



University of Arizona, Department of Computer Science

CSc 372 — Assignment 6 — Due noon, Mon Nov 14 — 8%

Christian Collberg
November 2, 2005

1 Introduction

The purpose of this assignment is to get some experience writing a slightly larger Prolog program. We will also become more proficient with pattern-matching, which we have already practiced a bit in the Prolog 133t translator.

Every predicate should be commented. At the very least, the comments should state what the predicate does, which arguments it takes, and what result it produces.

You should make your predicates as simple and elegant as possible.

You will be graded primarily on **correctness**, **elegance**, **clarity**, and **documentation**.

Input files to the programs in this assignment can be found here: <http://www.cs.arizona.edu/~collberg/Teaching/372/2005/Assignments>

You can work on this assignment in teams of two.

2 Text-to-Speech

In this assignment we are going to build a *text-to-speech* system, a Prolog program which reads out a plain English text. A lot of research has already gone into the production of such systems, which can be seen from the following quote:

“Speech research is like a huge pit — you can throw any amount of money into it and nothing comes out.”

US federal research funder

Programs with speech output are particularly useful for individuals who have problems reading text on a screen, such as the visually impaired, dyslexics, or pre-schoolers. Combined with an optical character reader, a text-to-speech system becomes a tool to read out text from books and newspapers, material otherwise inaccessible to those with reading difficulties. The addition of speech of course also enhances the appeal of any computer game!

We will be using a very crude method for converting text to speech, namely stringing together and playing out the phonemes that make up each word. A real system needs to be much more sophisticated in order to produce intelligible speech. Intonation (rising and falling pitch), rhythm, and stress are all important aspects of computer generated speech which we will be ignoring here.

English pronunciation is very difficult. Why, for example, are these five words all pronounced differently: cough, enough, plough, though, through?! The poem *The Chaos* by Dutchman G.N. Trenite (1870–1946) expresses some of the bewilderment of the second language learner:

```
Dearest creature in Creation
Studying English pronunciation,
    I will teach you in my verse
        Sounds like corpse, corps, horse and worse.
It will keep you, Susy, busy,
Make your head with heat grow dizzy; ...
```

Nevertheless, it has been shown that a simple rule-based system coupled with a small exception table of common words not covered by the rules will fare remarkably well.

In section 5 is a set of rules to translate an English word to the corresponding phonemic representation. Your tasks are as follows:

1. Write a Prolog predicate `talk(S,P)` which, given an English sentence `S`, will produce a list of phonemes `P` for the pronunciation of this sentence. [70 points]

```
| ?- talk([a,s,e,x,u,a,l],P).
P = [ae,z,eh,k,s,yu,w,ax,l]
```

2. Write a predicate `talk` that reads a sentence from standard input (the last character should be a period), produces the relevant string of phonemes, and calls the Java program `play.java` to speak out the phonemes: [5 points]

```
| ?- talk.
hello there.
Executing "java play phonemes.zip h eh l silent aa pause dh er silent"
```

- The files `play.java`, `phonemes.zip`, and `sentence.pl` can be found here: <http://www.cs.arizona.edu/~collberg/Teaching/372/2005/Assignments>.
- `play.java` will first have to be compiled (`javac play.java` on `lectura`). It's first argument is the file of phonemes and the remaining arguments are the phonemes to play out.
- The file `sentence.pl` contains predicates for reading in a sentence and converting it to a list of characters (atoms):

```
| ?- readsentence(S).
hello there.

S = [h,e,l,l,o,blank,t,h,e,r,e] ?
```

`readsentence(S)` assumes that a sentence always ends in a period.

- The GNU Prolog predicate `system(S)` calls a shell command from Prolog:

```
| ?- system('ls').
CVS match.pl phonemes.pl sentence.pl phonemes.zip
```

3. Extend your program to read out numbers. “1973” should, for example, be read as [25 points]

one-thousand-nine-hundred-and-seventy-three.

