FNLP Tutorial 4

1 The CKY Algorithm

1. Determine the potential parses of the sentence "The women fish with bait" according to the PCFG below, using the CKY algorithm (see Lecture 15). Number the symbols you put in the chart in the order they would be computed. For each chart item, assume that candidate grammar rules are searched in the order they are listed below. Use these numbers to construct backpointers in the chart. For example, when constructing the 6th symbol NP out of a determiner with symbol number 2 and a noun with symbol number 3, you could indicate that by putting '6: NP (2, 3)'. (This is not a widely used custom, but a useful one when doing CKY on paper for the context of this tutorial.)

2. What are the probabilities of the parse trees?

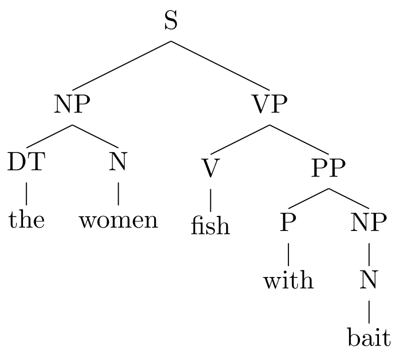
$$
\begin{aligned}
\text{S} &\rightarrow \text{NP} \quad \text{VP} \ (1)\\
\text{NP} &\rightarrow \text{DT} \quad \text{N} \ (0.5)\\
\text{NP} &\rightarrow \text{N} \quad \text{N} \ (0.1)\\
\text{NP} &\rightarrow \text{N} \ (0.4)\\
\text{VP} &\rightarrow \text{V} \quad \text{PP} \ (1)\\
\text{PP} &\rightarrow \text{P} \quad \text{NP} \ (1)\\
\text{DT} &\rightarrow \text{the} \ (1)\\
\text{P} &\rightarrow \text{with} \ (1)\\
\text{V} &\rightarrow \text{fish} \ (1)\\
\text{N} &\rightarrow \text{women} \ (0.5) \mid \text{fish} \ (0.3) \mid \text{bait} \ (0.2)
\end{aligned}
$$

Solution

1. Here is the CKY chart:

the	women	fish	with	bait
1: DT	10: NP(1,2)			15: S(10,13)
	2: N, 3: NP(2)	11: NP(2,5)		14: S(3,13)
		4: V, 5: N, 6: NP(5)		13: VP(4,12)
			7: P	12: PP(7,9)
				8: N, 9: NP(8)

The resulting parse looks like this:



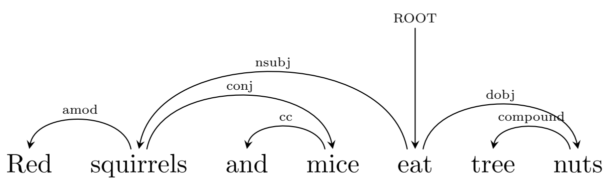
2. There is only one valid parse. The parse tree has the following probability: $1 \times 0.5 \times 1 \times 1 \times 0.2 \times 0.5 \times 0.4 \times 1 \times 1 \times 1 = 0.02$.

2 Dependency Parsing

Consider the following sentence: "Red squirrels and mice eat tree nuts."

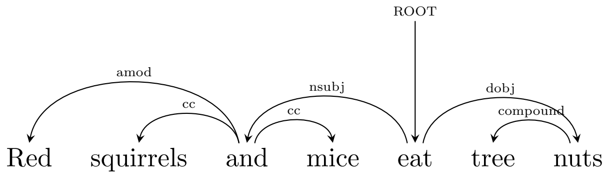
1. This sentence contains an ambiguity: point out that ambiguity by giving paraphrases of the different meanings. Which interpretation is the most salient, and why?
2. Assume that when creating dependency trees we treat conjunction as described here (https://universaldependencies.org/u/dep/conj.html). The assumption that is crucial to the usage of dependency trees (relations between words are asymmetric and binary) is violated when we construct a dependency tree for a sentence with a conjunction: explain why.
3. Provide the dependency tree for the sentence. You can use the following labels to mark the arcs: amod, compound, conj, cc, nsubj, dobj, root. J&M, Figure 14.2, 3rd edition provides explanations per label.
4. Using this way of representing conjunction, could we represent both interpretations discussed in (1) above?
5. If you could change the way conjunction is represented in any way you would like, you would be able to represent the least salient interpretation of the sentence: provide that dependency tree.

