Leveraging Lexical Resources for the Detection of Event Relations

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Abstract

This paper discusses the benefits and limitations of drawing conceptual inferences based on entries in a rich verb lexicon, VerbNet. Automatic sense tagging and semantic role labeling can be used to match predicate arguments structures in a sentence with specific syntactic and semantic frames from the lexicon, allowing conceptual inferences to be drawn. However, as with any hand-crafted resource, the entries do not always contain the desired inferences. Links to an ontology are suggested as a means of broadening the range of possible inferences.

1. Introduction

Recent efforts at providing a shallow semantic analysis based on supervised systems trained on data labeled with sense tags and semantic role labels are increasingly successful (see CoNLL 2008). However, there is much more to "understanding" sentences than sense tags and semantic role labels. In particular, once the events themselves have been identified, it is essential to recognize any temporal or causal relations between them, and to infer changes in state that might have occurred (Pustejovsky et al. 2005). Resources like TimeBank are directed at the task of identifying temporal relations (Day et al. 2003), while lexical resources such as VerbNet (Dang et al. 1998) and FrameNet (Baker et al. 1998) show promise for inferring causation and enablement relations. This inference process is illustrated here with several examples. Examples are also provided of extending the range of inferences through links to an ontology such as the ISI Omega Ontology (Philpot et al. 2005).

1.1 VerbNet Background

VerbNet (Kipper-Schuler 2005) is a hierarchical domain-independent, broad-coverage verb lexicon with mappings to several widely-used verb resources, including WordNet (Miller 1990, Fellbaum 1998), Xtag (Xtag 2001), and FrameNet (Baker et al. 1998). It includes syntactic and semantic information for classes of English verbs derived and then extended from Levin's original classification (Levin 1993).

Each verb class in VerbNet is described by a set of members, thematic roles for the predicate-argument structure of these members, selectional restrictions on the arguments, and frames consisting of a syntactic description and semantic predicates. The original Levin classes have been refined and new subclasses added to achieve syntactic and semantic coherence among members.

1.1.1 Syntactic Frames Each VN class contains a set of syntactic descriptions, or syntactic frames, depicting the possible surface realizations of the argument structure for constructions such as transitive, intransitive, prepositional phrases, resultatives, and a large set of diathesis alternations listed by Levin as part of each verb class. Each syntactic frame consists of thematic roles (such as *Agent, Theme,* and *Location*), the verb, and other lexical items which may be required for a particular construction or alternation.

Semantic restrictions (such as *animate, human,* and *organization*) are used to constrain the types of thematic roles allowed in the classes. Each syntactic frame may also be constrained in terms of which prepositions are allowed. Additionally, further restrictions may be imposed on thematic roles to indicate the syntactic nature of the constituent likely to be associated with the thematic role. Levin classes are characterized primarily by NP and PP complements. Examples of syntactic frames are shown below:

"John hit the ball."
Agent V Patient

"John hit at the window."
Agent V at Patient

"John hit the sticks together."
Agent V Patient(+Plural) together

Some classes also refer to sentential complementation, although this extends only to the distinction between finite and nonfinite clauses, as in the various subclasses of *Verbs of Communication*. In VN the frames for class *Tell-37.2* shown in the examples below are illustrative of how the distinction between finite and nonfinite complement clauses is implemented.

Sentential Complement (finite)
"Susan told Helen that the room was too hot."
Agent V Recipient Topic(+sentential –infinitival)
Sentential Complement (nonfinite):
"Susan told Helen to avoid the crowd."
Agent V Recipient Topic(+infinitival -wh_inf)

1.1.2 Semantic Predicates Semantic predicates which denote the relations between participants and events are used to convey the key components of meaning for each class in VerbNet. The semantic information for the verbs in VerbNet is expressed as a conjunction of semantic predicates, such as *motion, contact* or *cause*. As the classes may be distinguished by their temporal characteristics (e.g., *Verbs of Assuming a Position* vs. *Verbs of Spatial Configuration*), it is also necessary to convey information about when each of the predicates applies. In order to capture this information, semantic predicates are associated with an event variable, *e*, and often with START(*e*), END(*e*) or DURING(*e*) arguments to indicate that the semantic predicate is in force either at the START, the END, or DURING the related time period for the entire event. Relations between verbs (or classes), such as antonymy and entailment present in WordNet, and relations between verbs (and verb classes), such as the ones found in FrameNet, can be predicted by inspecting the VN semantic predicates.

