ArgO: Aɴ Oɴᴛᴏʟᴏɢʏ fᴏʀ Aʀɢᴜᴍᴇɴᴛs

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*Abstract*: Although the last decade has seen a proliferation of ontological approaches to arguments, many of them employ ad hoc solutions to representing arguments, lack interoperability with other ontologies, or cover arguments only as part of a broader approach to evidence. To solve these problems, we present the Arguments Ontology (ArgO), a small ontology for arguments that is designed to be imported and easily extended by researchers who work in different upper-level ontology frameworks, different logics, and different approaches to argument evaluation. Unlike most approaches to arguments, ArgO utilizes Basic Formal Ontology (BFO) as an upper-level ontology but remains compatible with many commonly used ontologies such as the Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE), the Information Artifact Ontology (IAO), and the Information Entity Ontology (INFO). Critically, our proposal is principled, based on rigorous definitions and formal axioms out of which characterizations of arguments naturally fall. It is our hope that ArgO may assist researchers in many projects, including: integrating heterogeneous sources of evidence, structuring the content of semantic wikis, and enhancing semantic reasoning.

*Keywords*: Ontology, Arguments, Basic Formal Ontology, Semantic Reasoning

1. Introduction

Information systems in many domains—e.g., law, medicine, historical records, and humanities journals—structure and store data concerning arguments. The representation of arguments across fields is critical to understanding motivations of and disputes among actors, and evaluating evidence for or against various claims.Take, for instance, the following argument:

Whereas Iraq continues to aid and harbor other international terrorist organizations, the Congress of the United States is warranted in granting support for the President to use the Armed Forces of the United States to defend the United States against the continuing threat posed by Iraq.[[3]](#footnote-3)

This passage is a modification of the joint resolution authorizing the use of force by the United States against Iraq during the second Iraq war. The original passage provides many other reasons that attempt to justify and lend support for Congress’s decision. In its modified form here, we see only one reason, presented in the first sentence, whereas the final sentence contains the conclusion of the argument. We can look at this passage as a mere set of statements, but this is uninformative—what is necessary to grasp is the structure of the argument itself, that there is a direction of the intended inference whereby we move from the premises to the conclusion. Once we understand this structure, we can see that this passage is not merely a report or a description, but a concerted effort to have us accept the conclusion.

The rationale for the second Iraq war was one of the most widely discussed issues of the last decade, and the sources of evidence for premises concerning the debate are scattered in many different places. In this regard, it is not so different from many other projects in science, where aggregating evidence from disparate sources and identifying their evidential relations to a conclusion is a massive investigative undertaking. Representing such complicated sources of evidence is one task for formal representations of arguments. A second task is to structure a procedure of evaluation. This allows a formal treatment of arguments to aid investigation, guiding an investigative process through a series of steps. Such tools are widely used in education assessment[[4]](#footnote-4), as well as in research and medical ethics[[5]](#footnote-5), where argument schemes are used to guide a participant through a process of evaluation and documentation.

To begin putting these pieces together with the aid of computational reasoning, we need to understand texts not only as consisting of word tokens and characters, but also as being about things in the world, and as expressing content that bears relationships of logical entailment and support. In information science, this work is performed by ontologies, critical tools for integrating data across different languages, servers, and conceptual frameworks. An ontology is a representation of reality comprised of a taxonomy as a proper part, whose representations are intended to designate some combination of universals, defined classes, and certain relations between them.[[6]](#footnote-6) These ontologies are routinely implemented in a decidable formal language, such as the web ontology language (OWL), allowing them to be understood by machines.In the last decade, many ontologies for representing arguments have been developed with the goal of structuring, integrating, and reasoning over represented chains of inference.

A well-designed ontology of arguments requires adherence to certain methodological requirements. For instance, contemporary ontology reasoning resources require precise formal representations of data, often as logically defined classes linked together in a taxonomic structure of class and subclass relations.[[7]](#footnote-7) Moreover, precise formal representation should be compatible with, where possible, at least one widely-used upper-level ontology. This is because ontologies were designed, in part, to solve the problem of data silos, stockpiles of data coded in parochial languages inaccessible to other semantic technologies[[8]](#footnote-8) and upper-level ontologies provide a lingua franca into which consistently extended domain-level ontologies may be translated, thereby improving accessibility among data sets in various domains. In our survey, arguments in ontologies (and more broadly in semantic technologies), have often been produced for single, one-off projects. Such projects too often reflect the insular concerns of a single researcher’s data set, or the particular end-goals of a single project. Thus, they often fail to meet a series of criteria we believe are necessary for creating an ontology of arguments that may be re-purposed by multiple researchers who may use the same ontology for different projects.

In addition to methodological requirements, the domain of arguments suggests other adequacy constraints. For example, arguments are often expressed through combinations of sentences, but we should not confuse arguments with collections of sentences. Sentences are grammatical entities used by speakers of a language to convey meaning or content. For example, the English sentence “Snow is white” may be used by a speaker to express that *Snow is white*, i.e. that the world is as the speaker describes. Arguments are not grammatical entities. Rather, arguments are collections of expressed contents of grammatical entities. Witness, a given sentence and expressed content may come apart. One may use the German sentence “Schnee is weiss” to express the content *Snow is white*, the same content expressed by the English speaker. In other words, the same content may be expressed by distinct sentences. In the other direction, a sentence type may express distinct contents, e.g. when I utter “I am late for class” is the same sentence type, but expresses different content if uttered by someone else. Indeed, some sentences do not appear to express any content, e.g. “Green ideals peep curiously.” Hence, a sentence may be used to express distinct content, or no content at all. Clearly, sentences and what they express come apart, and these remarks generalize to arguments. For an argument may be expressed in both English and German sentences, yet have the same content. Similarly, were you and I both to utter “I am hungry, therefore someone is hungry”, we would express distinct arguments. Clearly then too, collections of sentences and the arguments they express come apart, facts an ontology of arguments should be flexible enough to reflect.

Relatedly, sentences and sentence content should be distinguished from force, i.e. the force of an assertion, the force of a command, etc. The same sentence may be used to express content with different force. For example, “You miss me” may be used to make an assertion (describing an addressee’s feelings), a command (that you do miss me), or question (wondering whether you do). In each case the sentence is the same, and in each case the content expressed is as well. What is conveyed, however, may be distinct in terms of force, e.g. assertion, command, question, etc. Assertions are typically associated with declarative sentences. As such we will largely concern ourselves with the contents and combinations of contents of declarative sentences. Nevertheless, an ontology of arguments should remain open to arguments involving content conveyed with other speech acts, e.g. commands, questions. To take just the first, commands are typically associated imperative sentences. For example:

* + - * 1. Hold the door if you want to keep your job!
        2. You want to keep your job
        3. Hence, hold the door!

The first and third lines plausibly represent content expressed using imperative sentences, conveyed with the force of commands. Since there are such arguments, they are plausibly within purview of an ontology of arguments. Similar remarks apply to arguments involving questions. Relatedly, an argument ontology should remain, as far as possible, compatible with multiple approaches to logic. For one, adequate characterizations of imperative and interrogative content suggest logics more permissive than classical will be needed.[[9]](#footnote-9) For another, arguments routinely involve sentences employing modal notions, e.g. claims about obligation, permissibility, necessity, possibility, etc., formal representations of which typically go beyond classical logic. For a third, arguments in some domains may be better suited by representation with non-classical domains, e.g. mathematics represented within intuitionist frameworks. An adequate ontology of arguments will permit users the flexibility to choose which logic best characterizes a domain.

Constituents of arguments have different roles, another adequacy constraint. Intuitively, arguments have a number of premises and a single conclusion which follows from the premises. In some cases, an argument may involve a supposition used to support the conclusion in some manner.

(1) If Susan leaves work early she’ll go home and to the gym

(2) SUPPOSE Susan leaves work early

(3) Hence, Susan will go home and to the gym

(4) Hence, Susan will go home

(5) Hence, if Susan leaves work early then Susan will go home

Here we have a simple argument involving a plausibly supposition, reflected on line (2), with consequences extending to line (4). Given line (1) and the supposed line (2), line (5) intuitively follows. In other cases, an argument may have a single premise and conclusion, the content of which is the same. For example, the following question-begging argument plausibly represents the same content playing two roles:

* + - * 1. God exists
        2. Hence, God exists

An argument ontology should permit distinguishing the mere repetition of sentence content in an argument, from claims that certain content follows from other content, and should similarly reflect the use of content as a supposition rather than a premise. Relatedly, an argument ontology should permit representing differences in validity and soundness. The question-begging argument is, by classical standards, valid. Whether it is sound, however, depends on whether the premise is true. Now, whether it is true or not is a matter of the world. This is the case independent of whether any individual is convinced by the argument. Typically, however, arguments are offered to persuade individuals to accept a conclusion. In such cases, whether the premise is true or not is important, but what becomes more salient are the reasons individuals have for accepting or rejecting the premise. Hence, an argument ontology should reflect the role reasons play in accepting or rejecting premises. A natural way to do so is by representing arguments in a canonical form, where premises are explicit, so that reasons for or against them may be easily associated. Moreover, explicitly characterizing the structure of arguments provides an avenue for counterarguments to be posed to targeted premises or the conclusion of a given argument, with accompanying reasons for accepting and rejected premises. An argument ontology then should permit comparisons of arguments and reasons in this manner.

