

# Towards New Ways of Modeling Deontic Concepts in Ontologies

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**Abstract.** This paper is part of an ongoing research project that explores different approaches to modeling deontic concepts (i.e., concepts regarding obligation or permission) in ontologies. While deontic concepts are of considerable practical significance in fields such as law, security, medicine, and ethics, they often prove challenging to model effectively. In response to this difficulty, this paper surveys existing solutions and proposes some features of a novel comprehensive approach to their modeling. We open by discussing possible ways to defining deontic concepts and the specific difficulties that set them apart from other modalities. Next, we analyze existing approaches to modeling deontic concepts, focusing on their advantages and limitations, before moving on to a discussion of the similarities between modeling deontic concepts and modeling affordances. We also investigate the requirements for modeling deontic terms and propose some novel approaches. We conclude by offering suggestions and possible directions for future work.

**Keywords.** deontic concepts, ontology, obligation, permission

## 1. Introduction

While deontic concepts may seem as if they are simply a matter of theoretical interest – a rather abstract sub-species of modal concepts lacking practical application – we argue that deontic concepts often demonstrate considerable practical significance for law, security, medicine, and ethics. More specifically, deontic concepts are deeply caught up in the workings of many social institutions and commercial organizations; their internal structure often consists of different norms and rules and laws often formally specify their external environment.

Deontic notions are employed in most situations that involve some attempt to regulate or coordinate our actions and lives together. Regulation and coordination require rules, principles, and norms that guide institutions, groups, and individuals to control their own actions and to evaluate and judge the actions of others in particular ways. Because these contexts and situations involve deontic notions, properly modeling deontic concepts requires at once modeling several auxiliary entities and relations.

Current research in different fields of ontology modeling makes clear that the need for proper representations of deontic entities is increasing. For example, legal ontologies require models of obligations or rights guaranteed by different laws, obligations of different parties of a contract, or the rights of a user of a software product based on a license.

Similarly, biomedical ontologies require representations of deontic relations such as the obligations of health-care professionals to their patients, the obligations of health-care professionals to the administration, the administration's obligations to health-care professionals, a patient's informed consent (permission) to proceed with a specific treatment, and an individual's right to information about a relative's medical condition. Moreover, software development, information systems design and enterprise modeling use deontic concepts to model various kinds of requirements and obligations. For our purposes, it is also helpful to note that the cognitive systems used in artificial agent behavior modeling [28] may profit from our insights into best practices for modeling deontic concepts.

These considerations inspire our analysis of selected existing approaches to modeling these concepts as well as our proposal for a more comprehensive approach to such modeling.

The remainder of the paper unfolds as follows: Section 2 discusses definitions of a deontic concept. Section 3 surveys existing approaches to modeling deontic concepts. Section 4 describes requirements for modeling deontic concepts and proposes some features of a comprehensive approach to their modeling. Finally, the last section discusses possible extensions of our work and concludes our thinking.

## 2. What is a deontic concept?

When trying to analyze deontic concepts one of the first problems we encounter is the lack of a proper definition of the term itself. More specifically, deontic concepts are usually described by a list of examples (usually obligation or permission) or by stating that "Deontic modality is concerned with logic of obligation and permission" [9, p. 136]). These definitions fail to provide any sense of the semantic core common to these terms or a sense of which other concepts qualify as deontic and why. Other authors deal with this problem by simply listing all the terms that they believe qualify as a deontic concept [20].

Other approaches attempt to avoid listing deontic terms and make an effort to capture their common properties by relating them to subject's emotions. These delineations define deontic modality as a modality that connotes a speaker's degree of requirement of, desire for, or commitment to the realization of something [24].

While the majority of authors dealing with deontic concepts agree that they are *modal* concepts (deontic logic is often considered a modal logic, broadly understood), the "modal concept", like the deontic concept, is often also only described with a list of examples of individual modal terms [14]. In a linguistic sense, modal concepts are used to modify descriptions of states of affairs. A standard (non-modal) description of a state of affairs provides a description of things, relations, etc. as actually existing. A description of a state of affairs that uses a modal concept presents a state of affairs not as existing but as having a different ontological status. Discussions about states of affairs that have been linguistically or logically assigned the modal status of being *possible* or *necessary* date back to Aristotle [22].