Solution

1. The scope of the adjective is ambiguous. The sentence could either mean that "Mice and red squirrels eat tree nuts" (i.e. the mice need not be red), or that the "Red squirrels and red mice eat tree nuts" (both the squirrels and the mice are red). The first interpretation is the most salient, because mice are usually not red.
2. Dependency relationships are asymmetric and binary because they exist between one head and one dependent. However, in the case of this sentence there is a conjunction ("red squirrels and mice"), that signifies a symmetric relationship between "red squirrels" and "mice". Neither of the conjuncts is the head, but when only using asymmetric and binary dependency relationships in our dependency trees, we are forced to express conjunction in a manner that does not fit its symmetric character.
3. 

4. No. According to the universal dependencies format, the first conjunct is used as the head of the conjunction. As a result, we could not see the difference between “red” only modifying “squirrels” or modifying the entire conjunction.

5. For example, you could make “and” the head of the phrase. This is a Prague-style tree (https://aclanthology.org/P13-1051/) where ”red” modifies both squirrels and mice.



3 Compositional Semantics

Consider the following sentence: “Some student ate every apple with a fork.”

1. Explain why this sentence is ambiguous.

2. Provide paraphrases that express the different interpretations that are possible due to the ambiguity.

3. Give the FOL representation of those interpretations. Use Davidsonian semantics as introduced in Lecture 21 (March 11^{th}).

4. Finally, provide the lambda calculus derivation of “A student eats a green apple” using the grammar below. Adjectives were not included in the lecture. Which of the following captures the role of “green” best? Use that representation in your derivation.

   (a) $\lambda x.green(x)$
   (b) $\lambda P.\lambda x.(green(x) \wedge P(x))$
   (c) $\lambda P.\lambda Q.\lambda x.(P(x) \wedge green(x) \wedge Q(x))$

5. Adjectives were not included in the lecture because they are not always straightforward. If we treated all adjectives analogously to “green”, we could make invalid inferences. Can you think of two adjectives where this would be the case?

S	$\rightarrow$	NP VP	*NP.Sem(VP.Sem)*
NP	$\rightarrow$	Det N′	*Det.Sem(N.Sem)*
VP	$\rightarrow$	Vt NP	*Vt.Sem(NP.Sem)*
N′	$\rightarrow$	A N′	*A.Sem(N′.Sem)*
N′	$\rightarrow$	N	*N.Sem*
N	$\rightarrow$	student	$\lambda x.student(x)$
N	$\rightarrow$	apple	$\lambda x.apple(x)$
Vt	$\rightarrow$	eat	$\lambda R.\lambda z.R(\lambda y.eat(z,y))$
Det	$\rightarrow$	a	$\lambda P.\lambda Q.\exists x.(P(x) \wedge Q(x))$
A	$\rightarrow$	green	???

Solution

1. There are two scope ambiguities related to the existential and universal quantifiers: (1) does the existential quantifier in “some student” take scope over the universal quantifier in “every apple”, or the other way around? (2) does the universal quantifier in “every apple” takes cope over the existential quantifier in “a fork”, or the other way around?
   (Technically, one might say “with a fork” also has an attachment ambiguity, where it could be that the eating happens with a fork, or that every apple has a fork, and one eats both

