1. Representing Meaning and Computational Semantics (25 points)

(a) Create a FOPC (first order predicate calculus) meaning representation for the sentence Draco tormented a wizard. Use FrameNet to motivate your representation (and explain how you have done so). Give another sentence that has a different syntactic parse, but that would yield the same meaning representation. You can either show the parse trees, or just explain the differences in words.

Exists e Exists y Tormented (e) ^ Agent (e, Draco) ^ Experiencer (e, y) ^ Wizard (y)

In FrameNet, the verb torment is classified as Cause_to_experience, with an Agent who causes the torment and an Experiencer who experiences it. In the representation above, e is an instance of the torment event, the agent of the event is Draco, the experiencer of the event is y, and y is a wizard. The existentials e and y are used to indicate that we are referring to a specific event that was experienced by y, a wizard.

A parse-tree representation of the sentence "Draco tormented a wizard." follows:

```
NN ----- wizard
    /
   /  
NP 
   /  
VP  DT ----- a
    /  
 S  VBD ----- tormented 
     |
 NP ----- NNP ----- Draco
```

A representation of a different sentence that would result in the same FOPC representation follows:
(b) Add semantic attachments to the following CFG grammar to handle predicate adjectives such as Walmart is cheap.

\[
\begin{align*}
S & \rightarrow NP \ VP \\
NP & \rightarrow \text{ProperNoun} \\
VP & \rightarrow \text{Verb} \ \text{Adj} \\
\text{ProperNoun} & \rightarrow \text{Walmart} \\
\text{Verb} & \rightarrow \text{is} \\
\text{Adj} & \rightarrow \text{cheap}
\end{align*}
\]

Show how they can be used to derive the target meaning representation Cheap(Walmart), assuming Walmart is a constant.

\[
\begin{align*}
S & \rightarrow NP \ VP \ {\{\text{VP.sem} (NP.sem)\}} \\
NP & \rightarrow \text{ProperNoun} \ {\{\text{ProperNoun.sem}\}} \\
VP & \rightarrow \text{Verb} \ \text{Adj} \ {\{\text{Verb.sem} (\text{Adj.sem})\}} \\
\text{ProperNoun} & \rightarrow \text{Walmart} \ {\{Lx.x (\text{Walmart})\}} \\
\text{Verb} & \rightarrow \text{is} \ {\{LP.Lx P(x)\}} \\
\text{Adj} & \rightarrow \text{cheap} \ {\{Lx.x (\text{Cheap})\}}
\end{align*}
\]

The derivation of Cheap (Walmart) from “Walmart is cheap.” follows:

\[
\begin{align*}
\text{VP.sem} (\text{NP.sem}) \\
\text{VP.sem} (\text{ProperNoun.sem}) \\
\text{VP.sem} (Lx.x (\text{Walmart})) \\
\text{VP.sem} (\text{Walmart}) \\
(LP.Lx P(x) (Lx.x (\text{Cheap}))) (\text{Walmart}) \\
(LP.Lx P(x) (\text{Cheap})) (\text{Walmart}) \\
Lx \text{Cheap} (x) (\text{Walmart}) \\
\text{Cheap} (\text{Walmart})
\end{align*}
\]
2. Lexical Semantics (25 points)

(a) Using WordNet, describe appropriate selectional restrictions on the verbs "drink" and "kiss."

Selectional restrictions from WordNet for the verb drink follow:

- To take in liquids
- To consume alcohol
- To propose a toast to
- To be fascinated or spell-bound by; to pay close attention to
- To drink excessive amounts of alcohol; to be an alcoholic

The different senses of the verb are described as follows:

- For the sense of the verb that refers to taking in liquids, the theme of drinking refers to consuming liquids, specifically alcohol in certain senses. But the selectional restriction is that the argument must be drinkable.
- For the sense of proposing a toast, the selectional restriction would refer to something worth celebrating or noting via a toast.
- For the sense of being fascinated by, the selectional restriction would be an entity or event that captures the imagination fully.
- For the intransitive sense, there is no selectional restriction because it takes no object.

