SCO V1.1.0. development Protocol

Aim

To implement the Sustainability Core Ontology (SCO) by establishing an SCO representation that is compliant with the Unified Foundational Ontology (UFO).

SCO Description

Sustainability is characterized by three major theoretical challenges (Ubbiali *et al.*, 2024):

1. The polysemy of the term sustainability.
2. The relationship between sustainability and sustainable development.
3. The complexity underlying sustainability.

The Sustainability Core Ontology (SCO) is a middle-level ontology modeling those challenges with the purpose of supporting sustainability ontologies in consistently addressing sustainability and harmonizing with each other.

Currently, SCO reuses Basic Formal Ontology (BFO), one of the existing Top-Level Ontologies (TLOs), as the upper-level ontology. Nevertheless, we consider it essential to commit SCO representation to other TLOs. This will assist in establishing a consistent representation of sustainability shared across ontology communities and approaches. No matter which TLO has been chosen to design a sustainability ontology, a representation of sustainability theoretical challenges according to such a TLO will be available to reuse, strengthening representation consistency while fostering interoperability across ontology efforts for sustainability.

This document describes the process of alignment of SCO to the Unified Foundational Ontology (UFO). UFO counts among the major internationally recognized alternatives to BFO. UFO has been constructed with reference to the General Formal Ontology (GFO) and the Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE), two other existing TLOs (Guizzardi *et al.*, 2022). In addition, several ontologies that address domains of primary relevance to sustainability, such as resilience (Barcelos *et al.*, 2024) and risk and value (Sales *et al.*, 2018), employ UFO as the upper-level ontology.

SCO V1.1.0 is the new release of SCO, accounting for these implementations. SCO V1.1.0 is composed of two segments: SCO-B (B for BFO) and SCO-U (U for UFO). SCO-B aligns the SCO vocabulary with BFO (as SCO V1.0.1). SCO-U aligns the SCO vocabulary with gUFO (UFO implementation in the Web Ontology Language (OWL)). SCO V1.1.0 also provides a SKOS vocabulary-based mapping between the two segments. SCO V1.1.0 is formalized in OWL and covers three natural languages, English, French, and Italian. SCO V1.1.0 conforms to OBO-Foundry principles.

The most recent version of SCO-B segment can always be found at https://w3id.org/sco/sco-b. The most recent version of SCO-U segment can always be found at https://w3id.org/sco/sco-u. The most recent version of the mapping between SCO-U and SCO-B can always be found at https://w3id.org/sco/sco-u-b-mapping. The person responsible for SCO is Giorgio A. Ubbiali.

Methods and Materials

We constructed SCO V1.1.0 as follows, in OWL, using Protégé ontology editor.

SCO-B

Employing Protégé, we revised SCO V1.0. IRIs to correspond to the new ontology version. We also revised a few axioms that showed the need for adjustments, and we added some comments for future implementations. Please see the SCO-B OWL file for details.

SCO-U

In constructing this segment, we followed a *translation process*, i.e. we employed the existing BFO-compliant representation as an initial guiding reference point to further design a UFO-compliant representation. We consider it noteworthy to clarify this point as certain advantages and disadvantages ensue. We had a starting account of sustainability challenges that was grounded in an ontologically sound representation of reality, thereby supporting a consistent understanding of these challenges. In addition, proceeding as such promoted the exploration and construction of possible alignments between the two TLOs. On the other hand, however, UFO-compliant representation underwent the influence of the BFO-compliant representation, yielding possible slightly different results compared to if it had been started from scratch. Altogether, we decided to proceed as such because, having previously developed a BFO-compliant representation of sustainability challenges, our genuine interpretation of those challenges is filtered through that representation. We considered it more intellectually honest to openly recognize and endorse this standpoint and further deal with deriving benefits and drawbacks.

We imported gUFO.ttl file and the representation of dispositions, modes, and tropes from the Common Ontology of Value and Risk (COVER). See the SCO-U COVER import file. UFO theorizes about such entities, but gUFO does not provide a related OWL representation. Precisely, imports have been performed in a copy of SCO V1.0.1, where, in the later development stages, BFO-compliant representation has been deleted. We proceeded as such to limit possible inconsistencies and support the translation process.

Subsequently, we constructed the SCO-U taxonomical hierarchy, extending gUFO. We employed the BFO-compliant hierarchy as a starting guiding point, and we referred to the publication listed in the "SCO-U reference file". We evaluated the SCO is_A (specialization) hierarchy extending BFO. We identified the adequate and most corresponding position for SCO classes within the gUFO "individual" class hierarchy, and

we specialized it with SCO-U classes accordingly. We further instantiated the "type" class hierarchies for SCO-U classes (punning). SCO-U and SCO-B hierarchies are in accordance.

Next, we established the SCO-U axiomatization. Once more, we employed the BFO-compliant representation of SCO as a starting guiding point, and we referred to the publication listed in the "SCO-U reference file". We evaluated the SCO axiomatization according to BFO. We constructed adequate and corresponding axioms for SCO-U. When gUFO object properties were sufficient, we employed them. If the need arose, we created new object properties. Similarly, to ensure a satisfactory representation, we also needed to create a few novel classes, individuals, and object properties. For instance, a model of system agency that was compliant with UFO required the inclusion of classes specifying the gUFO "situation" class for agency. See the SCO-U OWL file for details and related comments. SCO-U and SCO-B axiomatizations are in accordance.

We finally created definitions, using SCO-B as a reference point and following Arp et al. (2015) and Smith (2013) recommendations. SCO-U and SCO-B definitions are in accordance. Several comments for implementations have been added to the OWL file. When judged relevant, we reported these considerations in the SCO-B file as well. See directly SCO OWL files for details.

Validation

We validated SCO-B and SCO-U using the automatic reasoners ELK 0.5.0 and HermiT 1.4.3.456 through Protégé plugging in. No logic inconsistencies were detected. We further verify SCO-U through the Protégé plugin of UFO validation rules. See the annotations to SCO-U in the ontology file for details on this point. During the entire process of construction of the SCO-U segment, we also carried out discussions with subject matter experts.

Mapping between SCO-B and SCO-U

We constructed the mapping between SCO-U and SCO-B using the SKOS Vocabulary. We referred to the publications listed in the "SCO-U reference file" to ensure consistency in mapping. We punned SCO-B classes to treat them as individuals, and we instantiated the SKOS "concept" class with both SCO-U and SCO-B punned classes. SCO-U already includes classes treated as individuals (see previous paragraphs). We further used SKOS mapping object properties to establish the mapping between the two SCO V1.1.0 segments.

Future Implementations

Current implementations seek to move toward the establishment of a core common ontological hub that can effectively support the integration and interconnection of new and existing representations of sustainability and related ontologies. To further proceed in such a direction, we envision the following implementations for SCO. SCO may include additional segments, aligning with other TLOs, such as the Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE). Further, we envisage expanding the current SCO representation

to cover additional features relating to sustainability and complexity, such as system behaviors, scales and levels of analysis, and change. The works of Calhau *et al.* (2023) and Calhau *et al.* (2024) may be a source of insights to drive these latter implementations.

Get in Touch

Please contact Giorgio A. Ubbiali in case you wish to get involved and participate in the development of SCO.

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