The Information Management Framework

Top-Level Categories

Categories for the Top-Level Ontology of the Information Management Framework

Version final draft2 – March 2022

Contents

Executive Summary

This report identifies the top categories that characterise the top-level ontology that will underpin the Information Management Framework's Foundation Data Model (where top categories exclusively and exhaustively divide the world's entities by their fundamental kinds or natures). With these in place, the IMF's top-level ontology has been characterised.

A thin slices approach (described in *Developing Thin Slices* (Partridge, forthcoming)) has been adopted for the development of the foundation data model. The category structure described in this report is being used as the foundation for that process. With these categories in place, that process has a firm foundation.

1. Introduction

1.1 Background

In 2017, the National Infrastructure Commission published *Data for the Public Good* (NIC, 2017) which set out a number of recommendations including the development of a UK National Digital Twin supported by an Information Management Framework[1] of standards for sharing infrastructure data, under the guidance of a Digital Framework Task Group set up by the Centre for Digital Built Britain.

Much work has been done following this, but in particular

- A vision of how society can benefit from a UK National Digital Twin is set out in *Flourishing Systems* (Schooling, 2020).
- The direction for the technical standards, guidance and common resources needed as part of the Information Management Framework is set out in *The pathway towards an Information Management Framework* (Hetherington, 2020) and updated in *Managing Shared Data* (West, forthcoming).

In particular they identified the need for:

- A **Foundation Data Model**: a data model that provides the structure and meaning of data incorporating a top-level ontology based on science and engineering principles, enabling it to be extended to support the broadest possible scope consistently.
- A **Reference Data Library**: the classes and properties needed for the UK National Digital Twin that enable different organizations and sectors to describe things consistently.
- An **Integration Architecture**: the technical means, including open-source software, for sharing data securely with authorised users.

1.2 Purpose

This report sets out the top-level categories that are the Top-Level Ontology for the Information Management Framework's Foundation Data Model.

1.3 Target audience

This report is directed at an audience with a technical expertise in ontology.

[1] In "Data for the Public Good" what we now call the Information Management Framework was called the Digital Framework.

2. Report structure

There are two main sections in the body of the document. The first of these provides the context, establishing the landscape, and the subsequent section provides the content for this landscape. Details have been relegated to the first three appendices with a glossary in the fourth appendix.

3. Context

This section of the report provides an overall picture of the landscape into which the report fits by giving the context for the content in the following section. It firstly provides a broad context. This describes how the report fits into the Information Management Framework of the UK's National Digital Twin programme, linking it with related work. It secondly provides the narrower context. This describes how the report supplies a critical component – the minimal foundation – for the Information Management Framework's thin slices approach.

3.1 Broad context: National Digital Twin programme's Information Management Framework

This report is part of the output of the Information Management Framework of the UK's National Digital Twin programme. The creation of a National Digital Twin is a recommendation of the National Infrastructure Commission's report '*Data for the public good*' (NIC, 2017). This will give a system of systems view of national infrastructure enabling better decisions for better outcomes in its development by connecting digital twins across different sectors in the UK.

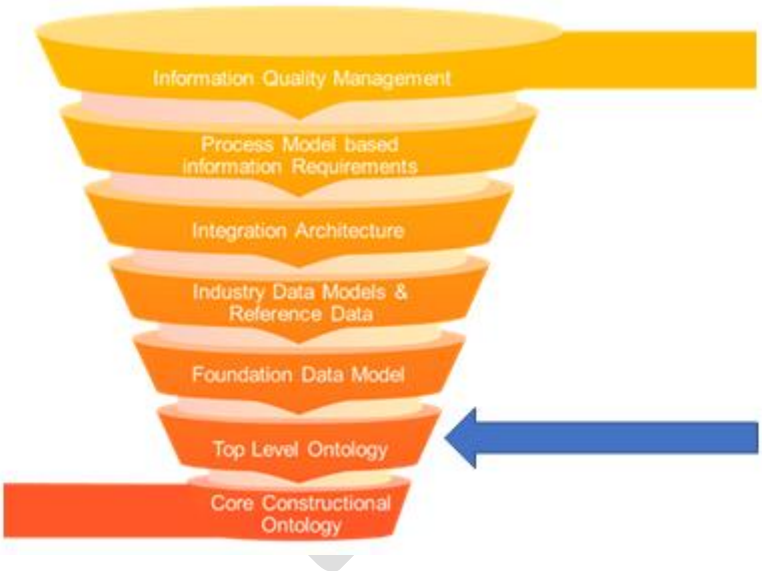

Figure 1 – Information Management Framework: Seven Circles approach

The pathway towards an Information Management Framework: (Hetherington, 2020) recommends the adoption of an Information Management Framework (IMF) that includes a Foundation Data Model (FDM) as a key component**.** *Managing Shared Data* (West, forthcoming) describes the seven circles – shown graphically in Figure 1 – that is being used set out the more technical elements of the IMF. The focus of this report is on the sixth circle – the Top-level Ontology (TLO) – and, by association, the seventh circle – the Core Constructional Ontology (CCO).

The Approach to Develop the Foundation Data Model for the Information Management Framework (West, 2020) determined that four selected 4-dimensionalist TLOs – the *selected TLOs* - best met the technical requirements of the FDM. It further recommended that these be used to develop a TLO that is used to found an FDM seed and that seed is underpinned by rigorously established foundations. This report describes the categories that will form the core of the TLO and found the FDM. *Core Constructional Ontology* (Florio, forthcoming) provides a formalisation of these top-level categories, giving it a rigorous foundation.

3.2 Narrow context: Guide for the Thin Slice Approach

The IMF has adopted a Thin Slice Methodology, whereby the IMF team work closely with a data owner on a useful part of their data to both help them on the path to developing their own information management quality system and identify elements of the FDM and Reference Data Library. A central part of this is taking a 'thin slice' of the dataset and mining its ontological content.