An argument ontology meeting the above adequacy constraints provides a firm foundation for computational reasoning and gains the advantages of upper-level compatibility, while remaining flexible enough to accommodate a wide range of arguments and counterarguments. For clarity, the adequacy constraints are provided here:

1. The ontology should have logically defined classes whose definitions employ an Aristotelian or genus-species form.

2. The ontology should depict arguments in a canonical manner, as consisting of reasons for a conclusion.

3. The ontology should allow researchers to distinguish sentences, from the sentence content expressed by those sentences, as well as the content itself from its particular function within an argument.

4. The ontology should be capable of representing not only the intended structure of an argument, but also the potential weaknesses of an argument either with its present classes, or by being open to a future ontology that extends it.

5. The ontology should allow multiple approaches to logic, such that it is not committed to a single logic (e.g. classical logic).

6. The ontology should be compatible with a widely used upper-level ontology, such as Basic Formal Ontology (BFO).

In addition to these criteria, we also advocate for a realist approach to ontology, according to which thought, experience, and knowledge are characteristically (if also partially and fallibly) about reality, as opposed to merely about concepts or ideas. This means that we take arguments to be bona fide parts of the world, independent of ideas or perspectives of them. This realist approach to ontology design is a hallmark of the BFO framework[[10]](#footnote-10), and we have found it is critical to sustainable efforts in the field.

In our survey of ontologies of arguments, we have not encountered an ontology of arguments that can meet all of these criteria. In particular, there is no other ontology of arguments with which we are familiar that satisfies our third criteria, as many ontologies simply allow Unicode strings in a digital text to count as parts of arguments. As for the other criteria, some ontologies of arguments succeed in part, but no ontology satisfies them all, and for this reason, they are nearly always incapable of being re-used for other projects.

Literature Review

In our review, we have found that current ontological approaches to arguments can often be concerned with broad approaches to evidence rather than arguments *per se*, and this orientation leads to errors. For example, in the Legal Knowledge Interchange Format (LKIF) Core Ontology, an argument is understood as “a reason that is expressed through some medium.”[[11]](#footnote-11) This notion of argument seems more in line with what Duncan Kennedy has called, “argument bites,” stereotyped bits of reasoning “that legal reasoners use when the legal issue is one that permits a reference to the policies or purposes or underlying objectives of the legal order, rather than a legal issue that can be satisfactorily resolved through deductive rule application or by reference to binding precedent.”[[12]](#footnote-12) In this way, the LKIF characterizes arguments as principles that are appealed to in a variety of legal contexts.

This approach fails criterion two, for we believe that even among legal experts, this use of “argument” is peculiar, reflecting the particular concern that legal ontologies have with norms, rules, precedents, and principles of the law and interpretation, rather than more complex arguments involving multiple inferences and chains of reasoning tied together by subconclusions.[[13]](#footnote-13) We hold that arguments involve such reasons, principles, or appeals as items of a collection[[14]](#footnote-14), and that arguments themselves are not to be identified as any one of these in isolation. Arguments include a particular conclusion that is being asserted by the arguer, as well as the particular reasons, suppositions, conjectures, and premises that the arguer takes to speak in favor of, provide support for, or entail the conclusion.

This mistake may also be a consequence of the popular use of argumentation schemes in implementations of computational reasoning. On a first approximation, schemes are stereotypical inference patterns used in both deductive and inductive arguments. Many researchers in artificial intelligence and argument mapping have proposed hierarchies that reflect different approaches to the form of such schemes. One such approach is detailed in Walton (1995), which provides an account of a ‘Walton scheme’, an account that has been influential for researchers wishing to show the consequences of presumptive reasoning on automated inference. Each Walton scheme includes a conclusion and a set of premises along with critical questions, where the critical questions allow users to identify the weakness of an argument and anticipate weaknesses in the argument based on the kind of scheme being employed.

Such schemes are useful extensions of argument ontologies[[15]](#footnote-15), but ontologists should be careful to distinguish schemes from arguments.[[16]](#footnote-16) In our survey, we often found that ontologists often implemented schemes as classes, and then treated individual arguments as instances of the class ‘scheme’.[[17]](#footnote-17) This is incorrect, since it violates the true path rule according to which everything that is true of the parent class may be said of the child of that parent. A scheme is not an argument; it is distinguished from arguments in containing variables in its statement parts. Moreover, it has a different function: a scheme is not created to convince others of the truth of its conclusion; rather, it is intended to function as a clarifying description of the logical structure of arguments together, perhaps, with a description of the weakness of such structures, and critical questions that may be asked of an argument given its logical form. For these reasons, it is wrong to identify particular arguments as instances of a scheme.

One goal of ontologies of arguments is to be able to depict and reason over an extended web of inferences, where interrelations of nodes and edges are used to connect some information to the information that is inferred from it or negated by it. Such inference chains may form long and often highly complex links that, in turn, might have different properties of support or force. The Argument Interchange Format (AIF) is one example of such an effort.[[18]](#footnote-18) The AIF is designed to depict not arguments (which the AIF does not define) but instead ‘argument entities’, which it represents as nodes in a directed graph it calls an “argument network”. While the AIF itself demonstrates the utility of programming languages to show the relatedness of arguments, the AIF itself is inconsistent with the use and goals of upper-level ontologies, since it does not distinguish the representation of information from the representation of the world that the information is about within the class structure of its ontology.

Other ontologies of arguments may also define the class argument, too broadly, construing arguments “as analogies, as counterevidence, as (rhetorical) questions, as hypotheticals, and even in the form of irony.”[[19]](#footnote-19) Of course, arguments are routinely communicated and recorded, among other places, in court transcripts that involve analogies, rhetorical questions, hypotheticals, and irony. Indeed, in many such cases what is pragmatically implicated is an assertion. For example, a rhetorical question such as “Weren’t you at the shopping mart Tuesday” pragmatically implicates in certain circumstances the assertion “You were at the shopping mart on Tuesday.” Similarly, analogies of the form S has property P; T is relevantly similar to S; hence, T has property P (or similar property P’) may be countenanced as arguments. Similar still, Jonathan Swift’s *Modest Proposal*[[20]](#footnote-20) seems an example of irony employed as argument, in particular, to reductio ad absurdum. Nevertheless, such an understanding of arguments falls short of capturing the domain. What is it about, say, Swift’s wickedly ironic *Modest Proposal* that makes the work also express an argument? Similarly, what is it about an argument by analogy that separates it from mere analogies (e.g. that ravens are like writing desks)? A natural answer to these questions is structure, and a natural explication of structure in the domain of arguments appeals to premises, suppositions, and a conclusion. Simply permitting, say, analogies as arguments overlooks this distinction.

The model of argument defended by Toulmin[[21]](#footnote-21) has been used by researchers such as the Argument Model Ontology (AMO)[[22]](#footnote-22), who are interested in providing semantic support for evidence. According to Toulmin, much of what it is to be an argument varies from field to field, with some features being field-dependent and others being field-invariant. He therefore focuses on an analysis of arguments that emphasizes justification rather than inference, where one begins with a claim and seeks justification for it. Such arguments he calls ‘practical arguments’. Toulmin details six components required for their analysis: claims, evidence, warrant, backing, rebuttal, and qualifiers.

Although Toulmin’s account of practical arguments has been influential on researchers in argumentation theory, its implementations in ontologies like the AMO fail to clearly demarcate arguments from the background of related sources of evidence and counterevidence. Using Toulmin’s categories, the AMO class ‘argument’ inherits the following restrictions: a) has\_evidence min 1, b) has\_warrant min 1, and c) has\_claim exactly 1. Thus, it both excludes arguments containing only one premise or supposition as well as circular arguments in which a statement is used to infer itself, and also allows for arguments that may have parts other than those included in the Toulmin model, for the AMO does not, in its implementation, provide a closure axiom for its class ‘argument’, so it is unclear what is excluded from its extension. Also, in failure of our third criterion, there is no distinction drawn between propositions considered independently of any argument, from propositions that appear to be doing a specific kind of work within an argument whereupon the AMO could call them warrants, evidences, backings, claims, and so on.

There are no processes in the AMO as well, which leads to an unwelcome proliferation of relations in their OWL implementation. This can happen when it is assumed that predicates in a sentence express relations, as when the sentence “Barry argues for liberty” appears to show arguing as a way Barry is related to liberty. This is unfortunate, since when relations proliferate in an ontology, they can keep information from being found through other connections that may otherwise be available by using classes. If we instead treated the example with classes, we could say that Barry is an instance of a person, who engages in an instance of an act of arguing, where this act creates an argument, and that argument has a conclusion, where the conclusion is a statement in favor of liberty. Treating the verb in this sentence as an instance of class of activity rather than as an instance of a relation also allows us to more easily state when and where this act occurred.