To provide a more informative definition that can guide modeling efforts we suggest approaching deontic concepts as modal concepts that involve evaluative judgments. Section 4 explores this suggestion in more detail.

### 3. Existing approaches to modeling deontic concepts

#### 3.1. Pattern-based modeling

Ontology design patterns (ODP) are commonly used to model deontic concepts. In this vein, Johannesson [16] presents a pattern for modeling deontic concepts, namely, a *General Deontic Object Pattern*. Johannesson's pattern uses *deontic object types*, i.e., abstract object types that entail obligations, such as work order, activity assignment, or marriage. Individual *deontic objects* are linked to some roles (described by some role descriptions), have some subject matter, have a goal, and can be represented by a physical object.

A deontic object representing employment may include the roles of employee and employer. The subject matter of this object is the entity of object type activity. The goal represents the purpose of the employment from the point of view of the employer, e.g., a skilled technician that provides maintenance for a device. The employment object can be represented by a particular physical object, e.g., an actual paper with an employment contract.

Another approach uses the well-known ontology design pattern "Descriptions and Situation" (D&S)<sup>1</sup> [12,19]. One of the common use cases for the D&S pattern is modeling the legal domain. The legal domain is more complex than most others because it combines physical and social worlds with deontic concepts related to law. Gangemi et al. [13] use the D&S pattern to develop their *Core Legal Ontology* (CLO), built on top of DOLCE [18]. This ontology distinguishes *modal descriptions* (e.g., duties, powers, liabilities, etc.) that represent deontic concepts, their sources (e.g., regulations such as contracts and bundles of norms), and their subjects (natural persons, organizations, etc.).

The D&S pattern has been also proposed as a basis of other models based on affordance theory. Section 3.3 presents these models in more detail.

#### 3.2. BFO based deontic concept modeling

*Basic Formal Ontology* (BFO) is a well-known foundational ontology developed by Arp et al. [4] that provides the basis for several ontologies that attempt to model deontic concepts. *Document Acts Ontology* (d-acts) is an OWL ontology linked to BFO developed by Almeida [1] and Brochhausen [8] for representing social acts that create new entities relevant to social life. D-acts ontology uses the term *declaration* for a social act that creates rights and obligations. Declarations that use documents that are signed or stamped are called document acts. D-acts is based on the *documents acts theory* by Smith [25] inspired by philosophical work of Reinach [23] on the responsibilities that endure within an institution. D-acts ontology reuses some of the concepts central to *Information Artefact Ontology* (IAO) that is also part of BFO-based family of ontologies. More specifically, it represents the kinds of acts that document acts theory presents as *Social Generically Dependent Continuants* (SGDCs). Accordingly, deontic entities are modeled as socio-legal SGDCs (see also [2,3]). Unfortunately these papers discuss just proper categorizing of deontic concepts within the BFO class hierarchy. Other issues such as proper modeling of subject and object (see below) of deontic term are not addressed there.

Ontology as developed by Donohue [10] focuses on formally representing deontic entities and their relationships in the biomedical field, e.g., a health-care professional's

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<sup>1</sup><http://ontologydesignpatterns.org/wiki/Submissions:DescriptionAndSituation>

obligations to her patients, a patient's claim to an information requisite for informed consent. Notably, Donohue's ontology is useful for other domains of interest such as legal knowledge bases or military doctrine and intelligence. For our purposes, it is helpful to note that Donohue's work is based on the work by Almeida [1] and, moreover, that his ontology also emerges from BFO foundational ontology. Donohue argues that categorizing terms such as obligation or right as SGDCs is untenable. Instead he proposes to categorize these deontic concepts within the class of *directive information entities* (DIE) under BFO-based IAO. DIE is defined as "an information content entity whose concretizations indicate to their bearer how to realize them in a process" [26]. While Donohue believes this is the case of obligations, we think that some obligations contain no indication how they are to be realized.

Another related BFO-aligned ontology is *Informed Consent Ontology* (ICO) by Lin et al. [17]. ICO also originates in a biomedical context and also reuses some concepts from IAO and describes document acts. However, this ontology is very specific and focuses only on concepts related to informed consent. A rudimentary *Requirement ontology*<sup>2</sup> was developed by Nowara as part of *Decision ontology* (see [6]). While there were efforts to integrate it with BFO-based IAO ontology, this project was not completed. However, it is important to note here that all these works focus primarily on modeling deontic concepts as legal constructs and usually emerge in biomedical contexts.

