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Meaning Holism and Indeterminacy of Reference in Ontologies (Extended Abstract)*

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Abstract

According to meaning holism, the meanings of all the words in a language are interdependent. If this was true, then the very practice of building largely interconnected set of ontologies would be threatened. We examine here the extent of the severity of meaning holism for ontology engineering, based on a definition of the meaning of a class term in an ontology, with regard to the classical analytic/synthetic distinction. We show that meaning holism is not as pervasive in ontologies as traditionally assumed in philosophy of language when interpreting the meaning of a class term as a collection of statements expressing necessary conditions on this term. Still, meaning holism presents substantial challenges for ontology engineering and requires mitigation strategies. We also investigate the related phenomenon of indeterminacy of reference and show how anchoring formal ontologies in natural language can mitigate this problem, even if not fully control it.

1 Introduction

Ontologies aim to facilitate semantic interoperability, enabling agents to share the meanings of the terms they use. Quine [1980] has discussed "meaning holism", defined in the Stanford Encyclopedia of Philosophy as follows [Jackman, 2020]:

> (H) "The determinants of the meanings of our terms are interconnected in a way that leads a change in the meaning of any single term to produce a change in the meanings of each of the rest."

If meaning holism were as severe as formulated above, then adding any new term or altering the meaning of any existing term within an ontology would change the meanings of all terms within the ontology. Thus, it would pose a very significant obstacle to the practical and sound use of ontologies. Vindicating the common practice of developing evolving, interconnected ontologies requires to analyze the real extent of the issue of meaning holism.

This raises two critical questions that this paper will address: First, how can we define meaning in applied ontologies? Second, what is the extent of meaning holism in ontologies, compared to its characterization in (H)?

2 Philosophy of Language, Meaning and Reference

A phenomenon linked to meaning holism, and also challenging for the field of ontologies, is known as the "indeterminacy of reference", famously articulated by Quine [2013] by the "Gavagai" thought experiment. In a nutshell, various assignments of references to words are compatible with the empirical evidence about the behavior of speakers of a language. The interconnectedness of meanings within language is a cause of both meaning holism and indeterminacy of reference.

Throughout Western philosophy, there has been considerable interest in the distinction between analytic and synthetic statements, dating back to Kant [1998]. An analytic statement is one whose truth is determined purely by the meanings of its terms, e.g. "Bachelors are unmarried men." A synthetic statement, on the other hand, is one whose truth or falsity is determined not solely by the meanings of its terms, e.g. "Bachelors are happy." This semantic distinction should be contrasted with the epistemological distinction between *a priori* statements (those justifiable independently of experience) and *a posteriori* statements. In this paper, we will only consider analytic statements that are *a priori* and synthetic statements that are *a posteriori*.

Although the notion of analyticity has been famously criticized by Quine [1980], Neuhaus and Hastings [2022] suggest that analyticity lies at the core of ontology development. This perspective is to be contrasted to claims such as: "Ontology is concerned with representing the results of science at the level of general theory (the generalizations and laws of science)" [Arp *et al.*, 2015], which advocate for ontology to reflect our best scientific knowledge of the world.

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Guarino *et al.* [2009] compare extensional and intensional accounts of meaning and identify Carnapian "meaning postulates" with the axioms of an ontology. If one believes in the analytic/synthetic distinction, though, not every axiom should be seen as an expression of meaning.

The OBO Foundry introduces two annotation properties aimed at capturing meaning: "Definition" (IAO_0000115) and "Elucidation" (IAO_0000600).

In OWL, we could envision generalizing such annotation properties in order to tag statements as analytic or synthetic. To borrow a famous example by Quine [1980], suppose that we define stipulatively the term "VH" in an OWL ontology as a "Vertebrate with a heart", and state that it was found that, as a matter of fact, in our world, VHs are exactly the vertebrates with a kidney. Then we might introduce the two following statements, the first one being tagged analytic and the second one as synthetic:

(AX_H) VH EquivalentTo (Vertebrate and has_part some Heart)

(AX_K) VH EquivalentTo (Vertebrate and has_part some Kidney)

On the opposite, if one would want to define VH as a "Vertebrate with a kidney" and express that as a matter of fact, the VHs are exactly the vertebrates with a heart, one would tag AX_H as synthetic and AX_K as analytic.