This process is described in the report, *Developing Thin Slices* (Partridge, forthcoming). This report explains that a top-level ontological approach should include both a top-level foundation and a grounding process. It explains how the IMF's TLO and FDM are being developed using a thin slice approach incorporating this grounding process. It outlines the IMF's grounding process and how this needs to be guided by a minimal foundation based upon a TLO. The top categories described in this report will be used as the process's minimal foundation.

The report describes the process as agile, involving the selection of appropriate thin slices from datasets to rigorously validate and refine the proposed foundation – as well as exemplify at the data level what grounded data looks like. (Partridge, forthcoming) describes some early examples. The process mines the ontological content for the FDM, bottom up from existing data sets. It focuses on data quality at scale to ensure that the emerging structures are firmly grounded. The process rigorously validates, cleans and transforms the data enriching the semantics and refactoring it so that it cleanly and correctly fits under the minimal foundation. The process has been developed to minimise costs and risks – while maintaining quality to maximise benefits. The output of one round of the process can be a stage in the evolution of the FDM and become an input to a subsequent round as new data (and so requirements) are taken into account. This staged life-cycle approach accommodates the evolution of the FDM in response to emerging requirements.

The process is guided by the minimal foundation. This needs to be sufficiently minimal that it supports, but doesn't constrain, the analysis. It also needs to be a sufficiently rich foundation that it can both validate and, where indicated, refine both itself and the mined content. This report describes the minimal foundation that the IMF is adopting.

4. Content

This section describes the top-level categories that compose the minimal foundation which the IMF has selected to use to guide its thin slice grounding process; the foundation upon which the FDM seed is being founded. The first section explains the requirement for a minimal foundation – recapitulating (Partridge, forthcoming). The IMF approach involves identifying the TLO's categories (the top-level categories) as an appropriate system of objects to act as a foundation for the thin slices grounding process. The next section describes these categories. The section after that explains the selection of the categories and describes the approach to refining these – constructionalism. It explains why this gives rise to the suitable categories for the minimal foundation so that, when formalised, they provide a rigorous unified structure. The next section then describes the IMF's selected top-level categories.

4.1 The requirement for a minimal foundation

The IMF's thin slices approach mines – perhaps, more appropriately, salvages – ontological content from existing datasets. If one is interested in interoperability, then it makes sense to use a top-level foundation (based upon a TLO) to guide this process. This helps to ensure that the various, independently developed, thin slices have an interoperable common structure. Typically, the benefits of the approach are heavily dependent upon the appropriateness and quality of the top-level foundation adopted. They are, of course, equally dependent upon the quality of the process that is being guided.

With no top-level to guide the process, the ontological commitments would be far from clear and so the top-level commitments would be completely inscrutable. In this situation, a common picture is unlikely to arise in independent thin slices. Hence, the process's foundation needs to be sufficiently general and complete to be able to provide guidance across the range of thin slice domains. However, the thin slices grounding process also plays a validation and assurance role. So, as far as possible, the foundation should make the minimal commitment it can, allowing as much as possible of the ontological commitment to be subject to the validation process.

This suggests an architectural accommodation. One aims for a balance where the foundation is sufficiently ontologically rich and complex to guide the analysis effectively, but also sufficiently minimal that it does not hinder or block emerging refinements or otherwise render the validation ineffective. One seeds the grounding process with a foundation that is sufficient to make the top-level ontological commitments scrutable. This could then guide the ontological mining. One also makes this as minimal as possible to maximise the benefits of bottom-up grounding. To be as open as possible to refinement as the lower-level ontological commitments emerge from and are confirmed in the data.

A natural candidate for the top-level foundation are an ontology's top-level categories. These are a comprehensive system of mutually exclusive, very general kinds into which entities in the ontology divide. They provide completeness as these exclusively and exhaustively divide all entities. They provide one kind of minimality as they are both necessary and sufficient to provide this completeness. Anything smaller would be incomplete, anything bigger would include unnecessary objects. They provide another kind of minimality by being as general as possible. Ontic category systems are a well-studied area in philosophy and further details on these are provided in Appendix A.

4.2 Selecting the top-level categories and giving them a rigorous, constructional, foundation

As noted above, *The Approach to Develop the Foundation Data Model for the Information Management Framework* (West, 2020) identified a family of TLOs that form the basis for the NDTs TLO: "There are four Top-Level Ontologies that meet all the technical requirements: BORO, IDEAS, HQDM and ISO 15926-2. They are distinct from the other Top-Level Ontologies in being 4-dimensionalist. They are otherwise also all closely related in that they all take BORO's 4-dimensionalist foundation as their starting point, although they have been developed with different purposes in mind from there. … It is further recommended that these be used to develop a TLO that is used to found an FDM seed and that seed is underpinned by rigorously established foundations." (West, 2020, p. 4).

In the first half of the twentieth century, there was significant interest in (and development of) constructional approaches in philosophy. In the last three decades, there has been a revival of interest. Building upon this, in the last five years or so, there has been significant work in exploring and developing a constructional framework for these TLOs (Partridge, 2017) (Partridge, 2019) (Partridge, forthcoming) and (Partridge, 2021)**.** This is relevant as the constructional approach provides a solid framework for establishing an appropriate minimal foundation.

The constructional approach involves a system of constructors that create objects. In this system, one starts with some objects, often called givens. Constructed objects keep emerging as the result of the application of constructors to the currently available objects. Once the constructions have been exhausted, the ontology is complete. What is important from the perspective of requirements for a minimal foundation, is that the constructional approach enables clear answers to be given about the number and nature of the categories as well as the completeness of ontology. It makes these features explicit and transparent. The type of the constructor determines the category of the objects it generates. So once one has the list of constructors, one also has the list of the categories. Similarly, as an object can only be either given or constructed. Once one knows the givens and the constructors, one knows what objects can exist.

