

Enhancing Conceptual Description through Resource Linking and Exploration of Semantic Relations

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Abstract

The paper presents current efforts towards linking two large lexical semantic resources – WordNet and FrameNet – to the end of their mutual enrichment and the facilitation of the access, extraction and analysis of various types of semantic and syntactic information. In the second part of the paper, we go on to examine the relation of inheritance and other semantic relations as represented in WordNet and FrameNet and how they correspond to each other when the resources are aligned. We discuss the implications with respect to the enhancement of the two resources through the definition of new relations and the detailisation of conceptual frames.

1 Introduction

The first part of the paper outlines the principles and procedures of aligning WordNet and FrameNet. The focus is on WordNet as the main lexical-semantic structure (the verbal domain, in particular), which we aim at enhancing with richer linguistic description from FrameNet and VerbNet. The second part of the paper proposes an analysis of the correspondences between the frame-to-frame relations in FrameNet and the synset-to-synset relations in WordNet.

The aim is two-fold: (a) from a theoretical perspective, to provide insights into the scope and definition of overlapping or corresponding relations and the relational structure of the two resources, to establish similarities and discrepancies that may come from different semantic construal or from errors; (b) from an applied perspective, to provide directions for the mutual enhancement and improvement of (i) the relational structure of the two resources; (ii) the accuracy of the frame assignment based on the theoretical observations.

The contribution of the paper consists in:

- An implementation of a mapping between WordNet synsets and FrameNet frames by extending existing mappings using the hierarchical structure of WordNet and the concept of inheritance. In addition, considerable improvements on the data are made including disambiguation of FrameNet frame assignment (selecting a single frame for a given synset, where the mapping has yielded more than one), correction of errors, consistency checks.
- A theoretical study of frame relations and their correspondences in WordNet and discovery of existing but inexplicit relations in one of the resources that are mappable to the other to the end of enhancing the relational structure of both resources and proposing procedures for a more reliable frame assignment using semantic inheritance.

This work is a key part of ongoing research on defining a conceptual framework for encoding semantic relations between verb and noun synsets based on a detailed conceptual representation of verbs and the identification of semantic classes of nouns satisfying the selectional restrictions imposed on frame elements in the verb's frame.

After a brief discussion of related work (Section 2), we outline the alignment between WordNet and FrameNet (Section 3) based on existing mappings and procedures for their enhancement and expanding. Section 4 focuses on the theoretical and practical aspects of semantic relations in FrameNet and how they are reflected (with respective semantic relations) within WordNet. Section 5 sketches the implications from these observations, while (Section 6) focuses on the role of this research in the context of other ongoing research.

2 Related work

One of the main directions of development of semantic resources is finding ways of uniting their strengths through integrating them and exploiting their features in a complementary way. Mapping

of existing semantic resources has been undertaken in a number of works (cf. section 3.1).

Another line of research in the development and enhancement of the interconnected resources is explicitly linking and generalising existing, but unrelated information in them. A poorly studied direction of research has been the exploration and use of the internal structure of these resources towards their mutual enhancement. One area of research along these lines has been the extension of frame relations by using information from WordNet. (Virk et al., 2016) propose a supervised model for enriching FrameNet’s relational structure through predicting new frame-to-frame relations using structural features from the existing FrameNet network, information from the WordNet relations between synsets, and corpus-collected lexical associations. Leseva et al. (2018) have employed features of both relational structures to develop an algorithm for assigning FrameNet frames to WordNet synsets by transferring the relational knowledge for pairs of related synsets to matching lexical units and frames in FrameNet.

An interesting theoretical and practical issue arising from the mapping of the ‘building blocks’ of the two resources is how the underlying relational structures relate and correspond to each other, how they can be mapped to each other, and further explored. In the second part of this paper, we have attempted to tackle this issue.

3 Aligning WordNet and FrameNet

Our work relies on two main resources – WordNet (WN) and FrameNet (FN), and employ VerbNet (VN) as a complementary resource in some tasks related to alignment and verification. We use WordNet (Miller, 1995; Fellbaum, 1999) as the basic lexical resource. FN (Baker et al., 1998) represents conceptual structures (frames) which describe particular types of objects, situations, etc. along with their participants, or frame elements (Ruppenhofer et al., 2016). Frames are then assigned to lexical units (LUs), e.g. the verb *mature* is assigned the frame *Aging* with the description ‘An Entity is undergoing a change in age typically associated with some deterioration or change in state’. FrameNet is internally structured using a set of relations, which are discussed in Section 4. The VerbNet (Kipper-Schuler, 2005; Kipper et al., 2008) classes represent formations of verbs with shared semantic and syntactic properties and be-

haviour organised in a shallow hierarchy.