These errors of scope are not made by the Semanticscience Integrated Ontology (SIO), an ontology developed to facilitate biomedical knowledge discovery.[[23]](#footnote-23) The SIO is distinguished among the ontological treatments of arguments we have surveyed by representing arguments in a canonical manner familiar to most readers of introductory logic textbooks. Its subclasses of arguments include valid, sound, deductive, and inductive arguments, and it also includes premises and conclusions among its classes, which facilitates the representation of argument parts. Furthermore, it includes an exclusively binary treatment of truth and falsity, implementing truth-values as subclasses of the class ‘information quality entity’. This allows SIO to be used to represent not only arguments with true premises, but also arguments with false ones, and to distinguish the true from the false. For many purposes, this may be a valuable feature to have. For instance, if statements known to be true or false can be tagged as such, then the ontology may be used to query for all those arguments that rest on false premises, where upon the evidence for their conclusions may be re-evaluated. In addition, further properties such as soundness—defined as the property of a deductive argument that is both valid and has all true premises—may be inferred by looking for valid arguments with all true premises.

However, there are many parts of SIO that could be improved. First, the ontology itself does not use and is not compatible with common upper-level ontologies or widely used ontologies of information, and it would need to be rebuilt in order to become so. For instance, all information content entities[[24]](#footnote-24) in SIO are a subclass of ‘object’, which is defined as “an entity that is wholly identifiable at any instant of time during which it exists”. This definition is at odds with the BFO definition of ‘object’, which defines an object as a maximal causally unified material entity. Furthermore, the definition of ‘information content entity’ is ‘an object that requires some background knowledge or procedure to correctly interpret’. This definition is simultaneously too broad and too narrow, as there are some material artifacts (e.g. a computer) that fit this definition but are not themselves information content entities, and there are also information content entities that do not require any special background knowledge or procedure to correctly interpret, apart from the mere knowledge of a language or symbol system, and this does not seem to be the author’s intended meaning.

Second, the SIO asserts that all arguments are a kind of ‘proposition’, where proposition is incorrectly defined as “a sentence expressing something true or false.”[[25]](#footnote-25) Most researchers in logic and the philosophy of language conceive of propositions not as sentences, but rather as the meaning or content sentences express. And even where this distinction is clearly made, the propositions expressed by sentences are not themselves arguments, since an atomic sentence may be a sentence, but because it contains no inference, cannot be an argument. Finally, like AMO, the SIO fails criterion three, for it draws no distinction between a proposition and when that proposition is used as part of an argument, as say, a premise, subconclusion, or supposition. Users of the ontology are thus required to choose whether they want to count some instance of a proposition as one or all of these, when whether a statement is a premise, conclusion, or subconclusion depends entirely on its relation to an argument, and that relation will itself vary across times and arguments.

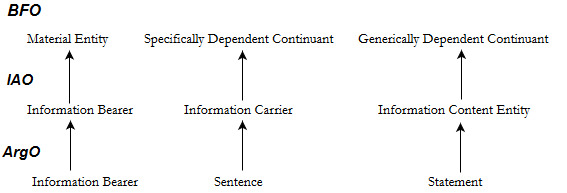
**ArGo: An Arguments Ontology**

In this section, we motivate and introduce the various classes and relations of ArgO, a small ontology of arguments designed to meet the preceding constraints. We provide a rigorous axiomatization in first-order logic, then gesture at natural extensions of ArgO users may wish to adopt.

*Statements, Background Ontological Commitments, and Arguments*

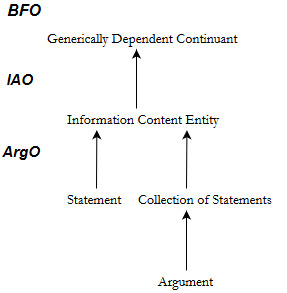
As examined above, sentences, sentence content, and force come apart. While remaining open to these subtleties, we restrict our topic here to *declarative sentences*, i.e. sentences typically used to affirm truth or falsity. We, moreover, restrict our attention to the sentence content of declarative sentences, *statements.* Statements are widely held to be the sentence content, or sentence meaning, of declarative sentences, primary bearers of truth values, and the objects of propositional attitudes such as belief.[[26]](#footnote-26) For example, the sentence “Susan is happy” expresses the statement *Susan is happy*, which may be believed or not, is truth-apt, and is plausibly the meaning of the declarative sentence quoted. The sentence itself is none of these. We are guided in our treatment of statements by BFO in general, and by the Information Artifact Ontology (IAO) in particular, which is a mid-level extension of BFO designed to represent information and information bearers. Statements fit naturally within the Information Artifact Ontology (IAO) as Information Content Entities, roughly, entities about things in the world, e.g. the content of sentences in a book, information encoded in xml files on a hard drive. With respect to BFO, Information Content Entities are Generically Dependent Continuant entities, those enduring entities lacking temporal parts which are identical across instances, e.g. a pdf on distinct laptops. Hence, we treat statements as, broadly, entities about reality which may have identical instances across bearers. Two observant friends of Susan, for instance, may both believe the same content *Susan is happy*, expressing this content by uttering respectively “Susan is happy”.

Though we do not deal at length with sentences, it is instructive to examine how BFO and IAO provide resources to distinguish sentences from statements. Starting with BFO, Generically Dependent Continuant entities are contrasted with Specifically Dependent Continuants, which are not shareable and do not have identical instances, though instances may resemble one another insofar as they are of the same type. Paradigm examples include the color of a given apple, or a given sequence of shapes of ink on a page. In every case, Specifically Dependent Continuants depend on some instance of the BFO class Material Entity, which consists of continuant entities that have matter as parts. For example, the Specifically Dependent Continuant redness depends on the Material Entity that is the apple, and the sequence of shapes on the ink. Generically Dependent Continuant entities also bear a relation of dependence. In every case, Generically Dependent Continuants must be concretized in some Specifically Dependent Continuant, and thus indirectly, must have some Material Entity bearer. For instance, the repeatable Generically Dependent Continuant pattern reflected in the Specifically Dependent Continuant shapes of the Material Entity ink, is said to be concretized in the shapes, which in turn depend on the ink. The IAO inherits these distinctions among Generically Dependent Continuants, Specifically Dependent Continuants, and Material Entities. Where Information Content Entity is an extension of Generically Dependent Continuant, the IAO extends Specifically Dependent Continuant with the class Information Carrier, and Material Entity with the class Information Bearer. Roughly, instances of the class Information Carrier are qualities of instances of the class Information Bearer. Applied to our ink on a page example, the repeatable Information Content Entity pattern is concretized in the shape Information Carrier which depends on the ink Information Bearer. We adopt these distinctions in ArgO, treating sentences as Information Carriers borne by various Information Bearers, though we will not have much more to say about these entities. For our purposes, it suffices to observe statements such as *Susan is happy* are Information Content Entities concretized in sentences that are Information Carriers, which are dependent on Information Bearers. We summarize the general ontological relationships graphically (the arrows reflect the *is­\_a* relation, read, e.g. “Information Bearer *is­\_a* Material Entity”, etc.):



*Diagram 1: Sentence, Statement extensions of BFO, IAO*

Much like statements, we claim arguments are best understood as Information Content Entities, through an intermediary class - Collection of Statements.[[27]](#footnote-27) The class Collection of Statements is itself a subclass of Information Content Entity, composed of instances of the class Statement. The further subclass Argument is, broadly, a Collection of Statements with a natural ordering of those statements.[[28]](#footnote-28) These extensions are reflected in the following:



*Diagram 2: Statement, Collection of Statements, Argument extensions of BFO, IAO*

Where instances of Collection of Statements may have no ordering, Arguments in every case must be ordered. Of course, arguments are not simply ordered collections of statements, but typically involve premises and conclusions. We turn to these features of ArgO next.

*Premises, Conclusions, and Suppositions*

When a statement is a constituent of an argument, it is typically as either a premise or conclusion. This is, importantly, independent of the identity of the statement. For example, a given statement which serves as the conclusion of an argument, as represented by line (3) of the following:

1. If Andrew is in El Paso, then Andrew is in Madrid
2. Andrew is in El Paso
3. Hence, Andrew is in Madrid

May serve as a premise in a distinct argument, as represented by line (2):

1. If Andrew is in Madrid, then Andrew is in Spain
2. Andrew is in Madrid
3. Hence, Andrew is in Spain

A natural thought then is that *being a premise* and *being a conclusion* are two roles a given statement can bear within the context of an argument.[[29]](#footnote-29) Early in our thinking, we explored using roles to distinguish statements from premises and conclusions by appealing to the BFO class Role which seemed appropriate for the task. Roles in BFO are realizable continuant entities which may be gained or lost by a bearer based on context, and which are in every case correlated with some process, entities with temporal parts extended in space and time. For example, a student role may be gained by an individual in an academic context, and is realized in such temporally extended processes as studying for an exam, completing coursework, etc.[[30]](#footnote-30) Similarly, premises and conclusions may naturally be understood as statements taking on different roles in argument contexts which are realized in respective processes of correlated types, e.g. an inferring process. A tidy result. Unfortunately, the BFO class Role is a subclass of Specifically Dependent Continuant, where a given instance of Role is borne by the Material Entity on which this Specifically Dependent Continuant depends. Since Specifically Dependent Continuants are disjoint from Generically Dependent Continuants, and Statements are extended from the latter class, Statements cannot bear Roles in the BFO sense. Hence, we cannot rely on this initially plausible class to characterize premises and conclusions.

