Functional Representation of Technical Artefacts in Ontology-Terminology Models

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Abstract

The ontological coverage of technical artefacts in terminography should take into account a functional representation of conceptual information. We present a model for a function-based description which enables direct interfacing of ontological properties and terminology, and which was developed in the context of a project on term variation in technical texts. Starting from related research in the field of knowledge engineering, we introduce the components of the ontological function macrocategory and discuss the implementation of the model in *lemon*.

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Category Extended Abstract

1 Introduction

In the framework of a larger terminology project carried out at Hildesheim University, we have been designing a formal ontology of technical artefacts relevant to the field of thermal insulation in buildings, subsequently using the ontology as a knowledge base for a technical e-dictionary. We have thus had the opportunity to reflect on the requirements that such an ontology must meet in order to represent in an exact, coherent and replicable way conceptual information regarding technical artefacts, complying at the same time with terminological description. In this contribution, we would like to report on preliminary work concerning the functional representation of technical artefacts within an ontology-terminology model.

Our report focuses on technical artefacts as one of the most prominent types of extra-linguistic objects from the point of view of terminology, terminography, and specialised translation. Semantic Web-oriented studies are making steady progress in the field of formal ontologies, especially with regard to ontology-related semantic deep learning tasks (cf. Gromann/ Declerck 2018 [7]), ontology learning techniques (cf. Asim et al. 2018 [1] for an overview), and the development of models for lexica representation (e.g. *lemon*, McCrae et al. 2011 [10]). However, little has been done so far to systematically describe the typical characteristics of certain classes of ontological objects. Some interesting ideas about the specific characteristics of technical artefacts emerge from studies in the field of domain knowledge engineering, in which particular attention is paid to functional aspects (cf. Section 3). We have taken this as our starting point for developing a model for terminology information systems.

This contribution shows how a function-based ontological description can be integrated in terminographic resources dealing with technical artefacts. After introducing function as a macrocategory in our ontological model (Section 2), we discuss the typical terminological implications of a function-based approach to knowledge engineering (Section 3). Next we present our model for a functional representation of technical artefacts (tested on texts

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concerning insulation products and power tools) and discuss its implementation in *lemon*, the lexicon model for ontologies (Section 4). We finally draw some conclusions on the accomplished work and its challenges and provide information on future work.

2 Function as an ontological macrocategory

By technical artefact we mean a physical object with technical features commercialised and used as a finished product. As pointed out in Giacomini (2018 [6]), technical artefacts can be appropriately described in terms of MATTER, FORM AND FUNCTION, three ontological macro-categories drawing on the Aristotelian description of inanimate objects, to which specific properties of an artefact can be linked. Functional knowledge plays a particularly crucial role in our cognitive perception of the artefact and is closely related to design intentions (Motta et al. 2011: 99 [12]). The dual nature of technical artefacts as the combination of structural and intentional conceptualisations has been highlighted in a number of recent studies in philosophy of science (cf., among others, Vermaas/ Houkes 2006 [14], Houkes/ Meijers 2006 [9] and Motta et al. 2011 [12]).

Borgo et al. (2016: 242 [2]) observe that several definitions of function have been formulated in engineering design, philosophy and ontology research. The unified definition of function for biological systems and technical artefacts proposed by Mizoguchi et al. (2016) [11] for a foundation ontology best suits our terminological purposes. According to the authors, different types of contexts identify different types of functions (here: functional roles): “In systemic contexts, the functional role is given by the systemic context where the appropriateness of its goal is determined with respect to the (goal provided by the) selected behavior of the overall system, which has the functional object as component. In the case of design contexts, the functional role is determined by the designer’s intention. Finally, in the case of the use context, the determination is given by the user’s intention” (ibid.: 141). Moreover, the notion of context in which the functions of an artefact are embedded legitimises a frame-based semantic approach to technical terminology as presented in (Giacomini 2018 [6], Faber 2012 [3]), with frames (Fillmore 2006 [4]) as complex cognitive structures identified against the background of a specified context.

