Abstract. The present preprint specifies and defines all Terms, Properties, Relationships and Axioms of ThingFO (Thing Foundational Ontology) v1.2, which is a slightly updated version of its predecessor, ThingFO v1.1. It is an ontology for particular and universal Things placed at the foundational level in the context of a four-layered ontological architecture named FCD-OntoArch (Foundational, Core, and Domain Ontological Architecture for Sciences). This is a five-layered ontological architecture, which considers Foundational, Core, Domain and Instance levels. In turn, the domain level is split down in two sub-levels, namely: Top-domain and Low-domain. Ontologies at the same level can be related to each other, except for the foundational level where only the ThingFO ontology is. In addition, ontologies’ terms and relationships at lower levels can be semantically enriched by ontologies’ terms and relationships from the higher levels. ThingFO and ontologies at the core level such as SituationCO, ProcessCO, ProjectCO, among others, are domain independent. ThingFO is made up of three main concepts, namely: Thing with the semantics of Particular, Thing Category with the semantics of Universal, and Assertion that represents human statements about different aspects of Particulars and Universals. Note that annotations of updates from the previous version (v1.1) to the current one (v1.2) can be found in Appendix A.

Fig. 1. ThingFO v1.2: Foundational Ontology for Things, which is placed at the foundational level in Figure 2. Annotations of updates from the previous version (v1.1) to the current one (v1.2) can be found in Appendix A. ThingFO v1.2 was accepted for publication in [8].
Fig. 2. Allocating the ThingFO component or module in the context of the five-layered ontological architecture so-called FCD-OntoArch (Foundational, Core, and Domain Ontological Architecture for Sciences) [3, 4]. ThingFO and ontologies at the core level such as SituationCO [7] and ProcessCO [2] are domain independent.

| Term | Definition |
|------|------------|
| **Thing**  
(synonym: Entity, Object, Particular, Instance) | It represents a particular or concrete, tangible or intangible object of a given particular world.  
**Note 1:** A particular object represents and implies unique individuals or instances, not a universal category. Therefore, a particular Thing generates instances, whereas a universal thing (Thing Category) does not generate instances, at least with valuable meaning of individual.  
**Note 2:** A Thing is not a Thing (particular object) without its Properties and its Powers, so “things, properties and powers all emerge simultaneously to form a unity” … “Things, properties and powers are necessary and sufficient for the existence of this unity” [1].  
**Note 3:** A Thing cannot exist or be in spatiotemporal isolation from other Things in a given particular world. In other words, a target Thing is always surrounded by other context Things, in any particular situation. |
| **Property** | It refers to the intrinsic constitution, structure, or parts of a particular Thing.  
**Note 1:** A Property is one member of the triad that conforms the unique individual named Thing.  
**Note 2:** A Property, which is one member of the triad that conforms a particular Thing can be seen as another particular Thing in another situation with its own Properties and Powers. |
| Term | Definition |
|------|------------|
| **Power** | It refers to what a particular Thing does, can do or behave.  
**Note 1:** A Power is one member of the triad that conforms the unique individual named Thing.  
**Note 2:** According to Fleetwood “Powers are the way of acting of a things’ properties; powers are a things’ properties in action” [1]. Also, he states that “Things have properties, these properties instantiate […] acting powers, and this ensemble of things, properties and powers cause any events that might occur”. |
| **Thing Category**  
(synonym: Entity Category, Universal) | It represents a universal of concrete Things conceived by the human being’s mind for abstraction and classification purposes.  
**Note 1:** A Thing Category does not exist, is or can be in a given particular world as a Thing does. Conversely, it may only be formed or developed mentally by human beings.  
**Note 2:** A Thing Category as universal does not generate instances—at least with valuable meaning of individual—but rather can be represented by more specific subcategories of Things. |
| **Assertion** | A positive and explicit statement that somebody makes about something concerning Things, or their categories, based on thoughts, perceptions, facts, intuitions, intentions, and/or beliefs that is conceived with an attempt at furnishing current or subsequent evidence.  
**Note 1:** The part of the previous phrase that indicates “…about something concerning Things…” means, for example, about the substance, structure, behavior, situations, quantity, quality, among other aspects of Things and Thing Categories.  
**Note 2:** The part of the previous phrase that indicates “…statement that somebody makes…” means that for instance a concrete human being—as a particular Thing-defines or conceives Assertions.  
**Note 3:** In order to be valuable, actionable and ultimately useful for any science, an Assertion should to a great extent be verified and validated by theoretical and/or empirical evidence.  
**Note 4:** An Assertion can be represented and modeled by means of informal, semiformal or formal specification languages. |
| **Assertion on Particulars** | It is an Assertion that somebody makes about something of one or more particular Things. |
| **Assertion on Universals** | It is an Assertion that somebody makes about something of one or more Thing Categories. |
| **Action-related Assertion** | It is an Assertion related to the interaction and happening of Things since acting Powers cause any events that might occur.  
**Note 1:** Particular Things can interact to each other, just as a Thing can act upon itself. See axioms A2 and A3. |
| Category                        | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Allotment-related Assertion    | It is an Assertion related to the assignment of something, which implies the assignment of a Thing to itself or to other Things.  
Note: For example, a particular resource (method, tool, person, etc.) is assigned to a task in a particular situation. Or, the specific amount of time a person gives him/herself to do an assignment. Or, the specific amount of time a professor gives their students to take a test. |
| Behavior-related Assertion     | It is an Assertion related to the Power, which represents the capability and responsibility that a Thing has and/or exhibits.  
Note: Behavior can be specified for Particulars and can also be generalized for Universals.                                                                                                                                                                                                                                                                                                                                 |
| Constraint-related Assertion   | It is an Assertion related to the specification of restrictions or conditions imposed to Things, Properties, relationships, interactions or Thing Categories that must be satisfied or evaluated to true in given situations or events.  
Note: Constraint-related Assertions can be specified for both Particulars and Universals.                                                                                                                                                                                                                                                                                                                                   |
| Intention-related Assertion    | It is an Assertion related to the aim to be achieved by somebody.  
Note 1: The statement of an Intention-related Assertion considers the propositional content of a goal purpose in a given situation and time frame.  
Note 2: Intention-related Assertions can be specified for both Particulars and Universals.                                                                                                                                                                                                                                                                                  |
| Quality-related Assertion      | It is an Assertion related to the requirements and constraints to be specified regarding the quality (distinguishing characteristic, attribute, or statement item) for a Thing and possibly related entities, which may be evaluable.  
Note 1: Quality (cost, etc.) requirements and constraints can be specified for a particular Thing in terms of its Properties or Powers, or in terms of both as a whole.  
Note 2: Quality requirements and constraints can be specified for Particulars and can also be abstracted or generalized for Universals.                                                                                                                                                                                                                          |
| Quantity-related Assertion     | It is an Assertion related to the countable, measurable and evaluable aspect of a Thing and possibly related entities, which can be specified by means of symbolic or numerical expressions.  
Note 1: Qualities of Things can be measured, evaluated and analyzed by specifying Quantity-related Assertions  
Note 2: Interrelated Things interact to each other conforming particular situations, i.e., specific circumstances, episodes and events that are of interest for an intended agent.  
Note 3: Interactions among particular Things both target entities and context entities in particular situations can be abstracted in generic situations.                                                                                                           |
and strategies as resources.