Reflection on how premises and conclusions operate in arguments reveals an alternative, however. Consider, a clear difference between statements on the one hand, and premises and conclusions on the other, is that premises and conclusions are always used in arguments, while statements need not be. Moreover, observe premises are linked to conclusions insofar as they are offered as support or evidence for conclusions in arguments. Plausibly, this link between premises and a conclusion is an action - passing from some collection of statements to another statement because one believes the latter is justified, supported, or entailed by the former statements. Such an act is naturally characterized as a BFO Process, since it plausibly has temporal parts and is not instantaneous. We reflect this link between premises and conclusions by adopting an *Act of inferring* class which extends the BFO Process class. Adopting this class, moreover, reveals the lines along which we may characterize these statements. Roughly, a premise is a statement that is the input of an act of inferring; a conclusion a statement that is the output of an act of inferring.

Witness, characterizing premises and conclusions in terms of an *Act of inferring* satisfies one intuition underwriting treating premises and conclusions as roles statements play in argument contexts. We observed premises and conclusions, like all BFO Roles, are correlated with processes. By defining premises and conclusions in terms of a relevant process directly, we gain this feature of Roles without needing to use this class. Of course, unable to use BFO Roles, we incur a cost - the claim that premises and conclusions are played by statements in an argument context, as we might say Student is a Role had by an individual in an Academic Context. As we observed, premises and conclusion are intimately bound to arguments, and so relativizing premises and conclusions to argument contexts is desirable. We will eventually augment our initial characterizations to accommodate this insight without appealing to BFO Roles, but first we examine a further common constituent of arguments – suppositions.

Supposition, like premises, provide support for the conclusion of an argument. Nevertheless, they are subtly distinct in that where premises used in an argument are affirmed by the arguer, suppositions are more often *accepted* rather than affirmed.[[31]](#footnote-31) Affirming a statement is closely tied with believing it, aims at truth, is typically informed by evidence, and is subject to rationality constraints. For example, sincerely affirming *It is raining outside now* entails belief the statement is true, and suggests one formed this belief based on evidence. Moreover, affirming is minimally restricted in that individuals seem unable to affirm what is clearly impossible, or at least experience significant cognitive resistance when attempting to do so.[[32]](#footnote-32) Premises in a given argument seem best described as affirmed, as they appear to share these characteristics. In contrast, merely accepting a statement is not so intimately tied to belief, need not aim at truth, may not be informed by evidence, and is not obviously subject to rationality constraints. For example, an individual might plausibly accept *It is raining outside now* while claiming they do not actually believe it, acknowledging the statement is false, but admitting they have no evidence either way. Indeed, one may accept what is clearly impossible with little cognitive resistance, e.g. accepting *it is neither raining outside now nor not raining outside now*. Relatedly, statements are typically accepted for the sake of some further goal, such as continuing a conversation, hypothetical deliberation, or indirect reasoning. Suppositions in a given argument seem best described as accepted, as they appear to share these characteristics. For suppositions, unlike premises, may be disbelieved, uninfluenced by evidence, known false, known impossible, and are often employed to explore the consequences of hypothetical commitments. We reflect these observations by characterizing a supposition as an accepted statement input to an act of inferring that provides support or justification for the conclusion of an argument. Similarly, we augment the above characterization of premise, where a premise is now an affirmed statement input to an act of inferring that provides support or justification for the conclusion of an argument. Moreover, we reflect the distinction between affirming and accepting as one between distinct acts, i.e. processes. An *act of affirming* is a process in which an agent participates, where the agent believes the statement is either true or false based on evidence and within some rationality constraints. An *act of supposing* is a process in which an agent participates, where the agent entertains a statement as true or false, regardless of belief, evidence, or rationality constraints, as input to an *act* *of inferring*. Note, the former act, unlike the latter, need not involve an *act of inferring*.

Are conclusions affirmed or accepted? In many cases, conclusions seem clearly affirmed. For example, consider the argument represented in:

1. If Andrew is in El Paso, then Andrew is in Madrid
2. Andres is in El Paso
3. Hence, Andrew is in Madrid

Where an individual making this argument affirms (1) and (2) and participates in an *Act of inferring* from the premises to the conclusion. Plausibly in this case, the individual affirms the content of (3) as well. In other cases, it is not so clear whether a conclusion is affirmed or accepted. Consider:

1. If Andrew is in El Paso, then Andrew is in Madrid and Andrew is in Spain
2. SUPPOSE **|** Andrew is in El Paso
3. **|** Hence, Andrew is in Madrid and Andrew is in Spain
4. **|** Hence, Andrew is in Spain
5. Hence, if Andrew is in El Paso, then Andrew is in Spain

Where an individual plausibly participates in several *Acts of inferring*, in particular, from (1) and (2) to (3), from (3) to (4), and finally from (1)-(4) to (5). Here it seems the respective outputs of these acts of inferring are in some cases accepted and some cases affirmed. For example, an individual affirming the content of (1), accepting the content of (2), and inferring to the content of line (3) is plausibly understood as accepting (3), rather than affirming it, as the individual does not thereby believe (3) is true full-stop. Similarly for line (4). Rather, what the individual affirms is a connection between what is supposed and associated consequences of the supposition. This is reflected in line (5), the output of (1)-(4), which is best understood as affirmed. Thus, generally speaking it seems conclusions may be affirmed *or* accepted, based on whether the input to an act of inferring resulting in the conclusion involves accepting, i.e. whether the input involves a supposition. With that in mind, we augment our characterization of conclusions as affirmed *or accepted* outputs of an act of inferring thought to be supported or justified by corresponding affirmed or accepted inputs.

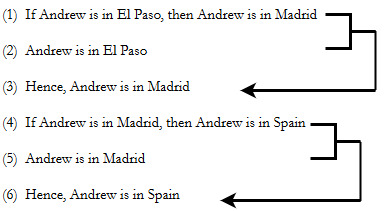
This last example suggests arguments may exhibit multiple conclusions. However, many treat a given argument as having only one conclusion (often distinguished as the “main conclusion”), a treatment we adopt as well. We turn next to explicating this feature of ArgO.

*Subconclusions and Complex Arguments*

Arguments are often complex, involving several premises and perhaps suppositions, and multiple inferential steps taken towards the main conclusion. Consider our initial pair of arguments collapsed into a single argument:

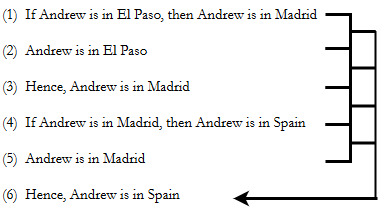
1. If Andrew is in El Paso, then Andrew is in Madrid
2. Andrew is in El Paso
3. Hence, Andrew is in Madrid
4. If Andrew is in Madrid, then Andrew is in Spain
5. Andrew is in Madrid
6. Hence, Andrew is in Spain

There are at least two ways to view the argument, as two simple arguments involving two acts of inferring, as depicted below (where the arrows indicate distinct acts of inferring):



*Diagram 3: Arguments Simple-A and Simple-B*

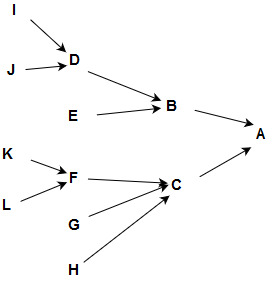
Or as one complex argument, involving a single act of inferring:



*Diagram 4: Argument C*

In Diagram 3, we have two acts of inferring, four premises (1), (2), (4), (5), and two conclusions (3), (6). Plausibly, we have two distinct arguments each with their own act of inferring. Call the argument reflected in (1)-(3), Simple-A, and that reflected in (4)-(6), Simple-B. In Diagram 4, we have one act of inferring, five premises (1)-(5), and one conclusion (6). Plausibly, there is one argument here; call it C. Observe, Simple-A and Simple-B are clearly components of C. Observe too, the content of (3) and (5) is the same. However, with respect to Simple-A, this content is the output of an act of inferring, i.e. a conclusion, and with respect to Simple-B, this content is input to an act of inferring, i.e. a premise. Similarly in C, this content is a premise. It is standard to consider the function of (3) in C is as a *subconclusion* of C, an inferential step towards the main conclusion of the argument, represented by (6). However, treating (3) as a subconclusion of a single argument in this manner overlooks the role (3) plays among the component arguments of C. Strictly speaking, subconclusions should be characterized with respect to multiple connected arguments. Moreover, connections among components arguments in a complex argument should reflect the role played by subconclusions.

Intuitively, complex arguments have parts. BFO provides resources with which to capture this relationship, a parthood relation holding between continuants, and in particular, Generically Dependent Continuants.[[33]](#footnote-33) With these resources we may define a class relevant to our characterization of subconclusion - Complex Argument. A Complex Argument is an Argument with at least two Argument proper parts, which has only Argument parts. Since the parthood relation is a partial order, characterizing complex arguments in this manner generates ordering among arguments of greater complexity. Thus, a complex argument Amay be decomposed into complex parts, B and C, themselves decomposable into complex parts. Ultimately, the decomposition will result in simple argument parts, represented by I, J, E, K, L, G, and H below. The directed arrows represent parthood, e.g. Argument I is part of Argument D, which is part of Argument B, and so on:



*Diagram 5: Partial order over complex argument parts*

The class subconclusion can then be understood as a statement that is an affirmed/accepted input to an act of inferring in an argument and affirmed/accepted output to an act of inferring in an argument distinct from the first, where both arguments are parts of some complex argument. This definition of Complex Argument ensures any instance involves an act of inferring and has proper Argument parts each with their own acts of inferring, and hence, premises and conclusions. Combined with the plausible commitment that each instance of Argument involves only *one* conclusion, so that each component argument to a complex has its own conclusion, as does the complex argument of which they are parts, entails each instance of Complex Argument involves an instance of Subconclusion. Thus, our definition of subconclusion appeals to multiple arguments and the respective roles such statements play in them, as desired.