3.1 Existing mappings

Previous efforts at linking these resources include Shi and Mihalcea (2005), Baker and Fellbaum (2009), WordFrameNet¹ (Laparra and Rigau, 2009; Laparra and Rigau, 2010), MapNet² (Tonelli and Pighin, 2009), and more enhanced proposals, such as the system Semlink³ (Palmer, 2009) which brings together WN, FN and VN with PropBank, and its follow-up Semlink+ that brings in mapping to Ontonotes (Palmer et al., 2014). Analysis of the available resources for linking WN, FN and VN, as well as procedures for automatically extending the mapping, are presented by Leseva et al. (2018).

These efforts generally suffer from limited coverage and compatibility issues due to multiple release versions of the original resources. Moreover, to the best of our knowledge, no further checks and verification have been performed on the results. This reduces considerably their applicability and further development.

A complementary approach is to exploit the relational structure of the two resources through assigning frames to synsets not only on the basis of direct correspondence between FN LUs and WN literals, but also on the basis of the inheritance of conceptual features in hypernym trees and the assignment of frames by inheritance from hypernyms to hyponyms. The main drawback of this approach is that for deeper level WN synsets the inherited frames may be underspecified. Our current and prospective work builds upon this paradigm, notably by looking for ways of refining previous proposals (Leseva et al., 2018) through validation which results in enriching the frame structure with systematic relations (e.g. causative, inchoative, etc. frame correspondences). Further, we envisage to define new, more detailed frames on the basis of more rigid selectional restrictions on frame elements.

3.2 Linking procedures

Linking FN to WN is not straightforward. There are two principal types of mappings that have already been applied on the lexical resources discussed in section 3.1: (a) lexical mapping – lexical units (from one resource) have been assigned

¹<http://adimen.si.ehu.es/web/WordFrameNet>

²<https://hlt-nlp.fbk.eu/technologies/mapnet>

³<https://verbs.colorado.edu/semllink/>

categories from another, e.g. a FN lexical unit is mapped to a WN literal and hence its FN frame is also assigned to the literal (and the synset); and (b) structural mapping – classification categories from one resource have been aligned to categories from another, e.g. a VN class assigned to a synset is linked to a FN frame, so the FN frame is transferred onto the synset. In this way we are able to verify individual mappings by examining the result in terms of the overall structure.

Initially, our mapping is based on three sources of existing lexical mappings: 2,817 direct mappings provided within FN (Baker and Fellbaum, 2009), 3,134 from eXtendedWordFrameNet (Laparra and Rigau, 2010), and 1,833 from MapNet (Tonelli and Pighin, 2009). Structural mapping using VN contributed 1,335 mappings. Overall, there are 4,306 unique WN synset to FN frame mappings. The main procedure we apply to improve and extend mapping coverage is based on the relations of inheritance within WordNet. First, we manually verified the frames assigned to 250 out of the 566 root verb synsets: we corrected 75 mappings and assigned valid frames to additional selected 27 root synsets with a large number of hyponyms. We then transferred the hypernym's frame to its hyponyms in the cases where the hyponyms are not directly mapped to FN frames. As a result, we obtained an extended coverage of 12,880 synsets (with an assigned FN frame). With the further defined procedures we aim at improving the quality of this assignment.

The procedures for validation of frame assignments to verb synsets include: (i) manual checks of the assigned frame; (ii) checks for existing but unmapped correspondences between literals and LUs (e.g., by reapplying lexical mapping); (iii) automatic or semiautomatic consistency checks based on correspondences between VN classes (or superclasses) and FN frames; (iv) automatic or semiautomatic consistency checks based on systematic relations within the resources, e.g. causativity. If no appropriate frame exists, we propose to posit a new category (and a frame) provided that it is predictable and complying with FN's frame structure. For instance, while *Motion* is linked to *Cause_motion*, *Self_motion* (e.g. *jump:1*, *leap:1* 'move forward by leaps and bounds') does not have a causative counterpart to which verbs such as *jump:11*, *leap:4* 'cause to jump or leap' can be mapped, so we formulate one.

