Abstract

Semantic feature norms, originally utilized in the field of psycholinguistics as a tool for studying human semantic representation and computation, have recently attracted the attention of some NLP/IR researchers who wish to improve their task performances. However, currently available semantic feature norms are, by nature, not well-structured, making them difficult to integrate into existing resources of various kinds. In this paper, by examining an actual set of semantic feature norms, we investigate which types of semantic features should be migrated into Linked Data in Linguistics (LDL) and how the migration could be done.

1 Introduction

Recently, some NLP/IR researchers have become interested in incorporating psycholinguistic features into their applications to improve task performance (Kwong, 2012; Tanaka et al., 2013). Among a range of psycholinguistic features, such as imageability, concreteness, and familiarity (Paivio et al., 1968), the most attractive is a set of semantic feature norms introduced by McRae et al. (2005). It captures prominent associative knowledge about a concept possessed by humans. Silberer and Lapata (2012), for example, employ semantic feature norms as a proxy for human sensorimotor experiences in their semantic representation model, and report improved performance in word association and word similarity computation tasks. However, currently available semantic feature norms are, by nature, not well-structured, making them difficult to integrate into existing resources of various kinds.

Given this background, in this paper, we extract a tentative set of psycholinguistically significant semantic feature types, and draw a technical map to structurize corresponding semantic feature norms by observing the Linked Data paradigm. Note that psycholinguistically significant semantic feature types, in particular, dictate semantic relations that amply observe associations by humans; however, those are usually not considered in existing lexico-ontological resources.

2 Semantic Feature Norms

2.1 Overview of McRae’s Database

In this paper, we take the well-known set of semantic feature norms provided by McRae et al. (2005) (henceforth, McRae’s database) as an actual example. This database provides a total of 7,526 semantic feature norms assigned to 541 living and nonliving basic-level concepts, each organized on the basis of experimental data collected from a large number of participants. McRae’s database also presents a range of supplementary information, including statistical data about the semantic features.

Table 1 displays some of the semantic feature norms given to describe alligator. Although not fully shown in the table, more than ten features are used to describe several aspects of alligator. In Table 1, Brain Region (BR) Labels are also shown, each of which roughly classifies semantic features from the perspective...
2.2 Semantic Feature Keywords

As exemplified in Table 1, all of the semantic features are prefixed by predefined keywords or key phrases (e.g., beh_ in "beh_ eats_people"; "lives_in swamps"). These keywords and key phrases (henceforth, semantic-feature keywords) can be utilized to classify semantic features into basic types.

| Semantic-feature keyword | # of variations |
|--------------------------|-----------------|
| used_for                 | 469             |
| has                      | 257             |
| is                       | 247             |
| has_a                    | 192             |
| a                        | 139             |
| beh_                     | 138             |
| used_by                  | 113             |
| made_of                  | 113             |
| requires                 | 66              |
| inbeh_                   | 64              |
| lives_in                 | 57              |
| found_in                 | 52              |
| associated_with          | 44              |
| worn_for                 | 43              |
| eg_                      | 40              |

Table 2: Productive semantic-feature keywords.

Although McRae et al. (2005) described around twenty semantic-feature keywords, the database actually classifies almost one hundred semantic-feature keywords, including presumably erroneous ones. Table 2 lists fifteen of the most productive semantic-feature keywords, in the sense of how many variations they have in the semantic feature norm instances. Most of the semantic feature keywords are self-descriptive; however, note that beh_ signifies behavior exhibited by animate beings (e.g., "alligator beh_eats_people"), while inbeh_ denotes that an inanimate being does something seemingly on its own (e.g., "airplane inbeh_crashes").

3 Structurizing Semantic Feature Norms

Figure 1, which corresponds to the alligator example shown in Table 1, illustrates a fundamental method of structurizing the semantic feature norms in McRae’s database into a Linked Data graph. The graph is constructed as follows: (1) A subject node is created for the target concept; (2) the subject node is linked with a set of triple objects, each representing a semantic feature; (3) a residual feature expression2 is analyzed where necessary; and (4) each of the triple predicates carries a corresponding semantic feature type. In addition, the constructs of the graph should be linked with existing external Linked Data constructs whenever possible. In Fig. 1, word nodes are assumed to be linked with corresponding WordNet synset nodes by semantically disambiguating them. We may further need to resolve named entities, if we are to link them, for example, with DBPedia nodes.

To actualize this illustration, we first need to create an inventory of triple predicates by identifying a reasonable set of semantic feature types, and then derive the sub-types where necessary.