Hence, the application of a constructional approach to the selected TLOs provides us with a clear-cut minimal foundation but also to underwrite an extensional criterion of identity. This is outlined in the next section. Appendix B provides more detail on the constructional approach and Appendix C links the TLO categories in this constructional ontology with the 4-dimensionalist TLOs chosen to develop the FDM seed.

The constructional approach also provides a useful way to not only unify the formalisation of the minimal foundation. By developing a general formalisation of the construction operation, one can use this across the individual constructors in the ontology. This formalisation has been done in *Core Constructional Ontology* (Florio, forthcoming). This provides a rigorously established foundation.

The IMF team has substantial experience of working with this process and this gives us confidence that we have selected a suitable system of ontic categories. We have found not only that the foundation's minimality is suitably balanced for both efficiency and validation, but also that its richness facilitates the analysis.

4.3 The IMF's Category-based, Constructional, Minimal Foundation

The IMF's minimal foundation is composed of the categories common to the selected TLOs (the mapping in Appendix C). It is a complete constructional framework (see Appendix B), one that generates all the objects needed for the ontology.

It uses four constructors (three fundamental and one derived):

1. Sum Constructor
2. Set Constructor
3. Tuple Constructor
4. Union Constructor (derived)

These are sufficient to construct all the objects and grounding relations in the IMF ontology.

There are three (categories) types of object:

1. Individuals
2. Sets

3. Tuples

Where individuals are concrete particulars that exist in space and time. Sets are collection of objects – of any category. Tuples are individual relations – where the places of the relation can be objects of any category.

And four (categories of) grounding relations:

1. part-of-whole relations
2. element-of-set relations
3. tuple-place relations
4. sub-super-set-of relations

A construction using the sum constructor takes individuals and constructs the fusion of them creating part-of-whole relations between its inputs and output – as shown graphically in Figure 2. Hence all individuals are the sum of other individuals, including the limit case where they are the sums of themselves. A construction using the set constructor takes objects and constructs the set of them creating element-of-set relations between its inputs and output – as shown graphically in Figure 3.

A construction using the tuple constructor takes objects (in an order) and constructs a tuple from them creating tuple-place relations between its inputs and output – as shown graphically in Figure 4. (Note: while this is similar to the tuples used in relational databases, it is not exactly the same.)