2. Data Analysis

The syntactic and semantic information within each VerbNet class provides a means by which we can map verb arguments from instances in our data to the thematic roles associated with the appropriate sense and frame of the verb as presented in VerbNet. As our first step in establishing relations between verbs, we will focus on the semantic predicates associated with the appropriate verb sense in its relevant VerbNet class. The automatic processing is aimed at providing the link between a sentence and an underlying semantic representation that supports inferences.

2.1 Verb *Provide*

Consider the following from a set of documents that have been collected from a Weblog.

While many of the weapons used by the insurgency are leftovers from the Iran-Iraq war, Iran is still ***providing*** *deadly weapons such as EFPs -LRB- or Explosively Formed Projectiles -RRB-.*

One of the verbs of interest in this sentence is *provide*, of which there are 65 instances in our document set in total. The appropriate sense in this case is associated with membership in the *Fulfill* class. The verb in this sentence is in the simple transitive frame, which would map to the following semantic roles and their associated predicates:

ROLES
Agent [+animate | +organization]
Theme
Recipient [+animate | +organization]

FRAME SEMANTICS
has_possession(start(E), Agent, Theme)
has_possession(end(E), ?Recipient, Theme)
transfer(during(E), Theme)
cause(Agent, E)

Accurate automatic parsing and semantic role labeling (SRL) will allow us to map the verb arguments onto the thematic role positions in the **has_possession** and **cause** semantic predicates. We can then make the following assertions indicating that Iran **has_possession** of the "weapons" and is transferring them to an unknown Recipient (?Recipient):

has_possession(start(E), Iran, weapons)
has_possession(end(E), ?Recipient, weapons)
transfer(during(E), weapons)
cause(Iran, E)

Given that the sentence also contains a relation between "the insurgency" and the "use of weapons" it is likely, although not certain, that the filler of "?Recipient" could be "insurgency". Another sentence from the same document set confirms this by declaring:

"We have evidence that Iran ***provided*** *insurgents with explosive devices and trained them to use these weapons, produced between 2004 and 2006," said MG Caldwell.*

This sentence would allow us to establish the following relations:
has_possession(start(E), Iran, weapons)
has_possession(end(E), insurgents, weapons)
transfer(during(E), weapons)
cause(Iran, E)

Notice that these relations are "subordinated" (in the Timebank sense) to the "saying event." The confidence in the relations is relative to confidence in the speaker. In addition, *provide* is a key enabling relation, since **having possession** of an OBJECT is a prerequisite for **using** it.

2.2 Verb *Capture*

Another verb that is associated with a change of possession is *capture*. Our first instance, given below, indicates that the US forces (implicit) *captured* a document.

*Last year, a **captured** document showed al-Qaeda's 'hit list' of Sunni politicians, tribal leaders, clerics and Baathists in Anbar.*

Using parsing and SRL to map this sentence onto the following VerbNet thematic roles from the *Steal* class results in the predicates below:

ROLES
Agent [+animate | +organization]
Theme
Source [+animate | [+location & -region]]
Beneficiary [+animate]

FRAME SEMANTICS
Manner(during(E), illegal, ?Agent)
has_possession(start(E), ?Source, document)
has_possession(end(E), ?Agent, document)
not(has_possession(start(E), ?Source, document))
transfer(during(E), document)
cause(Agent, E)

Note that the verb here is used as a past participial modifier, rather than a matrix verb, which however still supports identification of the Theme semantic role, in this case "the document." Inferring with certainty that the Agent is the "US forces" and the Source is "al-Qaeda" is probably beyond current co-reference capabilities. Note also that "capturing PERSONS" rather than OBJECTS would result in quite different inferences. Capturing an OBJECT implies the ability to **use** it. In this sentence **use** of the document enables knowledge of the "hit list." Consider the following sentence.