Selection restrictions from WordNet for the verb kiss follow:

- To touch with the lips or press the lips (against someone's mouth or other body part) as an expression of love, greeting, etc.
- To touch lightly or gently

The different senses of the verb are described as follows:

- For the sense of the verb that refers to pressing one's lips against someone or something in an expression of affection or greeting, the selectional restriction would be primarily to a person but could also apply to an object of affection. For example, when one reaches the shore after a long voyage, one might kiss the ground as an affectionate greeting of sorts, or when one wins an award, one might kiss the trophy received.
- For the sense of touching lightly or gently, the selectional restriction is on something against which the subject can lightly touch. Continuing with our seafaring theme, for example, a boat could kiss or gently touch the dock, or metaphorically, the sun could kiss the petals of a flower.

(b) Using the WSJ corpus from Homework 2 (Q3), analyze how well your selection restrictions worked.

The WSJ corpus we used contains very few references to the verb drink. The instances I found are described as follows:

- “If you drink more, you get more” is an implicit reference to alcohol consumption.
- “We’re not saying drink more, we’re saying trade up” is another implicit reference to alcohol consumption, though this one could be referring metaphorically to taking more of something.
- “Characters drink Salty Dogs” refers to consumption of a specific type of cocktail, again alcoholic in nature.
- “When I’m drinking, I bowl better” is another reference to consuming alcohol, this time during a physical activity, bowling.
- “Taken up with endless scenes of many people either fighting or drinking to celebrate victory” is a reference to the theme of making a celebratory toast, again with undertones of drinking alcoholic beverages.
The corpus we worked with contains no references to the verb kiss.

3. Computational Lexical Semantics (25 points)

(a) Jurafsky and Martin, 20.1-20.2 (p. 679), but using only the following as your corpus:

At 05:20:59 GMT this morning, the Echostar XI satellite was successfully launched into a geosynchronous transfer orbit atop a Zenith-3SL carrier rocket.

20.1 Collect a small corpus of example sentences of varying lengths from any newspaper or magazine. Using WordNet or any standard dictionary, determine how many senses there are for each of the open-class words in each sentence. How many distinct combinations of senses are there for each sentence? How does this number seem to vary with sentence length?

The open-class words of our sentence-length corpus have the following number of senses:

- morning (4 noun senses)
- satellite (3 noun senses, 1 verb sense, 1 adjective sense)
- successfully (1 adverb sense)
- launched (6 verb senses)
- geosynchronous (1 adjective sense)
- transfer (6 noun senses, 9 verb senses)
- orbit (5 noun senses, 1 verb sense)
- carrier (11 noun senses)
- rocket (5 noun senses, 2 verb senses)
- GMT (1 noun sense)
- Echostar (no results)
- X1 (no results)
- Zenith-3SL (no results)

There are 831,600 (4 * 5 * 1 * 6 * 1 * 15 * 6 * 11 * 7) permutations of all possible word senses for the open-class words in this sentence. It would appear that the number of possible combinations would increase with the distinct number of open-class words in each sentence, since each potentially contributes more possibilities to the permutation.

20.2 Using WordNet or a standard reference dictionary, tag each open-class word in your corpus with its correct tag. Was choosing the correct sense always a straightforward task? Report on any difficulties you encountered.

- NN \rightarrow morning (Noun sense 1)
  \[S: (n) \text{morning, morn, morning time, forenoon} \text{ (the time period between dawn and noon)} \quad \text{“I spent the morning running errands”}\]
  Selecting this sense was a straightforward task.

- NN \rightarrow satellite (Noun sense 1)
  \[S: (n) \text{satellite, artificial satellite, orbiter} \text{ (man-made equipment that orbits around the earth or the moon)} \]
  Selecting this sense was a straightforward task.