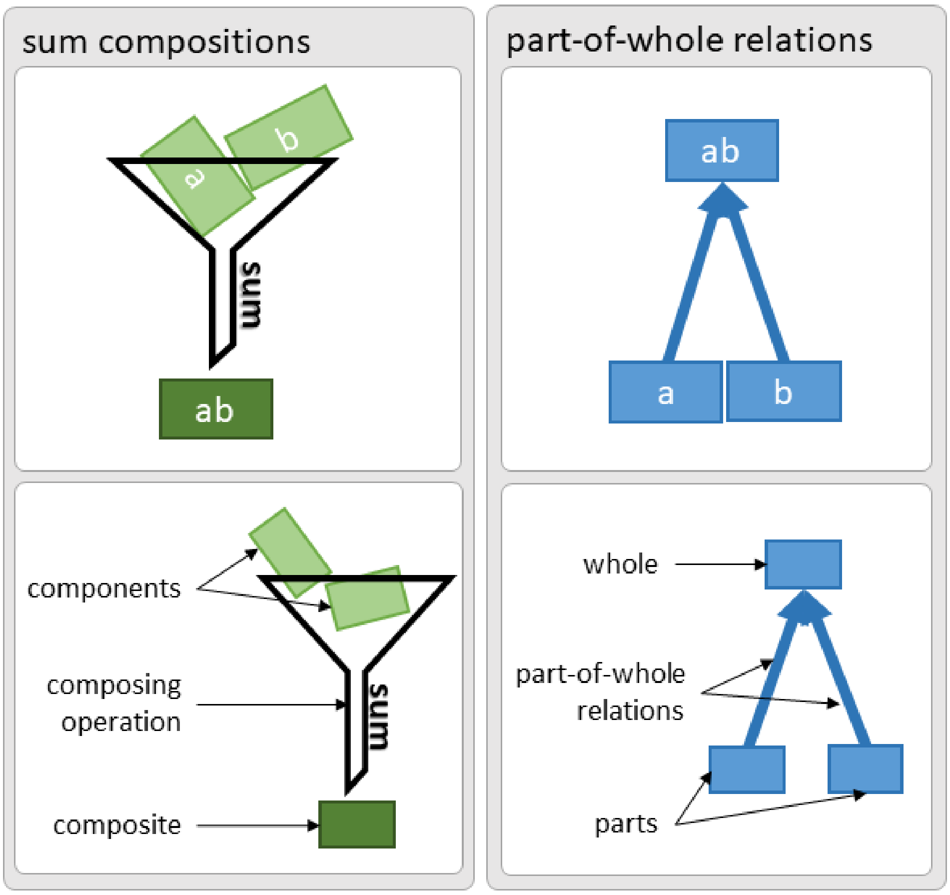

Figure 2 - Sum construction example

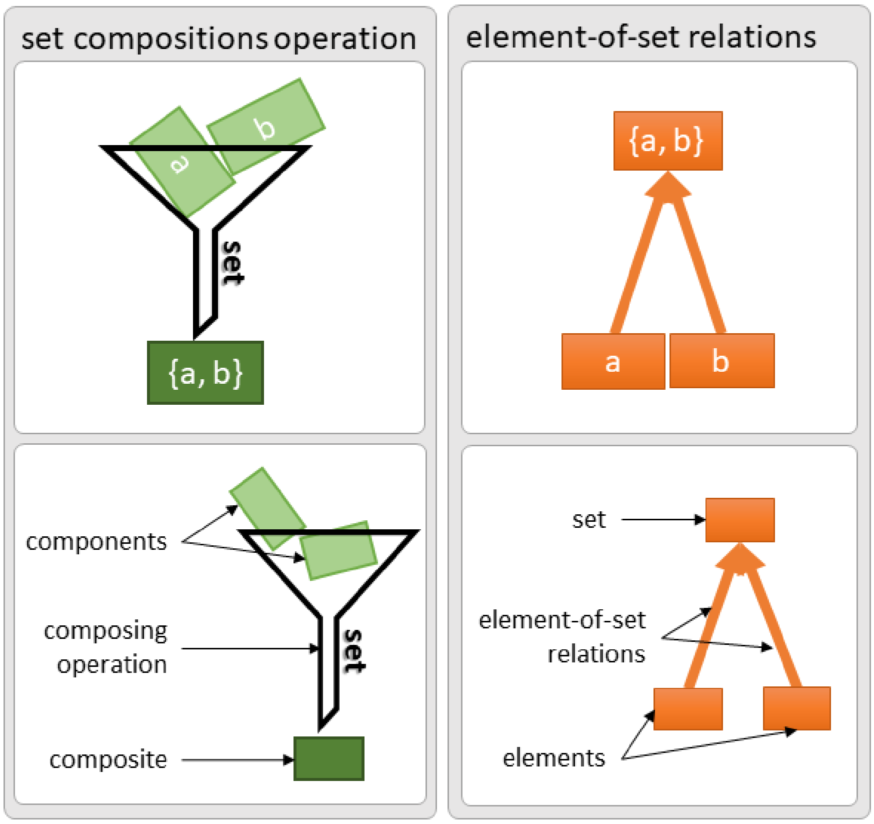

Figure 3 – Set construction example

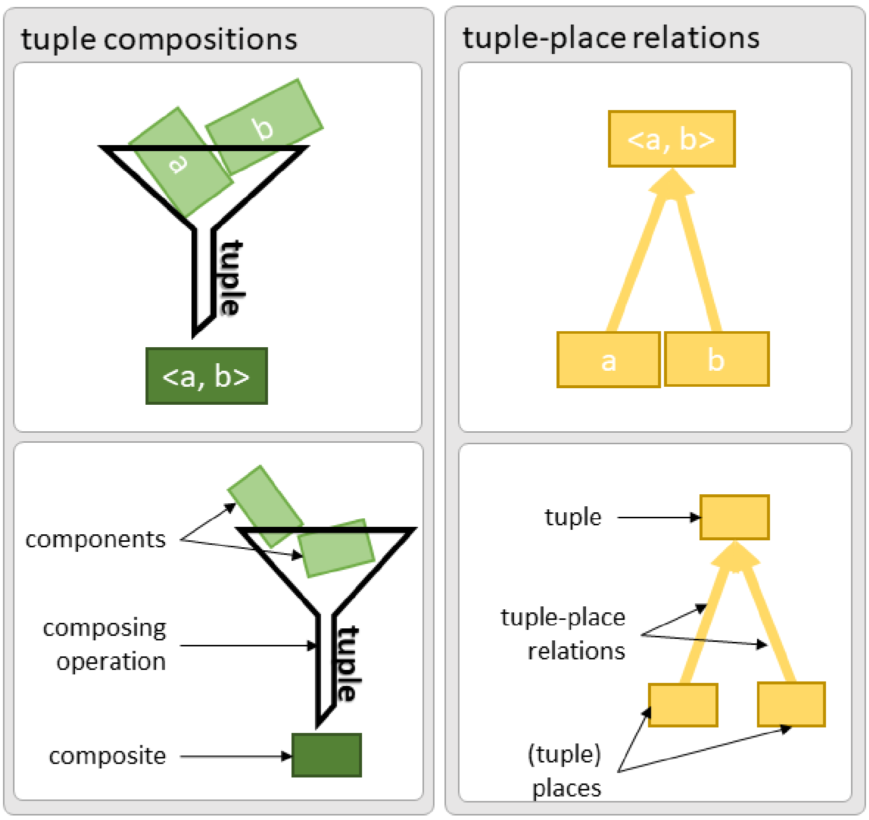

Figure 4 - Tuple construction example

A construction using the union constructor takes sets and constructs the union of them – a set - creating sub-super-set-of relations between its inputs and output – as shown graphically in Figure 5.

The remaining components of the TLOs act as a library of patterns to be consulted when deploying the top-level in the grounding process – which validates and refines them. Once quality assured, these patterns can be added to the core model. One can see this clearly in the thin slices we have published (for more detail see (Partridge, forthcoming) . Firstly in the UNICLASS thin slice, which re-uses (among others) the powertype pattern – documented in (Partridge, 2016). Secondly, in the Onomatology thin slice, which re-uses the naming pattern – documented in (Partridge, 2019).