As a further sign that activity continues against the Mahdi Army, Special Iraqi Army Forces captured a weapons smuggler who "funnels weapons and improvised explosive devices to rogue Jaysh Al Mahdi elements for use in attacks against Iraqi and Coalition Forces. "

Here, a key inference from **has_possession(end(E), Special Iraqi Army Forces, weapons smuggler)** would be that the "weapons smuggler" can be **prevented** from pursuing his smuggling. "Possession" enables control over the captured person's activities.

Another critical enabling relation has to do with changing the location of persons or objects. For instance, the verb *move* as used in the following sentence:

*On January 11, the Pakistani military attacked a Taliban convoy **moving** into Afghanistan from the Pakistani border town of Gorvek in North Waziristan.*

This sentence indicates that the Taliban was in the process of moving into Afghanistan when they were attacked by the Pakistani military. In addition to recognizing that the Taliban convoy is changing location it is especially important to be accurate about the temporal relations between these two events. Even though the "move" event is mentioned after the "attack" event, the "move" event actually instigated the "attack," rather than the reverse. Independently of the temporal ordering of the events, we would get instantiations of the following semantic predicates from the "path" frame in the *Slide* class:

ROLES
Agent [+int_control]
Theme [+concrete]
Location [+concrete]

PP PATH-PP
syntax Theme V {to} Destination
semantics
motion(during(E), Theme)
location(end(E), Theme, Destination) →

motion(during(E), Taliban convoy)
location(end(E), Taliban convoy, Afghanistan)

2.3 Verb *Launch*

The verb *launch* has 21 instances in our data. It is considered an aspectual verb with its main semantic content taken from the activity it is "starting." In this corpus there are no CONCRETE OBJECTS being launched, only activities such as "attacks," "air strikes," "operations" and "raiding parties." This fits the *Establish* class sense of *launch*. As illustrated below, the semantic representation indicates that the *Coalition forces* are the Agent of an *attack* Event.

*"According to eyewitnesses and local reporters in Kunar province, Coalition forces **launched** a fierce attack on a small enclave in the village of Mandaghel, approximately 17 miles from the border with Pakistan, on Friday afternoon,"*

ROLES
Agent [+animate | +organization]
Theme

semantics
begin(E, Theme) cause(Agent, E) →

begin(E, attack) cause(Coalition forces, E)

The locative and temporal adjuncts, identified by SRL as an ArgM-LOC and an ArgM-TMP, would be associated with the "attack." So the location of the village being attacked is "a small enclave in the village of Mandaghel,

17 miles from the Pakistan border" and it occurred on the "Friday afternoon" prior to the news report.

"According to eyewitnesses and local reporters in Kunar province, [Agent Coalition forces] ***launched*** *[Activity a fierce attack] [Destination on a small enclave in the village of Mandaghel], [ArgM-LOC approximately 17 miles from the border with Pakistan], [ArgM-TMP on Friday afternoon].*

2.4 Verb *Release*

Our final example focuses on ***release***, which appears 25 times. Consider the following sentence where release would be a member of the FREE class:

Yemen March 4, 2007 Yemen has ***released*** *over 100 Islamist "militants," including 19 who fought alongside the deceased al-Qaeda in Iraq leader Abu Musab al-Zarqawi.*

ROLES
Cause
Source [+animate | +organization]
Theme

FRAMES NP-PP OF PP
example "It freed him of guilt."

syntax Cause V Source {of} Theme

semantics
cause(Cause, E)
not(free(start(E), Theme, Source))
free(end(E), Theme, Source)

This VerbNet class is too specific to this particular example, and needs to be generalized to include animate *Agents* as well as *Causes*. It would also need to have another syntactic frame associated with it, allowing for an optional From-PP. The sentence could just as easily have read:

Yemen March 4, 2007 Yemen has released over 100 Islamist "militants ***[from prison]****," including 19 who fought alongside the deceased al-Qaeda in Iraq leader Abu Musab al-Zarqawi.*

The semantic predicates would receive the following instantiation

cause(Yemen, E)
not(free(start(E), militants, [prison]))
free(end(E), militants, [prison]).

