Possible Extensions to FrameNet: Formulation of a General Syntax-Semantics Interface

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L arge-scale lexical semantic resources that provide relational information about words have recently received much focus in Natural Language Processing (NLP). In particular, corpora with predicate-argument structure annotation have been employed as the backbone for the development of shallow semantic parsing systems that automatically identify the semantic relationships, or semantic roles, conveyed by sentential constituents (Gildea and Jurafsky, 2002). Given an input sentence and a *predicator* the system labels constituents with general roles like Agent, Patient, Theme, etc. or more specific roles, as in (1). As a first step towards text understanding semantic role labeling has proved useful for a variety of NLP applications (including Information Extraction, Question Answering, Machine Translation, Summarization).

(1) [$_{Cognizer}$ I] *admired* [$_{Evaluee}$ him] [$_{Degree}$ greatly] [$_{Reason}$ for his bravery and his cheerfulness].

Corpora with semantic role labels also lend themselves to extraction of linguistic knowledge at a syntax-semantics interface. The range of semantic and syntactic combinatorial properties (*valences*) of each word in each of its senses can be documented in terms of annotated corpus attestations. For instance, the valence pattern for *admire* in (1) is shown in (2).

(2) Cognizer: NP Subject
Evaluee: NP Direct object

Degree: Adverbial Dependent
Reason: Prepositional (PP-*for*) Dependent

This data can support the formulation of generalizations concerning possible mappings of semantic roles to grammatical functions. So-called *linking generalizations* capture how predicates relate in terms of semantic and syntactic features and can serve as a remedy for the severe problem of sparse data which is inherent in lexical semantic annotation. It is a well-known bottleneck that within sensible sizes of manually annotated data the coverage of individual predicators in specific senses and constructions may be insufficient, i.e. some predicators may have only a handful annotated sentences. These gaps can be 'filled' with data from semantically related predicates. This study addresses the problem of generalizing over annotations built within the FrameNet paradigm.

T he Berkeley FrameNet project (Baker et al., 1998) is creating an online lexical database containing semantic descriptions of words based on Fillmore's (1985) theory of frame semantics. The basic unit of analysis is the semantic frame, i.e. a schematic representation of a stereotypical scene or situation. Each frame is associated with a set of predicates (including verbs, nouns, and adjectives) and a set of semantic roles (called *frame elements*, FEs) encoding the participants and props in the designated scene. FrameNet currently contains more than 960 frames covering more than 11,600 lexical items exemplified in more than 150,000 annotated sentences. The Judgment frame, for instance, which is evoked by *admire* in (1) is shown in Table 1.

FrameNet provides additional information about the grammatical properties of lexical units and the syntactic patterns in which they appear. Syntactic information is represented in terms of a phrase structure (PT) and a grammatical function (GF) annotation layer. Table 2 shows the distinct annotation layers for sentence (1).[1]

Frames are situated in semantic space by means of various kinds of directed (asymmetric) relations.[2] Each relation associates a less dependent or more general frame (Parent) with a more dependent or less general frame (Child). The hierarchical organization of frames and the specification of

[1]The Ext label marks arguments that in the terminology of the Government and Binding theory are referred to as External (i.e. subjects of finite verbs).

[2]A detailed description of these relations can be found in the FrameNet Book (Ruppenhofer et al.) pp. 104-111.

Frame: JUDGMENT	
Definition	A Cognizer makes a judgment about an Evaluee. The judgment may be positive (e.g. *respect*) or negative (e.g. *condemn*) and this information is recorded in the semantic types Positive and Negative on the Lexical Units of this frame. There may be a specific Reason for the Cognizer's judgment, or there may be a capacity or Role in which the Evaluee is judged.
FEs	**Cognizer**: [The boss] *appreciates* you for your diligence. **Evaluee**: The boss *appreciates* [you] for your diligence. **Expressor**: She viewed him with an *appreciative* [gaze]. **Reason**: I *admire* you [for your intellect].
Predicates	accolade.n, accuse.v, admiration.n, admire.v, admiring.a, applaud.v, appreciate.v, appreciation.n, appreciative.a, approbation.n, approving.a, blame.n, blame.v, boo.v, ...

Table 1: The Judgment frame

Argument	I	him	greatly	for his bravery ...
FE	Cognizer	Evaluee	Degree	Reason
PT	NP	NP	PP	PP
GF	Ext	Obj	Dep	Dep

Table 2: Example of FrameNet's multilayer annotation

frame element identities or analogs across frames should enable abstractions concerning possible syntax-semantics mappings.