An envisaged direction for refining the inheritance assignment is by employing relational information based on the exploration of FN-to-WN relations discussed below, as well as through identifying meaningful information in the WN glosses that may point to a more appropriate frame.

4 Theoretical and practical aspects of semantic relations within FrameNet reflected in WordNet

FN and WN each have its own relational structure which is based on conceptual relations between language units (WN) or conceptual representations (FN). The WN structure is by far the richer in types and instances of relations; in addition to the conceptual relations it comprises lexical relations, derivational relations and some other relations. Although the relations in the two resources have different number and scope, at least part of them are grounded in similar universal assumptions which leads to partial overlap, depending on their definition and the specific information in the resources. For instance, there is a clear correspondence between the *Inheritance* relation in FrameNet and the *hypernymy* relation in WordNet, to the extent that both represent a modelling of the is-a relation (Ruppenhofer et al., 2016), or between the *Causativity* relation (FN) and the *causes* relation (WN). Figure 1 presents the process of linking WN and FN. In what follows, we are going to explore how the FN frame-to-frame relations translate into WN relations (when they do) and to outline the main trends in the correspondence between relations in the two resources.

The core part of the data to be examined are pairs or longer chains of WN synsets such that: (a) are related through a given WN relation, and (b) are assigned FN frames, which are (c) related through a particular FN relation.

The main WN relation to be considered is hypernymy, which is the principal tree structure organising relation in the resource. We take into account both direct hypernymy (direct relation between a parent and a child node) and indirect hypernymy (where the hypernym is not a parent of the hyponym but there are intermediate parents between them). Other relations that emerge from the studied data are: antonymy, also see, causes, verb group, as well as some distant shared hypernyms (i.e. the synsets are in the same tree). Below we present the definition and theoretical grounding

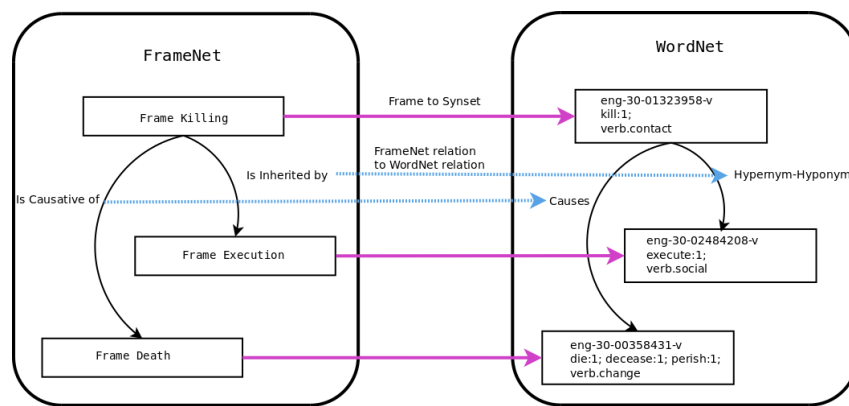


Figure 1: Representation of WordNet to FrameNet linking.

of FN relations (Ruppenhofer et al., 2016), along with the observations about their correspondence with WN relations.

4.1 Inheritance (Is Inherited by ↔ Inherits from)

Inheritance is defined as the strongest relation in FN; it denotes a relationship between a more general (parent) frame, and a more specific (child) frame in such a way that the child frame elaborates the parent frame. The basic idea, although not always straightforwardly applicable, is that each semantic fact about the parent must correspond to an equally specific or more specific fact about the child (Ruppenhofer et al., 2016, p. 81-82). This means that, generally, there should be a correspondence between entities, frame elements, frame relations and semantic characteristics in the parent and the child frame (Petrucci, 2015).

Example 1. Frame Killing Is Inherited by frame Execution

Frame: *Killing*

Core frame elements: Killer; Victim:Sentient; Cause; Means:State_of_affairs; Instrument:Physical_entity

FN definition: A Killer or Cause causes the death of the Victim.

Example synset: kill:1

Frame: *Execution*

Core frame elements: Executioner:Sentient; Executed:Sentient

FN Definition: An Executioner punishes an individual (Executed) with death as a consequence of some action of the Evaluee (the Reason).

Example synsets: execute:1 (direct hyponym of kill:1); hang:3 (indirect hyponym)

As per the definition of *Inheritance*, the configurations of the two frames are similar and the frame elements in the parent frame have correspondences in the child frame, which may be the same or more specific: e.g. Killer has no selectional restrictions, unlike its more specific descendant Executioner (which is specified as Sentient).