It also has a very generic **free** semantic predicate associated with it, which would probably need to be made more specific.

3. Limitations

In any hand-crafted lexical resource there will always be missing verbs or semantic predicates that are too specific. There are other more serious limitations to this approach which become apparent when an application is attempted. In a paper by Zaenen et al. (2008), semantic predicates in the VerbNet frames were used to make inferences for change of location verbs. They found that while the information obtained in VerbNet was useful in identifying predications expressing location, the role and frame assignments across verbs of location within VerbNet were not consistently encoded. Specifically, the authors point out that the start and end point information is not always available across all change of location verbs. For instance, in class 9.3 (e.g. *funnel* as in "*Funnel* the liquid from the bottle into the cup"), although an explicit mention of the Source is possible ("the bottle"), it is not typically mentioned and is not included in the set of semantic predicates. In class 9.5 (e.g. *pour* as in "He *poured* the water from the bowl into the cup"), because of the variety of prepositions and manners of pouring that can occur, there is a Prep(E, Theme, Location) predicate instead of either a start or an end predicate. (See Figure 1) A reasoning system relies on predictable, consistent labeling of concepts in order to trigger the application of inference rules. This is not always compatible with a desire to capture differences in meaning. One solution, as suggested by Zaenen et al., would be to simply add the start and end location information into the frame semantics of many additional VerbNet classes, making the predicates somewhat more redundant but also more consistent. As described in the next section, we advocate the alternative solution of explicitly linking the VerbNet classes to an ontology where complete and consistent inference rules are expected to reside at the upper level nodes. These rules could present the locative start and end information for every verb for which it is available, without disturbing the current semantic information derived from Levin's original verb classification.

4. Ontology

The Omega ontology is a part of the OntoNotes project, which is annotating over 900K words of English corpora with multiple layers of semantic and syntactic information (Hovy et al. 2007). An inventory of verb senses is being developed through manual clustering of polysemous verbs in WordNet (Duffield et al. 2007). These OntoNotes verb senses are then inserted into the larger Omega ontology (Philpot et al. 2005), and VerbNet classification has been used to aid us in the creation of verb categories.

In an effort to systematically tackle verbs of similar semantics, we divided the verbs in the inventory into their VerbNet classes. We then examined the senses of the verbs in each VerbNet class individually to link the semantically related senses into the ontology. Verbs in the inventory that were not members of any VerbNet class were manually