However, this is not a trivial task. From the different types of frame-to-frame relations distinguished by FrameNet inheritance is the strongest semantic relation and therefore, the most plausible to propagate valence information. Inheritance between frames and frame elements is conditioned by the set of semantic components underlying the frame definitions, i.e. FE membership, semantic types, frame relations to other frames, relationships among the FEs, and semantic types on the FEs.[3]

[3] *Semantic types* encode information that is not representable in terms of frames and

For example, the Coming_to_believe frame inherits from Event and *uses* the (non-lexical) Mental_activity frame.[4] It does not directly inherit from Mental_activity, because it does not refer to a purely cognitive state but is an instance of mental process or event. Thus verbs that evoke Coming_to_believe (*conclude*, *deduce*, *guess*, *infer*, etc.) cannot formally share their valence properties with verbs that evoke frames inheriting from Mental_activity (e.g. *believe*, *imagine*, *know*, *suspect* in the Awareness frame). Note, however, that FE correspondences between Coming_to_believe and Event are hard to establish whereas mappings of FEs (and their surface realizations) between Coming_to_believe and Awareness are straightforward:

(3) [$_{Cognizer}$ I] have *concluded* [$_{Content}$ that most Americans sleep too much]. [Coming_to_believe]

(4) [$_{Cognizer}$ Pat] *believes* [$_{Content}$ that things will change for the better]. [Awareness]

A similar complication is illustrated in the inheritance relation between Intentionally_act and Visiting: despite the apparent argument structure similarities between verbs in these frames (exemplified below) an identity link between the Act FE of Intentionally_act and the Entity FE of Visiting is not possible, in that these FEs are associated with different semantic types, i.e. Act is of type State_of_affairs whereas Entity is of type Physical_object.

(5) [$_{Agent}$ It] had *carried out* [$_{Act}$ 113 uranium conversion experiments]. [Intentionally_act]

(6) [$_{Agent}$ You] have to *visit* [$_{Entity}$ your parents] every once in a while. [Visiting]

Thus a taxonomic description of events and participant roles (like that implemented by FrameNet) is doomed to miss argument structure commonalities between lexical units that are related at a more abstract semantic level. It turns out that fine-grained semantic or ontological distinctions complicate the picture of the frame hierarchy and restrict the propagation of valence information across it.

frame element hierarchies, e.g. basic typing of fillers of frame elements referring to some (external) ontological classification, meta-descriptions on frames such as the type Non-Lexical on frames containing no lexical units, descriptions of aspects of semantic variation between lexical units such as the Positive and Negative types in the Judgment frame.

[4]The *Uses* relation involves a specific frame making reference in a general kind of way to a more general frame: that is, part of the scene evoked by the more specific frame refers to the structure of a more abstract or schematic frame.

O n the basis of these observations (indicating that semantic role annotation is a complicated task whose product is deeply influenced by its design philosophy and underlying criteria - a point already made by Ellsworth et al., 2004), we revisit the theoretical underpinnings of the prickly notion of semantic role. The definition of coherent semantic notions at an appropriate level of abstraction seems to be a prerequisite for a general, principled syntax-semantics interface. This is in accordance with a somewhat intuitive conception of roles as classificatory categories capturing semantic similarities across eventualities. Gildea and Jurafsky (2002) have already attempted to manually group the sense-specific roles posited by FrameNet into 18 frame-independent, abstract roles that were shown to be more easily learnable by an automatic role labeling system.[5] On the other hand, role labels that encode structural characterizations of the readings of arguments rather than merely ontological descriptions of the corresponding participants is a way out of the complications mentioned previously about FrameNet roles.

To this aim we espouse and extend the insights of Dowty's (1991) Proto-Role hypothesis proposing to explicitly associate arguments with prototypical properties *entailed* by the semantics of predicates. Each Proto-Role *entailment* representing a grammatically pervasive concept (i.e. a property having direct effect on the grammatical behavior of predicators) is defined in terms of an abstract semantic relation that necessarily underlies the meaning of the predicate. Thus a Proto-Role description of argument structure implements an essentially relational (structural) approach to participant roles.