- RB \rightarrow successfully (Adverb sense 1)
  \[S: (adv) \text{successfully} \text{ (with success; in a successful manner)} \quad \text{“she performed the surgery successfully”}\]
  Selecting this sense was obviously a straightforward task.

- VB \rightarrow launched (Verb sense 2)
S: (v) launch (propel with force) "launch the space shuttle"; "Launch a ship"
Selecting this sense was a straightforward task.

• JJ → geosynchronous (Adjective sense 1)
  S: (adj) geosynchronous (of or having an orbit with a fixed period of 24 hours (although the
  position in the orbit may not be fixed with respect to the earth))
Selecting this sense was obviously a straightforward task.

• NN → transfer (Noun sense 1)
  S: (n) transportation, transport, transfer, transferral, conveyance (the act of moving something from
  one location to another)
Selecting this sense was slightly challenging, since noun sense 3 was also a reasonable candidate.
I elected to go with the first sense of the noun form because it seemed more appropriate in our
context.

• NN → orbit (Noun sense 1)
  S: (n) orbit, celestial orbit (the (usually elliptical) path described by one celestial body in its
  revolution about another) "he plotted the orbit of the moon"
Selecting this sense was a straightforward task.

• NN → carrier (Noun sense 2)
  S: (n) carrier (a self-propelled wheeled vehicle designed specifically to carry something)
  "refrigerated carriers have revolutionized the grocery business"
Selecting this sense was a straightforward task, though the reference to a wheeled vehicle in the
definition of the sense is somewhat inappropriate.

• NN → rocket (Noun sense 1)
  S: (n) rocket, projectile (any vehicle self-propelled by a rocket engine)
Selecting this sense was a straightforward task.

• NN → GMT (Noun sense 1)
  S: (n) Greenwich Mean Time, Greenwich Time, GMT, universal time, UT, UT1 (the local time at the
  0 meridian passing through Greenwich, England; it is the same everywhere)
Selecting this sense was a straightforward task.

As noted, most of the selections were pretty straightforward. Only a couple of selections posed any real
challenge. I can easily envision scenarios that would be far less straightforward, however.

(b) Use the "one sense per collocation" bootstrapping approach to seed a training set with 5 sentences
from the WSJ corpus from Homework 2, for two broad senses of the word "space". (To make better use
of this rather small corpus, you can use morphological variations.) Discuss how well your approach
worked. Also discuss how your two senses map onto the WordNet senses for "space."

For the first collocation approach, I elected to couple the word “program” with the word “space” to look for
sentences that referred to the following sense of the noun space from WordNet:

  S: (n) outer space, space (any location outside the Earth's atmosphere) "the astronauts walked in
  outer space without a tether"; "the first major milestone in space exploration was in 1957, when the
  USSR's Sputnik 1 orbited the Earth" (Noun sense 4)

The five sentences found in the WSJ corpus follow:

• "Aerospace earnings sagged 37% for the quarter and 15% for the year, largely due to lower B-1B
  program profit; the last of the bombers rolled out in April 1988."
• "No single bill this year includes more discretionary spending for domestic programs and, apart from
  the space station, the measure incorporates far-reaching provisions affecting the federal mortgage
  market."
• "The Soviets have a world-leading space program, the guests noted."
• “We have obtained through the development of Cosmos (the Soviet space program) technologies you don't see anywhere else.”
• “It's a world leader in auto manufacturing, but its aviation industry is struggling, and its space program is years behind the U.S., the Europeans and the Soviets.”

All five sentences refer to the intended sense of space, so the goal was successfully met.

For the second collocation approach, I elected to couple the word “advert” with the word “space” to search for sentences that referred to the following sense of the noun space from WordNet:

S: (n) space (an area reserved for some particular purpose) “the laboratory’s floor space” (Noun sense 3)

The sentences found in the WSJ corpus follow:

• “Newsweek said it will introduce the Circulation Credit Plan, which awards space credits to advertisers on renewal advertising.”
• “In this era of frantic competition for ad dollars, a lot of revenue-desperate magazines are getting pretty cozy with advertisers -- fawning over them in articles and offering pages of advertorial space.”
• “Los Angeles is a sprawling, balkanized newspaper market, and advertisers seemed to feel they could buy space in the mammoth Times, then target a particular area with one of the regional dailies.”