### 3.3. Modeling affordances

Deontic concepts are related to the concept of *affordance*, making some modeling approaches analogous. Affordances theory was introduced by Gibson [15] who understood the "environment" as a space of opportunities for agential action. Affordances are these opportunities, e.g., a button offers an agent the opportunity to push it.

Thinking of an agent's action space as offering affordances for him to act is similar to thinking of an agent as *allowed* to perform a set of actions in a given situation. These actions are *permissible*, i.e., not *prohibited*. The deeper point here is that deontic concepts can therefore be modeled in some contexts in a similar manner to affordances and vice versa (for more information about modeling affordances see e.g. [27]).

Another connection exists between modeling affordances and deontic concepts. In some cases it makes sense to model both types of notions alongside each other. If some action is prohibited or obligatory, then this action has to be possible – otherwise it makes no sense to interpret it as a prohibited action (e.g., it makes no sense to prohibit a robot from teleporting). In these cases, the application of deontic concepts presupposes affordances. Therefore, a deontic concept may be modeled in such cases as a special case or property of affordance it (e.g., allowed affordance or prohibited affordance). Although there are models (mentioned below) that use affordance theory, relation between this theory and modeling deontic concepts has not been explored in research yet.

Affordance theory and D&S pattern has been proposed as a basis for the definition of situation-driven behavior selection and arbitration models for cognitive agents [5]. It uses behavior-based robotics principles to model the behavior selection of artificial cognitive agents. Behavior selection (or behavior arbitration) is the cognitive process that leads to the decision that compels a subject to perform an action in a given circumstance at a particular point in time.

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<sup>2</sup><https://code.google.com/archive/p/requirement-ontology/>

Another similar approach is Asprino et al.'s [5] *Affordance Ontology Design Pattern*. This approach focuses on the physical objects (e.g., doors) that offer the opportunity of performing an action (e.g., open). This pattern relies on D&S ODP and a frame-based representation scheme [21].

## 4. Requirements for modeling deontic concepts

### 4.1. Ontological commitments

Modeling deontic concepts in ontology first requires investigating ontological choices. Modeling these concepts implies the need to accept some general modeling constraints that in turn drive the general ontological approach to conceptualizing reality, sometimes called ontological (modeling) commitment. The problem of ontological commitment is a problem in meta-ontology caught up in the question of what kinds of entities exist (or are to be modeled) according to a given theory (modeling approach) [7]. In the case of deontic concepts this relates more specifically to the problem of representing modality and time.

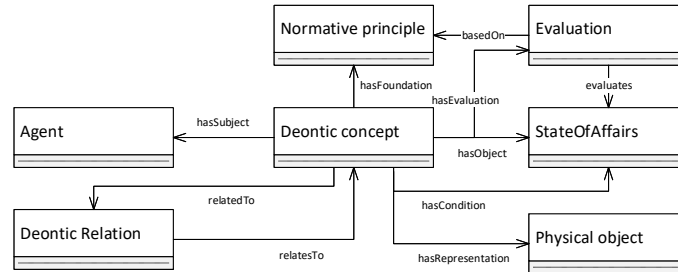
The need to model deontic concepts therefore relates to a preference in the standard dichotomy of actualism/possibilism [18]. In methodologies of ontology engineering, actualism uses an ontology as a model of only what is actually in existence. Meanwhile, possibilist methodology admits possible entities (*possibilia*) such as possible situations or possible worlds as well. While we may understand an obligation as something that actually exists, it is usually related to some possibility. *Kant's law* states  $OB(p) \rightarrow \diamond p$  i.e., if something is obligatory then it is possible [20]: an action that is obligatory is therefore possible but may or may not emerge; the same holds for the state of affairs produced by this action. While in some cases it may be feasible to abstain from modeling *possibilia* and focus only on modeling actual entities – this more reductive approach to modeling producing less complex ontologies – it is important to keep in mind that deontic concepts as modal concepts necessary imply *possibilia*.