Based on this definition, one should expect a considerable overlap between *Inheritance* and *hyponymy*: that is, when a pair of WN synsets is related through hypernymy and their corresponding frames are related through a frame-to-frame relation in FN, this relation should be *Inheritance*.

What the data show (Table 1) diverges from this expectation in two ways: (a) there is another frame-to-frame relation which is very strongly favoured for a counterpart of the hypernymy relation, i.e. *Using* (compare results in Table 1); (b) in a substantial number (20%) of the cases we find out an inverse relationship, i.e. for a hypernym-hyponym pair, the hyponym is assigned the more general (parent) frame, and the hypernym – the child frame in an existing *Inheritance* relation (the last two rows in Table 1). This is illustrated in Example 2 where the hyponym is assigned the frame *Respond to a proposal*, while the hypernym receives the child frame *Agree or refuse to act*.

Example 2.

Hypernym: refuse:1, decline:3; **Gloss:** show unwillingness towards; **Frame:** *Agree or refuse to act*
Hyponym: reject:4, spurn:1; **Gloss:** reject with contempt; **Frame:** *Respond to proposal*

When looking closely at the data, we find out that in a substantial number of the cases of reversed relation, this is not so much the result of incorrect automatic assignment of frames, as the result of different construal of the conceptual

| WN relation | Is Inherited by | | Is Used by | | Is Perspectivized in | | Has Subframe(s) | | Causative of | |
|--------------------|-----------------|--------|------------|--------|----------------------|--------|-----------------|--------|--------------|--------|
| | total# | #diff. | total# | #diff. | total# | #diff. | total# | #diff. | total# | #diff. |
| Direct hypernymy | 84 | 43 | 67 | 33 | 3 | 2 | 6 | 2 | 13 | 7 |
| Indirect hypernymy | 454 | 66 | 576 | 70 | 37 | 2 | 129 | 2 | 41 | 8 |
| Direct hyponymy | 35 | 22 | 39 | 13 | 0 | 0 | 0 | 0 | 11 | 6 |
| Indirect hyponymy | 108 | 21 | 51 | 18 | 0 | 0 | 0 | 0 | 36 | 6 |

Table 1: WN relations hypernymy/hyponymy for different FN relations.

and the lexical domain as the parent and child frames show a high level of similarity. This is the case, though not in all instances, with frame pairs such as *Referring_by_name* and *Labeling*, *Ingest_substance* and *Ingestion*, *Statement* and *Telling*, *Statement* and *Affirm_or_deny*, *Assistance* and *Supporting*, *Change_position_on_a_scale* and *Proliferating_in_number*, among others.

4.2 Using (Is Used by ↔ Uses)

Another hierarchical relation in FN is *Using*. It is defined as a relationship between two frames where the first one makes reference in a very general kind of way to the structure of a more abstract, schematic frame (Ruppenhofer et al., 2016). The definition has been further specified as a relation between a child frame and parent frame in which only some of the FEs in the parent have a corresponding entity in the child, and if such exist, they are more specific (Petrucci and de Melo, 2012); hence, the relation may be viewed as a kind of weak Inheritance (Petrucci, 2015).

The data confirm that the majority of synsets mapped to FN frames with the *Using* relation are hypernym-hyponym pairs; also, the numbers for *Using* are similar to the respective numbers for the *Inheritance* relation, as shown in Table 1.

Example 3. Frame *Placing* Is Used by frame *Arranging*

Frame: *Placing*

Core frame elements: Agent:Sentient; Cause; Theme:Physical_object; Goal:Goal

FN definition: An Agent places a Theme at a location, the Goal, which is profiled.

Example synset: put:1, set:1, place:1, pose:5

Frame: *Arranging*

Core frame elements: Agent:Sentient; Theme:Physical_object; Configuration

FN Definition: An Agent puts a complex Theme into a particular Configuration.

Example synsets: arrange:1, set up:5

The child frame and the parent frame to which it refers have similar configurations of elements,

with the more specific Configuration (of things) corresponding to Goal (principally a location).

Similarly to *Inheritance*, cases of inverse assignment of the *Using* relation, where a hypernym is assigned a child frame, and a hyponym – a parent frame, are also found on a regular basis (12% of the cases) although not as often as with the *Inheritance* relation. Examples like (4) show that synset members and language units may be mapped to descriptions with different level of specification: in this case *garage:1* is construed as more specific in WordNet, but is assigned the more general *Placing* frame than its hypernym, which receives the frame *Storing*.