- You should be able to handle numbers at least up to 9999.
- You don’t have to handle negative numbers.
- I am giving you some leeway in how to solve this part of the assignment. You could, for example, translate

```
[s,h,e,blank,w,a,s,blank,o,n,l,y,blank,1,6,o,n,l,y,blank,1,6]
```

into

```
[s,h,e,blank,w,a,s,blank,o,n,l,y,blank,
s,i,x,t,e,e,n,blank,o,n,l,y,blank,s,i,x,t,e,e,n]
```

and then translate the resulting string as usual. Alternatively, a better-sounding translation could be had by making use of these hard-coded phonetic transcriptions of the number-words:

```
zIHrOW, wAHn, tUW, THrIY, fOWr, fAYv, sIHks, sEHvAXn, EYt, nAYn, tEHn, IYIE-
HvAXn, twEHlv, THERtIYn, fOWrtIYn, fIHftIYn, sIHkstIYn, sEHvEHntIYn, EYtIYn, nAYn-
tIYn, twEHntIY, THERtIY, fAOrtIY, fIHftIY, sIHkstIY, sEHvEHntIY, EYtIY, nAYntIY hAH-
ndrEHd, THAWzAEnd, mIHIIYAXn, bIHIIYAXn, AEnd
```

A file `numbers.txt` containing these number-words can be found here: <http://www.cs.arizona.edu/~collberg/Teaching/372/2005/Assignments>.

- Make sure to describe in your code how your number translation works.

3 Phonetic Rules for English

Section 5 contains about 350 rules which map English words to their phonetic pronunciation. They came out of a project run by the United States Naval Research Laboratory in 1976¹. The idea is to search the rule set sequentially (from top to bottom) to find a rule which matches the first unmatched letter in the current word. This process is repeated with the next unmatched character. At each step the rules produce one or more English phonemes.

The rules have four major parts: the *left context*, the *match*, the *right context* and the *output*. Here’s an example:

```
% Pattern-letter, Pattern-number, LeftContext, MatchChars, RightContext, Phonemes
pattern(a, 27, [vowel,cons0], [a,l,s], none, [ax,lz]).
```

The match is the letter or letters consumed by the rule. The left and right contexts describe which letters should occur to the left and the right of the matched letters, in order for the rule to be applicable. The output, finally, gives the phonemes corresponding to the matched letters.

¹The relevant document is *Automatic Translation of English Text to Phonetics by Means of Letter-to-Sound Rules*, by Honey Sue Elovitz, Rodney W. Johnson, McHugh, and Shore, Report 7948 of the United States Naval Research Laboratory, 1976.

The Phoneme codes : Vowels			
Phoneme	Example	Phoneme	Example
IY	bEEt	IH	bIt
EY	gAte	EH	gEt
AE	fAt	AA	fAther
AO	lAWn	OW	lOne
UH	fUll	UW	fOOl
ER	mURdER	AX	About
AH	bUt	AY	hIde
AW	hOW	OY	tOY
YU	YOU		
p	Pack	b	Back
t	Time	d	Dime
k	Coat	g	Goat
f	Fault	v	Vault
TH	eTHer	DH	eiTHer
s	Sue	z	Zoo
SH	leaSH	ZH	leiSure
HH	How	m	suM
n	suN	NG	suNG
l	Laugh	w	Wear
y	Young	r	Rate
CH	CHar	j	Jar
WH	WHere		

Table 1: Arpabet phonemes.

For example, the rule a.27

```
pattern(a, 27, [vowel,cons0], [a,l,s], none, [ax,lz]).
```

says that the letters [a,l,s] could be pronounced as [ax,lz] if they appear at the end of a word and are preceded by a vowel and zero or more consonants.

The phonemes are represented by the single lower-case letters or pairs of upper-case letters given in Table 1².

Here are some examples:

Word	Phonemes
thimble	/TH,l,m,b,l/
blind	/b,l,AY,n,d/

The left and right context conditions consist of strings of letters or letter-categories, such as vowel and consonant. The rules use the categories given in Table 2.

²This transcription system is sometimes referred to as the *arpabet*.

Context Symbols		
Here	phonemes.pl	Explanation
\mathcal{V}_+	vowel	One or more vowels (A, O, U, E, I, Y ^a).
\mathcal{C}_*	cons0	Zero or more consonants (B, C, D, F, G, H, J, K, L, M, N, P, Q, R, S, T, V, W, X, Z).
\mathcal{C}_1	cons1	One consonant.
\mathcal{C}_v	consv	One voiced consonant (B, D, V, G, J, L, M, N, R, W or Z).
\mathcal{S}	suffix	One of ER, E, ES, ED, ING, ELY (a suffix) (Found in right context only).
\mathcal{F}	front	One of E, I or Y (a “front” vowel).
\mathcal{A}	any	Anything.
\mathcal{N}	none	Nothing.
a-z	a-z	Matches the character itself.