3 Function models in knowledge engineering and their terminological implications

Some of the function models proposed in the field of knowledge engineering are designed to be integrated into upper ontologies, and not for interfacing with a terminology layer of a terminology resource. Others, however, describe conceptual elements of a domain ontology and can therefore be used for immediate classification of terminological elements. This is for example the case of the Reconciled Functional Basis (RFB) model presented by Hirtz et al. (2002 [8]) and aimed at supporting taxonomical modelling of engineering functions (e.g. isolate, move, associate) and flows (e.g. pressure, energy, velocity). In Reconciled Functional Basis, function and flow primary classes increase in specification at the secondary and tertiary levels and are associated to specific terms (typically verbs for functions and nouns for flows), e.g. in the following function set (Figure 1):

This model has successfully been applied to engineering design tasks (for instance to the building of an engineering-to-biology thesaurus, cf. Nagel et al. 2010 [13]). Its main drawback, however, is its potential ambiguity from the point of view of natural language, i.e. the semantic ambiguity of terms simultaneously attributed to more than one function

Class (Primary)	*Secondary*	*Tertiary*	*Correspondents*
Branch	Separate		Isolate, sever, disjoin
		Divide	Detach, *isolate*, release, sort, split, disconnect, subtract
		Extract	Refine, filter, purify, percolate, strain, *clear*
		Remove	Cut, drill, lathe, polish, sand
	Distribute		Diffuse, dispel, disperse, dissipate, diverge, scatter
Channel	Import		Form entrance, *allow*, input, *capture*
	Export		Dispose, eject, *emit*, empty, *remove*, destroy, eliminate
	Transfer		Carry, deliver
		Transport	Advance, lift, move
		Transmit	Conduct, convey
	Guide		Direct, shift, steer, straighten, switch
		Translate	Move, relocate
		Rotate	Spin, turn
		Allow DOF	*Constrain*, unfasten, unlock
Connect	Couple		Associate, connect
		Join	Assemble, fasten
		Link	Attach
	Mix		Add, blend, coalesce, combine, pack

Figure 1 Example of engineering functions in Reconciled Functional Basis (Hirtz et al. 2002).

or flow class, as well as the non-exhaustiveness of terminological coverage. The example of the RFB model shows that, for obtaining a coherent treatment of natural language, the ontology structure and contents should not condition the terminological component of the model. Instead of a strict top-down method, a terminology-oriented approach to ontology design should also take advantage from corpus-based terminological analysis to grasp relevant ontological aspects (combined top-down and bottom-up approach). In the next section, examples will be shown for the representation of function-related ontological properties by relying on domain corpus data concerning technical artefacts.

4 Normal function and functional properties of technical artefacts

Functional representation

As mentioned in the previous section, we use a corpus-based method to derive from specialised texts relevant information for the compilation of the domain ontology. In the context of the main study, terms and term relations were automatically extracted from a corpus of German technical texts and associated with elements of a previously defined frame "Functionality of the technical artefact" (for details of the extraction process, cf. Giacomini 2017 [5]). The syntactic and semantic behaviour of artefact-related terms in texts revealed a range of conceptual features that are crucial to knowledge representation. The validation experiments we later carried out not only in the field of thermal insulation but also in other technical subfields (power tools and semiconductor devices), show that a technical artefact usually has a *normal function* NF (e.g. a function conforming to a norm, also *systemic function* according to Mizoguchi et al. 2016 [11], or *use plan* according to Vermaas/ Houkes 2006 [14]): a thermal insulation product, for instance, is normally intended for thermally insulating a part of a building. The context in which the normal function of an artefact is performed can be interpreted as the sum of different conceptual constituents, which we call *functional properties* (FP):

(a) FP_project: Activity required of a technical artefact (TA) in its normal function.
(b) FP_location: Location in which a TA is used in its normal function.
(c) FP_patient: Object on which a TA operates in its normal function.
(d) FP_patient stuff: Material of FP_patient requiring the use of a certain TA to accomplish a certain function.

(e) FP_preparation: Process of making a TA ready for operation.
(f) FP_placement: Process of establishing a (physical) contact between TA and FP_patient before its FP_operation.
(g) FP_operation: Way in which a TA is used and operates in its normal function, typically procedural information or special techniques.
(h) FP_instrument: Medium by which FP_preparation, FP_placement, or FP_operation can be carried out on a TA used in its normal function.
(i) FP_agent: Performer of an action in which a TA is used in its normal function.

