“On Event Structure in the Torn Dress” *

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*The title is comprised from part of titles of major papers being discussed, namely Pustejovsky [Pus91] and Fong [Fon01].
1 Introduction

This document discusses relevance of the techniques employed in [Pus91] to example sentences and ideas presented in [Fon01]. The document goes beyond just a mechanical attempt to apply the techniques from one paper to another; it also discusses the pros, cons, and other findings in the two papers. A relationship is made to other works in Lexical Semantics and Lexicon; the sources are cited where appropriate. If there are no citations, the text is a sole responsibility of the author.

2 Goal

The main goal of this work is to illustrate on how to one can possibly represent semantics of sentences using tools presented in the papers ([Pus91], [Fon01]) and others and derive a computational lexicon.

3 Semantic Analysis

The below sentence samples have been taken from [Fon01]. All the follow up discussion will be around these examples.

1. (a) Cathie mended the torn dress.
   (b) Cathie mended the red dress.

As Fong herself says in [Fon01], the both events of the above fit the same event template (LCS):

(c) \([x \text{ CAUSE } \text{BECOME } [y <\text{mended}>]]\]

This is possible for the lexeme mend\(^1\) because 1b has implicit torn adjective in it. I claim that (b) and the below are equivalent:

(d) Cathie mended the torn red dress.

The red is just a bit more specific type of dress being mended. Otherwise, why would one mend a dress which is not torn? The torn state of the dress changes to become mended; hence, state transition is in place. Another part of dress’ state, as being red is undefined (but is likely to be still the same) at the event culmination.

We can build the event structure, ES, LCS’, and LCS following the style of Pustejovsky in [Pus91] and Fong in [Fon01]. I have replaced the not notation to “!”. For ES and LCS’ I use the notation from Pustejovsky, and LCS is from Fong because it resembles more conventional use of predicates than that of Pustejovsky.
As for the refined structure for a specific, red, dress it won’t change much, that just a part of state will remain the same.

One may argue, that the dress might change the color during the mending process because we can only guess that it is still red but don’t have enough evidence from the sentence being analyzed that the red property persists. Then we could adjust the state template \([\text{IS } \text{dress <red>]}\) to be \([\text{IS } \text{dress <red>} \mid \text{IS } \text{dress [NOT <red>]}]\) and assign the first part of the disjunct a higher likelihood than the second (I use “|” to indicate OR and “&” to indicate AND).

In this analysis if we assume red being a constant throughout the process we can claim than the original template (c) holds. Since it is a transition, we could also write (notational sugar):

(e) \(T_{torn}^{mended}(\text{dress}) \& \text{red(\text{dress})}\).

2. (a) The plumber fixed every leaky faucet.
   (b) The plumber fixed every blue faucet.

These two examples are similar to that of (1). Both assume the faucets fixed were leaking water, hence there’s a state transition with respect to the property of every fixed faucet to become not
leaky. Additional semantic bit in here is that the adjective every makes it plural and this fact may shift the event type sometimes.

\[
\text{ES: } \quad T \\
/ \quad \backslash \\
/ \\
\text{LCS': } P \quad S \\
| \\
| \\
\text{act}(p, \text{every}(\text{faucet})) \neg \text{leaky}(\text{faucet}) \\
\quad \& \quad \text{leaky}(\text{faucet}) \quad | \\
\quad \text{fixed}(\text{faucet}) \\
\text{LCS (1): } [p \text{ CAUSE } \text{BECOME } \text{EVERY } [\text{faucet } <\text{fixed}>]]] \\
\text{LCS (2): } [p \text{ CAUSE } \text{BECOME } [\text{faucets } <\text{fixed}>]]]
\]

The second case restricts the act of fixing only to leaky blue faucets (there may be, let say, leaky red faucets that have not been not fixed). The blue property of (b) does not change since it is not in the opposition to or in a synnet with leaky.

\[
\text{ES: } \quad T \\
/ \quad \backslash \\
/ \\
\text{LCS': } P \quad S \\
| \\
| \\
\text{act}(p, \text{every}(\text{faucet})) \neg \text{leaky}(\text{faucet}) \quad | \\
\quad \& \quad \text{blue}(\text{faucet}) \quad | \\
\quad \& \quad \text{leaky}(\text{faucet}) \quad \text{fixed}(\text{faucet}) \quad \& \quad \text{blue}(\text{faucet}) \\
\text{LCS (1): } [p \text{ CAUSE } \text{BECOME } \text{EVERY } [\text{faucet } <\text{fixed}>]]] \quad \& \quad [\text{IS } [\text{faucet } <\text{blue}>]] \\
\text{LCS (2): } [p \text{ CAUSE } \text{BECOME } [\text{faucets } <\text{fixed}>]]] \quad \& \quad [\text{ARE } [\text{faucets } <\text{blue}>]]]
\]