Example 4.

Hypernym: store:2; **Gloss:** find a place for and put away for storage; **Frame:** *Storing*

Hyponym: garage:1 **Gloss:** keep or store in a garage; **Frame:** *Placing*

The inverse assignment in many of the cases concerns frame pairs which display higher level of similarity and a weaker hierarchical relation. Such frame pairs, though not exclusively, include: *Placing–Storing*, *Abounding_with–Mass_motion*, *Attempt_suasion–Suasion*, *Evidence–Explaining_the_facts*.

The inverse frame assignment with both *Inheritance* and *Using* represents an interesting theoretical issue with respect to the analysis of lexical units (verbs) in terms of their lexical definitions and their conceptual properties.

4.3 Perspective (Is Perspectivized in ↔ Perspective on)

Perspective is defined as similar to, but more specific and restrictive than *Using* (Ruppenhofer et al., 2016, p. 82). It indicates that a situation viewed as neutral may be specified by means of perspectivised frames that represent different possible points-of-view on the neutral state-of-affairs.

It follows from this definition that the neutral frame is more abstract than the perspectivised frames and that there should be a great extent of

correspondence between the conceptual description and frame elements of the neutral and the perspectivised frames; these features *Perspective on* shares to a degree with both *Inheritance* and *Using*. It is not surprising, then, that this relation may translate as the *hypernymy-hyponymy* relation (Table 1), and in fact, this is the only WN relation that corresponds to it, even though in a very limited way: only 2 pairs of frames are found to be represented by related synsets: *Transfer* – which is perspectivised in *Giving* (cf. Example 5) and *Hostile_encounter* – which is perspectivised in *Attack*:

Example 5.

Hypernym: give:3; **Gloss:** transfer possession of something concrete or abstract to somebody; **Frame:** *Transfer*

Hyponym: contribute:2, give:25, chip in:1; **Gloss:** contribute to some cause; **Frame:** *Giving*

Apart from the actual WN relations, we find *Perspective on* between synsets having a common direct or indirect hypernym, where the same pairs *Giving-Transfer* and *Hostile_encounter-Attack* are the only two discovered. Only among more structurally distant pairs of synsets do we find other pairs of neutral-perspectivised frames: *Transfer-Receiving*, *Import_export_scenario-Importing*, *Import_export_scenario-Exporting*.

This observation shows that the kind of semantic generalisation underlying the *Perspective* relation does not correlate well with the WN conceptual and lexical relations. In fact, looking more in depth into the data, we find out that synsets related through a WN relation may be perspectivised frames of a non-lexical neutral frame. Such example is provided by the antonym pair *import:1* (bring in from abroad') – *export:1* (sell or transfer abroad'): the two synsets are assigned the frames *Importing* and *Exporting*, respectively, which perspectivise the neutral *Import_export_scenario*, and although they have a common hypernym *trade:1*, *merchandise:1*, there is no suitable lexicalisation of the neutral frame. A similar case is presented by other converse (antonym) pairs.

4.4 Subframe (Has Subframe(s) ↔ Subframe of)

Subframe is a relation between a complex frame referring to sequences of states and transitions, each of which can itself be separately described as a frame, and the frames denoting these states or transitions (Ruppenhofer et al., 2016, p. 83–

84). It is also noted that the frame elements of the complex frame may be connected to the frame elements of the subparts, although not all frame elements of one need have any relation to the other. Another feature of this relation is that the ordering and other temporal relationships of the subframes can be specified by the binary *Precedence* relation.

The definition of *Subframe* allows for it to correspond to hypernymy, which, apart from 2 instances of *also see*, is the only WN corresponding relation (Table 1), even though it is represented in a very limited way – only 2 pairs of frames are found, *Cause_motion-Placing* and *Cause_motion-Removing* (Example 6), and the predominant trend is for non-direct, rather than for direct hypernymy.

Example 6.

Hypernym: raise:2, lift:1, elevate:2, get up:3; **Gloss:** raise from a lower to a higher position; **Frame:** *Cause_motion*

Hyponym: shoulder:1; **Gloss:** lift onto one's shoulders; **Frame:** *Placing*

In more distant structural relations between WN synsets with common non-direct, distant hypernyms, other pairs of frame-to-frame relations are found as well, such as *Traversing-Departing*, *Traversing-Arriving*, *Intentional_traversing-Quitting_a_place*, *Self_motion-Quitting_a_place*.