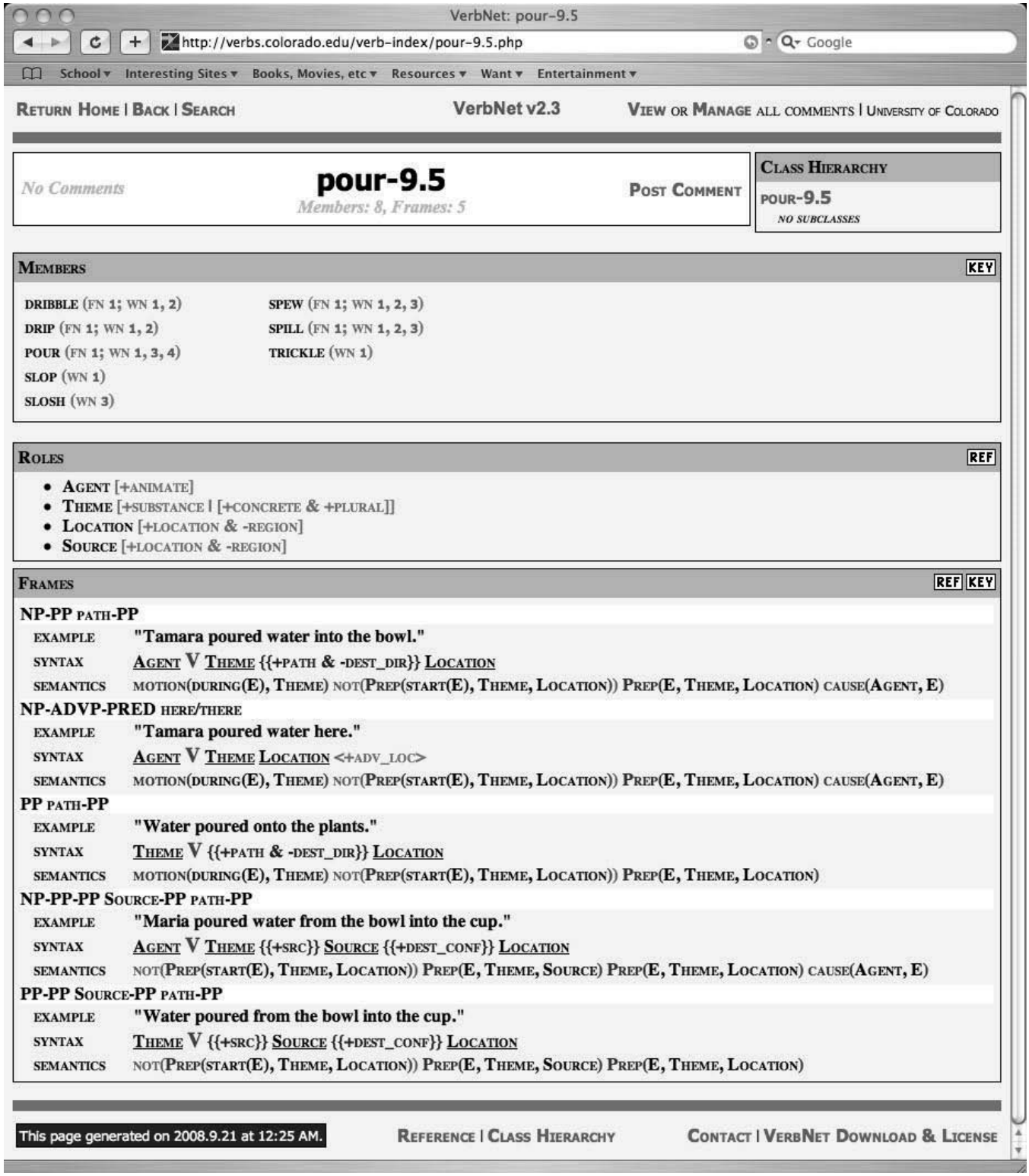

Figure 1 VerbNet Entry for *Pour* class

classified into the existing classes on semantics alone. A verb that is a member of one VerbNet class may have other senses that are semantically relevant to another class. We currently have a total of 617 verbs (including 1168 senses) classified into 30 classes that have been inserted into the ontology. Figure 2 illustrates the current upper level nodes with the verb classes that are associated with them. Several classes, such as Send/Carry, appear under many different nodes, so would activate inference rules in all of them. Any verb inference rules that specify Start and End Locations would be associated with Change of Location.

The verb classes in the ontology are not identical with the VerbNet classes. Take for instance VerbNet class 37-Verbs of Communication that currently contains 222 unique members in VerbNet. So far we have placed 122 unique verbs in our ontology under the classification of Verbs of Communication. 71 of the verbs are members of VerbNet class 37 and were the initial members of this ontological class (e.g., *sniff, inform, read, question*). 51 additional verbs' senses were later included in this ontological class based on semantics. Some of these verbs are found elsewhere in VerbNet (e.g., *show* from VN 27.5-conjecture and *misinterpret* from VN 87.2-comprehend) or do not exist in VerbNet at all (e.g., *testify, outline* and *highlight*). The 151 VerbNet 37 class members not yet included in the Omega ontology are either semantically monosemous or of infrequent usage (e.g., *rasp, splutter, grumble, interrogate*). Future plans include the addition of monosemous verbs.

