of a contract, instructions by a superior, and pressing an ‘agree’ button on a website. These creations of deontic states are quite different from the evaluation of deontic states when a seller might want to know whether he or the buyer is responsible for paying import taxes for the goods that he shipped to the buyer, or when an Internet consumer wants to know whether he has to pay if someone makes fraudulent use of the credit card number he gave to an Internet merchant. In advanced applications of multi-agent systems the agents must be able to reason about the creation as well as the evaluation of deontic states, because in electronic communication the agents should be able to reason whether they commit themselves or create any liability by the messages they exchange. Lack of this reasoning capacity becomes more dangerous as agents become more autonomous.
3 Causal theories

Causal approaches distinguish between explained and unexplained abnormalities in nonmonotonic temporal reasoning. For example, in the well-known Yale shooting problem [12] the non-persistence of a gun being loaded is explained by firing the gun, whereas in the also widely discussed stolen car problem [16] the non-persistence of a car being parked remains unexplained in the sense that it is not inferred when the car was stolen. In this section we extend a temporal logic based on causal theories with agents and deontic states such as obligations, permissions and prohibitions. We closely follow the logic proposed in Grünwald’s PhD thesis [10], that also gives an excellent survey on the state of the art in the area of nonmonotonic temporal reasoning. (Our results can easily be transferred to other approaches)

The major choice of this extension is how we deal with persistence, because persistence of deontic states is different from persistence of brute facts. First, deontic operators are indexed by two temporal operators: one for the deontic operator and one for the fact the deontic operator refers to. For example, today we can have the obligation to go to a party next week, for example because we promised to do so, but next week we may have the more important obligation to save a child from drowning. In this case the obligation to go to the party is overridden or defeated by the obligation to save the child. Second, it is clear that in absence of interventions and abnormalities we desire to derive ‘the light is on at moment t + 1’ from ‘the light is on at moment t’ by a persistence axiom. However, what do we desire to derive from ‘at moment t the light should be on at moment t +1’?

1. Do we desire to infer that this obligation still holds at a later moment in time, i.e. ‘at moment t + 1 the light should be on at moment t +2,’ or
2. Do we desire to infer that the obligation also holds for later moments, e.g. ‘at moment t the light should be on at moment t + 2 + 1’?

Moreover, what do we expect if we have an obligation that refers to an event instead of a fluent, such as ‘at moment t you should turn the light on at moment t + 1’? In this paper we assume that only the first item above is derived, and it is derived for fluenets as well as events, because this derivation is closest in spirit to the non-deontic derivation. The persistence axioms for the deontic operators formalize the intuition that a deontic operator is only defeated by some explicit intervention.

3.1 Basic entities

The basic entities of Grünwald’s first-order theories are fluenets (properties of the world that persist), dependent fluenets (that do not persist), events and (nonnegative integer) timepoints. He uses a many sorted first-order language $L(D,E,F)$ that depends on the three sets $D,E$ and $F$. It contains five sorts: booleans (with constants $B = \{true, false\}$), time points ($\mathbb{N}_0 = \{0,1,2,\ldots\}$), events ($E$), fluenets ($F$) and dependent fluenets ($D$). We write $|$ for first-order entailment.

We extend this language in two ways. First we introduce finite sets of:

institutions, which we write as $I = \{i_1, \ldots, i_n\}$, and

agents normally including an agent $\epsilon$ for external interventions (e.g. nature), which we write as $A = \{a_1, \ldots, a_n, \epsilon\}$.