We take care here to emphasize two features of our commitments thus far. First, assuming the following is an argument:

1. If Andrew is in El Paso, then Andrew is in Madrid
2. Andrew is in El Paso
3. If Andrew is in Madrid, then Andrew is in Spain
4. Hence, Andrew is in Spain

Does not entail it is a *complex* argument. For one, it is unclear how many acts of inferring are involved. Relatedly, it is not obvious this argument is decomposable into argument parts. One may object, claiming (1) and (2) clearly entail the antecedent of line (3), call it (3\*), which together clearly entail (4). Hence, three arguments are exhibited implicitly in (1)-(4) which are intuitively parts of this argument, and which involve a statement as a subconclusion. Hence, (1)-(4) is complex. But this objection misunderstands the task of representing arguments with ontologies. (1)-(4) and the assumed *act of inferring* from (1)-(3) to (4) do not entail the existence of a further *act of inferring*, say, from (1)-(2) to (3\*). Regardless of how obvious the step may seem, licensing normative corrections extends beyond our task of representing arguments. Yet without this addition, this argument is not obviously decomposable into argument parts, and if not, this argument is not complex.

Second, subconclusions interact with suppositions in a satisfying way on our proposal. We illustrate by returning to our example argument involving a supposition, which we may characterize as complex:

1. If Andrew is in El Paso, then Andrew is in Madrid and Andrew is in Spain
2. SUPPOSE **|** Andrew is in El Paso
3. **|** Hence, Andrew is in Madrid and Andrew is in Spain
4. **|** Hence, Andrew is in Spain
5. Hence, if Andrew is in El Paso, then Andrew is in Spain

Here we have three arguments. First, from (1) and (2) to (3); second, from (3) to (4); third, from (1)-(4) to (5). Call the first, again, Simple-A, the second Simple-B, and the third C. Clearly Simple-A and Simple-B are parts of C. Clearly too we have subconclusions on (3) and (4). With respect to Simple-A, (3) is the conclusion, and with respect to Simple-B and C, (3) is a premise. On the other hand, with respect to Simple-B, (4) is the conclusion, and with respect to C, (4) is a premise. Hence, both (3) and (4) are subconclusions. Moreover, with respect to Simple-A, (3) is plausibly understood as accepted, as is (4) with respect to Simple-B, and as are both (3) and (4) with respect to C. Then much like our characterization of conclusions, subconclusions may be accepted as in this complex argument, or affirmed as in the example with which we began this section.

*Revisiting Arguments*

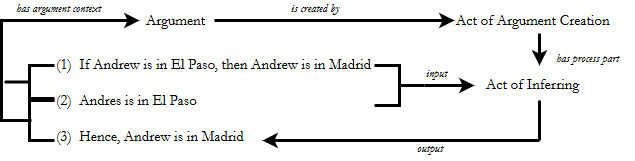
We observed earlier premises and conclusions are intuitively relativized to arguments. We may add suppositions and subconclusions are intuitively relativized to arguments as well. We capture this with the relation *has argument context* holding between premises, suppositions, conclusions, or subconclusions, and arguments. In the case of premises, suppositions, and conclusions, an argument context is unique. For example, a given premise has one and only one argument context. Similar remarks apply to suppositions and conclusions. While this entails that, say, a premise in one argument cannot be identical to a premise in a different argument, the consequence is a feature not a bug. A statement itself *can* be identical across arguments, even if its role is not. Thus, while we cannot, strictly speaking, say two arguments share a premise, we can still say the same statement is a premise in two arguments. This feature permits tracking of statements across arguments independently of how they are used in arguments. In contrast to premises, conclusions, and suppositions, subconclusions are not relativized to unique arguments, but rather, to combinations of complex arguments and decomposable parts, reflecting the cross-argument definition of the class. Hence, a subconclusion may bear the *has argument context* relation to more than one argument.

Taking stock, we have Arguments as ordered collections of statements involving premises, suppositions, and a single conclusion, and Complex Arguments as Arguments with only proper Argument parts, and at least two such. In turn, the class Premise consists of affirmed inputs of acts of inferring in a unique argument context, while Conclusion consists of affirmed or accepted outputs of acts of inferring in a unique argument context. The class Supposition consists of accepted inputs of acts of inferring in unique argument contexts, while Subconclusion consists of affirmed/accepted inputs and outputs of distinct acts of inferring in distinct Arguments which are proper parts of a Complex Argument. Our characterizations thus far reference make use of various acts which deserve attention. We turn next to the process side of ArgO, which provides a satisfying parallel to the preceding.

*Arguing, Creating Arguments, and Chains of Reasoning*

We have made much use of the *act of inferring* process in our discussion. Yet, this is not the only act of import for our topic. Consider, there are many different purposes one might have in constructing an argument. The paradigm case involves arguing, where an individual provides an argument with the intent of convincing others the conclusion of the argument is true. We characterize this process as an *act of arguing*. One can argue successfully or unsuccessfully, but one cannot argue without intending to convince one’s audience of some conclusion. Of course, one may have no intention to convince others of some conclusion; one may be creating an argument for its own sake, or for the purpose of interpretation and analysis, or to anticipate what an opponent might say during a debate. In such cases, one is not arguing; rather, one is merely creating arguments, which we characterize as a process of *act of argument creation*. An *act of arguing* may have an *act of argument creation* as process part, if in the process of arguing one creates an argument.[[34]](#footnote-34) Then again, it might not. Quite often, when engaging in an *act of arguing* we merely reuse arguments. When we do so, we engage in an *act of arguing* that has no *act of argument creation* as process part.

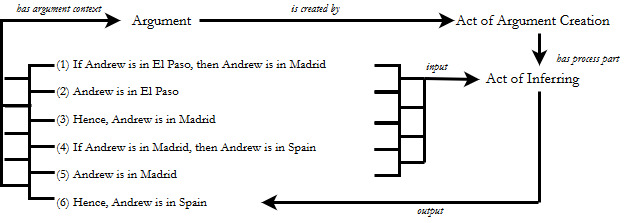
As the paradigm case, however, *act of argument creation* will be our focus. Plausibly, creating an argument involves steps. We are, in fact, already familiar with one such step, an *act of inferring*. Thus, we say an *act of argument creation* typically has proper process parts, such as an *act of inferring*. An *act of argument creation* with *act of inferring* as process part is related to the argument which it creates. We capture this with the *is created by* relation which holds between an *act of argument creation* and an instance of Argument. In the simple case, we can depict the relationships as:



*Diagram 6: Simple Act of Argument Creation*

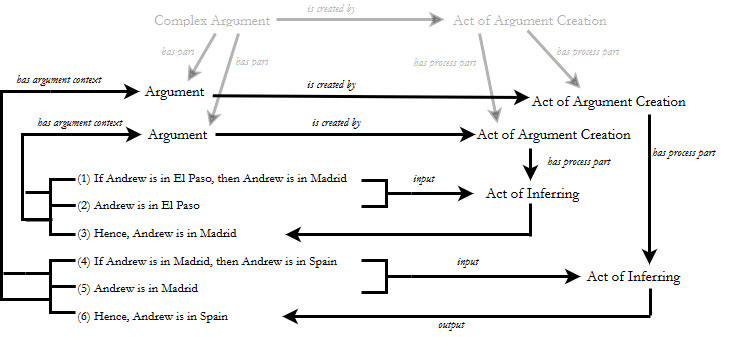
Here, we have a simple argument with familiar premises (1) and (2), conclusion (3), and an act of inferring. The premises and conclusion, moreover, have a unique Argument as argument context, which is created by an Act of Argument Creation having the Act of Inferring as process part.