All three sentences match the intended sense of space, presumably because the term selected for collocation, advert, nicely limited the context in which this particular use of the word space would appear.

4. **Computational Discourse (25 points)**

(a) Using the word frequencies shown in the matrix on p. 7 from the Chapter 21 class notes, divide the data into three pseudo-sentences consisting of sentences 1-22 (assume 22 is the column with the second usage of “scientist”), 23-44 (assume 44 is the column with the second usage of “species”), and 45-66 (the last column shown). Compute the similarity between pseudo-sentences, using the three different ways to compute similarity that were discussed in class:

- dot product of vectors of word counts (no need to do cosine normalization)
- introduction of new terms
- lexical chains

For each type of similarity, which gap is more likely to be a segment boundary because it is a deeper valley?

The image from the slides follows.
The following summary table shows the statistics I derived to answer the questions. The columns labeled PS1, PS2, and PS3 indicate how many occurrences I found of each term in each of the three pseudo-sentences. The column labeled Intro indicates the pseudo-sentence in which the word was first introduced. And the column labeled Chain shows the range of pseudo-sentences in which the word appeared if it crossed a boundary; if no chain for the word crossed a boundary, I list none. Note that I allowed gaps of two intervening sentences (a threshold value of 3) sentences or fewer, but disallowed gaps of three sentences or greater. I had to make judgment calls in some cases because the graphic isn’t labeled with vertical lines, but my response is consistent with the indications in the annotated figure above.

<table>
<thead>
<tr>
<th>Word</th>
<th>PS1</th>
<th>PS2</th>
<th>PS3</th>
<th>Intro</th>
<th>Chain</th>
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<td>0</td>
<td>4</td>
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<td>0</td>
<td>2</td>
<td>PS3</td>
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<td>0</td>
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<td>9</td>
<td>14</td>
<td>3</td>
<td>PS1</td>
<td>1-2</td>
</tr>
<tr>
<td>move</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>PS2</td>
<td>None</td>
</tr>
</tbody>
</table>
For the dot product of vectors of word counts, the word frequencies of the pseudo-sentences given the indicated ranges follow:

PS1/PS2: 148

0 + 4 + 0 + 0 + 0 + 0 + 1 + 0 + 4 + 0 + 4 + 9 + 126 + 0 + 0 + 0 + 0 + 0 + 0 + 0

PS2/PS3: 104

0 + 4 + 0 + 0 + 0 + 0 + 4 + 4 + 7 + 0 + 0 + 15 + 42 + 2 + 12 + 0 + 4 + 2 + 6 + 2

The smaller number indicates a greater difference between PS2 and PS3 than between PS1 and PS2. Presumably, the first two pseudo-sentences have greater continuity because they have a greater overlap in terms.

For the introduction of new terms, the different pseudo-sentences introduce the following numbers of new terms:

PS1: 11 new terms
PS2: 7 new terms
PS3: 3 new terms

PS1 + PS2 = 18
PS2 + PS3 = 10

More new terms are introduced between pseudo-sentences PS1 and PS2 than between PS2 and PS3. So in this case, the greater difference between the first and second pseudo-sentences indicates that they are more likely to represent a boundary.

For lexical chains, I elected to view the range of coverage for a term as respecting a threshold of $t = 3$, as described previously, so a gap of two sentences is allowed, but no more. In my original response, I'd commented as follows on the issue posted by Dr. Litman.