Proto-Role properties are associated with arguments in a many-to-one fashion: each argument is marked with one or more of a set of meaning components entailed by the meaning of the predicator. Prepositional complements are also marked with verbal entailments (to which prepositions may contribute additional, more specific content). Yet no attempt is made to formalize this content; prepositional semantics is represented solely in terms of the common basis it shares with the verbal meaning.

The annotations below exemplify a tentative set of Proto-Role properties covering the semantics of a broad range of verbs displaying various syntactic

[5]Note that general role labels posited by lexical semantic resources such as PropBank (Kingsbury et al., 2002) and VerbNet (Kipper et al., 2000) lack a well-founded semantic basis. PropBank labels are defined on a per-verb basis while no consistent mapping is ensured between a label and a semantic role across verbs. In VerbNet, on the other hand, the coherence of roles is only ensured within fine-grained classes of verbs that share exactly the same syntactic properties.

patterns beyond the basic transitivity construction considered by Dowty.[6]

(7) [$_{Conceiver}$ The other two] *pondered* [$_{Conceived}$ over this morsel] as they tramped along behind him.

(8) [$_{Conceiver,Intentional}$ They] *tested* [$_{Conceived}$ the software] [$_{Conceived\_bsoa}$ for similar bugs].

(9) I think *stereotyping* [$_{Conceived}$ people] [$_{Conceived\_bsoa}$ by appearance] is stupid.

(10) [$_{Conceiver}$ The jury] has *found out* [$_{Conceived}$ the truth] [$_{Conceived\_bsoa}$ about the suspect].

(11) [$_{Conceiver,Intentional}$ The court] *categorized* [$_{Conceived,Entity}$ the issue] [$_{Conceived,Predicate}$ as a collateral question].

(12) [$_{Conceiver,Intentional}$ Opposition members] *accuse* [$_{Conceived,Entity}$ the council] [$_{Conceived,Predicate}$ of acting purely ideologically].

The sentences in (7)-(12) involve an underlying relation in terms of which a Conceiver is entailed to have a notion or perception of some participant (while the reverse entailment pattern does not necessarily go through). In event types in which a Conceiver is entailed to have a notion of more than one entity Conceived arguments are distinguished on the basis of their salience in the overall semantics of the predicate. For instance, a verb like *test* intuitively lexicalizes a dyadic relation between a tester and a tested entity. A sought entity denoted by a *for*-PP is represented in terms of a secondary Notion relation situated in the background of the primary relation. Conceived entities that are peripheral to the essential relation lexicalized by the predicate are associated with a more specific property termed *Conceived_background_state_of_affairs* (Conceived_bsoa).[7]

The examples (11) and (12) include additional tags (Entity and Predicate) distinguishing equally significant conceived arguments in terms of a predicative relation (assigned within the Conceiver's mental model). These sentences also involve an entailment of Intentionality which marks entities characterized by conscious choice, decision, or control over the course of an inherently intentional action.

[6]This set builds on the lists of entailments proposed by Wechsler (1995) and Davis (2001).

[7]Arguments marked with the entailment Conceived_bsoa receive less *focus* in the meaning of a predicate.

(13) [$_{Causer}$ Diet] *influences* [$_{Causee}$ disease].

(14) [$_{Causer}$ My sister] has *changed* [$_{Causee,Change\_of\_state}$ her hair color] [$_{Source\_state}$ from red] [$_{End\_state}$ to blue].

(15) [$_{Mover}$ A woman in red] *entered* [$_{Path\_goal}$ the room].

(16) [$_{Mover}$ The bullet] *overtook* [$_{Stationary}$ the arrow].

(17) [$_{Causer}$ John] *ran* [$_{Causee,[Mover]}$ the car] [$_{[Path\_goal]}$ into the field].

(18) [$_{Possessor}$ This house] *lacks* [$_{Possessed}$ a guest room].

(19) [$_{Causer}$ They] *submitted* [$_{Causee,[Possessed]}$ their evidence] [$_{[Possessor]}$ to their committee].

(20) [$_{Condition}$ Code 1425] *bans* [$_{Conditioned}$ large trucks in tunnels].

(21) [$_{Condition}$ Jo] *violated* [$_{Conditioned}$ the no trespassing law].

(22) [$_{Condition}$ This game] *demands* [$_{Conditioned}$ great skill].

(23) [$_{Condition}$ The adjective 'beautiful'] denotes [$_{Conditioned}$ a quality which can be found in many different objects].