Table 1 illustrates the functional representation of two technical artefacts, an insulation roll and a circular saw. Here, we have manually attributed textual data (single-word terms, multi-word terms, and sentences) retrieved from online specialised texts in English to the different functional properties (sources: `https://www.tooled-up.com/artwork/ProdPDF`, `https://www.hilti.be`, `https://www.insulationsuperstore.co.uk`) . Depending on the artefact, some properties may be indicated as non-relevant (n.r.) for the given corpus contexts.

Table 1 Normal function (NF) and Functional properties (FP) of technical artefacts.

Functional representation	**Insulation roll**	**Circular saw**
NF	thermally insulate	saw
FP_project	to insulate a roof	to cut a wooden plank
FP_location	building	n.r.
FP_patient	roof	plank
FP_patient stuff	wood	wood
FP_preparation	to roll out	to switch on
FP_placement	a) push between the rafters, b) all joints must be taped	a) position the saw on the guide rail, b) position the saw against the workpiece
FP_operation	n.r. (not explicitly expressed in the available data set)	a) rotation, b) guide the circular saw along the cutting line, c) carry out a trial cut
FP_instrument	tape	teethed blade
FP_agent	craftsman	craftsman

The combination of normal function and functional properties lays the foundations for a functional representation of a technical artefact in a formal ontology. In the next future, we intend to explore the possibility of automatically processing our data sets to obtain function-related information from technical texts both in German and in English.

Integration in *lemon*

For terminographical purposes, this functional representation could be embedded in the lexicon model for ontologies (*lemon*), which was developed for enriching ontologies with natural language data (`https://www.w3.org/2016/05/ontolex`). Our present task is to test the extent to which our functional terminology description can be supported by the *lemon* model, specifically by the Ontolex module, and to propose the inclusion of some necessary components. The main benefit of this is the possibility of expanding the conceptual coverage of technical terminology, especially of multi-word terms (e.g. *thermally insulate*) and longer text segments (e.g. *position the saw on the guide rail*), in *lemon*.

Ontolex employs the rdfs:label to express lexicalisations. Semantic properties, in particular, are represented by means of the denote property as well as the sense and reference properties, which link lexical entries (and their lexical senses) to ontology entities. Given a Lexical Entry *building* with the Lexical Sense "building" in the domain of thermal insulation, we may use the reference property to relate this sense to the corresponding ontological predicate:

```
:lex_building a ontolex:LexicalEntry;
    ontolex:canonicalForm :form_building;
    ontolex:sense :building_sense.

:form_building ontolex:writtenRep "building"@en.

:building_sense a ontolex:LexicalSense;
    ontolex:reference <http://dbpedia.org/ontology/building>.
```

In addition to this, an indirect link of the Lexical Sense "building" to an Ontology Entity can take place via the Lexical Concept class, which is relevant for our functional representation of technical artefacts. In order to allow for a functional representation of concepts, in fact, we should specify normal functions and functional properties as *lemon* object properties. We propose, for instance, the integration of these properties at the Lexical Concept level. This means that, for the given example, the Lexical Concept "building" should be represented as rdfs:label FP_location property of the Lexical Concept "insulation roll":

```
:insulation_roll a ontolex:LexicalEntry;
    ontolex:sense :insulation_roll_sense;
    ontolex:evokes :insulation_roll.
:building a ontolex:LexicalConcept;
    ontolex:FP_location :insulation_roll.
```

The same can be done of the other functional properties and of the normal function of a technical artefact. Some (structural and conceptual) challenges concern, for instance, the exact location in which functional labels should be included into Ontolex, i.e. possibly at the Lexical Sense level as well. Moreover, in order to make the most of the potential of the functional model in technical terminology, lexical representation should take into account not only Lexical Entries in the form of single-word and multi-word terms, but also other relevant textual patterns (e.g. *push between the rafters* in Table 1) referring to functional features of artefacts. Finding a suitable solution to these challenges is our objective in the near future.

5 Conclusions and future work

Our research is aimed at finding helpful solutions for interfacing ontology and terminology in terminographic resources dealing with technical artefacts. At the moment, we are verifying the feasibility of a formalisation of our functional model in *lemon* by adding normal functions and functional properties to the Ontolex module in the form of new object properties. The current experimental results are rather promising, as they show a good flexibility of the functional model in adapting to different technical domains. The work ahead will also involve evaluation of the proposed functional model as well as the implementation of a frame-based layer to further enrich the semantic description and cross-referencing of terms with context-dependent information.

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