I took a look at the paper titled "TextTiling: Segmenting Text into Multi-paragraph Subtopic Passages," by Marti Hearst of Xerox PARC (1997), which includes the original example graphic introduced in the class slides for Chapter 21. A copy of that image follows.
The text of the paper describes the approach taken as follows:

This approach is illustrated in Figure 3(c). A lexical chain for term \( t \) is considered active across a sentence gap if instances of \( t \) occur within some distance threshold of one another. In the figure, all three instances of the word A occur within the distance threshold. The third B, however, follows too far after the second B to continue the chain.

But no mention is made of the span between the two occurrences of D, and the threshold between the two of them (3) is just as great as the threshold between the two occurrences of B that are cited as having too great a distance between them to be considered active.

In light of my amended answer, my results are now as follows:

PS1 – PS2: 1
PS2 – PS3: 3

The gap from PS1 to PS2 is greater because there are fewer overlapping terms. This would indicate that the boundary between PS1 and PS2 is more relevant than that between PS2 and PS3, which have more terms in common.

(b) Jurafsky and Martin, 21.5 (p. 723)

Consider the following passage, from Brennan et al. (1987):

(21.99) \( u0: \) Brennan drives an Alfa Romeo.
\( u1: \) She drives too fast.
\( u2: \) Friedman races her on weekends.
\( u3: \) She goes to Laguna Seca.

Identify the referent that the BFP algorithm finds for the pronoun in the final sentence. Do you agree with this choice, or do you find the example ambiguous? Discuss why introducing a new noun phrase in subject position with a pronominalized reference in object position might lead to an ambiguity for a subject pronoun in the next sentence. What preferences are competing here?
u0: Brennan drives an Alfa Romeo.

CF(u0) = [Brennan, Alfa Romeo]
CB(u0) = undefined
CP(u0) = Brennan

u1: She drives too fast.

Assume she refers to Brennan:

CF(u1) = [Brennan]
CB(u1) = Brennan
CP(u1) = Brennan
Result = Continue (CP(u1) = CB(u1); CB(u0) = undefined)

Assume she refers to Alfa Romeo:

CF(u1) = [Alfa Romeo]
CB(u1) = Brennan
CP(u1) = Alfa Romeo
Result = Retain (CP(u1) ≠ CB(u1); CB(u0) = undefined)

The first transition is preferred because it is a Continue rather than a Retain.

u2: Friedman races her on weekends.

Assume her refers to Brennan.

CF(u2) = [Friedman, Brennan]
CB(u2) = Brennan
CP(u2) = Friedman
Result = Retain (CP(u2) ≠ CB(u2); CB(u2) = CB(u1))

Assume she refers to Friedman.

CF(u2) = [Friedman, Laguna Seca]
CB(u2) = Friedman
CP(u2) = Friedman
Result = Shift (CP(u2) = CB(u3); CB(u3) ≠ CB(u2))

The second transition is preferred because it is a Continue rather than a Shift. Given that preference, the final sentence without the pronoun would be “Brennan goes to Laguna Seca.” But the resolution is fairly ambiguous because the sentence could just as easily be interpreted as “Friedman goes to Laguna Seca,” which I personally favor.

u3: She goes to Laguna Seca.

Assume she refers to Friedman.

CF(u3) = [Friedman, Laguna Seca]
CB(u3) = Friedman
CP(u3) = Friedman
Result = Shift (CP(u3) = CB(u3); CB(u3) ≠ CB(u2))

Assume she refers to Brennan.

CF(u3) = [Brennan, Laguna Seca]
CB(u3) = Brennan
CP(u3) = Brennan
Result = Continue (CP(u3) = CB(u3); CB(u3) = CB(u2))

Introducing a new noun phrase in the subject position with a pronoun in the object position results in ambiguity for the next sentence because it becomes unclear whether the subject pronoun in the next
sentence agrees with the previous subject or with the previous object pronoun. In the resolution via the transitions, as shown, the referent of the subject pronoun in the final sentence becomes the object of the previous sentence. But it is possibly more natural if that pronoun refers to the subject of the previous sentence. The ambiguity is unavoidable in this case, even if the pronominalized subject favors the object in our resolution steps.