Note that analytic and synthetic statements do not play the same role when using ontologies to make judgment of instantiations: analytic statements effectively constrain the reference of a term, whereas synthetic statement express a regularity that is contingent upon how the world is. If AX_H is tagged as analytic and AX_K as synthetic, then the reference of "VH" is the class of vertebrate with a heart. One might take the risk to classify a particular organism with a kidney as an instance of VH on the basis of AX_K, but one might be wrong, since synthetic axioms express empirical and thus falsifiable knowledge. Thus, synthetic statements can merely act as heuristic devices when making judgments of instantiation. This role difference between analytic and synthetic statements can provide a rationale for labeling statements as either analytic or synthetic in ontological engineering, a practice that seems to be currently uncommon or even entirely absent to our knowledge.

3 Definitions, Primitiveness and Circularity

An ontology introduces terms and statements in both natural and formal languages [Neuhaus, 2018]. For instance, in OWL 2, the formal language used is the description logic SROIQ(D) [Horrocks *et al.*, 2006]. In this paper, we concentrate on terms that refer to a class (by contrast to a relation or a particular). OWL class terms are IRIs, to which natural language labels can be associated. Additionally, they can be linked with natural language statements through annotation properties, and appear within axioms in description logic.

The meaning specification (abbreviated "meaning" in the remainder of this paper) of each class term is constituted by some of those statements. We will distinguish between the "formal" meaning of a term, expressed by formal statements, and the "natural language" meaning of a term, conveyed through natural language statements. We will concentrate in this paper on the former; note however that natural language might be an integral, indispensable part of an ontology, as argued by Neuhaus and Smith [2008]: an ontology in which the correspondence between formal terms and natural language would be totally severed would likely be impossible to understand by anyone.

In a first conception, the meaning of a term is identified by its definition, which is an analytic formal or natural language statement expressing a necessary and sufficient condition (NSC, the *definiens*) for the term (the *definiendum*) that does not mention the *definiendum*.

In practice, both natural language definitions and formal definitions can be found within an ontology. In OWL, definitions take the form of an axiom 'A EquivalentTo Expr' (where Expr is an anonymous class that does not mention A) – but not all such axioms are definitions, as illustrated by the example of synthetic axioms such as AX_K above: they might express a coincidence between two classes that is due to natural regularities.

When constructing formal definitions within ontologies, terms are used to define other terms, and these defining terms may themselves be formally defined using additional terms. At some level, this process must lead to one of the following scenarios: circularity (that is: the formal definition of the term t_0 uses a term t_1 whose definition uses a term t_2 … whose definition uses this term t_0); primitiveness, when there is no NSC formal statement associated with some terms in the ontology; or a combination of both.

To illustrate, consider the OWL ontology O_I in Table 1 involving both primitiveness and circularity. First, F_004 and R_005 are primitive. Second, F_002 is defined in terms of F_003, and F_003 is defined in terms of F_002; thus, their definitions are circular. As we shall see, both cases of primitivity and circularity present challenges regarding the indeterminacy of reference within ontologies.

Term	**Label**	**Natural Language Definition**	**Formal Definition**
F_002	Chair	"A chair is an entity in which inheres a chair function."	F_002 EquivalentTo (R_005^{-1} some F_003)
F_003	Chair function	"A chair function is a function that inheres in a chair."	F_003 EquivalentTo [F_004 and (R_005 some F_002)]
F_004	Function	*Primitive*	*Primitive*
R_005	inheres in	*Primitive*	*Primitive*

Table 1: Terms, labels and definitions in the ontology O_I

4 Indeterminacy of Reference

When considering solely the formal statements within a theory, numerous interpretations of primitive terms within an ontology can arise. For instance, even if a singular interpretation of the primitive terms R_005 and F_004 is assumed in the ontology O_I, it can have several models. For example, within a BFO-inspired ontology, F_002 and F_003 could be interpreted as the classes *Table* and *Table function*, *Chair* and *Chair function*, *Door* and *Door function*, and so forth.

Thus, one cannot ascertain whether two ontology users refer to the same portion of reality, even when they use the same language and endorse the same theory. In other words, two individuals might accept identical statements and consequently delineate reality in isomorphic ways, yet there may still be discrepancies in their references: certain terms may denote distinct portions of reality based on their interpretations, which could vary slightly or significantly.

The indeterminacy can be partially alleviated by linking our ontological language to natural language through natural language definitions (see also Neuhaus and Hastings [2022] for considerations on the importance of natural language in ontologies). However, if one follows Quine, natural languages themselves are vulnerable to the problem of indeterminacy of reference. Consequently, the indeterminacy of reference in natural language will contaminate the ontological language.

Overall, the indeterminacy of reference permeates all languages, including ontological ones. This uncertainty persists even when agents employ perfectly identical ontological statements, making it unclear whether they are referring to the same reality using the same terms. At best we can mitigate this phenomenon by providing well-chosen additional statements, without certainty that we can fully control it.

