Formalizing FLINT: a logic of preconditions and consequences of actions

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We present ongoing work on the formalization of FLINT, an action-focused framework for representing interpretations of normative sources [15,16,1].

Drawing on the relational theory of norms [10,6], FLINT emphasizes how norms constrain behavior by modeling them as prerequisites and consequences of actions, rather than using traditional deontic notions like obligation and permission. For example, instead of stating that something is forbidden, FLINT provides criteria for a regulatory action (such as issuing a fine), along with the resulting consequences. In this way, an interpretation of a normative source in FLINT describes who can take what actions against whom, under which conditions, and what the consequences of those actions are.

The central concepts in FLINT are *facts*, which together characterize the states of the normative system, and *acts*, which define potential actions by agents that impact the facts, thereby altering the state.

So far, literature on FLINT has focused on defining the central concepts (e.g. *action*, *precondition*, *postcondition*, *duty*) in an informal way [15,16] and by means of an ontology, which establishes relations between these concepts [1]. There is also an executable implementation of FLINT called eFlint [14,13], which was developed independently of the FLINT ontology and is based on Event Calculus [8]. A formal semantics for the concepts in the FLINT ontology is still lacking.

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The development of a formal semantics for FLINT would serve multiple purposes. First, it makes the concepts used in FLINT much more precise, as it requires making explicit choices about their definitions. Second, a semantics can be combined with deduction rules, which allow us to reason about norms in FLINT. Third, it enables a thorough comparison with other formal representations of norms, in particular other languages with dynamic aspects which, like FLINT, are based on Hohfeld's conception of legal relations [5,9,11,17,7,2].

We argue that a suitable basis for a formalization of FLINT can be found in PDL, in which $[\alpha]\varphi$ is used to express that every execution of action α will make φ true [3,12]. While Event Calculus is more expressive, PDL offers a more lightweight formalism suitable for modeling simple dynamic systems. It can be used to reason about which actions can be performed in a particular state, and which other actions become available as a result of performing an action. This kind of reasoning reveals how norms affect our ability to act. We have also identified extensions of PDL that are needed to formalize all concepts of the FLINT ontology.

First, although necessary and sufficient preconditions for actions can be expressed in PDL, formulas in PDL always hold true relative to a particular state. Preconditions in FLINT should hold globally, so a global modality G is needed. For example, $G(\varphi \leftrightarrow \neg[\alpha]\bot)$ expresses that α can be performed in all and only those states in which φ holds.

Second, postconditions in FLINT state exactly what changes to a state when an action is performed. A formula of the form $[\alpha]\varphi$ expresses only that φ becomes true whenever α is executed, but leaves open the possibility that other things change as well, or that α cannot be performed at all. We therefore need a new postcondition-operator $\blacktriangleright$ with a global semantics, that expresses exactly what changes to a state when an action is performed. A formula of the form $\alpha \blacktriangleright \varphi$ expresses that whenever α occurs in a given state, φ will hold in the subsequent state, while independent formulas retain their truth values.

Third, an action in FLINT can create or resolve a duty to carry out an action. In the FLINT ontology, a duty signifies the expectation that a specific action will be performed. This can be expressed using $\Box\alpha$, where α denotes an action. Because there are no complex actions in FLINT, its ambitions regarding the expressiveness of duties are low, and the semantics can remain simple. However, extending the ontology to support duties directed toward achieving a goal (i.e., duties satisfied when a certain proposition becomes true) or duties involving the omission of an action would increase the complexity of its semantics.

Fourth, FLINT makes a distinction between types of actions and instances of that type, and between types of facts and instances of these. Interpretations of normative texts in FLINT are about the types, while specific cases or scenarios are about the instances. This distinction requires extending the logic to a first-order setting, which introduces several complexities.

The first steps toward addressing these issues are taken in [4]. A detailed treatment and extension of this work are planned for a forthcoming paper.

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