^aNote that in English Y is sometimes a vowel (*try*) and sometimes a consonant (*yellow*).

Table 2: Letter categories used in this document and in `phonemes.pl`.

Here are some examples:

The context	matches the string
$\mathcal{V}_+\mathcal{C}_*$	a
$\mathcal{V}_+\mathcal{C}_*$	all
$\mathcal{V}_+\mathcal{C}_*$	aell
$\mathcal{V}_+\mathcal{C}_1$	ael
$\mathcal{C}_1\mathcal{F}\mathcal{C}_*\mathcal{V}_+$	tire
$\mathcal{C}_1\mathcal{S}$	led
$\mathcal{I}\mathcal{C}_1$	is
$\mathcal{V}_+\mathcal{C}_*\mathcal{C}\mathcal{H}$	orch

Finally, let’s look at how the rules are used in matching. Our example word will be `asexual`:

Step	Rule	Left Context	Match	Right Context	Output
1	A.14	-	a	sexual ($\mathcal{C}_1 = s, \mathcal{F} = e, \mathcal{C}_* = x, \mathcal{V}_+ = u$)	/AE/
2	S.9	a ($\mathcal{V}_+ = a$)	s	exual ($\mathcal{V}_+ = e$)	/z/
3	E.52	as	e	xual	/EH/
4	X.1	ase	x	ual	/k,s/
5	U.35	asex	u	al	/YU/
6	A.26	asexu ($\mathcal{V}_+ = u, \mathcal{C}_* = _$)	al	-	/AX,l/

In other words, the rules say that `asexual` should be pronounced as /AE,z,EH,k,s,YU,AX,l/. Does this coincide with your own intuition?

4 Submission and Assessment

The deadline for this assignment is noon, Mon Nov 14. This assignment is worth 8% of your final grade.

You should submit the assignment electronically using the Unix command

```
turnin cs372.6 speech.pl README
```

The README file should list the members of your team, both their real name and their CS login.

Don't show your code to anyone, don't read anyone else's code, don't discuss the details of your code with anyone. If you need help with the assignment see the instructor.

5 The Rule-Set

Rule	Left Context	Match	Right Context	Output	Example
A.1	\mathcal{A}	A	\mathcal{N}	AX	
A.2	\mathcal{N}	ARE	\mathcal{N}	AAr	
A.3	\mathcal{N}	AR	O	AXr	
A.4	\mathcal{A}	AR	\mathcal{V}_+	EHR	
A.5	\mathcal{C}_1	AS	\mathcal{V}_+	EYs	
A.6	\mathcal{A}	A	WA	AX	
A.7	\mathcal{A}	AW	\mathcal{A}	AO	lawn
A.8	\mathcal{C}_*	ANY	\mathcal{A}	EHnIY	Delany
A.9	\mathcal{A}	A	$\mathcal{C}_1\mathcal{F}\mathcal{V}_+$	EY	
A.10	$\mathcal{V}_+\mathcal{C}_*$	ALLY	\mathcal{A}	AXIIY	
A.11	\mathcal{N}	AL	\mathcal{V}_+	AXl	
A.12	\mathcal{A}	AGAIN	\mathcal{A}	AXgEHn	
A.13	$\mathcal{V}_+\mathcal{C}_*$	AG	E	IHj	
A.14	\mathcal{A}	A	$\mathcal{C}_1\mathcal{F}\mathcal{C}_*\mathcal{V}_+$	AE	
A.15	\mathcal{C}_*	A	$\mathcal{C}_1\mathcal{F}$	EY	
A.16	\mathcal{A}	A	$\mathcal{C}_1\mathcal{S}$	EY	
A.17	\mathcal{N}	ARR	\mathcal{A}	AXr	arrive
A.18	\mathcal{A}	ARR	\mathcal{A}	AEr	carrot
A.19	\mathcal{C}_*	AR	\mathcal{N}	AAr	tar, star, arm
A.20	\mathcal{A}	AR	\mathcal{N}	ER	
A.21	\mathcal{A}	AR	\mathcal{A}	AAr	art
A.22	\mathcal{A}	AIR	\mathcal{A}	EHR	
A.23	\mathcal{A}	AI	\mathcal{A}	EY	Daisy
A.24	\mathcal{A}	AY	\mathcal{A}	EY	play
A.25	\mathcal{A}	AU	\mathcal{A}	AO	Paul, cauliflower
A.26	$\mathcal{V}_+\mathcal{C}_*$	AL	\mathcal{N}	AXl	
A.27	$\mathcal{V}_+\mathcal{C}_*$	ALS	\mathcal{N}	AXlz	
A.28	\mathcal{A}	ALK	\mathcal{A}	AOk	stalker
A.29	\mathcal{A}	AL	\mathcal{C}_1	AOl	
A.30	\mathcal{C}_*	ABLE	\mathcal{A}	EYbAXl	
A.31	\mathcal{A}	ABLE	\mathcal{A}	AXbAXl	
A.32	\mathcal{A}	ANG	\mathcal{F}	EYnj	
A.33	\mathcal{A}	A	\mathcal{A}	AE	