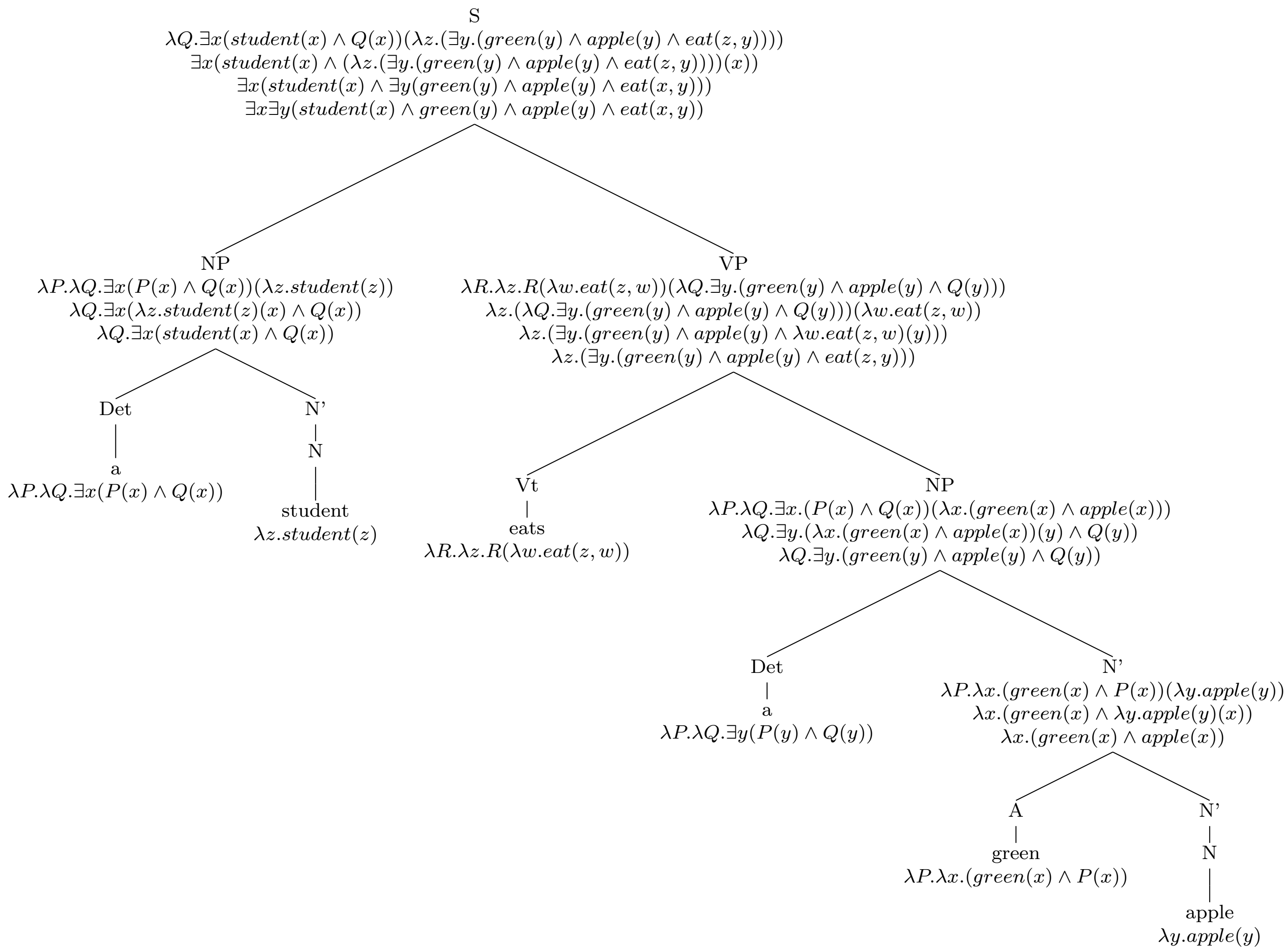
the apple and the fork. Because the latter interpretation seems humanly impossible and thus highly unlikely, we omit it in this question.)

2. (a) There is one specific student that ate every apple with one specific fork. (specific student, specific fork)
   (b) There is one specific student that ate every apple with some fork (need not be the same fork every time). (specific student, not a specific fork)
   (c) Every apple was eaten by some student with some fork. (not a specific student, not a specific fork)
   (d) There is one specific fork and for every apple there is some student that ate the apple with that fork. (specific fork, not a specific student)

3. (a) $\exists x \exists y(Student(x) \wedge Fork(y) \wedge \forall z(Apple(z) \rightarrow \exists e(Eats(e, x, z) \wedge e \prec n \wedge With(e, y))))$
   (b) $\exists x(Student(x) \wedge \forall y(Apple(y) \rightarrow \exists e \exists z(Fork(z) \wedge Eats(e, x, y) \wedge e \prec n \wedge With(e, z))))$
   (c) $\forall x(Apple(x) \rightarrow \exists e \exists y \exists z(Student(y) \wedge Fork(z) \wedge Eats(e, y, x) \wedge e \prec n \wedge With(e, z))$
   (d) $\exists x(Fork(x) \wedge \forall y(Apple(y) \rightarrow \exists e \exists z(Student(z) \wedge Eats(e, z, y) \wedge e \prec n \wedge With(e, x))))$

4. See the tree below for the derivation. (b) is the right representation: an adjective applies to N'. N' has a higher type, so λP is necessary, which rules out (a). One way to construct an N' is via the rule $N' \rightarrow A \quad N'$, therefore the λ-term of that rule better have the same type as N'. In option (c), this would not be the case: if we apply the semantics of the $N' \rightarrow A \quad N'$ to "green" and "apple", we would get: $\lambda P.\lambda Q.\lambda x.(P(x) \wedge green(x) \wedge Q(x))(\lambda x.apple(x))$, which becomes $\lambda Q.\lambda x.(apple(x) \wedge green(x) \wedge Q(x)))$ after β-reduction. That term has a different type than what we started with for "apple" ($\lambda x.apple(x)$).