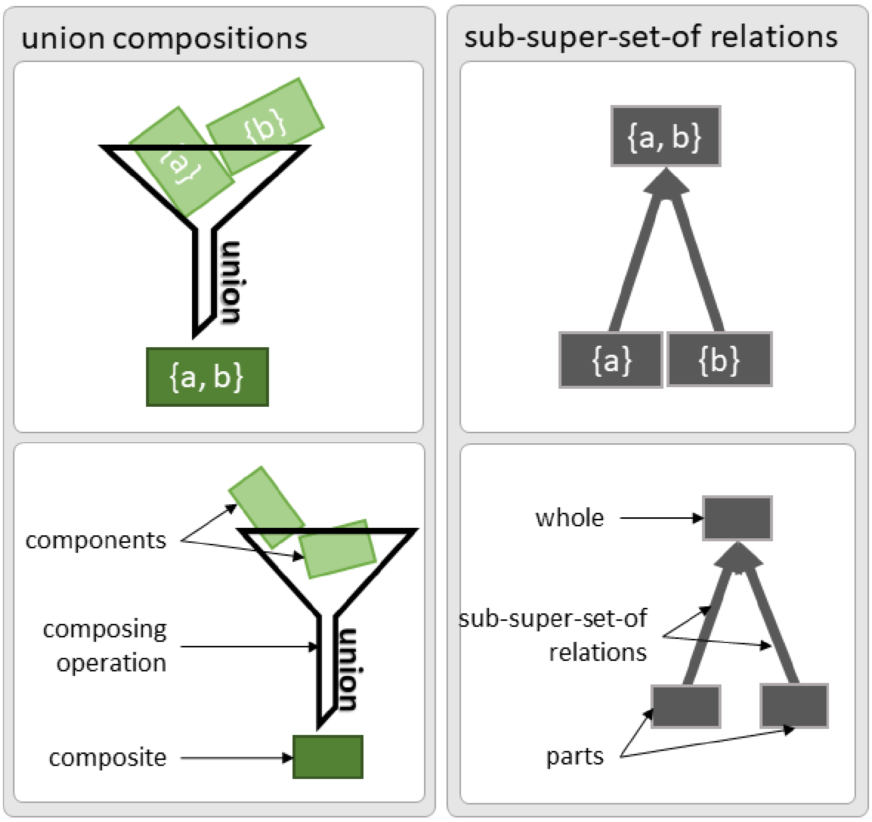

Figure 5 - Union construction example

4.4 Top-Level Ontology Categories – UML Model

These categories can be visualised in a UML-like model. The first two figures show the objects and relations hierarchies.

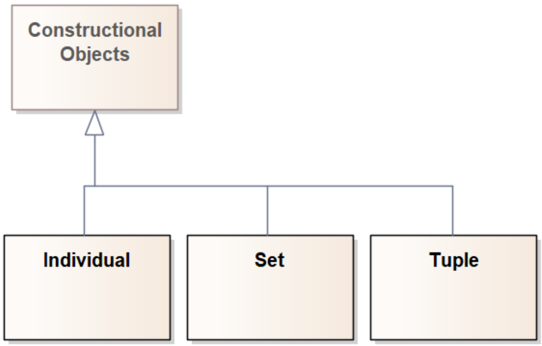

Figure 6 – Constructional Objects hierarchy

Figure *6* shows the three constructor categories, the types of Constructional Objects; Individual, Set and Tuple.

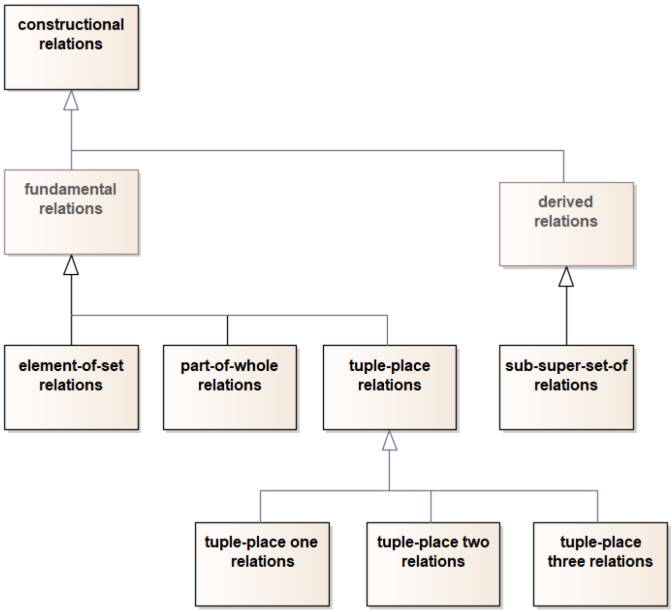

Figure 7 – constructional relations hierarchy

Figure 7 shows the four relational constructor categories, the types of constructional relations; part-of-whole relations, element-of-set relations, tuple-place relations and sub-super-set-of relations. As the model shows, the first three are fundamental and the fourth derived. Furthermore, the tuple-place relations are subdivided by their position or place.

The next four figures show the connections between the Constructional Objects and associated constructional relations.

Figure 8 shows that element-of-set relations relate Set to any Constructional Objects. Figure 9 shows that part-of-whole relations relate Individual to Individual. Figure 10 shows that tuple-place relations relate Tuple to any Constructional Objects. Figure 11 shows that sub-super-set-of relations relate Set to Set.