Rule	Left Context	Match	Right Context	Output	Example
B.1	\mathcal{N}	BE	$\mathcal{C}_1\mathcal{V}_+$	bIH	
B.2	\mathcal{A}	BEING	\mathcal{A}	bIYIHNG	
B.3	\mathcal{N}	BOTH	\mathcal{N}	bOWTH	
B.4	\mathcal{N}	BUS	\mathcal{V}_+	bIH ζ	
B.5	\mathcal{A}	BUIL	\mathcal{A}	bIHl	
B.6	\mathcal{A}	B	\mathcal{A}	b	
C.1	\mathcal{N}	CH	\mathcal{C}_1	k	
C.2	$\mathcal{C}_1\mathcal{E}$	CH	\mathcal{A}	k	
C.3	\mathcal{A}	CH	\mathcal{A}	CH	
C.4	S	CI	\mathcal{V}_+	sAY	
C.5	\mathcal{A}	CI	\mathcal{A}	SH	
C.6	\mathcal{A}	CI	O	SH	
C.7	\mathcal{A}	CI	EN	SH	
C.8	\mathcal{A}	C	\mathcal{F}	s	
C.9	\mathcal{A}	CK	\mathcal{A}	k	
C.10	\mathcal{A}	COM	\mathcal{S}	kAHm	
C.11	\mathcal{A}	C	\mathcal{A}	k	
D.1	$\mathcal{V}_+\mathcal{C}_*$	DED	\mathcal{N}	dIHd	
D.2	$\mathcal{C}_v\mathcal{E}$	D	\mathcal{N}	d	
D.3	$\mathcal{V}_+\mathcal{C}_1\mathcal{C}_*\mathcal{E}$	D	\mathcal{N}	t	
D.4	\mathcal{N}	DE	$\mathcal{C}_1\mathcal{V}_+$	dIH	
D.5	\mathcal{N}	DO	\mathcal{N}	dUW	
D.6	\mathcal{N}	DOES	\mathcal{A}	dAH ζ	
D.7	\mathcal{N}	DOING	\mathcal{A}	dUWIHNG	
D.8	\mathcal{N}	DOW	\mathcal{A}	dAW	
D.9	\mathcal{A}	DU	\mathcal{A}	jUW	
D.10	\mathcal{A}	D	\mathcal{A}	d	
E.1	$\mathcal{V}_+\mathcal{C}_*$	E	\mathcal{N}	Silent	
E.2	$\mathcal{C}_1\mathcal{C}_*$	E	\mathcal{N}	Silent	
E.3	\mathcal{C}_*	E	\mathcal{N}	IY	
E.4	\mathcal{V}_+	ED	\mathcal{N}	d	
E.5	$\mathcal{V}_+\mathcal{C}_*$	E	D	Silent	
E.6	\mathcal{A}	EV	ER	EH ν	
E.7	\mathcal{A}	E	$\mathcal{C}_1\mathcal{S}$	IY	
E.8	\mathcal{A}	ERI	\mathcal{V}_+	IYrIY	
E.9	\mathcal{A}	ERI	\mathcal{A}	EHrIH	
E.10	$\mathcal{V}_+\mathcal{C}_*$	ER	\mathcal{V}_+	ER	
E.11	\mathcal{A}	ER	\mathcal{V}_+	EHr	
E.12	\mathcal{A}	ER	\mathcal{A}	ER	
E.13	\mathcal{N}	EVEN	\mathcal{A}	IY ν EHn	
E.14	$\mathcal{V}_+\mathcal{C}_*$	E	W	Silent	
E.15	T	EW	\mathcal{A}	UW	
E.16	S	EW	\mathcal{A}	UW	
E.17	R	EW	\mathcal{A}	UW	
E.18	D	EW	\mathcal{A}	UW	
E.19	L	EW	\mathcal{A}	UW	
E.20	Z	EW	\mathcal{A}	UW	
E.21	N	EW	\mathcal{A}	UW	
E.22	J	EW	\mathcal{A}	UW	
E.23	TH	EW	\mathcal{A}	UW	
E.24	CH	EW	\mathcal{A}	UW	
E.25	SH	EW	\mathcal{A}	UW	
E.26	\mathcal{A}	EW	\mathcal{A}	YU ω	