5 Meaning Holism

Not all class terms in an ontology have definitions: in some ontologies, some terms are characterized by a set of necessary conditions [NC] without any necessary and sufficient condition [NSC] providing a formal or natural language definition.

Assume that the analytic/synthetic distinction is valid, *pace* Quine. We define the analytic formal theory of the ontology as the collection of statements tagged as analytic in the formal theory of the ontology (it is thus a *fiat* decision of the ontology creator which statements are analytic). We can then consider the deductive closure of this theory, namely, the collection of statements that can be deductively inferred from them using the underlying logic. Given the definition of analyticity, any statement in the deductive closure of the analytic theory is also analytic.

We base our account on the idea that the meaning of a class term A is constituted by a subset of statements in this deductive closure, namely the general analytic statements concerning A – statements that apply to any instances of A, i.e., by *necessary* analytic conditions on that class term.

An additional restriction must be made though. To take an OWL ontology as example, tautologies such as ‘A SubClassOf (B or not-B)’ or ‘A SubClassOf (A or B)’ should not be part of the meaning of A. Also, if ‘A SubClassOf C’ is part of the meaning of A, then ‘A SubClassOf (C and (B or not B))’ should not be part of the meaning of A, as it is tautologically equivalent to ‘A SubClassOf C’. Therefore, we restrict the formal meaning of a class term to axioms that have undergone a process of tautology elimination:

(MEAN) The formal meaning of a class term in an ontology O is the collection of axioms expressing NC (including NSC) on this term entailed by O’s analytic theory after a process of tautology elimination.

In particular, this can be operationalized in OWL:

($MEAN^{OWL}$) The formal meaning of a class term A in an OWL ontology O is the collection of axioms of the form ‘A SubClassOf Expr’ and ‘A EquivalentTo Expr’ (where Expr is a named or anonymous class) entailed by O’s analytic theory after a process of tautology elimination.

Let’s now illustrate meaning holism with an example. Consider an initial theory containing only the analytic statement AX_H. Suppose now that we modify the meaning of Vertebrate by adding the following analytic axiom: ‘Vertebrate SubClassOf Animal’. As a result, the deductive closure of the new analytic theory will now include the theorem ‘VH SubClassOf (Animal and has_part some Heart)’ and thus, the meaning of VH is changed. Hence, adopting MEAN implies that the meanings of certain terms in an ontology are interconnected, as explained by meaning holism. As we will see, however, meaning holism is not as pervasive as claimed by HOL.

Let’s examine the OWL ontology made of the following analytic axioms (based on [Jackman, 2020]):

(AX_1) Squirrel SubClassOf Animal
(AX_2) Koala SubClassOf Animal
(AX_3) Black_squirrel SubClassOf Squirrel

This example shows that meaning holism does not operate as systematically as stated by (H) when we endorse $MEAN^{OWL}$. Let’s start with an analytic theory limited to AX_1. When adding AX_2 or AX_3 to the theory, no NC on Squirrel is added to the deductive closure of the theory. Thus, the meaning of Squirrel remains unchanged.

Therefore, meaning holism is not as systematic as claimed in (H) when one adopts MEAN within formal ontologies: the meanings of some terms can be changed without altering the meaning of some other terms.

In cases where an axiom of the form ‘A SubClassOf Expr’ or ‘A EquivalentTo Expr’ belongs to the meaning of A and B appears in Expr, we will say that the meaning of A *depends on* the meaning of B.

In this conception, the meaning of a term is determined by its necessary conditions, while changes or additions of sufficient conditions generally do not alter the meanings of other terms (e.g. adding ‘A SubClassOf B’ to the ontology’s analytic theory generally does not change the meaning of B). However, there are some clarifications and caveats to consider.

First, this does not preclude cases where the meaning of a class depends on one of its subclasses. For example, in an ontology with the following axioms:

(AX_4) A SubClassOf B
(AX_5) B SubClassOf (R some A)

the meaning of B depends on the meaning of A due to AX_5 (but not in virtue of AX_4).

Secondly, necessary conditions on a class can impose necessary conditions on another class that is not a subclass of it. For instance, if the analytic axiom 'A SubClassOf not-B' (indicating that A and B are disjoint) is added to the theory, then the equivalent statement 'B SubClassOf not-A' appears in the deductive closure of the theory, and thus the meaning of B according to MEAN has been changed. Additionally, if class A is covered by the class 'C or D' (i.e., 'A SubClassOf (C or D)' is in the analytic theory) and the axioms 'C SubClassOf Expr' and 'D SubClassOf Expr' are added, then the axiom 'A SubClassOf Expr' is added in the deductive closure of the theory, altering the meaning of A.