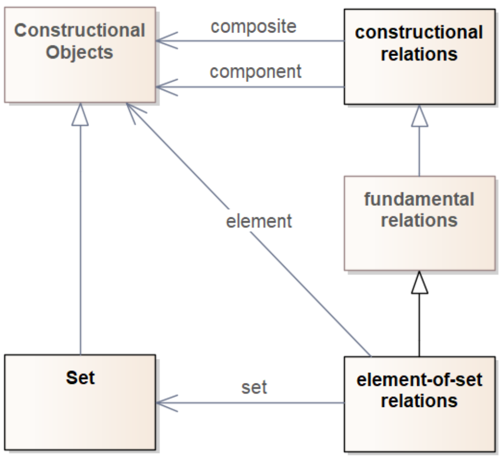

Figure 8 - element-of-set relations

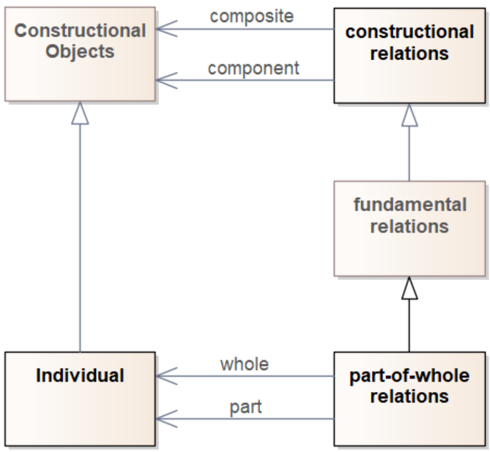

Figure 9 - part-of-whole relations

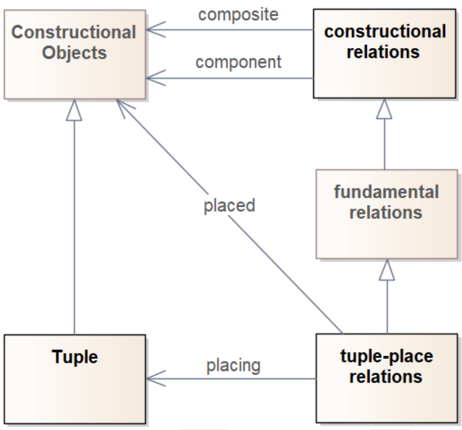

Figure 10 - tuple-place relations

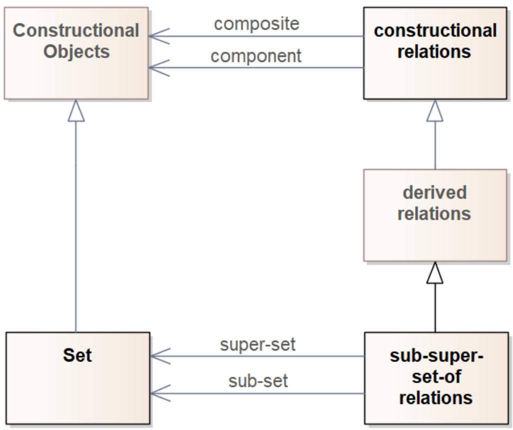

Figure 11 – sub-super-set-of relations

5. Conclusion

This report described the category-based TLO that is being used as the minimal foundation for the thin slices grounding process. It explains how the constructional approach both provides a basis for clearly establishing its minimality as well as its formalisation. These indicate its suitability as a foundation. The minimality provides confidence in the scope and the formalisation in its rigorously established foundations.

Appendix A. Background: Category Systems – Ontic and Conceptual

A.1 The notion of a category

This report describes a system of top-level categories and, in this appendix, we explain in more detail the notion of category we are using. This notion emerged in philosophy and involves exclusively and exhaustively dividing the world's entities by the fundamental kinds or natures into related categories; which then characterise an ontology.

A.2 Categorical predication

Jonathon Lowe has a useful way to think about these categories in terms of how we classify. "When we say of something that it 'is an object', or 'is an event', or 'is a property' – just to cite a few examples – we are engaging in what I propose to call *categorial predication*: we are assigning something to a *certain ontological category*." (Lowe, 2013, p. 50). See also (Lowe, 2012). This is, he says, very different from taxonomic classification which presupposes the ontological categories (maybe implicitly). The general ontological categories are the foundation of classification, without a presupposition of some prior category.

A.3 Two broad types of category system

From a historical perspective one sees two broad types of category system.

Firstly, there are ontic (or realist) category systems of which Aristotle's is the prime example (Ackrill, 1963). These aim to classify reality, cutting nature at the joints. They mark the real divisions between things that determine the basic categorical structure of the world (Van Inwagen, 2011). And, in so doing, provide an inventory of everything there is, answering the most basic of philosophical questions: "What is there?" (Quine, 1948).

Secondly, there are conceptual category systems of which Kant's is the prime example (Kant, 1934). These aim to classify our concepts and so "are due to the nature of the mind and are imposed by the mind on the objects which it knows" (Paton, 1936, p. 258).

A.4 Ordered category systems

Both these types are often summarised as a list – where the simplified representation is not attempting to capture the underlying system of relations between the categories. In the twentieth century a view of ontology, developed that regarded ontology as flat – as essentially a list. This is typically associated with Quine (for example, (Quine, 1948)) . It is reflected in Jonathon Lowe's description in *The Oxford Companion to Philosophy* of ontology as "the set of things whose existence is acknowledged by a particular theory or system of thought." In the last few decades there has been a shift, often grouped together under the label 'Neo-Aristotelian'. This typically takes issue with the flat Quinean view of ontology (Quine, 1948). Instead, it proposes that there is an underlying ontological structure (Schaffer, 2009, p. 354) – and that this structure is more than a set, more than a sorted list of categories, rather that it is structured by some sort of metaphysical grounding – these different structures are illustrated in Figure 12. This, as the label 'Neo-Aristotelan' suggests, is a return to the original notion of the categories as an ordered system rather than a list. From our perspective here, we are interested in category systems – and the examples here are systems in this sense. Our minimal foundation is a category system in the sense that it incorporates an interconnecting system of ordered grounding relations.