NOTE: In the above, I (perhaps astonishingly incorrectly) use EVERY as if it were a predicate to enumerate all the faucet instances that could be replaced by a normal (“for-all”) symbol (forgot how to spell it in \LaTeX\) and a variable as we do in predicate logic, or as in LCS (2) use plural form instead (this actually helps understand and encode semantics of an NP). LCS (2), however, might not indicate the “for-all” meaning.

3. Mary fixed the flat tire.

This entails that the deflated tire became full of air and is no longer flat as cause by Mary’s actions. This would be an achievement.
4. **John mixed the powdered milk into the water.**

This indicates that the milk made it to the water and the water became *milky* vs. *milkless* in a sense that the two substances fused (regardless the quantity), hence the change of state. Likewise, one can argue that the milk became *watery* vs. *dry* (as in powder). Also, since there is an actor, it is an achievement according to [Pus91].

5. **The father comforted the crying child.**

The act of comforting does not necessarily imply the child is no longer crying, so there is no state transition, but rather a process.
6. John painted the white house blue.

This is an accomplishment since the house that has previously been white became blue in color, so there is event culmination.
7. Mary rescued the drowning man.

This is an accomplishment since the man is no longer drowning and it’s an agentive action.

ES: T
   /   \
   /   \
LCS’: P S
      |    |
an(m, man) & drowning(man) !drowning(man)
      |    |
      rescued(man)

LCS: [m CAUSE [BECOME [man <rescued>]]]

8. Mary cleaned the dirty table.

This is a process since the table is not necessarily clean after Mary has finished the cleaning process.

ES: P
   / \ 
   / \ 
LCS’: e1.....en
       |     |
act(m, table) & dirty(table) & clean(table)
       |     |
LCS: [m CLEAN [table <dirty>]] & [m CAUSE [BECOME [table <cleaned>]]]]

Note, as usual, cleaned table does not mean it is entirely clean, hence the sentence does not convey culmination of the cleaning event.

9. The waiter filled every empty glass with water.

As a result of waiter’s actions all empty glasses have changed their state from empty to full with water. The with water part, the PP, is an extra bit of information indicating the exact type of liquid used to fill the glasses with, but does not affect or shift the event type in any way, just like (1) or (2). The act of filling for the waiter is a process, whereas for empty glasses having become full is a change of state, hence a transition, with a subtype of accomplishment because the adjective every makes the completed.
NOTE: the state <filled-with-water> may be broken into a finer granularity in LCS predicates like it's done in LCS'.

10. (a) **John brushed the dirty carpet.**

   (b) **John brushed the dirty carpet clean.**

   These two items are, in fact, quite distinct. (a) is a typical process which does not entail the final state of the carpet (it might still remain partially dirty), whereas (b) is an accomplishment event because it has the transition with the culmination point from a process to state being clean as a result of John's action. Clearly, adverbs may shift the event type of a verb from one to another.

There is hidden state change in here of the carpet from *not brushed* to (somewhat) *brushed*, but not necessarily clean (\([\text{carpet <brushed>]} \neq \text{[carpet <clean>]}\)). It occurred to me I have to capture this information.
lexeme
{
    SPELLING: x
    PRONUNCIATION: y
    SENSE: s : {s1, s2}
    POS: /tag
}

---

Figure 1: Original Feature Structure of a Lexeme

The below is for (b):

```
ES:
   T
     / \ 
    /   \   
   LCS': P S
     |   | 
act(j, carpet) & carpet(dirty) !dirty(carpet)
     | 
    clean(carpet)

LCS: [j CAUSE [BECOME [carpet <clean>]]]
```

4 Lexicon

First, let us start off with the lexicon of the given example sentences. The first type of lexical entries in our lexicon, lexemes, will comply with the feature structure presented in [Mok03], Figure 1. The structure was originally derived from [JM00] and [Arn01]. For this work we simplify the lexeme structure by leaving out the phonological form of the lexeme because it is unused throughout the paper. Likewise, our lexicon is rather short and we do not deal with polysemy, the SENSE feature will be a scalar value rather than a set of related senses. Hence, our lexeme will have the structure presented Figure 2.