Although *Subframe* is much better represented through (indirect) hypernymy than *Perspective*, it shares with it the feature that much like the neutral frame, the complex frame may represent a conceptual structure that does not have a lexicalised correspondence and that it is feasible to look for WN relations between subframes of a complex frame (rather than between a complex frame and a subframe). Another supporting example comes from the domain of antonymy – two synsets related by means of the *antonymy* relation may be assigned subframes of a complex frame, e.g. *fall asleep:1*, *dope off:1...* (*Fall_asleep*) <antonym> *wake up:2* (*Waking_up*) with respect to *Sleep_wake_cycle*.

4.5 Precedence (Precedes ↔ Is Preceded by)

This relation holds between component subframes of a single complex frame and provides additional information by specifying the chronological ordering of the states and events (subevents) within a complex event (Ruppenhofer et al., 2016; Petruck, 2015). A small number of *Precedence* instances are found among antonyms (12 pairs) and the majority of the instances are between synsets having

a common (direct or indirect) hypernym. The following pairs of frame-to-frame relations are found with antonyms: *Placing–Removing*, *Arriving–Departing*, *Activity_stop–Activity_ongoing*:

Example 7.

Antonym: file in:1; **Gloss:** enter by marching in a file; **Frame:** *Arriving*

Antonym: file out:1; **Gloss:** march out, in a file; **Frame:** *Departing*

This relation may result in complex structures involving a number of subframes such as the notable example of the *Sleep_wake_cycle* (Petrucci, 2015). It does not have a counterpart in the WN structure, but it may be transferred, thus bringing an additional dimension of semantic description through linking otherwise unrelated subevents and through specifying their temporal ordering.

4.6 Causation (Causative of) and Inchoativity (Inchoative of)

Causation and *Inchoativity* are systematic non-inheritance relationships between stative frames and the inchoative and causative frames that refer to them (Ruppenhofer et al., 2016, p. 85). Obviously, *Causation* should correspond straightforwardly to the WN relation *causes*. In fact, it does in a small number of cases (30 pairs), which is due to the fact that this relation has not been implemented consistently in FN (Ruppenhofer et al., 2016, p. 85). It may well be argued that its implementation needs to be enhanced in WordNet as well, as a lot of pairs for which this relation holds have not been linked in the resource. For instance, while the causative and the inchoative sense of *freeze* (see Example 8.) are connected through the *causes* relation, the respective antonym senses have been collapsed in a single synset: *dissolve:9*, *thaw:1*, *unfreeze:1*, *unthaw:1*, *dethaw:1*, *melt:2* (become or cause to become soft or liquid’).

Example 8.

Synset (causes): *freeze:4*; **Gloss:** cause to freeze; **Frame:** *Cause_change_of_phase*

Synset (is caused by): *freeze:2*; **Gloss:** change to ice; **Frame:** *Change_of_phase*

The lack of the *causes* relation between causative and inchoative senses is well observed, for instance, in the hypernym trees whose roots are *change:1*, *alter:1*, *modify:3* (‘cause to change; make different; cause a transformation’) *causes* > *change:2* (‘undergo a change; become different in

essence; losing one’s or its original nature’).

There are a considerable number of hypernym-hyponym pairs (see Table 1) that have been assigned the *Causation* relation. A look at the data shows that these are cases of wrong frame assignment as exemplified in the following case where the causative *boost:2* (‘give a boost to; be beneficial to’) has been assigned the inchoative frame *Change_position_on_a_scale* instead of the causative frame of the parent synset *increase:2* (‘make bigger or more’), i.e. *Cause_change_of_position_on_a_scale*. Such errors in the assignment are commonly found due to the similarity of the formulation of meanings and the common morphological roots of the causative and the inchoative members.

There are 39 correspondences between FN *Causative of* and WN *verb group*, most of which refer to true causative–inchoative pairs which have not been identified as members of the *causes* relation in WN, as in the following example: *corrode:1*, *eat:6*, *rust:2* (‘cause to deteriorate due to the action of water, air, or an acid’), with the frame *Corroding_cause* – *corrode:2*, *rust:1* (‘become destroyed by water, air, or a corrosive such as an acid’), with the frame *Corroding*. In these cases, we propose the addition of the more informative *causes* relation between the respective pairs.

The *Inchoativity* relation is very poorly represented in the data so we do not consider it herein.