Rule	Left Context	Match	Right Context	Output	Example
E.27	\mathcal{A}	E	O	IY	
E.28	\mathcal{V}_+C_*S	ES	\mathcal{N}	IHz	
E.29	\mathcal{V}_+C_*C	ES	\mathcal{N}	IHz	
E.30	\mathcal{V}_+C_*G	ES	\mathcal{N}	IHz	
E.31	\mathcal{V}_+C_*Z	ES	\mathcal{N}	IHz	
E.32	\mathcal{V}_+C_*X	ES	\mathcal{N}	IHz	
E.33	\mathcal{V}_+C_*J	ES	\mathcal{N}	IHz	
E.34	\mathcal{V}_+C_*CH	ES	\mathcal{N}	IHz	
E.35	\mathcal{V}_+C_*SH	ES	\mathcal{N}	IHz	
E.36	\mathcal{V}_+C_*	E	S	Silent	
E.37	\mathcal{V}_+C_*	ELY	\mathcal{N}	IY	
E.38	\mathcal{V}_+C_*	EMENT	\mathcal{A}	mEHnt	
E.39	\mathcal{A}	EFUL	\mathcal{A}	fUhl	
E.40	\mathcal{A}	EE	\mathcal{A}	IY	
E.41	\mathcal{A}	EARN	\mathcal{A}	ERn	
E.42	\mathcal{N}	EAR	\mathcal{C}_1	ER	
E.43	\mathcal{A}	EAD	\mathcal{A}	EHd	
E.44	\mathcal{V}_+C_*	EA	\mathcal{N}	IYAX	
E.45	\mathcal{A}	EA	SU	EH	
E.46	\mathcal{A}	EA	\mathcal{A}	IY	
E.47	\mathcal{A}	EIGH	\mathcal{A}	EY	
E.48	\mathcal{A}	EI	\mathcal{A}	IY	
E.49	\mathcal{N}	EYE	\mathcal{A}	AY	
E.50	\mathcal{A}	EY	\mathcal{A}	IY	
E.51	\mathcal{A}	EU	\mathcal{A}	YUw	
E.52	\mathcal{A}	E	\mathcal{A}	EH	
F.1	\mathcal{A}	FUL	\mathcal{A}	fUhl	
F.2	\mathcal{A}	F	\mathcal{A}	f	
G.1	\mathcal{A}	GIV	\mathcal{A}	gIHv	
G.2	\mathcal{N}	G	\mathcal{IC}_1	g	
G.3	\mathcal{A}	GE	T	gEH	
G.4	SU	GGES	\mathcal{A}	gjEHs	
G.5	\mathcal{A}	GG	\mathcal{A}	g	
G.6	$B\mathcal{V}_+$	G	\mathcal{A}	g	
G.7	\mathcal{A}	G	\mathcal{F}	j	
G.8	\mathcal{A}	GREAT	\mathcal{A}	grEYt	
G.9	\mathcal{V}_+	GH	\mathcal{A}	Silent	
G.10	\mathcal{A}	G	\mathcal{A}	g	
H.1	\mathcal{N}	HAV	\mathcal{A}	hAEv	
H.2	\mathcal{N}	HERE	\mathcal{A}	hIYr	
H.3	\mathcal{N}	HOUR	\mathcal{A}	AWER	
H.4	\mathcal{A}	HOW	\mathcal{A}	hAW	
H.5	\mathcal{A}	H	\mathcal{V}_+	h	
H.6	\mathcal{A}	H	\mathcal{A}	Silent	
I.1	\mathcal{N}	IN	\mathcal{A}	IHn	
I.2	\mathcal{N}	I	\mathcal{N}	AY	
I.3	\mathcal{A}	IN	D	AYn	
I.4	\mathcal{A}	IER	\mathcal{A}	IYER	
I.5	\mathcal{V}_+C_*R	IED	\mathcal{A}	IYd	
I.6	\mathcal{A}	IED	\mathcal{N}	AYd	
I.7	\mathcal{A}	IEN	\mathcal{A}	IYEHn	
I.8	\mathcal{A}	IE	T	AYEH	
I.9	C_*	I	S	AY	