The new lexeme representation is a 3-tuple of the form: name\{X, S, T\}, where X is the word’s spelling, S is its sense, T is its POS tag, and name is a name of the lexeme, an index, uniquely identifying the lexical entry in the lexicon. The tag T is of a Penn Tagset, [Sat90]. The word sense has been adapted from the online Webster’s dictionary, [web03].

Pustejovský and Fong seem to drift away from the feature-based approach in their work as being not scalable for a decent computational lexicon. Yet, some feature-based work is preserved, so I will keep the lexeme as a set of features in addition to new types of lexical entries presented afterwards.
Figure 2: Simplified Feature Structure of a Lexeme

4.1 Lexemes

4.1.1 Verbs

1. mend\textsuperscript{1} \{to mend, “to repair; to fix”, /VB\}
2. mend\textsuperscript{2} \{mended, “repaired; fixed”, /VBD\}
3. mend\textsuperscript{3} \{mending, “repairing; fixing”, /VBG\}
4. fix\textsuperscript{3} \{fixed, “repaired”, /VBD\}
5. mix\textsuperscript{1} \{mixed, “formed by mixing components”, /VBD\}
6. comfort\textsuperscript{1} \{comforted, “eased the grief or trouble of; pleased, calmed down”, /VBD\}
7. cry\textsuperscript{1} \{crying, “shedding tears often noisily”, /VBG\}
8. paint\textsuperscript{1} \{painted, “covered with paint”, /VBD\}
9. rescue\textsuperscript{1} \{rescued, “saved from death”, /VBD\}
10. drown\textsuperscript{1} \{drowning, “becoming pulled under the water or other liquid”, /VBG\}
11. clean\textsuperscript{1} \{cleaned, “rid of dirt”, /VBG\}
12. fill\textsuperscript{1} \{filled, “made full; cancelled emptiness”, /VBD\}
13. brush\textsuperscript{1} \{brushed, “cleaned”, /VBD\}

4.1.2 Nouns

1. person-cathie \{Cathie, “first name of a person; agent”, /NNP\}
2. person-mary \{Mary, “first name of a person; agent”, /NNP\}
3. person-john \{John, “first name of a person; agent”, /NNP\}
4. dress\textsuperscript{1} \{dress, “piece of women’s clothing; long”, /NN\}
5. plumber

6. faucet

7. tire

8. milk

9. water

10. father

11. child

12. house

13. man

14. table

15. waiter

16. glass

17. carpet

4.1.3 Adverbs

1. blue

2. clean

4.1.4 Adjectives

1. mended

2. torn

3. red

4. blue

5. white

6. leaky

7. flat
8. powdered\textsuperscript{1}\{\textit{powdered}, “dried; made of powder”, /JJ\}

9. every\textsuperscript{1}\{\textit{every}, “being each individual or part of a group without exception”, /JJ\}

10. empty\textsuperscript{1}\{\textit{empty}, “not full; containing nothing”, /JJ\}

11. dirty\textsuperscript{1}\{\textit{dirty}, “not clean”, /JJ\}

4.1.5 Others

1. the\textsuperscript{1}\{\textit{the}, “definite article”, /DT\}

2. into\textsuperscript{1}\{\textit{into}, “inside of”, /IN\}

3. with\textsuperscript{1}\{\textit{with}, “used as a function word to indicate the means, cause, agent, or instrumentality”, /IN\}

4.2 Semantic Bits

This section presents types of lexical items, other than feature-based lexemes, that capture lexical semantics of the lexemes and their composition via lexical and otherwise relations.

4.2.1 Event Types

For our event types of verbs in the sentences in this lexicon we have only transitions $T$ and processes $P$. There is also a $S$ state after transition that could be reflected on the affected objects in the example sentences. There are two types of $T$’s, achievements and accomplishments, let’s name them explicitly as $T_{\text{achievement}}$ and $T_{\text{accomplishment}}$.

Thus our event types in the lexicon:

- $T$
- $T_{\text{achievement}}$
- $T_{\text{accomplishment}}$
- $P$
- $S$
4.2.2 Event Templates

Other type of lexical entries in our lexicon are event templates that can be derived from the Semantic Analysis (Section 3). These entries can be linked to the appropriate lexemes and their compositions. Note, the variables in these templates also have restrictions of what they can be (i.e. which lexemes they can be assigned to). For example, for causative verbs there has to be an animate agent (e.g. Cathie) or a subject that can have an animate role (e.g. as Microsoft Corporation in “Microsoft Corporation was not afraid of law suits against it.”). This is to say that a carpet cannot mend a dress, for example. Making an analogy to security in computing world, these facts can be added to the lexicon as a data structure similar to an ACL (access-control list) matrix that indicates which semantic capabilities lexemes posses or do not posses based on their roles.