The predicates in (13)-(14) are described in terms of a Causation relation; (15)-(16) involve a Motion relation and (18) a Possession relation. Verbs of caused motion (17) or caused possession (19) are annotated in terms of both Causation and Motion/Possession. We represent them as involving a main event and a caused subevent keeping track of the embedded status of entailments in the caused event by representing them in square brackets. Finally, (20)-(24) involve none of the above entailments. The semantics of these verbs are treated in terms of a general relation entailing that properties of some entity β are dependent on an entity α (while the converse entailment pattern does not necessarily go through). We refer to this relation with the term Conditioning and associate it with appropriate Proto-Role properties capturing the semantics of a broad range of verbs conforming to the basic transitivity pattern that motivated Dowty's Proto-Role hypothesis.[8]

[8]In each of the above sentences we can conclude something about the object participant (i.e. that it is necessary, illegal, or linguistically expressed) on the basis of the subject referent (i.e. the characteristics of the game, the regulations specified by the code, the usage of the adjective *beautiful*). By contrast, no property of the subject referent is necessarily conditioned by the object: the semantics of *ban*, for example, does not allow us to characterize code 1425 as fair/unfair, severe/lax, complete/incomplete, new/old, etc. on the basis of the NP 'large trucks in tunnels'; similarly, we cannot infer whether the word *beautiful* is a verb or a noun or an adjective on the basis of the content of the NP 'a quality which can be found in many different objects'.

A corpus annotation study was carried out juxtaposing frame-semantic structures and entailment-based annotations. In specific, a portion of the FrameNet corpora was annotated with Proto-Role properties. We concentrated on a set of English verbs selecting from the FrameNet lexicon 275 random frames containing verbal predicates. For each verb in these frames we extracted collections of example annotated sentences as well as sentences from the FrameNet full-text annotation corpora. In the comprised dataset we annotated Proto-Role entailments on top of FrameNet annotations semi-automatically, i.e. by mapping FEs to entailments at a frame level, adding this information to the data in a new annotation layer, and correcting the entailment annotations by examining the argument structures of individual predicators for possible inconsistencies indicating finer semantic distinctions. In total more than 900 lexical units were considered in ∼25K sentences.

From the newly annotated data we extracted mappings of entailments to grammatical categories. The syntactic realizations of Proto-Role properties readily generalize over syntactic and semantic features of verbs pertaining to distinct FrameNet frames. Valence generalizations are formally rendered in terms of classes (called *Lexicalization Types*, *L-Types*) abstracting away from the semantics of individual predicators. In effect, L-Types can be thought of as non-lexicalized frames specifying syntactic mapping constraints.

For instance, predicates such as *believe* and *desire* (evoking the frames Religious_Belief and Desiring, respectively) involve arguments that are equivalent in terms of entailments. Hence they are categorized in a single L-Type called Notion L-Type. Table 3 shows the correspondences between entailments and FEs.

Notion L-Type	Religious_belief	Desiring
Conceiver	Believer	Experiencer
Conceived, (Entity)	Element	Focal_participant
Conceived_bsoa, Predicate	Role	Role_of_focal_participant

Table 3: The Notion L-Type

(24) If [$_{Conceiver}$ he] *believes* [$_{Conceived,Entity}$ in Jesus] [$_{Conceived\_bsoa,Predicate}$ as his Saviour], he can be baptized.

(25) [$_{Conceiver}$ He] *wanted* [$_{Conceived,Entity}$ Smith] [$_{Conceived\_bsoa,Predicate}$ as the new producer.

In a similar fashion, *operate*, *research*, and *ratify* can be grouped together

in an argument structure type called Intentionality L-Type, despite specific differences in the definition of the frames they evoke (Using, Research and Ratification, respectively). While Role and Purpose, for example, are core frame elements in the Using frame, Purpose is peripheral in Research and Ratification. Furthermore, Research and Ratification have no Role frame element (even though this sort of argument is clearly present in the structures exemplified in (27b-c). In the Intentionality L-type we can also categorize verbs such as *carry out* and *visit* that were discussed previously.