4.7 See also

See also is a relation that has no direct semantic meaning but rather serves to differentiate frames which are similar and confusable (Ruppenhofer et al., 2016, p. 85, 82). It may be construed in quite different ways, which is reflected in the data, through its mapping to a greater variety of WN relations: *also see* (16 pairs), *antonymy* (8 pairs), *verb group* (22 pairs), *causes* (3 pairs), *hypernymy* (582 pairs). Example 9 illustrates a *See also* relation that corresponds to the WN *also see* relation and denotes an unspecified relation of similarity between the *Placing* and the *Filling* frame, which represent different profilings of a situation.

Example 9.

Also see synset: *put:1*, *set:1*, *place:1*, *pose:5*; **Gloss:** put into a certain place or abstract location; **Frame:** *Placing*

Also see synset: *put on:7*, *apply:4*; **Gloss:** apply to a surface; **Frame:** *Filling*

The greatest part of the synsets with an actual WN relation whose frames are linked by means of *See also* are related through *hypernymy*. A typical case is presented in Example 10.

Example 10.

Hypernym: search:4; **Gloss:** subject to a search; **Frame:** *Scrutiny*

Hyponym: frisk:2; **Gloss:** search as for concealed weapons by running the hands rapidly over the clothing and through the pockets; **Frame:** *Seeking*

The difference between the two frames is stated as one of different primary focus (to the Sought entity or to the Ground)⁴. While this semantic difference is captured by the distinct conceptual structures, it seems to be too fine and does not create a problem in construing *search:4* as the hypernym of *frisk:2*. Judging from the examples of the hypernym–hyponym pairs and the definition of the frames, the same conclusion is valid for many other pairs of frames, such as: *Sound_movement–Make_noise*, *Exchanging–Replacing*, *Cause_motion–Manipulation*, *Worry–Experiencer_focused_emotion*, *Placing–Filling*, *Motion–Ride_vehicle* among others.

In addition, when examining the *See also* pairs we find out that many of them are in fact linked through another, more informative relation, e.g. Using: *Cause_motion–Bringing*, *Motion–Operate_vehicle*; Inheritance: *Motion–Self_motion*, *Deciding–Choosing*; Subframe: *Cause_motion–Placing*, *Cause_motion–Removing*.

5 Implications from the observations

The main conclusions that we can make based on the observations so far are:

(1) The internal structure of FrameNet and WordNet is determined primarily by the notion of inheritance (and several non-inheritance relations). In FrameNet this notion is represented by the relations of *Inheritance* (strong inheritance), *Using* (weak inheritance) and *See also* (an unspecified relation of similarity often construable as inheritance), as well as by relations such as *Sub-*

frame, and *Perspective on*, although in a limited way. WN inheritance is implemented through the *hypernymy-hyponymy* relation. The comparison between the two structures sheds light on the nature of inheritance and hypernymy, especially in the ways it may diverge from the notion of subsumption. Especially interesting are the cases of inverted relations as they may point to errors in assignment or to a variability in semantic construal.

(2) A practical implication from the comparison refers to the insights into the possible ways of perfecting or enhancing the two resources. We have paid special attention to the way FN relations are translated into WN relations. Particularly interesting are cases where relations showing significant similarity in their scope do not correspond in the two resources. Such cases point to peculiarities in the relational structure of the two resources or assignment errors. Inverted relations are also a productive source of information as they point to greater hypernym–hyponym similarity than in straightforward cases and may give clues as to possible collapsing of hierarchical information.

(3) Validation procedures for discovering incorrect assignments of FN frames to WN synsets have been proposed on the basis of discrepancies between the two structures through: (i) identifying incompatible relations in the two resources, e.g. FN *Causative_of* and corresponding hypernym–hyponym pairs; (ii) adding relations based on observations, e.g. adding the *causes* relation between synsets related through *verb_group*; (iii) finding out inaccurately assigned frames by considering pairs of frames not related in FrameNet, but assigned to synsets related through a particular WN relation, e.g. *Cause_motion–Self_motion*, *Cause_to_be_dry–Express_publicly*, etc.