Second, we call the set $D \cup E \cup F$ the brute facts, and we extend the set of brute facts with functions for deontic facts (not nested) and institutional facts (nested) as follows:

Deontic facts are new constants $O^{\alpha_1}_{\epsilon_1}x^{\alpha_2}_{\epsilon_2}x^{\alpha_3}_{\epsilon_3}$, $P^{\alpha_1}_{\epsilon_1}x^{\alpha_2}_{\epsilon_2}x^{\alpha_3}_{\epsilon_3}$ and $W^{\alpha_1}_{\epsilon_1}x^{\alpha_2}_{\epsilon_2}x^{\alpha_3}_{\epsilon_3}$ for agents $a_1, a_2 \in A$, time points $t_1, t_2 \in \mathbb{N}_0$, and constant $x$ of $D, E$ and $F$, to be read as ‘at moment $t$ it is obligatory / explicitly permitted / forbidden / waived for agent $a_1$ towards agent $a_2$ that $x$ holds at moment $t_2$.’ We write $O^{\alpha_1}_{\epsilon_1}x^{\alpha_2}_{\epsilon_2}$ for $O^{\alpha_1}_{\epsilon_1}x^{\alpha_2}_{\epsilon_2}x^{\alpha_3}_{\epsilon_3}$, etc.

Institutional facts are deontic facts together with new constants $P^{\alpha_1}_{\epsilon_1}x^{\alpha_2}_{\epsilon_2}x^{\alpha_3}_{\epsilon_3}$ with $\alpha_1, a_2 \in A$ and $\phi$ an institutional fact.

The distinction between empowerment and permission is that the first is a dynamic and the latter a static notion: respectively a precondition for changing deontic states and a precondition for non-violation. For example, a priest may be empowered to marry two people in the sense that going through the ceremony counts as being married, but he may not be permitted to do so in the sense that he is violating a prohibition when he goes through the ceremony [22].

As discussed above, we assume that all deontic and institutional facts are fluenets; but just like all other fluenets they may be dependent or not, i.e. they persist or not. Dependent fluenets are necessary to formalize the indirect effects of actions [10], a discussion on this topic is outside the scope of this paper. We do not assume any relation between a brute fact and its deontic and institutional facts: if $x$ is an independent fluent then $\Omega x_2$ may still be a dependent fluent, and vice versa. The extended sets of constants are written as $D^\ast, E$ and $F^\ast$, where $\pi$ stands for normative. Usually we define predicates for $D^\ast \cup E \cup F^\ast$ and we call their combined sort ‘observables’.

The new constants correspond to modal logic expressions ‘proposition $p$ is obligatory’ $\textit{Op}$, ‘$p$ is explicitly permitted’ $\textit{Pp}$, ‘$p$ is forbidden’ $\textit{Fp}$, ‘$p$ is waived’ $\textit{Wp}$ where $\pi$ means that $p$ is unmourned when all four modal sentences are false ($\neg\textit{Op} \land \neg\textit{Pp} \land \neg\textit{Fp} \land \neg\textit{Wp}$). Note that the main distinction between modal logic and our logic is that in modal logic we can also encode principles such as the much debated $\textit{O(p \land q)} \supset (\textit{Op} \land \textit{Oq})$. Moreover, in some modal deontic logics nested operators are allowed. We do not incorporate these extensions because sometimes they can be encoded in a different way (see below) and in general they do not seem to be necessary in computer science applications. Moreover, this lack of expressive power is the main reason that our first-order logic is more efficient than modal logic.

Grünwald’s logic contains the following functions and predicates.

We introduce the agent parameter of $\textit{Do}$ and we add the $\textit{Declare}$ and $\textit{Cld}$ predicates.

$\textit{Ho}$: $\textit{Ho}(x^t)$ denotes that observable $x$ holds at time $t$;

$\textit{Do}$: $\textit{Do}_a(x^t, b)$ denotes that an intervention takes place and the value of observable $x$ at time $t$ has been set to value $b$ by an (unspecified) action of agent $a$; We say that there is a sufficient cause that $x$ will (not) hold at timepoint $t$; We write $\textit{Do}(x^t, b)$ for $\textit{Do}_a(x^t, b)$;

$\textit{Declare}$: $\textit{Declare}_a(x^t)$ denotes that if $\textit{Ho}(\textit{Pown}_a(x^t))$ then $\textit{Do}_a(x^t, \textit{TRUE})$;

$\textit{Pown}_a(x^t)$ denotes that $x$ is in the domain of action of agent $a$.