Rule	Left Context	Match	Right Context	Output	Example
I.10	\mathcal{A}	I	\mathcal{S}	IY	
I.11	\mathcal{A}	IE	\mathcal{A}	IY	
I.12	\mathcal{A}	I	$\mathcal{C}_1\mathcal{FC}_*\mathcal{V}_+$	IH	
I.13	\mathcal{A}	IR	\mathcal{V}_+	AYr	
I.14	\mathcal{A}	IZ	\mathcal{S}	AYz	
I.15	\mathcal{A}	IS	\mathcal{S}	AYz	
I.16	\mathcal{A}	I	\mathcal{DS}	AY	
I.17	\mathcal{FC}_1	I	$\mathcal{C}_1\mathcal{F}$	IH	
I.18	\mathcal{A}	I	\mathcal{TS}	AY	
I.19	$\mathcal{V}_+\mathcal{C}_1\mathcal{C}_*$	I	$\mathcal{C}_1\mathcal{F}$	IH	
I.20	\mathcal{A}	I	$\mathcal{C}_1\mathcal{F}$	AY	
I.21	\mathcal{A}	IR	\mathcal{A}	ER	
I.22	\mathcal{A}	IGH	\mathcal{A}	AY	
I.23	\mathcal{A}	ILD	\mathcal{A}	AYld	
I.24	\mathcal{A}	IGN	\mathcal{N}	AYn	
I.25	\mathcal{A}	IGN	\mathcal{C}_1	AYn	
I.26	\mathcal{A}	IGN	\mathcal{S}	AYn	
I.27	\mathcal{A}	IQUE	\mathcal{A}	IYk	
I.28	\mathcal{A}	I	\mathcal{A}	IH	
J.1	\mathcal{A}	J	\mathcal{A}	j	
K.1	\mathcal{N}	K	\mathcal{N}	Silent	
K.2	\mathcal{A}	K	\mathcal{A}	k	
L.1	\mathcal{A}	LO	\mathcal{CV}_+	lOW	
L.2	L	L	\mathcal{A}	Silent	
L.3	$\mathcal{V}_+\mathcal{C}_1\mathcal{C}_*$	L	\mathcal{S}	AXl	
L.4	\mathcal{A}	LEAD	\mathcal{A}	lIYd	
L.5	\mathcal{A}	L	\mathcal{A}	l	
M.1	\mathcal{A}	MOV	\mathcal{A}	mUWv	
M.2	\mathcal{A}	M	\mathcal{A}	m	
N.1	E	NG	\mathcal{F}	nj	
N.2	\mathcal{A}	NG	R	NGg	
N.3	\mathcal{A}	NG	\mathcal{V}_+	NGg	
N.4	\mathcal{A}	NGL	\mathcal{S}	NGgAXl	
N.5	\mathcal{A}	NG	\mathcal{A}	NG	
N.6	\mathcal{A}	NK	\mathcal{A}	NGk	
N.7	\mathcal{N}	NOW	\mathcal{N}	nAW	
N.8	\mathcal{A}	N	\mathcal{A}	n	
O.1	\mathcal{A}	OF	\mathcal{N}	AXv	
O.2	\mathcal{A}	OROUGH	\mathcal{A}	EROW	
O.3	$\mathcal{V}_+\mathcal{C}_*$	OR	\mathcal{N}	ER	
O.4	$\mathcal{V}_+\mathcal{C}_*$	ORS	\mathcal{N}	ERz	
O.5	\mathcal{A}	OR	\mathcal{A}	AOr	
O.6	\mathcal{N}	ONE	\mathcal{A}	wAHn	
O.7	\mathcal{A}	OW	\mathcal{A}	OW	
O.8	\mathcal{N}	OVER	\mathcal{A}	OWvER	
O.9	\mathcal{A}	OV	\mathcal{A}	AHv	
O.10	\mathcal{A}	O	$\mathcal{C}_1\mathcal{S}$	OW	
O.11	\mathcal{A}	O	$\mathcal{C}_1\mathcal{EN}$	OW	
O.12	\mathcal{A}	O	$\mathcal{C}_1\mathcal{IV}_+$	OW	
O.13	\mathcal{A}	OL	D	OWl	
O.14	\mathcal{A}	OUGHT	\mathcal{A}	AOt	
O.15	\mathcal{A}	OUGH	\mathcal{A}	AHf	
O.16	\mathcal{N}	OU	\mathcal{A}	AW	