Note 2: A quantity or a relationship between quantities can be formalized, for instance, by mathematical, statistical or logical expressions.

Note 3: Quantity-related Assertions can be specified for both Particulars and Universals.

### Relation-related Assertion

It is an Assertion related to logical or natural associations between two or more Things and their categories.

**Note 1:** A Thing cannot exist or be in spatiotemporal isolation from other Things in a given particular world. Therefore, a Thing is related to another Things.

**Note 2:** Relationships can be specified for Particulars and can also be represented for Thing Categories.

### Situation-related Assertion

It is an Assertion related to the combination of circumstances, episodes, and relationships/events between target Things and context entities that surround them, or their categories, which is of interest or meaningful to be represented or modeled for an intended agent.

**Note 1:** A Situation can be represented statically or dynamically depending on the intention of the agent.

**Note 2:** Situations can be specified for Particulars and can also be generalized for Universals.

### Structure-related Assertion

It is an Assertion related to the Property, which represents the intrinsic constitution, structure, or parts of a Thing.

**Note:** Structural aspects can be specified for Particulars and can also be abstracted for Universals.

### Substance-related Assertion

It is an Assertion related to the ontological significance and essential import of a Thing as a whole entity, or a set of Things.

**Note:** Substance aspects can be specified for Particulars and can also be abstracted for Universals.

### Time-related Assertion

It is an Assertion related to the time as a Thing or its Properties or Power, which can imply specifying temporal boundaries or limits, among other aspects, for different situations and events.