Moreover, in modal logic sometimes ‘$p$ is weakly permitted’ $\textit{Pw}p \equiv \neg\textit{Fp} \equiv \neg\textit{OP} \equiv \neg\textit{O}p$ is defined too. We do not consider weak permissions in this paper, because they do not increase the expressive power of the logic.
the next section we show how this desired behavior is achieved by
true at moment
truth values with a constant (it is true or false) and the latter three (it
Gr"un
\temporal index of the outer
definition for a descriptive deontic logic, because we can simply de
\text{EQ}
\text{CONS}
\text{EQ}
\text{CONS}
\nu_\alpha, v, t' : \text{Ho}(O^e_t(x^f_t)) \supset \text{Ho}(W^e_t x^f_t)
\forall \nu_\alpha, x, t, t' : \text{Ho}(P^e_t x^f_t) \supset \text{Ho}(W^e_t x^f_t)
\forall \nu_\alpha, x, t, t' : \neg(\text{Ho}(O^e_t x^f_t) \land \text{Ho}(W^e_t x^f_t))
\forall \nu_\alpha, x, t, t' : \neg(\text{Ho}(F^e_t x^f_t) \land \text{Ho}(P^e_t x^f_t))
\forall \nu_\alpha, x, t, t' : \text{Do}(O^e_t x^f_t, b) \supset \text{Do}(P^e_t x^f_t, b)
\forall \nu_\alpha, x, t, t' : \text{Do}(F^e_t x^f_t, b) \supset \text{Do}(W^e_t x^f_t, b)
\forall \nu_\alpha, x, t, t' : \neg(\text{Do}(O^e_t x^f_t, b) \land \text{Do}(W^e_t x^f_t, b))
\forall \nu_\alpha, x, t, t' : \neg(\text{Do}(P^e_t x^f_t, b) \land \text{Do}(F^e_t x^f_t, b))
\forall \nu_\alpha, x, t, y, t', : \text{Decare} _\alpha (x^f_t) \land \text{Ho}(Pou_\alpha (x^f_t)) \supset \text{Do}_\alpha (x^f_t, \text{true})
\forall \nu_\alpha, x, t, y, t', : [\text{Clk}(O^e_t (x^f_t)) \mid O^e_t (y^f_t)) \land \text{Ho}(O^e_t (y^f_t)) \land \neg \text{Ho}(y^f_t)] \supset \text{Do}(O^e_t (x^f_t), \text{true})
\forall \nu_\alpha, x, t, y, t', : [\text{Clk}(F^e_t (x^f_t)) \mid O^e_t (y^f_t)) \land \text{Ho}(O^e_t (y^f_t)) \land \neg \text{Ho}(y^f_t)] \supset \text{Do}(F^e_t (x^f_t), \text{true})
\forall \nu_\alpha, x, t, y, t', : [\text{Clk}(O^e_t (x^f_t)) \mid F^e_t (y^f_t)) \land \text{Ho}(F^e_t (y^f_t)) \land \text{Ho}(y^f_t)] \supset \text{Do}_\alpha (O^e_t (x^f_t), \text{true})
\forall \nu_\alpha, x, t, y, t', : [\text{Clk}(F^e_t (x^f_t)) \mid F^e_t (y^f_t)) \land \text{Ho}(F^e_t (y^f_t)) \land \text{Ho}(y^f_t)] \supset \text{Do}_\alpha (F^e_t (x^f_t), \text{true})

and uniqueness-of-names and domain closure axioms for the sets
B, D^0, E and F^0. An uniqueness-of-names axiom for a finite set of
constants X = \{X_1, \ldots, X_n\} is the formula
\forall x : x = X_1 \lor \ldots \lor x = X_n