### 4.2. Required elements of a model of deontic concepts

Modeling deontic concepts requires representations of several entities and relations that provide answers to basic questions such as the who, what, and why of the deontic relation as well as to questions that help to specify necessary conditions and relate the matter at hand to other deontic concepts. More specifically, the required elements of a deontic model include:

*Subject* of the deontic concept – e.g. *the person* who has the obligation or right. The subject must be an agent because it is in a sense "up to him" which of the possible states of affairs related to the deontic concept will come into existence. This agent must have the ability to influence which of the possible states of affairs emerges (usually through an action).

*Object* of the deontic concept – e.g. *permission to proceed with specific medical treatment*. The object of a deontic concept is generally a possible state of affairs (or set of states of affairs) that may be obtained or may fail to be obtained depending on the subject's activity or inactivity. The object is more specifically related to the Kripke style



**Figure 1.** General structure of deontic concept model

semantics of deontic logics in which the meaning of different deontic logical concepts is captured using possible worlds. The object of an obligation is that some of the possible states of affairs emerges, while others do not.

There are influential theories with different view on the object of an obligation. Kant’s ethics considers the will (and indirectly the action) to be primary object of an obligation. Nonetheless, both the will and the action are connected to some state of affairs that is to be willed or realized by an action of an obligor. However, in specific cases where these states of affairs are closely linked to the different actions of various agents, we may simplify model by situating an action as the object of the deontic concept.

*Foundation* (or source) of the deontic concept – e.g., a law, a contract, or an ethical code. Deontic concepts are modal concepts that involve evaluative judgments. These evaluations are based on a value-providing principle. E.g., a law may evaluate one state of affairs as permissible or even obligatory while prohibiting another.

*Relation* of deontic concepts to other deontic concepts – Deontic concepts are often related to each other. A typical case of such a relation is detailed by Gangemi’s [13] assertion that: *Obligation*  $\rightarrow$  *Right* (if A has an obligation towards B, then B has a right towards A). Similarly, if a state of affairs S is obligatory, then all other states of affairs are prohibited. In many cases, these relations can be derived from deontic logics.

*Condition* of deontic concepts – Many applications of deontic concepts are often conditional in their structure. E.g., an obligation may produce an actual requirement or limitation only in particular situations or states of affairs (e.g., if someone is hurt, then an obligation emerges to provide first aid; if snow covers a road, then you cannot use (you are “prohibited” from using) a bike).

As we note above, we may include an optional *representation* of a deontic concept – a physical object that represents obligation (e.g., a physical contract or ticket) [16].

#### 4.3. Basing deontic concepts on evaluative judgments

We argue above that it is helpful to understand deontic concepts as modal concepts that involve evaluative judgments. Taken in this vein, deontic concepts do not present states of affairs as merely existing, but more specifically assign such states particular ontological modal statuses that relate to a form of evaluation (e.g., ethical or legal). Ethical principles, law, and similar normative bases generally distinguish between praiseworthy, blameworthy, and neutral states of affairs. We represent such evaluations as positive, negative, and neutral, respectively. Doing so enables us to describe several of the most common deontic concepts as follows:

*Obligation / Requirement* – obligatory state of affairs has a positive evaluation, other possible states of affairs have a negative evaluation.

*Permission / Right* – permitted states of affairs have a positive evaluation, other states of affairs have a neutral evaluation.

*Prohibition* – prohibited states of affairs have a negative evaluation, other states of affairs have a neutral evaluation.

Other deontic concepts may be modeled analogously. Omissible states of affairs can be modeled as non-obligatory, optional states of affairs can be modeled as permitted etc.

## 5. Conclusions

Solving the problem of how best to model deontic concepts is indispensable to the progress of many areas of ontology modeling. While a long history of scholarly work on this problem exists in the context of the Semantic Web, scholars have not yet determined a best practice for modeling deontic concepts.

This paper provides an overview of some existing approaches to modeling deontic concepts suited for specific applications, but not able, in our opinion, to serve as a general schema for how to model deontic concepts across diverse circumstances.

Future research done on how best to model deontic concepts for such comprehensive use must properly analyze the meaning of deontic concepts – i.e., must take into account deontic logics – and fulfill the requirements we outline in this paper. While we also introduce a value-based deontic modeling approach that we argue will prove generative for future modeling efforts, future research would do well to conduct further analysis on and to properly formalize this approach.

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