Rule	Left Context	Match	Right Context	Output	Example
O.17	H	OU	\mathcal{SV}_+	AW	
O.18	\mathcal{A}	OUS	\mathcal{A}	AXs	
O.19	\mathcal{A}	OUR	\mathcal{A}	AOr	
O.20	\mathcal{A}	OULD	\mathcal{A}	UHd	
O.21	\mathcal{C}_1	OU	$\mathcal{C}_1\mathcal{L}$	AH	
O.22	\mathcal{A}	OUP	\mathcal{A}	UWp	
O.23	\mathcal{A}	OU	\mathcal{A}	AW	
O.24	\mathcal{A}	OY	\mathcal{A}	OY	
O.25	\mathcal{A}	OING	\mathcal{A}	OWIHNG	
O.26	\mathcal{A}	OI	\mathcal{A}	OY	
O.27	\mathcal{A}	OOR	\mathcal{A}	AOr	
O.28	\mathcal{A}	OOK	\mathcal{A}	UHk	
O.29	\mathcal{A}	OOD	\mathcal{A}	UHd	
O.30	\mathcal{A}	OO	\mathcal{A}	UW	
O.31	\mathcal{A}	O	E	OW	
O.32	\mathcal{A}	O	\mathcal{N}	OW	
O.33	\mathcal{A}	OA	\mathcal{A}	OW	
O.34	\mathcal{N}	ONLY	\mathcal{A}	OWnIY	
O.35	\mathcal{N}	ONCE	\mathcal{A}	wAHns	
O.36	\mathcal{A}	ON'T	\mathcal{A}	OWnt	
O.37	\mathcal{C}	O	\mathcal{N}	AA	
O.38	\mathcal{A}	O	NG	AO	
O.39	$\mathcal{C}_1\mathcal{C}_*$	O	\mathcal{N}	AH	
O.40	I	ON	\mathcal{A}	AXn	
O.41	$\mathcal{V}_+\mathcal{C}_*$	ON	\mathcal{N}	AXn	
O.42	$\mathcal{V}_+\mathcal{C}_1$	ON	\mathcal{A}	AXn	
O.43	\mathcal{A}	O	ST	OW	
O.44	\mathcal{A}	OF	\mathcal{C}_1	AOf	
O.45	\mathcal{A}	OTHER	\mathcal{A}	AHDER	
O.46	\mathcal{A}	OSS	\mathcal{N}	AOs	
O.47	$\mathcal{V}_+\mathcal{C}_1\mathcal{C}_*$	OM	\mathcal{A}	AHm	
O.48	\mathcal{A}	O	\mathcal{A}	AA	
P.1	\mathcal{A}	PH	\mathcal{A}	f	
P.2	\mathcal{A}	PEOP	\mathcal{A}	pIYp	
P.3	\mathcal{A}	POW	\mathcal{A}	pAW	
P.4	\mathcal{A}	PUT	\mathcal{N}	pUHt	
P.5	\mathcal{A}	P	\mathcal{A}	p	
Q.1	\mathcal{A}	QUAR	\mathcal{A}	kwAOr	
Q.2	\mathcal{A}	QU	\mathcal{A}	kw	
Q.3	\mathcal{A}	Q	\mathcal{A}	k	
R.1	\mathcal{N}	RE	$\mathcal{C}_1\mathcal{V}_+$	rIY	
R.2	\mathcal{A}	R	\mathcal{A}	r	
S.1	\mathcal{A}	SH	\mathcal{A}	SH	
S.2	\mathcal{V}_+	SION	\mathcal{A}	ZHAXn	
S.3	\mathcal{A}	SOME	\mathcal{A}	sAHm	
S.4	\mathcal{V}_+	SUR	\mathcal{V}_+	ZHER	
S.5	\mathcal{A}	SUR	\mathcal{V}_+	SHER	
S.6	\mathcal{V}_+	SU	\mathcal{V}_+	ZHUW	
S.7	\mathcal{V}_+	SSU	\mathcal{V}_+	SHUW	
S.8	\mathcal{V}_+	SED	\mathcal{N}	zd	
S.9	\mathcal{V}_+	S	\mathcal{V}_+	z	
S.10	\mathcal{A}	SAID	\mathcal{A}	sEHd	
S.11	\mathcal{C}_1	SION	\mathcal{A}	SHAXn	