and a domain closure axiom for the set X is the axiom
Most axioms speak for themselves (the non-deontic ones are exten-
sively discussed by Gr"unwald). ‘Ought’ does not imply ‘is’ or vice
versa, which corresponds to the non-validity of the modal axioms
\text{Op} \supset p \supset \text{Op} \supset p \supset p \supset p. In our causal theories
this corresponds to the non-validity of \text{Ho}(O^e_t x^f_t) \supset \text{Ho}(x^f_t),
\text{Ho}(x^f_t) \supset \text{Ho}(O^e_t x^f_t), etc. The details of the stepwise minimiza-
tion of the abnormality predicates is quite complicated (1. minimize
(circumscribe) the \text{Do} predicate in \text{CONS}, keeping \text{Ho}, \text{Ab}_1 and \text{Ab}_2
fixed; 2. add the axioms in \text{EQ} to the theory resulting from 1.; 3.
minimize the \text{Ab}-predicates in the theory resulting from 2.) and discussed
extensively by Gr"unwald [10]. We refer the interested reader to this
literature.

4 A simple example with dead-lines

With events we can only formalize that actions have to occur at a
specified time point. However, usually something has to occur before
a certain time point, the so-called deadline. The following example
illustrates how dead-lines can be formalized with fluents in causal
deontic logic. It also illustrates why deontic facts have two temporal
references, one for the deontic operator and one for the brute facts.
Example 1 Let $A = \{\alpha, \epsilon\}$, $E = \{\text{Deliver}\}$, $F = \{\text{HasDelivered}\}$, $D = \emptyset$, and let all deontic and institutional facts be in $F$. Moreover, let CONS contain the following formulas, in which $\bullet$ is the deadline.

$$\text{Do}(\text{HasDelivered}^{\bullet}, \text{TRUE}) \land t: \text{Ho(Deliver}^{t}) \supset \text{Do}_{0}(\text{HasDelivered}^{t+1})$$

It is not obligatory that goods are delivered at a specific moment in time, like in $\text{Ho(HasDelivered}^{s})$, but they have to be delivered before the deadline $\bullet$.

5 Related research

This distinction between observations (Ho) and interventions (Do) is a fundamental insight from decision theory [21], see for example the Do predicate in Jeffrey’s logic of decision [14]. The relation with causal reasoning has been studied in causal decision theory, and causal theories and networks have been studied extensively recently in the reasoning about uncertainty community in artificial intelligence [26]. In deontic logic they have been discussed by Pearl [25]. As Grünwald discusses, the causality used in his theories is strongly related to ‘causes’ in [28], ‘caused’ in [19, 20], and occlusion in [27, 11].

The Do operator discussed in this paper is radically different from well-known modal operators like the STITT operator [13], although both take as argument a state description and they return an action. First, causal deontic logic formalizes explicit time and nonmonotonic temporal deontic reasoning. Second, the Do operator is descriptive, in the sense that it assumes a subjective notion of causality which remains unexplained. Only the consequences of the action are described, i.e. its effect on the physical state of the world. As argued extensively by Grünwald [10], the causal theories are a model (in the non-logical sense) for domains of action and change. To put the distinction in the words of the devil’s advocates: STITT theory cannot formalize the benchmark examples of nonmonotonic temporal reasoning, and causal theories do not attempt to explain what it means that an agent makes a choice (it only describes the consequences of this choice). It is an open problem whether the two can be unified.

We are not aware of any work on the combination of causal theories and deontic logic. Ong and Lee [24] have studied the use of abduction in bureaucratic rules, which they use to detect deontic dilemmas. They do not consider nonmonotonic temporal reasoning or causal rules, and they do not distinguish between situations where abduction is justified (observations) and situations where it is not (creations).

6 Concluding remarks

In this paper we investigated the relation between normative reasoning and causal reasoning, based on the fundamental distinction between observables and interventions. We suggested that deontic logic based on causal theories can be used for multi agent applications, as well as clarify old philosophical problems (partly due to simplifications in the base language). In further research we consider extensions of the language, which can either be observables (if the new concept is static, can be observed and thus has a truth value) or interventions (if the new concept is an action that can be performed, but does not have a truth value).

REFERENCES