The below is the list of event templates pertinent to the examples copied nearly verbatim from the ES, LCS’ and LCS analysis. A lexical entry for the event template would

1. mended-state1 \{T \text{achievment}, [x \text{ CAUSE [BECOME [y <mended>]]}]\}

2. mended-state2 \{T \text{achievment}, [x \text{ CAUSE [BECOME [y <mended>]]} & [IS [y <red>]]]\}

This can be reduced to mended-state1 if we reply on compositionality of mended-state1 and plain-single-state below under NPs. Similar reduction to the template list entries can be applied to a few items below.

3. fixed-state1 \{T \text{achievment}, [x \text{ CAUSE [BECOME [EVERY [y <fixed>]]]]}\}

4. fixed-state2 \{T \text{achievment}, [x \text{ CAUSE [BECOME [EVERY [y <fixed>]]]] & [IS [y <blue>]]}\}

5. fixed-state3 \{T \text{achievment}, [x \text{ CAUSE [BECOME [y <fixed>]]}]\}

6. mixed-state1 \{T \text{achievment}, [x \text{ CAUSE [BECOME [SUBSTANCE-OF [y <milky>] & [z <watery>]]]}]\}

7. comforted-state1 \{P, [x \text{ [COMFORT [y <crying>]]]] & [x \text{ CAUSE [BECOME [y <comforted>]]]}]\}

8. blue-state1 \{T \text{accomplishment}, [x \text{ CAUSE [BECOME [y <blue>]]}]\}

9. rescued-state2 \{T \text{accomplishment}, [x \text{ CAUSE [BECOME [y <rescued>]]}]\}

10. cleaned-state1 \{P, [x \text{ CLEAN [y <dirty>]]] & [x \text{ CAUSE [BECOME [y <cleaned>]]]}]\}

11. filled-water-state1 \{T \text{accomplishment}, [x \text{ CAUSE [BECOME [EVERY [y <filled-with-water>]]]}]\}

12. brushed-state1 \{P, [x \text{ [BRUSH [y <dirty>]]]] & [x \text{ CAUSE [BECOME [y <brushed>]]]}]\}

13. clean-state1 \{T, [x \text{ CAUSE [BECOME [y <clean>]]}]\}
4.2.3 Semantic Capture of NPs and Adverbials

4.2.3.1 NPs  Meaning of the NPs can be derived from the thematic roles in the sentence as presented in Chapter 16, [JM00] (due to lack of time this area remains unexplored at this moment). Additionally, we can infer some it from the Semantic Analysis (Section 3) and make up a template-like structure.

For example, [IS [y z]] can be used to represent a state of a noun z with a property of y. It can be nested ([IS [IS [dress ¡red¿ ¡torn¿]]]) and can be stored in the event template list. This is roughly equivalent to the below, on which semantic restriction is imposed, however (the set of values z and y, or JJ and NN, can take):

\[
\begin{align*}
\text{NP} & \rightarrow \text{JJ NP} \\
\text{NP} & \rightarrow \text{NN}
\end{align*}
\]

Thus, for our little lexicon we could write a few entries for the simple noun phrases we have:

1. plain-single-state: \{S, [IS [y z]]\}
2. mixture: \{S, [IS [y z] & IS [a b]]\}
3. multi-state: \{S, [IS [IS [x y] z]]\}

4.2.3.2 Adverbials  As it has been shown in the analysis, the adverbs, such as clean\(^2\) and blue\(^2\) shift the event type from \(P\) to \(T\).

[TO BE COMPLETED]

This can be encoded as a set of state rules, where input would be an /RB lexeme, it’s corresponding value in the referenced by the LET matrix (see below; sorry for jumping a little), if it yeilds 1, then change the event type of such a rule from \(P\) to \(T\). (Again, a matrix??)

[TO BE COMPLETED]

4.3 Lexicon Analysis

Compositional and generative properties of our lexicon would let it scale well as far as lexical semantic concerned. Using the event templates along with the lexeme’s features we could cover a lot more semantically correct phrases and sentences without unnecessary lexicon bloat as with pure feature-based model. This makes the lexicon match the infinite possibilities of a natural language in capturing semantics rather than defining it as a finite set of lexemes.