5 Discussion and Conclusion

To summarize, the problem of indeterminacy of reference pervades any language, including ontological ones, marked by circular definitions or primitive terms, leading to the possibility of unintended interpretations. It can be alleviated, though arguably not fully controlled, by incorporating carefully selected additional statements, formal or natural.

Analytic statements effectively constrain the reference of terms, whereas synthetic statements can be used at most as heuristic tools for judgments of instantiation: this motivates the introduction of the analytic/synthetic distinction into ontological engineering, a practice largely overlooked today.

Meaning holism as classically formulated in (H) would make the practice of ontological engineering nearly impossible. Fortunately, one can devise a reasonable, restricted theory of meaning, namely the top-down conception MEAN, which fits well with the consideration of ontologies as characterizing what is general in the world, and limits meaning holism. Moreover, it can be operationalized in OWL.

An open question is whether MEAN is still a too large conception of meaning and should be further restricted. Consider the OWL axiom 'A SubClassOf (R only B)', which would be, according to MEAN, part of the meaning of A. Intuitively, this axiom does not constrain all instances of A, but only the instances of A that are in relation R with something - namely, it states that this something must be a B. Thus, it is logically equivalent to: '(A and (R some Thing)) SubClassOf (R only B)'. Such axioms might have to be excluded from the meaning of A, and instead assigned to the meaning of any named class equivalent to (A and (R some Thing)).

Note that if we refuse the analytic/synthetic distinction, we could introduce the notion of "inferential role" as an operational proxy for meaning as the collection of formal statements expressing NCs on a term, after a process of tautology elimination, within the deductive closure of O's *whole* theory, including both analytic and synthetic statements (rather than within the deductive closure of O's *analytic* theory). This might be a good proxy for meaning if statements in an ontology are mostly analytic in nature, as suggested by Neuhaus and Hastings [2022] or as seemingly implicitly assumed by Guarino *et al.* [2009].

While MEAN limits meaning holism, any change of meaning of a term B might change the meaning of the terms whose meaning depend on B. This phenomenon is not enough controlled in the current practice of applied ontology using interconnected ontologies. One must be cautious not to alter the meaning of class terms by introducing or changing analytic necessary conditions—neither directly nor indirectly through disjunction axioms or axioms subclassing mutually covering classes. This holds for class terms that one did not author (as one might not have the same reference as the authors of the term [Fabry *et al.*, 2023]), or on class terms that one did author but have already been made public and thus might have been reused by someone else. In such a case, alternative strategies should be used, such as the introduction of a new term or suggesting changes to the author of the term. Future work will focus on developing a rigorously structured versioning system for terms to address this aspect of holism.

MEAN specifically applies to class terms. In OWL, one might consider adapting it to object property terms by considering the axioms in the R-Box, but the only axioms in the R-Box in SROIQ(D) are purely taxonomic axioms (using SubPropertyOf), domain/range axioms and axioms describing properties such as symmetry, irreflexivity, inverse property, etc. – which only very partially characterize relations. Therefore, further research is needed to delve deeper into the question of the meaning of object property terms in OWL and more generally of relation terms.

This analysis should also investigate the import of natural language statements in constraining ontologies. The analysis presented here should be operationalized in ontologies written in other languages than OWL, such as FOL or CLIF. Future work should also analyze further the analytic/synthetic distinction in ontology engineering (as initiated by Barton *et al.* [2025] in a framework of possible world semantics), the adoption or rejection of which would have consequences on whether a conception of meaning like MEAN should be used, or instead an operational substitute like the inferential role. The status of OntoClean [Guarino and Welty, 2009] metaproperties in determining the meaning of classes terms should be analyzed. The phenomena of indeterminacy of reference and meaning holism could also be analyzed in more formal frameworks of the nature of ontologies (e.g. considering that classes terms are associated to intensions [Guarino *et al.*, 2009], namely functions that associate to each possible world a portion of reality in this world; or identifying meanings with collections of propositions as proposed by Neuhaus [2018], rather than as collections of statements). Future work should also control other aspects that complicate the connection between meaning and reference, such as the possibility of making errors when expressing the meaning of a term in regard of its intended reference (as analyzed by Fabry *et al.* [2023]). Finally, the import of those issues for the Semantic Web should be analyzed: is such an endeavor possible at all given meaning holism?

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