Complex arguments typically involve a single *act of inferring* on one disambiguation and a corresponding single *act of argument creation*, as illustrated with a familiar example:



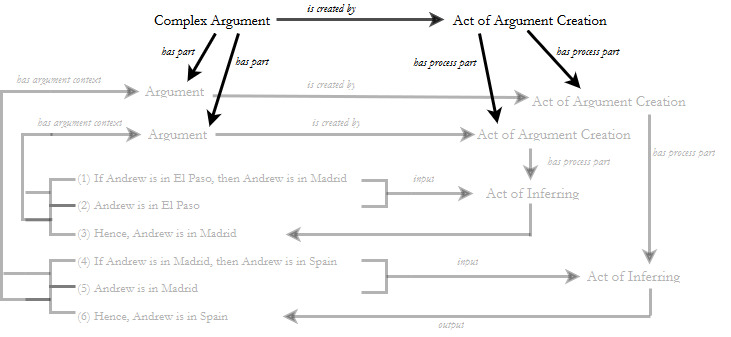
*Diagram 7: Complex argument with one act of inferring*

However, complex arguments have parts each of which involves an *act of inferring* and an *act of argument creation*, illustrated by a disambiguation of our familiar complex argument:



*Diagram 8: Complex argument emphasis on argument parts*

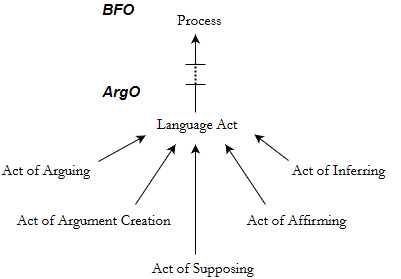
Here, we have two arguments each with an *act of inferring* and *act of argument creation*, and each of which stands in the *is created by* relation to a distinct argument. Since these distinct arguments are parts of a larger complex argument, plausibly they are tied to a larger *act of argument creation* which stands in the *is created by* relation to the complex argument. In pictures:



*Diagram 9: Complex argument emphasis on complex*

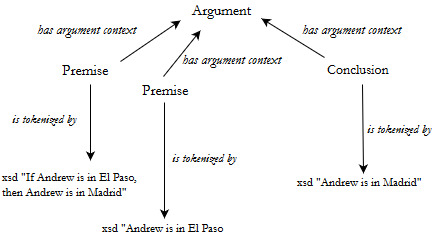
Here, we observe the complex argument *is created by* an *act of argument creation* which has as process parts two *acts of argument creation*, paralleling the argument parts which compose the complex argument.

The various acts we have deployed in our treatment of arguments are, of course, processes, but they are distinguished from other processes in that they involve language, e.g. baking/running vs act of arguing/act of argument creation. We thus unify these acts by extending the BFO class Process to Language Act, where a language act is an intentional act involving language. As before, we illustrate the extension (arrows indicate the *is\_a* relation):



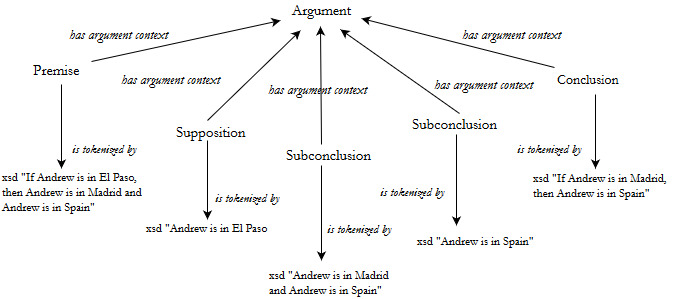
*Diagram 10: BFO Process and ArgO acts relationships*

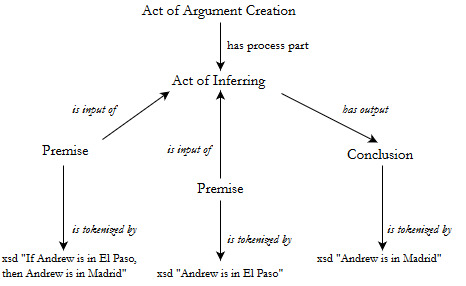
Note, the dashed line between Language Act and Process indicates there may be further classes between the two, e.g. Intentional Act. We rest with our extension as described, leaving discussions of intermediary classes for future work.

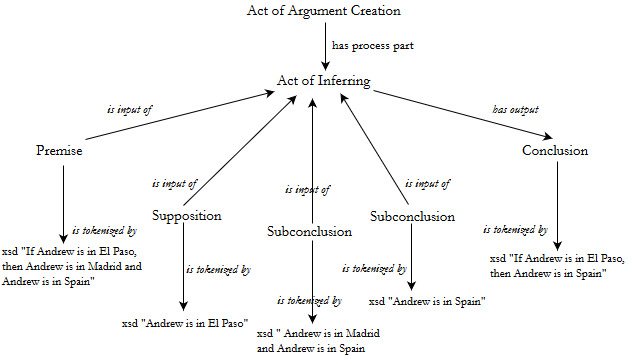


Before turning to our axiomatization of ArgO and formal results, it is illustrative to examine our complex argument example involving supposition, from a slightly different perspective than that above. Consider:

1. If Andrew is in El Paso, then Andrew is in Madrid and Andrew is in Spain
2. SUPPOSE **|** Andrew is in El Paso
3. **|** Hence, Andrew is in Madrid and Andrew is in Spain
4. **|** Hence, Andrew is in Spain
5. Hence, if Andrew is in El Paso, then Andrew is in Spain







[[35]](#footnote-35)

Note, despite speaking of processes, it is not necessary to know the precise order or time on which these various cognitive acts occur in order to posit their existence. Still, a natural temporal ordering suggests itself, where the *act of inferring* precedes the *act of concluding* in a standard ordering of temporal points or perhaps intervals. A full treatment of a given argument, we surmise, will reflect temporal precedence of cognitive acts. We leave this aspect, however, for specific users of our ontology to work out in each case.

We find using processes is a natural way to think about the function of a statement within an argument. In addition, it also allows for a symmetric pattern of ordering, since an act of argument creation will have acts of inferring, acts of concluding, and acts of supposition as process parts, and we can read off of these process part relationships the part relationships that hold among the argument and its parts. This means, for instance, that if a premise entails a subconclusion, and that subconclusion entails another subconclusion, that there is a parallel series of parthood relationships on the process side, such that there are two acts of inferring, both of which are process parts of an act of argument creation, both of which share a statement as a participant.

*ArgO and Adequacy Constraints*

Recall, we began our discussion by defending adequacy constraints an ontology of arguments should meet, after which we found many recent argument ontologies failed one or more of these conditions. In contrast, ArgO rests on logically defined classes employing a genus-species form [1] which the ontology inherits from retaining compatibility with BFO and IAO, meeting condition [6] as well. Sentences are distinguished from content, with both distinguished from the role content may play in an argument [3], roles being characterized in canonical argument contexts, as premises, conclusions, suppositions, and subconclusions [2]. Thus far, ArgO also meets [4] and [5], as it is compatible with the proposal that weaknesses of arguments can be represented, as well as multiple approaches to logic. Rather than leave this as mere possibility, we examine two extensions in later sections which demonstrate how these conditions may be met. We turn first to an axiomatization of ArgO and accompanying formal results.

*Axiomatization of ArgO*

ArgO is a small ontology consisting of only sixteen classes, designed to represent the domain of arguments. ArgO has been implemented in FOL and OWL 2 DL and each is a conservative extension of the Information Artifact Ontology (IAO), a widely used information ontology employed in the biomedical domain, which is itself a conservative extension of BFO.[[36]](#footnote-36)

Here we include sample axioms characterizing classes and relations of ArgO. The reader is directed to the ArgO github repository for the complete set of axioms.[[37]](#footnote-37) Our language is unsorted first-order logic supplemented with identity, with standard logical connectives. All variables are implicitly bound, and leading universal quantifiers are omitted. We reserve the variable “t” for instances of the BFO class “Temporal Region”.

We assert axioms characterizing the relationship between the classes of ArgO, the IAO, and BFO, such as:

1. *InformationContentEntity(x) 🡪 GenericallyDependentContinuant(x)*
2. *CollectionOfStatements(x) 🡪 InformationContentEntity(x)*
3. *Argument(x) 🡪 CollectionOfStatements(x)*
4. *ComplexArgument(x) 🡪 Argument(x)*
5. *Statement(x) 🡪 InformationContentEntity(x)*
6. *LanguageAct(x) 🡪 Process(x)*
7. *ActOfArguing(x) 🡪 (LanguageAct(x) & ~(ActOfArgumentCreation(x) | ActOfSupposing(x) | ActOfAffirming(x) | ActOfInferring(x)))*
8. *ActOfArgumentCreation(x) 🡪 (LanguageAct(x) & ~(ActOfArguing(x) | ActOfSupposing(x) | ActOfAffirming(x) | ActOfInferring(x)))*

We also assert these classes are disjoint. In addition, we assert axioms characterizing the classes of ArgO in accordance with the definitions defended above. For example:

1. *Argument(x) 🡪 ∃y∃z∃t (Statement(y) & Statement(z) & y≠z & hasArgumentContextAt(y,x,t) & hasArgumentContextAt(z,x,t))*
2. *ComplexArgument(x) 🡨🡪 ∃y∃z∃t (z≠y & Argument(y) & Argument(z) & continuantPartOfAt(y,x,t) & continuantPartOfAt(z,x,t))*
3. *Premise(x) 🡪 ∃y∃t (ActOfAffirming(y) & outputOf(x,y,t))*
4. *Conclusion(x) 🡪 ∃y∃t ((ActOfSupposing(y) | ActOfAffirming(y)) & outputOf(x,y,t))*
5. *Subconclusion(x) 🡪 ∃y∃z∃t∃w (hasArgumentContextAt(x,y,t) & hasArgumentContextAt(x,z,t) & y≠z & ComplexArgument(w) & continuantPartOfAt(y,w,t) & continuantPartOfAt(z,w,t))*
6. *ActOfArgumentCreation(x) 🡪 ∃y∃t (Argument(y) & isCreatedBy(y,x,t))*
7. *ActOfInferring(x) 🡪 ∃y∃z∃t (Statement(y) & Statement(z) & inputOf(y,x,t) & outputOf(z,x,t))*