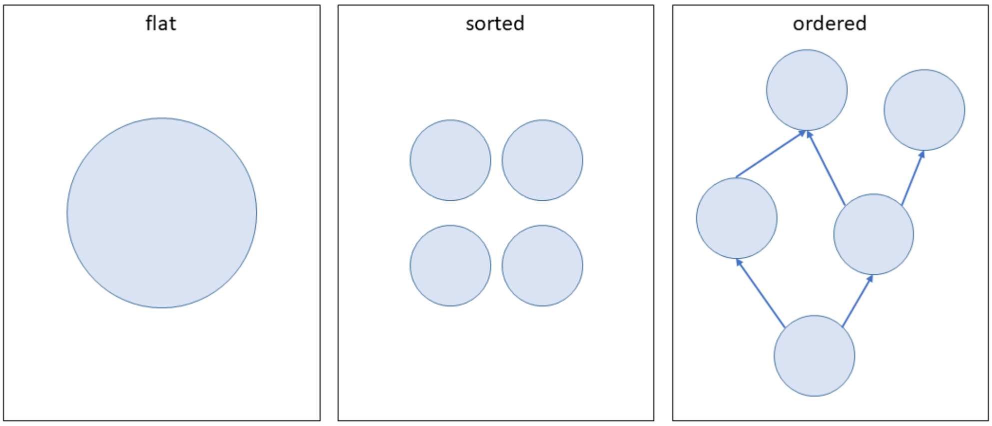

Figure 12 – Types of structure (from (Schaffer, 2009, p. 355))

A.5 Realist TLOs

Realist TLOs typically work with ontic category systems, not conceptual category systems. While Aristotle's is the prime ancient example, of such a system, there are many others. Recent realist category systems include:

- Samuel Alexander's *Space, Time and Deity* (Alexander, 1920) which postulates spacetime as "the one monistic entity that encompasses every entity and every feature in reality" (Fisher 2015, 246).
- Ingvar Johansson's *Ontological Investigations* (Johansson, 1989) which clearly states its interest is in the world: "This book is a book about the world. I am concerned with ontology, not merely with language" (Johansson, 1989, p. 1), and offers "a realist theory of categories regarded as real aspects of being" (Johansson, 1989, p. 2).
- Roderick Chisholm's *A Realistic Theory of Categories* (Chisholm, 1996) which asserts that it is "about the ultimate categories of reality" (Chisholm, 1996, p. 3).
- Joshua Hoffman and Gary Rosenkrantz's *Substance among other Categories* (Hoffman, 1994) which, interestingly, present a system of fundamental categories that is not necessarily exhaustive (Hoffman, 1994, p. 140).
- E. J. Lowe's *The Four-Category Ontology: A Metaphysical Foundation for Natural Science* (Lowe, 2006), which takes categories to be about "what kinds of things can exist and coexist" (Lowe, 2006, p. 5).

Even more recently, interest has grown in constructional ontologies – with constructional category systems. These are discussed in Appendix B.

A.6 Further material

There is a significant amount of material on this general topic, including:

- Amie Thomasson's entry, *Categories*, in The Stanford Encyclopedia of Philosophy (Thomasson, 2019)
- Panayot Butchvarov, *Categories* (Butchvarov, 1995)
- Peter van Inwagen, *What is an Ontological Category?* (Van Inwagen, 2013)
- Peter Simons, *Ontic Generation: Getting Everything From The Basics* (Simons, 2013a)
- Peter Simons, *Why Categories Matter: Grossmann and Beyond* (Simons, 2013b)
- Ludger Jansen, *Categories: The Top-Level-Ontology*. (Jansen, 2013)

Top-Level Categories

In the last half century, there has been a growing interest in applying computational category systems, usually known as Top-Level Ontologies (TLOs). (Partridge, 2020) provides a survey of the current situation in this area.

Appendix B. The Constructional Approach

This appendix explains in more detail both the general notion of constructional ontology that underlies a constructional approach and the specific constructional framework that arises from our application of this approach. One which provides a minimal foundation for the IMF's thin slices approach. Appendix C links the TLO categories in this minimal foundation with the 4-dimensionalist TLOs chosen to develop the FDM seed.

The notion of constructional ontology emerged in philosophy and characterises a constructional approach. In such an approach, there is a system of constructors that create objects. In this system, one starts with some objects, often called *givens*. Constructed objects keep emerging as the result of the application of constructors to the currently available objects. Once the constructions have been exhausted, the ontology is complete. The type of the constructor determines the category of the objects it generates.

This means the ontology can be simply characterised by three parameters: the givens with which one starts, the constructors one employs, and the constructed objects that emerge from applications of the constructors. This highlights two key features of the constructional approach.

- First, it gives us a very clear picture of the overall contents of the ontology, including a comprehensive view of the categories of objects – these are the types of fundamental constructors. For example, if the ontology includes only a set constructor, then all the objects in the ontology fall under one of these two categories: sets and givens. It starts with the givens, and the sets arise from repeated applications of the set constructor.
- Second, it gives us a clear picture of the identity criteria as these emerge from the constructional process: the identity of constructed objects is dictated by their constructors and the inputs of the constructions. For examples, two sets (i.e., objects obtained from the set constructor) are identical if and only if they are constructed from the same objects.

In short, a constructor determines the identity of the objects it generates as well as their category.

B.1 The context for constructional ontology

Constructional ontology has a fairly long and venerable history. Historical work that has a constructional flavour or is an outright example of a constructional approach includes:

- Carnap, "Der Logische Aufbau der Welt, Berlin 1928", 1933
- Goodman, "Steps Toward a Constructive Nominalism", 1947
- Goodman, "A world of individuals", 1956
- Scott, "On engendering an illusion of understanding", 1971
- Goodman, "On relations that generate", 1958
- Armstrong, "Dependency Structures of Data Base Relationships.", 1974

More recent work by Kit Fine has given a fresh impetus to constructional ontology:

- Fine, "The study of ontology", 1991
- Fine, The limits of abstraction, 2002
- Fine, "Our knowledge of mathematical objects", 2005
- Fine, "Towards a theory of part", 2010

Fine's ideas for developing a unified constructional ontology have inspired recent work that is central to the FDM work:

- de Cesare, "BORO as a Foundation to Enterprise Ontology", 2016
- Partridge, "Developing an Ontological Sandbox: Investigating Multi-level Modelling's Possible Metaphysical Structures", 2017
- Partridge, "Coordinate Systems: Level Ascending Ontological Options", 2019
- Partridge, "The Fantastic Combinations and Permutations of Co-ordinate Systems' Characterising Options: The Game of Constructional Ontology", forthcoming
- Florio, Core "Constructional Ontology: The Foundation for the Top-Level Ontology of the Information Management Framework", forthcoming

These reports are all part of the development of the constructional framework for the FDM, the Core Constructional Ontology (CCO), which we now describe. The last report is a rigorous formalisation of this framework.