Intentionality L-Type	Using	Research	Ratification
Conceiver, Intentional	Agent	Researcher	Ratifier
Conceived, (Entity)	Instrument	Question	Proposal
Conceived_bsoa, Predicate	Role		
Conceived_bsoa, Intention	Purpose	Purpose	Purpose

Table 4: The Intentionality L-Type

(26) a. [$_{Conceiver,Intentional}$ We] *operate* [$_{Conceived}$ a menu] [$_{Conceived\_bsoa,Intention}$ to get the best out of rations].

b. [$_{Conceiver,Intentional}$ We] *research* [$_{Conceived}$ this fungus] [$_{Conceived\_bsoa,Intention}$ to fight aliments in tobacco and tomato fields].

c. [$_{Conceiver,Intentional}$ The South] had to *ratify* [$_{Conceived}$ these amendments] [$_{Conceived\_bsoa,Intention}$ to be readmitted to the Union].

(27) a. There has been a long debate as to whether [$_{Conceived,Entity}$ the Severn Mill] *was operated* [$_{Conceived\_bsoa,Predicate}$ as a tide mill].

b. [$_{Conceived,Entity}$ Thin films] *are being researched* [$_{Conceived\_bsoa,Predicate}$ as a potential medium for integrated optical circuits].

c. [$_{Conceived,Entity}$ Such agreements] may *be ratified* [$_{Conceived\_bsoa,Predicate}$ as being in the public interest].

L-Types can be organized hierarchically. For instance, the Intentionality L-Type inherits from the Notion L-Type. Inheritance corresponds to a basic *is-a* type of relation in a sense that the combination of semantic properties in the Super-class must map to an equally or more specific combination in the Sub-class.

Valence information formalized in terms of abstract L-Types is useful both in a semantic role labeling scenario and from a linguistic point of view. Consider, for example, the prepositional realizations of conceived arguments in the above L-Types (shown in Tables 5 and 6). Entailment-preposition correspondences can be used for generalizing from seen to unseen predicates while they may also shed light to the semantics and use of individual prepositions. For instance, verbs lexicalizing a Desiring situation are found with prepositional arguments headed by *for*, *after*, *towards*, or *over* (but not *on*, *upon*, *of*, *at*, or *about*). Note that if a Desire relation is identified as a recurring concept systematically associated with particular grammatical relations (e.g. a *for*-PP), it can be represented in terms of a separate, more specific L-Type under the Notion L-Type.[9] Thus the initial classification capturing the general conditions that determine possible associations between the semantics of predicators and grammatical relations realizing their arguments (e.g. the fact that a conceived entity can only surface in subject position in a passive sentence) can be extended and refined on the basis of more specific semantic relations.

Notion L-Type	
Conceived, (Entity)	PP[over].Dep
	PP[on].Dep
	PP[upon].Dep
	PP[about].Dep
	PP[of].Dep
	PP[at].Dep
	PP[for].Dep
	PP[after].Dep
	PP[towards].Dep

Table 5: Corpus-induced prepositional realizations of Conceived arguments in Notion L-Type

From the annotated data we acquired 29 L-Types based on various combinations of Proto-Role properties: 7 Notion types, 7 Intentionality types, 8 Causation types, 4 Motion types, 2 Possession types, and 1 Conditioning type. 23 frames contained predicates for which none of our entailments seemed to hold. Most of these verbs (*resemble*, *adjoin*, *concern*, *fit*, *suit*, etc.)

[9] *For*-PPs are indeed associated with a desiderative sense with a wide range of verbs in various argument positions: 'He desperately hunted *for a new job*'. 'They searched the ground *for traces*'. 'John ran *for cover* when it started to rain'.

Intentionality L-Type	
Conceived, (Entity)	PP[on] PP[upon] PP[for] PP[about] PP[over] PP[of] PP[to]

Table 6: Corpus-induced prepositional realizations of Conceived arguments in Intentionality L-Type

involve what Dowty called perspective-dependent roles that we represent in terms of special tags termed Focal and Landmark (equivalent of traditional Figure and Ground labels). The linking patterns of these verbs depend on pragmatic or discourse factors rather than intrinsic semantic properties. In general, predicates that lexicalize situations with no fixed relationships between the participants display great variability in their argument realization options.

In an ideal environment mappings between FrameNet frames and L-Types that are based on meaning components relevant to linking could be specified by means of a separate relation complementary to the frame-to-frame relations currently specified by FrameNet. Such a relation referring exclusively to combinatorial features of lexical items would simplify the picture of the frame hierarchy in that it essentially decouples purely lexical semantic information (encoded by the various kinds of frame relations) from information that lies exactly at the borderline between syntax and semantics.

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