And similarly we assert axioms characterizing formal features of relations defended above:

1. *(Premise(x) & hasArgumentContextAt(x,y,t) & hasArgumentContextAt(x,z,t)) 🡪 y=z*
2. *(Conclusion(x) & hasArgumentContextAt(x,y,t) & hasArgumentContextAt(x,z,t))🡪 y=z*
3. *(isCreatedBy(x,y,t) & isCreatedBy(z,y,t))-> x=z) & ((isCreatedBy(x,y,t) & isCreatedBy(x,z,t))-> y=z)*
4. *(ComplexArgument(x) & ActOfArgumentCreation(y) & isCreatedBy(x,y,t))🡪 ∃z (ActOfArgumentCreation(z) & z≠y & occurrentPartOf(z,y))*
5. *(ActOfInferring(x) & ActOfArgumentCreation(y) & occurrentPartOf(x,y) & Statement(z) & (inputOf(z,x,t) | outputOf(z,x,t))) 🡪 ∃w(hasArgumentContextAt(z,w,t) & isCreatedBy(w,y,t))*

Additionally, we provide sample theorems which follow from our axiomatization. Proofs were generated with the automated theorem proving software Prover9, and can be found in our repository. Results include the *hasArgumentContextAt* and *isCreatedBy* relations are both irreflexive and asymmetric, as well as:

1. *(ActOfInferring(x) & ActOfArgumentCreation(y) & ActOfArgumentCreation(z) & occurrentPartOf(x,y) & occurrentPartOf(y,z)) 🡪 occurrentPartOf(x,z)*
2. *(Premise(x) & hasArgumentContextAt(x,y,t) & ActOfInferring(z) & inputOf(x,z,t)) 🡪 ∃w (ActOfArgumentCreation(w) & occurrentPartOf(z,w) & isCreatedBy(y,w,t))*
3. *(Conclusion(x) & hasArgumentContextAt(x,y,t) & ActOfInferring(z) & outputOf(x,z,t)) 🡪 ∃w (ActOfArgumentCreation(w) & occurrentPartOf(z,w) & isCreatedBy(y,w,t))*

Countermodels were also demonstrated for certain sentences, using the finite model checker Mace4 bundled with Prover9. For example, a countermodel (which can be found in our repository) was found for the following:

1. *(ActOfInferring(x) & ActOfArgumentCreation(y) & ActOfArgumentCreation(z) & occurrentPartOf(x,y) & occurrentPartOf(x,z))->y=z*

This is desirable. If an act of inferring is part of an act of argument creation which it itself part of another distinct act of argument creation, by the transitivity of parthood, the act of inferring should be part of the second act of argument creation. Moreover, using Mace4 we were also able to demonstrate satisfiability for our axiom set, and thus consistency.

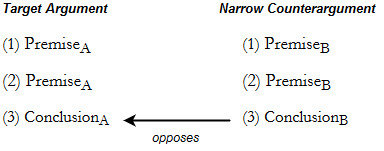
**Extensions to ArgO**

In this section we examine how ArgO meets conditions [4] and [5] in detail by introducing natural extensions of the ontology. The first extension displays how ArgO may be used to examine weaknesses among arguments. The second displays how ArgO may be used with different logical systems, e.g. classical, multi-valued, intuitionistic, etc. Each extension is accompanied by an axiomatization, demonstrating its formal relationship to ArgO.

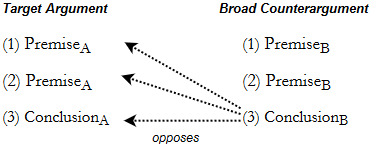
*Extensions: Narrow and Broad Counterarguments*

Attempts to convince others of the truth of some conclusion are often met with counterarguments. In every case, counterarguments are themselves arguments, but an argument is only a counterargument when it stands in a certain relation to another argument. Such relations come in many different forms. For example, for some argument A there may be some counterargument B if counterargument B has a conclusion that stands in a relation of contradiction to the conclusion of argument A. This is a narrow case, however. More often cases of counterarguments undermine, but do not contradict, some part of another argument. Broadly, some argument A may have some counterargument B if the conclusion of B raises concerns for the justification of one or more premises of A. Concerns over justification are evidential and not, strictly speaking, logical. Nevertheless, this is a notion of counterargument well worth representing.

Because counterarguments are partially constituted by a wide range of distinct relations, we do not treat them as a class in ArgO. Nevertheless, it is straightforward to use our classes to construct queries to return various kinds of counterargument. We need only extend our proposal slightly to include an *opposes* relation, which holds between premises, suppositions, conclusions, and subconclusions across argument contexts. This relation is broad enough to permit more refined sub-relations, e.g. *negates*, *contradicts*, *undermines*, etc. Hence, a query to return all of the narrow counterarguments for a given target argument, might look for all arguments whose conclusions stand in the *opposes* relation to the conclusion of the target argument. In pictures:



Similarly, a query to return all of the broad counterarguments for a given target argument, might look for all arguments with any premise, supposition, conclusion, or subconclusion that stands in the *opposes* relation to the conclusion of the target argument. In pictures:



Where the dotted arrow lines indicate the holding of any one of these opposes relations is sufficient to count an argument as a broad counterargument. Presumably, with the latter query issuing a larger return than the former.

*Extensions: Argument Schemas, Truth, Probability, Validity, etc.*

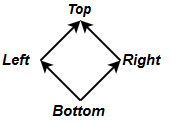
Many researchers who wish to extend the present ontology will likely want to incorporate a treatment of formal properties of arguments. In our desire to remain neutral with respect to different approaches, we have not built into our ontology a univocal treatment of this subject. This allows, for instance, researchers who wish to use Walton argument schemas with ArgO may do so by introducing a class of schemas under information content entity, with each particular schema serving as an instance of the class. In particular, the Walton argument schema called “abductive argument” includes cases of arguing from the existence of a data set in a given case to the best explanation of the data set. This instance of an argument schema can then be asserted to be describing particular arguments in corpora that share the “abductive argument” form.

As indicated above, statements are commonly understood as the bearers of truth or falsity. ArgO may accommodate evaluations of statements by adding the process *act of evaluation* which holds between statements and nominal measurements, when an individual evaluates a statement and assigns it a value of some sort. A natural thought would be to characterize the assignment of truth or falsity to a statement with text values, such as “True” and “False”. Text values on their own, however, do not bear relations to other text values. In other words, assigning “True” to a statement A and “False” to a statement B which contradicts A, only conveys that A and B have different evaluations, not that they are in conflict. To accommodate intuitive relationships among assignments, we recommend introducing subclasses of nominal measurement for each desired evaluation. In the standard case, the result will be two disjoint sibling subclasses, one class Top and one class Bottom, where intuitively the former is for those evaluations considered true and the latter for those considered false, and where the former is a mereological part of the latter. In pictures:



The class names stem from the observation that evaluations extended beyond, but including, the two valued case, can be modeled as lattice structures, where the value “True” is understood as the least upper bound of the lattice, and “False” the greatest lower bound. Lattices, moreover, are partial orders and so with boundaries in place, can be modelled with mereological relations which provide relationships among values one would expect. Hence, our recommendation is that while Bottom and Top are disjoint sibling subclasses of Nominal Measurement, the former is part of the latter.[[38]](#footnote-38)

The point generalizes, as demonstrated by the four-valued case. Let admissible statement evaluations include, in addition to truth and falsity, both true and false, and neither true nor false. Assume, as many-valued logics do, these are distinct values. We represent these values and the relationships among them with Bottom and Top as above, and by adding further disjoint sibling classes Left and Right, where we say Left is part of Top and discrete from Right, Right is part of Top and discrete from Left, and Bottom is part of Left, Right, and Top. In pictures:



Where the arrows indicate direction of parthood. Such a lattice structure is often used to provide semantics for logics of first-degree entailment. The conjunction of any two values is their greatest lower bound, the greatest thing from which one can get to both going in the direction of the arrows. For example, Left conjoined with Right is equivalent to Bottom, while Left conjoined with Top is equivalent to Left. On the other hand, the disjunction of two values is the least upper bound, the least thing from which one can get to by going down the arrows. For example, Left disjoined with Right is equivalent to Top, as is Left disjoined with Top. Negation alternates the values Bottom and Top, while leaving Left and Right unaffected. Hence, the lattice of values understood in terms of parthood imposes a structure from which one may read off the connectives of a four-valued logic.

Similar remarks apply for logics with greater than four values, e.g. fuzzy logic. Probabilities may be attributed along similar lines. Assuming for simplicity only five probability values (0, .25, .50, .75, 1), users may introduce corresponding subclasses of nominal measurement ordered through parthood. In pictures:

INSERT DIAGRAM HERE

Here we have Bottom as a proper part of Low Middle, which in turn is a proper part of Middle, and so on until Top, which is part of only itself. Hence, to evaluate a statement as having a 50% probability of being true, is to assign an instance of the Low Middle class to that statement, which includes at least a 25% probability of it being true, and trivially a 0% chance. Importantly, such an evaluation says the highest probability evaluation is 50%, no more.