Adding a “lexeme semantic capabilities” list (LSCL) could also restrain the templates the lexemes can be plugged into w/o cluttering the list of lexemes with pointer to allowed templates or the reverse. It can also be a lexeme-event-template (LET) matrix with rows as event templates indexes and columns are lexemes with a boolean entry indicating which \(x, y,\) and \(z\) (lexeme variables) allowed to be used in which templates.
Also, another observation that I made is when I put down all the event templates in the lexicon, with the names that all had “-state” in them. I did not do it intentionally rather more subconsciously. After noticing this, I thought that possibly we can model all this template structure as states only and allowed transitions between them. (This is a strongly personal opinion. I have not looked at the FrameNet project myself; only the presentation. Maybe the do the same?).

Thus a new definition, explicitly stated, of a computational lexicon would be:

1. A set of lexemes (feature-based).
2. A set of event templates.
3. Either LSCL or LET data structures.
4. Semantic relation matrix (SRM) among lexemes, as in the examples given by Fong in [Fon01] via antonym/synonym relationship one can find the semantic opposition and derive the event type based on that.

5 Summary, Critique, and Conclusions

The [Fon01] paper mostly focuses on semantic oppositions (eg. torn as opposed to mended in 1a when related to dress’ final state), but only briefly touches other types of relations (eg. red vs. torn when related to dress). Both papers mostly focus on the lexical semantics of verbs as related to events and almost no credit given to the semantics of NPs and others in relationship to the work done. None explicitly define what their lexical items in the lexicon would be and why. The presented material, however, allows to derive the meaning representation of the noun phrases, adverbials, and prepositional phrases and how they can shift event type from one another.

It is my belief that the resulting lexicon is quite comprehensive. The presented instances of it, however, are not perfect and incomplete and there’s no time left to fix them as this is being written. Thus, I will briefly summarize the current shortcomings of the above lexicon instance: the lexemes have the sense feature which is currently presented as just a dictionary (or my own) definition used for the sense in the example sentences. It has no event types or links to the templates in them. Instead, I could remove that feature altogether from the lexeme structure in favour template approach, but keep the rest. I have not provided a concrete example of the LCSL or LET structures to restrict lexemes to the templates. Additionally, these structures may suffer from large data sparseness as in the example of LET matrix making computational and storage aspect questionable w/o any optimization steps. I have not explored the semantic relations issue and the necessity of the SRM matrix, which is also likely to be sparse.

Derivation of the new entries for a general-purpose computational lexicon could be done through the semantic relations and analysis of verbs argument structure, categories, PPs, which are not explored in this work.

If this all is not at all sensible and hurts the beautiful mind, please forgive me for the pain I caused with my work. A lot more research, information-digesting, and summarizing time is required to produce a more quality work. Thus, consider this as a humble draft.
References

[Arn01] Doug Arnold. *Structural and Lexical Semantics, in: Introduction to Linguistics; course notes.* University of Essex, 2001.
URL: http://clwww.essex.ac.uk/course/LG111/2-lex-sem/index_3.html.

[Fon01] Sandiway Fong. *On Mending a Torn Dress: The Frame Problem and WordNet.* Carnegie Mellon University, Pittsburgh., 2001.

[JM00] Daniel S. Jurafsky and James H. Martin. *Speech and Language Processing.* Prentice-Hall, Inc., Pearson Higher Education, Upper Saddle River, New Jersey 07458, 2000. ISBN 0-13-095069-6.

[Mok03] Serguei A. Mokhov. *Presentation on Lexical Relations based on Chapter 16, Jurafsky and Martin and Arnold course notes.* October 2003.
URL: http://www.cs.concordia.ca/~teaching/comp774/2003/774-15-mokhov.pdf.

[Pus91] James Pustejovsky. *The Syntax of Event Structure.* Elsevier Science Publishers B.V., 1991.

[Sat90] Beatrice Satorini. *Extract From: Part-of-Speech Tagging Guidelines for the Penn Treebank Project (3rd Revision, 2nd printing).* June 1990.
URL: http://www.ldc.upenn.edu/sb/cis530/materials-2000/treebank-tagset.pdf.

[web03] *Merriam-Webster Dictionary.* Merriam-Webster, Incorporated, 2003.
URL: http://www.webster.com.