B.2 The Core Constructional Ontology (CCO)

The CCO can be characterised by the three parameters mentioned above: the givens with which one starts, the constructors one employs, and the constructed objects that emerge from the repeated applications of the constructors.

It is proposed that the CCO starts with a single given, the pluriverse, the sum of all possible worlds. There is a single, general pattern for constructors, from which we develop its three fundamental constructors: set, sum, and tuple. This specialisation involves characterising the patterns of identity involved in the construction and the conditions under which these constructors can be applied. From these emerge the key categories of constructed objects: sets, individuals, and tuples. Note, as new objects emerge, more possibilities become available for construction. For example, once two sets a and b have been constructed, we can construct their singletons or the set that has just these two objects as elements. The ontology is generated by exhausting all possible constructions.

This ontology has three characteristics that enable it to play a foundational role. The first is that it has *categorical completeness*. It characterises the three basic categories of objects: sets, individuals and tuples, together with their associated grounding relations; set-elements, super-subsets, whole-parts, and tuple-places. The second is *object completeness*. That is, it generates all the objects needed by the TLO. One might think of it as an '*object factory*' which supplies the objects that might be needed in any domain. The third characteristic is that these categories provide objects in the ontology with appropriate *identity criteria*. These are broadly extensional, based on the type of constructor and its input. For example, two sets are identical if and only if they are constructed from the same objects. Similarly, two sums are identical if and only if they have the same parts.

Our approach is unified in the following ways. First, it provides a *common development of three key kinds of objects*: sets, individuals, and tuples. Ontologies that involve sets and sums usually adopt set theory and mereology as separate theories, without an integrated development. Here we provide a unified treatment of sets, sums and tuples, as sui generis objects. So the three categories – sets, sums, and tuples – arise in similar ways through construction. Second, there is a *common basis for identity criteria*, which are crucial for the foundational role discussed above. Identity criteria for the objects of the basic types are extensional, with differences arising from the way the objects are constructed. Third, the approach offers *uniform ways of capturing key commonalities and differences among objects of the basic types*. Such commonalities and differences are captured by features of the underlying constructors.

We can summarise all this in terms of main benefits:

1. *Categorical differences are constructional differences*: in constructional approaches the ways of construction are the basis for differences in kinds of objects. So categorical differences are explained by constructional differences.
2. *Dependency*: some objects are built from others and hence 'depend upon' them. This provides an explanation of ontological dependence and the associated notion of grounding.
3. *Reduction*: the ontology is built out of a relatively small set of fundamental objects and thus achieves parsimony in an important sense (Schaffer, 2015).
4. *Consistency*: construction can be a basis for consistency, avoiding paradoxes such as those of Russell and Burali-Forti, although we need to take care with the construction process.

Appendix C. Selected TLOs and Their Minimal Components

This Appendix links the TLO categories described in this report with the set of 4-dimensionalist TLOs chosen to develop the FDM seed in (West, 2020).

The four TLOs (in alphabetic order) are:

- BORO
- IDEAS
- ISO 15926
- HQDM

As was noted at the time of their selection, they are "all closely related …, although they have been developed with different purposes in mind" (West, 2020, p. 4).

The components from this set that are included in the TLO's minimal foundation are listed in Table 1.

TLO (bCLEARer)	BORO	IDEAS	ISO 15926	HQDM
Constructional Objects	Objects	Thing	thing	thing
Individual	Elements	Individual	possible_individual	spatio_temporal _extent
Set	Types	Type	class	class
Tuple	Tuples	tuple	relationship	relationship
part-of-whole relations	wholes-parts	wholePart	composition_of_individual	aggregation
element-of-set relations	types-instances	typeInstance	classification	classification
sub-super-set-of relations	super-sub-types	superSubType	specialization	specialization
tuple-place relations	tuple-places	TupleType	end	end

Table 1 – Top-level components

This table illustrates that in practice things have multiple names and an ontology needs a naming pattern that supports this. Different communities can, and do, chose different names for the same object. The chosen TLOs all have a naming pattern that supports multiple names, so this naming variety can be easily handled. In practical terms, this just means different names need to be recognised in the model – where and when these names are needed. The bCLEARer names are different in some case, these have been chosen to both make clear the constructional motivation behind them and to distinguish them from the TLO names. At some stage, when the NDT's FDM stabilises, it will make sense to simplify things and pick a preferred set of names for use on 'official' occasions; however, there is no need for this now.

Appendix D. Glossary

This glossary briefly explains some of the specific terms raised in this report.

Term	Description
ontological pattern (in an ontology)	a recurring set of relations between object with a similar structure in an ontology
ontological commitment (of a dataset)	the objects whose existence the dataset commits to
top-level ontology	the general objects in an ontology that one would expect to find across most if not all domain ontologies (in the case of the NDT's IMF, it is composed of the top-level categories and their organising objects)
minimal foundation (for a thin slice)	a minimal, basis used across thin slices as a common foundation
(top-level) categories	categories are general kinds that exclusively and exhaustively divide the entities committed to by an ontology (top-level ontologies will typically have a system of categories at their top level - hence these are also called the top-level categories)
(top-level ontology) grounding process	the process (in a top-level ontological approach) which grounds a dataset in the top-level ontology

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Justin Price
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