

(D) Intergalactic Grammars (1/3) [5 points]

Your job as a linguist in the space federation is to translate between languages for the international team aboard the *U.S.S. Enterprise*. One day, you see some words flashing on your switchboard:

“Houston, we have a problem. Houston, we have a problem.”

“The Klingons?” you ask.

“Roger that. Klag is frantic. He won’t go back to the Pagh until we answer him,” came the reply.

“Copy. We are working on it. We will report back ASAP,” you respond.

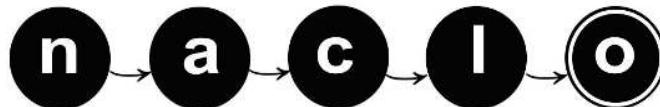
You know that the Klingons are grammarians, so you must make sure that you accurately translate your message into the Klingon language to avoid upsetting them further.

You think back to the last time you had to translate something. In that case, you needed to translate the Turkish sentence *bir kız bir kitap okudu* into English. First you looked up all of the Turkish words:

| Turkish | English |
|---------|---------|
| bir | a |
| kız | girl |
| kitap | book |
| okudu | read |

By replacing each Turkish word with its English equivalent, you got the translation *a girl a book read...* which didn’t seem quite right. Luckily, at that point your boss came over. (Your boss is very wise, as are all linguists, especially those who organize linguistics Olympiads). She told you that you can’t just translate Turkish to English word-for-word because Turkish and English use different word orders. She then handed you a file of Synchronous Context Free Grammars (SCFGs). An SCFG provides you with two systems of rules for constructing sentences in the correct word order, one system for each language. This way, you can translate not only words, but also word order, from one language to another. Here is the English-Turkish SCFG from the file she gave you:

| <English, Turkish> SCFG |
|--|
| $S \rightarrow <\text{NP VP}, \text{NP VP}>$ |
| $\text{VP} \rightarrow <\text{V NP}, \text{NP V}>$ |
| $\text{NP} \rightarrow <\text{a book}, \text{bir kitap}>$ |
| $\text{NP} \rightarrow <\text{a cat}, \text{bir kedi}>$ |
| $\text{NP} \rightarrow <\text{a girl}, \text{bir kız}>$ |
| $\text{NP} \rightarrow <\text{a turtle}, \text{bir kaplumbağa}>$ |
| $\text{V} \rightarrow <\text{ate}, \text{yedi}>$ |
| $\text{V} \rightarrow <\text{bit}, \text{ısrardı}>$ |
| $\text{V} \rightarrow <\text{chased}, \text{kovaladı}>$ |
| $\text{V} \rightarrow <\text{read}, \text{okudu}>$ |
| $\text{V} \rightarrow <\text{saw}, \text{gördü}>$ |



(D) Intergalactic Grammars (2/3)

Using this SCFG, you correctly translated *bir kız bir kitap okudu* into *a girl read a book*. You were also able to translate in the other direction, for example to translate *a turtle saw a cat* as *bir kaplumbağa bir kedi gördü*.

D1. Using only words in the <English, Turkish> SCFG presented above,

- a. Write an English sentence that is exactly 20 letters long (excluding spaces and punctuation).

- b. Translate your sentence into Turkish.

D2. Before you can answer the Klingons, you have to clarify something between the members on board the *U.S.S. Enterprise*. You have already translated something that Elif, who speaks Turkish, told Tovo, who speaks Malagasy, using the Turkish-Malagasy SCFG below on the left. The Malagasy sentences you generated are shown in the table on the right. Now, you need to translate the sentences for Elisabeth, who speaks English. Write the English translations of the following Malagasy sentences.

| <Turkish, Malagasy> SCFG | |
|--------------------------|---|
| S | \rightarrow <NP VP, VP NP > |
| VP | \rightarrow <NP V, V NP > |
| NP | \rightarrow <bir kaplumbağa, sokatra> |
| NP | \rightarrow <bir kedi, saka> |
| V | \rightarrow < görüdü, nahita> |
| V | \rightarrow < ısrırdı, nanaikitra > |
| V | \rightarrow < kovaladı, nanenjika > |
| V | \rightarrow < yedi, nihinana > |

| | Malagasy | English translation: |
|----|-------------------------|----------------------|
| a. | nahita sokatra saka | |
| b. | nanenjika saka sokatra | |
| c. | nanaikitra saka sokatra | |
| d. | nihinana saka sokatra | |

D3. You should probably get around to answering Klag, who is by now even more irate than before because you've spent so much time reminiscing about Turkish and Malagasy. Use the SCFG for English to Klingon (on the next page) to translate the following sentences into Klingon. Write your answers next to the associated letters in the answer spaces.

- a. The pet bites.
b. The *U.S.S. Enterprise* will battle the Klingons.
c. The leaders know that the Klingons know that the commander learned that a spy saw that the Klingons have a pet.

a.

b.

c.



(D) Intergalactic Grammars (3/3)

| <English, Klingon> SCFG | |
|---|--|
| S → <NP VP, VP NP> | |
| S → <Comp S, S Comp> | |
| VP → <V NP, NP V > | |
| VP → <V S, S V> | |
| VP → <bites, chop> | |
| Comp → <that, 'e'> | |
| NP → <the commander, la'> | |
| NP → <the Klingons, tlhInganpu'> | |
| NP → <the leaders, Devwl'pu'> | |
| NP → <a pet, Saj> | |
| NP → <the pet, Saj> | |
| NP → <a spy, ghoqwI'> | |
| NP → <the U.S.S. Enterprise, 'ejDo' 'entepray'> | |
| V → <have, lughaj> | |
| V → <know, SovTah> | |
| V → <learned, ghojpu'> | |
| V → <saw, leghpu'> | |
| V → <will battle, ghobrupqa'> | |

Context Free Grammars provide a set of rules to describe a natural (ie, human) language. Because of the ability of these rules to construct longer phrases and sentences from a finite list of smaller units, Context Free Grammars have been used in computer science as components of parsing and translation algorithms. Synchronous Context Free Grammars provide the CFGs of two languages simultaneously and matched up with each other. This is especially useful for translation purposes.