The basic strategy outlined has a number of benefits. First, evaluations of statements are treated as information entities, rather than as qualities of statements carrying unintuitive ontological commitments. Second, our proposal can admit of disagreements over evaluations of the same statements by relativizing evaluations to acts with participants. Third, since evaluations are independent of the extensions of statements, we can the evaluations of statements independent of questions about whether they correctly refer to reality. Finally, as displayed above, our approach is general, permitting various evaluations for statements.

**Future Work**

It is our wish that ArgO be re-used for many different projects, and for this reason, that it remain a relatively small mid-level ontology. In our experience, it is simply easier to re-use a small, well-defined, consistent ontology based on an expertly developed analysis of a domain, rather than a large ontology developed for an application. Large ontologies require large resources, expertise, and time to be well-developed, and because these are not readily available, large ontologies often take short cuts, making representation decisions not on the basis of ontological analysis, but rather to get some particular project-based query strategy to work. Such decisions are allowable in particular extensions that facilitate engineering applications, but if ontologists are to maintain a long-term strategy of data integration, such short cuts should be avoided.

In the future, we plan to provide interpreted extensions of ArgO that will offer further classes, properties, and distinctions relative to a system of logic, and we encourage others to do this as well. We believe that the formal features of OWL and OWL reasoners such as Hermit and Fact++ will allow for inferences also about the validity and soundness of arguments, relative to a system of logic. This remains an interesting project for future research to pursue.

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3. Adapted from a statement of the Office of the Press Secretary of the United States (2002). [↑](#footnote-ref-3)
4. Rapanta et al. (2016) [↑](#footnote-ref-4)
5. McCullough et al. (2004) [↑](#footnote-ref-5)
6. Arp et al. (2015), p. 181 [↑](#footnote-ref-6)
7. Many ontology reasoners (Fact++, Hermit) are based in a decidable fragment of first-order logic. In particular, of this family of so-called description logics, these reasoners employ SROIQ, an expressive fragment of first-order logic restricted to classes and binary relations, the latter having further sub-relation restrictions. SROIQ is the foundation of the widely-used web ontology language OWL2, found in Protégé. [↑](#footnote-ref-7)
8. See Smith (2012), Menzel, (2011), and Gruninger et al. (2014). [↑](#footnote-ref-8)
9. See (Parsons, 2013), (Clark-Younger, 2014). [↑](#footnote-ref-9)
10. Arp et al. (2015) [↑](#footnote-ref-10)
11. Breuker et al. (2006), p. 50 [↑](#footnote-ref-11)
12. Kennedy (1991), p. 75. [↑](#footnote-ref-12)
13. Cf. Baronett, *Logic,* Second Edition, Oxford University Press (2012), chapter 11: “legal arguments contain at least one premise and can be appreciated and understood when you are able to grasp the underlying logic.” [↑](#footnote-ref-13)
14. We introduce the term ‘collection’ as an alternative to ‘aggregate’. Whereas in BFO 2.0, any class of continuant may be a part of an aggregate, we avoid treating arguments as aggregates of sentence contents since, aggregates must be mereologically disjoint, and clearly a given argument may contain an identical sentence content in distinct positions of an ordering. For example, the argument: “(1) *Moles are happy*; (2) Hence, *moles are happy*” would not count as an aggregate of sentence contents, since the collection of (1) and (2) is not pairwise disjoint. Hence, we use the term ‘collection’, which does not require mereological disjointedness. Furthermore, we use the term ‘item’, as opposed to ‘member’ or ‘element’ as those terms are used in set theory, to further convey that arguments are not sets of sentence contents, as sets cannot contain the same member twice. [↑](#footnote-ref-14)
15. E.g., van Eemeren and Grootendorst (1992) have shown that argumentation schemes are useful in determining whether or not arguments are fallacious. [↑](#footnote-ref-15)
16. The AIF ontology accomplishes this distinction, but only by distinguishing within the graph I-nodes that represent the claims of a domain of discourse from S-nodes, which represent patterns of reasoning. However, we find our approach preferable, since what unites the instances of I-nodes and S-nodes is that they are both information content entities—a subclass of generically dependent continuant in BFO. Thus, we allow them to be part a single taxonomical structure. [↑](#footnote-ref-16)
17. Cf. the classification presented in Fang and Hirst (2011). [↑](#footnote-ref-17)
18. Rahwan, I & Banihashemi, B. (2008) discusses the AIF and updates it in their ArgDF ontology, which employs OWL-DL to reason over argument networks. [↑](#footnote-ref-18)
19. Breuker et al. (2006), p. 79 [↑](#footnote-ref-19)
20. Swift, Jonathan. *A Modest Proposal For preventing the Children of Poor People From being a Burthen to Their Parents or Country, and For making them Beneficial to the Publick* (1729) [↑](#footnote-ref-20)
21. Toulmin (2003) [↑](#footnote-ref-21)
22. Vitali and Peroni (2011) [↑](#footnote-ref-22)
23. Dumontier, et al. (2014) [↑](#footnote-ref-23)
24. The class ‘information content entity’ is broadly used among ontologies that employ the BFO framework. For a review on its characteristics and use, see Ceusters & Smith (2015). [↑](#footnote-ref-24)
25. The OWL version of the SIO was accessed April 16, 2017 here: <https://raw.githubusercontent.com/micheldumontier/semanticscience/master/ontology/sio/release/sio-release.owl> [↑](#footnote-ref-25)
26. See (McGrath, 2012). In philosophical traditions, the content of sentences is sometimes called a “proposition”. Entrenched long-standing disputes over this term make it unwieldy for our purposes. Hence, we stick with the more neutral of the two. We do not intend our use to commit us to abstracta which would conflict with the realism adopted by BFO (Ceusters & Smith, 2015). [↑](#footnote-ref-26)
27. Cf. The use of “Object” vs “Object Aggregate” in (BFO2.0), where “Aggregate of X” is permitted for any class of continuants. We avoid introducing aggregates along these lines since, among other reasons, aggregate components must be mereologically disjoint, but a given argument may have repeating statement parts in distinct positions, e.g. (1) God exists; (2) Hence, God exists, would not count as an aggregate of statements, since the content of (1) overlaps the content of (2). In contrast, our approach treats arguments as, in a sense, wholes, which have parts. [↑](#footnote-ref-27)
28. We leave open whether there are other disjoint siblings of Argument reflecting distinct orderings of statements. [↑](#footnote-ref-28)
29. Accordingly, an ontology of arguments should not treat statement as a subclass of premise, supposition, or conclusion. SIO which would treat *Andrew is in Madrid* not as a type of statement, but as a type of premise. This leaves SIO unable to say what content is in common between our sample arguments. More sharply, such a proposal would have difficulty explicating why an argument such as (1) *God exists*; (2) Hence, *God exists*, is a bad argument. [↑](#footnote-ref-29)
30. (BFO2.0, pg. 56-57). [↑](#footnote-ref-30)
31. Cp. (Stalnaker, 1984), (Arcangeli, 2016), (Toumela, 2000) [↑](#footnote-ref-31)
32. Observe too the converse relationship between believing and affirming: “I believe it is raining outside but I do not affirm it” suggests one may believe while not affirming, but the infelicity of “I affirm it is raining outside but I do not believe it” suggest affirming requires belief. For our purposes then, if one affirms a statement then they believe it, but not conversely. Additionally, supposing is independent of both believing and affirming. [↑](#footnote-ref-32)
33. More specifically, BFO’s mereology is bifurcated, with a ternary temporally indexed relation governing parts of continuants, and a binary relation governing parts of occurrents. We suppress the ternary index for continuants here. Both mereologies are provably equivalent to the minimal extensional mereology of (Simons, ). Hence, parthood is reflexive, antisymmetric, transitive, ensures weak supplements, and unique fusions for overlap. Proper parthood is easily defined in terms of parthood, e.g. x is proper part of y just in case x is part of y and x=/y, and is irreflexive, asymmetric, and transitive, and hence, i.e. a strict order. [↑](#footnote-ref-33)
34. Here we rely on the occurrent parthood relation of BFO, where a process part is an occurrent part of some other process. [↑](#footnote-ref-34)
35. Note: For simplicity, we collapse an important intermediary class: information bearers. Strictly, it is the information bearers that are the domain of the relationship ‘has text value’. Hence, each premise, subconclusion, and conclusion is concretized in an information bearing entity which bears a text value relationship to a literal. [↑](#footnote-ref-35)
36. More specifically, a theory T’, or consistent set of first-order axioms, is a (proof-theoretic) conservative extension of theory T iff T and T’ have overlapping signatures, and any theorem of T is a theorem of T’. In this sense, Argo represented as a theory, i.e. set of consistent first-order axioms, overlaps the signature(s) of IAO (and BFO), and any theorem entailed by IAO (or BFO) is entailed by Argo. [↑](#footnote-ref-36)
37. https://github.com/johnbeve/Argument-Ontology [↑](#footnote-ref-37)
38. This is, perhaps, more intuitive when evaluations are given numerical values rather than “True” or “False” which carry certain connotations. With “0” taken as the greatest lower bound and “1” as the least upper bound, the claim is that “0” is part of “1”. [↑](#footnote-ref-38)