**Note:** Time aspects can be specified for Particulars and can also be abstracted for Universals.

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**Amount of Own Terms: 19**

### Thing Component – ThingFO v1.2’s Properties or Attributes

| Term   | Attribute | Definition                                                                 |
|--------|-----------|---------------------------------------------------------------------------|
| Thing  | name      | Label or name that identifies the particular Thing.                        |
|        | description | An unambiguous textual statement describing a particular                  |
| **Property** name | Label or name that identifies the Property of a Thing. |
|-------------------|-------------------------------------------------------|
| **structural description** | An unambiguous textual statement describing the Property of a Thing in terms of its constituents, structure, or parts. |
| **Power** name | Label or name that identifies the Power of a Thing. |
| **behavioral description** | An unambiguous textual statement describing the Power of a Thing in terms of responsibilities, operations or actions. |
| **Thing Category** name | Label or name that identifies the Thing Category. |
| **descriptive statement** | An unambiguous textual description of the category aim as universal. |
| **property category** | An unambiguous textual description of the property category, when it needs to be represented. |
| **power category** | An unambiguous textual description of the power category, when it needs to be represented. |
| **Assertion** name | Label or name that identifies the Assertion. |
| **positive statement** | An explicit declaration of the Assertion to be defined. |
| Note 1: Regarding a particular Thing or category, a positive statement refers to what it is, was, or will be, and contains no indication of approval or disapproval. |
| Note 2: A positive statement should be based on current or subsequent empirical evidence. |
| **specification** | The explicit and detailed representation or model of the Assertion in a given language. |
| Note 1: Assertions can be modeled by means of informal, semiformal or formal specification languages. |
| Note 2: A specification can include text in natural language, mathematical and/or logical expressions, sketches, well-formed models and diagrams, multimedia resources, among other representations. |

**Amount of Properties: 13**

### Thing Component – ThingFO v1.2’s Non-taxonomic Relationships

| **Relationship** | **Definition** |
|------------------|----------------|
| acts upon        | A Power acts upon one or more Properties, so it can look at them or update the status of the Thing’s properties. |
| Note: Note that this relationship represents internal actions, i.e., on the same Thing, not on other Things. This constraint is specified by axiom |
A2. Particulars Things may belong to none or more Thing Categories.  
Note: In other words, a Thing Category predicates about a set of Particulars and their instances.

deals with particulars
An Assertion on Particulars deals with Things.

deals with universals
An Assertion on Universals deals with Thing Categories.

defines
A Thing defines none or many Assertions.  
Note: For example, a particular Thing such as a Human Agent defines or conceives Assertions, such as Goals, Situations, among others.

enables
A Property enables the Powers of a Thing.  
Note 1: Because the Properties of a Thing are there, the Entity behavior can be enabled and manifested.  
Note 2: Note that this relationship is restricted by axiom A1.

generalizes
An Assertion on Universals abstracts none or more Assertions on Particulars.

interacts with other
Due to the Power of a Thing, Things interact with each other.  
Note: Note that this relationship represents actions on other Things, not on the same Thing.  This constraint is specified by axiom A3.

is seen as other
A Property most of the time is seen as other particular Thing.

relates with (x3)
A Thing relates to other particular Things.  
A Thing Category may be related to other universal Things.  
An Assertion may be related to other Assertions.

Amount of non-taxonomic relationships: 12

**Thing Component – ThingFO v1.2's Axioms**

**A1 description**: All Property of a Thing enables only its Powers.

**A1 specification**:

\[
\forall t \forall prop \forall pow: [\text{Thing}(t) \land \text{Property}(prop) \land \text{partOf}(prop, t) \\
\land \text{Power}(pow) \land \text{enables}(prop, pow) \rightarrow \text{partOf}(pow, t)]
\]

**A2 description**: The Power of a Thing only acts upon its Properties.

**A2 specification**:
A3 description: The Power of a Thing only interacts with other Things.

A3 specification:

\[ \forall t, \forall p, \forall prop : \neg \exists t' \ (\text{Thing}(t) \land \text{Power}(p) \land \text{partOf}(p, t) \land \text{Property}(prop) \land \text{actsUpon}(p, prop) \rightarrow \text{partOf}(prop, t)) \]

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Appendix A: Updates from ThingFO v1.1 to ThingFO v1.2

Note that the ThingFO v1.1 ontology is documented in [5], and the first version (v1.0) was published as a conference paper in [4], which in turn was first released in April 2020 [6] as preprint. ThingFO v1.2 was accepted for publication in [8]. The main updates are:

- The elimination of two axioms from v1.1, namely: A1 and A2 respectively, since these constraints are now expressed in the diagram with the labels \{incomplete, disjoint\} and \{complete, disjoint\} respectively, as depicted in Fig. 1.

- The addition of three axioms, currently labeled A1, A2 and A3, which are specified in first-order logic.

- The term Thing Category has two new properties, namely: ‘property category’ and ‘power category’.

- The addition of the ‘Time-related Assertion’.

- The addition of the relationship ‘generalizes’ between Assertion on Universal and Assertion on Particulars.

- The addition of the relationship ‘defines’ between Thing and Assertion. Also, Note 2 in the term Assertion is new.

- The replacement of the inheritance relationship between Property and Thing by the association labeled ‘is seen as other’. That is, a Property can be seen as other Thing. This new relationship rather than inheritance allows the ThingFO model to be more actionable at lower levels.