5. Examples are "good" and "false": a "good linguist" isn't "good" (in the sense of a "good person") and a "false linguist" is not a linguist at all. If we blindly represented them as $\lambda x.Good(x) \wedge Linguist(x)$ and $\lambda x.False(x) \wedge Linguist(x)$ these inferences would be valid.



4 Discourse relations

Read Section 22.1.2 from J&M, 3rd edition. This subsection discusses the Penn Discourse Treebank, and how the corpus provides annotations for text spans that are related according to certain discourse connectives. The main purpose of the corpus is to identify arguments that share a discourse relation. The largest two classes identified are:

- Explicit relations: those connected with expressions from well-defined syntactic classes, among which because, when, since, although, and, or, however, otherwise, then, as a result, for example.
- Implicit relations: those where the relationship can be described by one of the connectives that is considered "explicit", without the connective being present in the sentence.

For the fragments below, (1) identify two arguments that have a discourse relationship, and (2) characterise it as explicit or implicit, while (3) specifying the type and subtype according to Figure 22.3 from Section 22.1.2 from J&M, 3rd edition. If no such relationship can be determined, indicate that. If you do think there is a relationship, but that it cannot be characterised with the discourse connectives, explain your reasoning. For examples of two consecutive sentences, the discourse relationship should be between those sentences (not within one of the two).

1. Ms. Bartlett's previous work, which earned her an international reputation in the non-horticultural art world, often took gardens as its nominal subject. Mayhap this metaphorical connection made the BPC Fine Arts Committee think she had a literal green thumb.

2. Jacobs is an international engineering and construction concern. Total capital investment at the site could be as much as $400 million, according to Intel.

3. The U.S. wants the removal of what it perceives as barriers to investment; Japan denies there are real barriers.

4. Hale Milgrim, 41 years old, senior vice president, marketing at Elecktra Entertainment Inc., was named president of Capitol Records Inc., a unit of this entertainment concern. Mr. Milgrim succeeds David Berman, who resigned last month.

5. It's harder to sell stocks when the sell programs come in because some market makers don't want to take the orders.

6. Marketers themselves are partly to blame: They've increased spending for coupons and other short-term promotions at the expense of image-building advertising. What's more, a flood of new products has given consumers a dizzying choice of brands, many of which are virtually carbon copies of one other.

Solution The examples are taken from PDTB Research Group et al. (2007), and were determined by human annotators. Keep in mind that what the relationship is could be open to interpretation: sometimes it is not that clear cut, and different annotators might disagree. We encourage you to discuss the different viewpoints in the tutorial in case of disagreements.

1. The discourse relationship exists between the first and second sentence. The relationship is cued by "mayhap this metaphorical connection". It could be marked as implicit because this is not a very obvious discourse connective, but one could also argue in favour of 'explicit'. The type of the relationship is contingency, with subtype reason.

2. There is no discourse relationship between these two sentences.

3. The discourse relationship exists between the two clauses separated by the semicolon. The relationship is implicit, and is of the type 'comparison', subtype 'contrast'.

4. The discourse relationship between the first and the second sentence cannot be captured using the relationships indicated in Figure 22.1.2 from J&M, 3rd edition. It is an entity relationship: the entity discussed in the first sentence ("Hale Milgrim") is the same entity discussed in the second sentence ("Mr. Milgrim"). J&M do discuss entity-based coherence in the main text of Section 22, in case you would like to read more about this.

5. The discourse relationship exists between "It's harder to sell stocks when the sell programs come in" and "some market makers don't want to take the orders". This is an explicit relationship indicated by discourse connective 'because'. It is a contingency relationship, of subtype 'cause'.

6. The discourse relationship between the first and second sentence is one of 'expansion'. It is made explicit through "what's more", and is of subtype conjunction.

References

PDTB Research Group et al. The penn discourse treebank 2.0 annotation manual. *December*, 17: 26–37, 2007.