4 Case Studies

We conducted our investigations by first extracting the tentative set of psycholinguistically significant semantic feature types shown in Table 3 from the ones already listed in Table 2 by performing the following actions:

- Excluding semantic feature types thought to be typical ontological constructs: these include, hyponymy (a), meronymy (has_a, made_of, part_of), telic/functional (used_for, used_by), exemplary (eg_), causal (causes), and their subtypes (e.g., worn_for).

- Putting off semantic feature types whose semantics are clear and relatively restricted, such as lives_in and found_in, which both specify concrete/abstract places.

2A residual feature expression denotes the natural language expression that follows a semantic-feature keyword: for example, "eats people" in "alligator beh_ eats people."
The following subsections examine these nominated semantic feature types in turn.

4.1 associated with

The "associated with" semantic feature type associates a target concept with something associated with it, without specifying any particular semantic restrictions. The fact that all of the instances are labeled with encyclopaedic BR Labels endorses this action. Furthermore, this semantic-feature keyword exhibits a very high type/token ratio (TTR) of 0.96, asserting that an associated object is highly specific to the target concept, as exemplified by the "Batman" example shown in Table 3. Recall here that a type refers to a distinct semantic feature expression (word/phrase) succeeding a semantic-feature keyword, while a token dictates an occurrence of a semantic feature expression type.

The only thing we can do to structure this semantic feature type is introduce a triple predicate such as, sfn:associated_with, as asserted in the above discussion.

4.2 is

The "is" semantic feature type in essence dictates several aspects/characteristics of a target concept from a variety of perspectives. In contrast to associated with, this semantic feature type computed a very low TTR of 0.15: where the number of feature expression types was 247, while that of tokens amounted to 1,651. This situation forced us to further classify the feature expression types.

The only thing we can do to structure this semantic feature type is introduce a triple predicate such as, sfn:associated_with, as asserted in the above discussion.

4.3 requires

The "requires" semantic feature type primarily specifies a typical object or entity that is somehow required by a nonliving target concept. In contrast to the is semantic feature type, we cannot introduce BR Labels to further classify this semantic feature type into a subclass, as many of them (80/93 = 86.0%) are annotated with encyclopaedic, and the rest with function.

Therefore, we decided to investigate the semantic types of the required things by ourselves, and induced a set of sub-categories to combine with requires. Table 5 lists the sub-categories and the corresponding instance frequencies. Note that we in essence adopted semantic criteria from the Princeton WordNet for distinguishing physical/abstract entities: We however added human and operation to adequately classify the required things. With this in mind, "bread requires baking," for example, can be tripleized as follows:

sfn:bread
   sfn:requires_operation
   sfn:baking .

4.4 beh-/inbeh-

The "beh-" and "inbeh-" semantic feature types should intrinsically be considered meta feature types, only signaling typical or salient behavior/movement described in the residual feature expression, as seen in the examples introduced above: "alligator beh_- eats people" and "airplane inbeh_- crashes." Furthermore, as each of these expressions, in general, form a verb phrase, we would need to linguistically analyze the verb phrase to extract its semantic content.

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Table 3: Psycholinguistically significant semantic feature types (tentative).

| Semantic feature type | Example feature expressions |
|-----------------------|-----------------------------|
| associated_with       | cape associated_with Batman |
| is                    | apple is crunchy            |
| requires              | bread requires baking       |
| beh_                  | alligator beh_- eats people |
| inbeh_-               | airplane inbeh_- crashes    |

Table 4: Distribution of BR Labels for is.

| BR Label                   | Token frequency |
|----------------------------|-----------------|
| visual-form_and_surface    | 546             |
| visual-color               | 350             |
| encyclopaedic              | 111             |
| tactile                    | 238             |
| function                   | 108             |
| visual-motion              | 40              |
| sound                      | 34              |
| smell                      | 20              |

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3We observed 93 instances of the requires type in McRae’s database, of which only two described living things.
Further specification of such a linguistic analysis and the representation of the analysis results, however, are beyond the scope of this paper. We here focus instead on the sub-typing of these semantic feature types. As done earlier, we first checked the TTRs: beh- type computed 0.33, while inbeh- type exhibited 0.55, showing that some of the semantic-feature expression types are moderately productive. We then checked the distribution of the BR Labels, shown in Table 6. The table clearly shows that only a few BR Labels are actually employed. Therefore, we decided to combine the BR Labels with these meta semantic feature types. Following this rationale, "alligator beh- eats people," for example, can be tripled as follows:

\[
\text{sfn:alligator} \\
\text{sfn:beh_visual-motion} \\
\text{sfn:eats_people .}
\]

Intriguingly, while the majority of the behaviors taken by animate beings (beh-type) are classified as visual-motion (267/419 = 63.7%), the behaviors taken by inanimate beings (inbeh-type) are distributed across three categories: encyclopaedic, sound, and visual-motion, implying that the visibility of a behavior plays a psychologically prominent role in the characterization of living things.