(4) Suggestion of additional groupings (relations) between synsets on the basis of existing relations. The purpose is to make explicit certain relationships that are not captured (systematically) in WordNet, such as the ones between synsets marked as being subframes of a non-lexicalised complex frame or perspectivised frames of a non-lexicalised neutral frame. The suggestion takes a cue from the way in which temporal relationships between subframes are made explicit through the *Precedence* relation. For instance, *fall asleep:1* and *wake up:2*, *awake:1* are mapped to the *Fall_asleep* and *Waking_up* FN frames and are both subframes of the *Sleep_wake_cycle*. While

⁴Seeking: A Cognizer_agent attempts to find some Sought_entity by examining some Ground. The success or failure of this activity (the Outcome) may be indicated. NB: This frame should be compared to the *Scrutiny* frame, in which the primary focus is on the Ground; <https://framenet2.icsi.berkeley.edu/fnReports/data/frameIndex.xml?frame=Seeking>

they are linked through the WN *antonymy* relation, their relationship with synsets representing other subframes of the same scenario remains unaccounted for: *get up:2*, *turn out:12* (*Getting up*) and *sleep:1*, *kip:1*, *slumber:1* (*Sleep*).

Towards the consistent representation of causativity, we suggest: (a) linking pairs of senses in corresponding causative and inchoative or stative trees, such as the causative and inchoative change trees (the roots synsets are themselves related through the *causes* relation); (b) transferring the *causes* relation to relevant LUs and frames.

(6) The study of the relational structure of the two resources, their overlap and possible improvement has more far-reaching impact with a view to the elaboration of the conceptual structure of verbs undertaken by our team. Based on the properties of the semantic relations in FN and their correlation with hypernymy, we attempt at formulating principles for transferring conceptual information based on the inheritance of features: in particular, configurations of frame elements and imposed selectional restrictions. The observations on *Inheritance* and *Using* are especially useful as they shed light on the specialisation that takes place from parent to child: reducing core frame elements by incorporating one of them in the verb meaning – e.g. *whip:4* incorporates the Instrument of *strike:1*; reducing the scope of the frame – e.g. *drive:1* as a hyponym of *operate:3* applies only to land vehicles; profiling a different frame element – e.g. *rob:1* profiles the Victim, while its hypernym *steal:1*; *rip off:2*, *rip:4* profiles the stolen Goods. Among the non-hierarchical relations *Causative_of* and the underrepresented *Inchoative_of* bear importance to the conceptual description as they determine the relations between similar structures with common major frame elements and selectional restrictions. The *See also* relation denotes similarity between conceptual structures that may very well translate as distinctions between similar configurations of frame elements (as in Example 10) or differences between similar (but not identical) sets of frame elements with similar semantic restrictions.

6 Conclusion and future work

The alignment between WordNet and FrameNet at the lexical level (literals within WordNet synsets – lexical units within frames) offers limited coverage and shows some inconsistencies in the repre-

sentation of semantic relations. The expansion of the coverage relies on: the understanding of the relational structure of both resources and exploring the possibility of identifying the frames relevant to certain synsets (based on inheritance and other semantic relations); defining new frames and synsets in order to provide consistency in the representation of relations, etc. The verification of the resources as well as their alignment and mutual enhancement can be based on automatic consistency checks of inheritance (both strong, e.g. Inheritance, and weak, e.g. relations such as Using, Perspective, Subframe) and on paying special attention to cases with inverted inheritance (frame F_1 , assigned to synset S_1 , is inherited by frame F_2 , assigned to synsets S_2 , but within WordNet S_2 is more general than S_1). Further exploration of inheritance can yield more (ir)regularities which may facilitate the enhancement of the resources.

This work is an integral part of our research on defining a conceptual framework for encoding semantic relations between verbs (as represented in synsets) and relevant sets of noun synsets to the end of creating a relationally densely populated semantic network. In particular, the study of inheritance and the remaining relations in FN and how they translate into WN relations enables us: (i) to formulate procedures for exploring the relational structure of the resources towards increasing the coverage of the mapping between FN frames and WN synsets based on these relations; (ii) to define more rigid and clear-cut conceptual classes of verbs on the basis of the enhanced mapping of conceptual frames; (iii) to undertake the building of a rich relational structure through defining relations between verbs belonging to particular frames and sets of nouns with particular semantic properties (as reflected in WN subtrees, ontological categories, etc.) corresponding to key frame elements in the verb's frame. The last task is sensitive to the precision and scope of the conceptual description and is thus dependent on the validation, extension and enhancement of the assignments.

Acknowledgments

This study has been carried out as part of the project *Towards a Semantic Network Enriched with a Variety of Semantic Relations* funded by the National Science Fund of the Republic of Bulgaria under the Fundamental Scientific Research Programme (Grant Agreement 10/3 of 14.12.2016).

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