5. Conclusion

These examples illustrate the potential use of VerbNet semantic predicates in conjunction with an ontology in the association of semantic representations with sentences. A similar approach could be applied to FrameNet, and we have a mapping from VerbNet to FrameNet, which would facilitate this. Additional feedback from researchers using these semantic predicates for reasoning systems would be extremely helpful in terms of expanding their scope and refining their specificity.

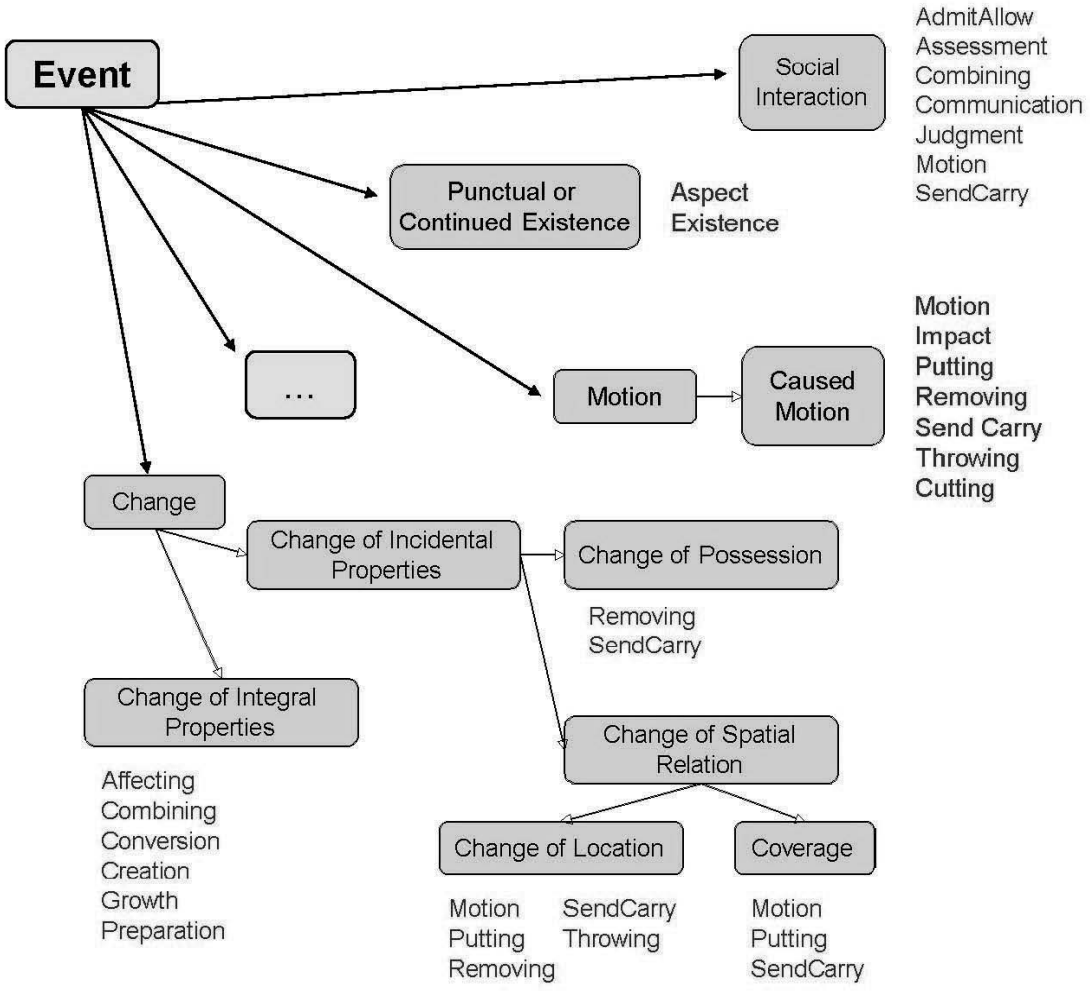

Figure 2 Upper level nodes in Verb

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