### 5 Discussion

Psycholinguistic semantic features, in general, can improve the performance of semantic tasks in NLP, as demonstrated by Silberer and Lapata (2012). In other words, semantic features that are focused more on human perception should be combined with linguistic features. In this sense, migration of psycholinguistic semantic feature norms into a Linked Data cloud could provide an opportunity for a range of NLP applications to exploit psycholinguistic semantic features in combination with linguistic features acquirable from existing lexico-ontological resources.

The true benefits to be derived from publishing them as Linked Data, in particular, should be underpinned by concrete NLP applications. They are unfortunately not very clear at the moment, but the key to success is to employ the structured set of psycholinguistic semantic features as a gateway to accessing existing resources of various kinds: including not only lexical/encyclopaedic resources such as WordNet, Wiktionary, and DB-Pedia, but also domain-specific ontologies such as GeoSpecies. In this scenario, enabling proper linking with external resources is quite important.

Another crucial issue that has to be addressed in order to achieve the goal is the fact that the coverage of semantic feature norms needs to be significantly widened because currently available psycholinguistic resources, such as McRae’s database, provide semantic features only for a limited number of concepts, notably, concrete concepts. Therefore, the development of a method to infer semantic features even for concepts not yet covered by existing resources (Johns and Jones, 2012) or, more importantly, a mechanism to mine useful properties from corpora (Baroni et al., 2010) would be highly appreciated.

### 6 Concluding Remarks

By examining the well-known McRae’s database (McRae et al., 2005), we organized a reasonable set of psycholinguistically significant semantic feature types, and sketched a scenario for migrating them into the LDL.

For short-to-medium-term future work, we plan to (1) investigate other less-frequent/less-prominent semantic features observed in McRae’s database; and (2) implement a computational process to actually convert the semantic feature norms into a set of Linked Data graphs.

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**Table 5: Semantic types of required things.**

| Semantic type       | Token frequency | Example feature expression                  |
|---------------------|-----------------|---------------------------------------------|
| physical entity     | 55              | balloon requires helium                     |
| human               | 19              | bus requires driver                         |
| operation           | 13              | bread requires baking                       |
| abstract entity     | 6               | unicycle requires balance                  |

**Table 6: Distribution of BR Labels for beh/inbeh.**

| Types          | encyclopedia | sound | visual-motion |
|----------------|--------------|-------|---------------|
| beh_-          | 95           | 56    | 267           |
| inbeh_-        | 33           | 50    | 32            |

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4Labels with less than two occurrences have been omitted.

5http://lod.geospecies.org/
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Appendix-A: Brain Region Labels
Each of the BR Labels assigned to a semantic feature norm in the database is based on a taxonomy called Brain Region Taxonomy (Cree and McRae, 2003). Table A-1 classifies the nine (plus one: taxonomic) categories defined by the BR taxonomy, and the corresponding token frequencies in the database. Cree and McRae (2003) argue that these categories represent knowledge types that are closely associated with corresponding brain regions.

As displayed in Table A-1, seven of the nine categories are linked with sensory channels/modes, of which three are associated with visual perception. In particular, the category visual-form-and-surface exhibits substantially high frequency, highlighting the fact that visibility plays a significant role in characterizing a concrete object psycholinguistically. The category function, on the other hand, organizes feature types, such as used for and used by, describing functional aspects of a target concept. Semantic features encoding other types of miscellaneous knowledge were labeled as encyclopaedic.

Appendix-B: Modeling with lemon
Figure B-1 exemplifies a more detailed modeling of the Linked Data graph presented in Fig. 1. In this modeling, McRae’s entire database is modeled as a lemon lexicon. That is, every content word in McRae’s database is modeled as a lexical entry, and the semantic feature types, derived in this paper, are modeled as sub-properties of lemon:senseRelation, which connects lemon:sense instances. In addition, linking to WordNet is represented by using lemon:reference, as in (McCrae et al., 2012), meaning that WordNet is treated as an external ontological resource.

Notice also that the residual semantic feature expression, such as “eats people,” is modeled as a phrasal lexical entry, whose internal linguistic structure is meanwhile represented by a syntactic dependency structure, represented by the blue cloud in the figure.

| BR Label             | Frequency |
|----------------------|-----------|
| visual-form-and-surface | 2,336     |
| visual-color          | 424       |
| visual-motion         | 339       |
| tactile               | 243       |
| sound                 | 142       |
| taste                 | 84        |
| smell                 | 24        |
| function              | 1,517     |
| encyclopaedic         | 1,417     |
| taxonomic             | 730       |

Table A-1: Distribution of the BR Labels.
Figure B-1: Modeling using lemon.