Rule	Left Context	Match	Right Context	Output	Example
S.12	\mathcal{A}	S	S	Silent	
S.13	\mathcal{C}_v	S	\mathcal{N}	z	
S.14	$\mathcal{V}_+ \mathcal{C}_* \mathcal{C}_v \mathcal{E}$	S	\mathcal{N}	z	
S.15	$\mathcal{V}_+ \mathcal{C}_1 \mathcal{C}_* \mathcal{V}_+ \mathcal{V}_+$	S	\mathcal{N}	z	
S.16	$\mathcal{V}_+ \mathcal{C}_1 \mathcal{C}_* \mathcal{V}_+$	S	\mathcal{N}	s	
S.17	U	S	\mathcal{N}	s	
S.18	$\mathcal{C}_* \mathcal{V}_+$	S	\mathcal{N}	z	
S.19	\mathcal{N}	SCH	\mathcal{A}	sk	
S.20	\mathcal{A}	S	\mathcal{CF}	Silent	
S.21	\mathcal{V}_+	SM	\mathcal{A}	zm	
S.22	\mathcal{V}_+	SN	'	zAXn	
S.23	\mathcal{A}	S	\mathcal{A}	s	
T.1	\mathcal{N}	THE	\mathcal{N}	DHAX	
T.2	\mathcal{A}	TO	\mathcal{N}	tUW	
T.3	\mathcal{A}	THAT	\mathcal{N}	DHAEt	
T.4	\mathcal{N}	THIS	\mathcal{N}	DHIHs	
T.5	\mathcal{N}	THEY	\mathcal{A}	DHEY	
T.6	\mathcal{N}	THERE	\mathcal{A}	DHEHr	
T.7	\mathcal{A}	THER	\mathcal{A}	DHER	
T.8	\mathcal{A}	THEIR	\mathcal{A}	DHEHr	
T.9	\mathcal{N}	THAN	\mathcal{N}	DHAEh	
T.10	\mathcal{N}	THEM	\mathcal{N}	DHEHm	
T.11	\mathcal{A}	THESE	\mathcal{N}	DHIYz	
T.12	\mathcal{N}	THEN	\mathcal{A}	DHEHn	
T.13	\mathcal{A}	THROUGH	\mathcal{A}	THrUW	
T.14	\mathcal{A}	THOSE	\mathcal{A}	DHOWz	
T.15	\mathcal{A}	THOUGH	\mathcal{N}	DHOW	
T.16	\mathcal{N}	THUS	\mathcal{A}	DHAHs	
T.17	\mathcal{A}	TH	\mathcal{A}	TH	
T.18	$\mathcal{V}_+ \mathcal{C}_*$	TED	\mathcal{N}	tIHd	
T.19	S	TI	$\mathcal{V}_+ \mathcal{N}$	CH	
T.20	\mathcal{A}	TI	O	SH	
T.21	\mathcal{A}	TI	\mathcal{A}	SH	
T.22	\mathcal{A}	TIEN	\mathcal{A}	SHAXn	
T.23	\mathcal{A}	TUR	\mathcal{V}_+	CHER	
T.24	\mathcal{A}	TU	\mathcal{A}	CHUW	
T.25	\mathcal{N}	TWO	\mathcal{A}	tUW	
T.26	\mathcal{A}	T	\mathcal{A}	t	
U.1	\mathcal{N}	UN	I	yUWn	
U.2	\mathcal{N}	UN	\mathcal{A}	AHn	
U.3	\mathcal{N}	UPON	\mathcal{A}	AXpAOn	
U.4	T	UR	\mathcal{V}_+	UHr	
U.5	S	UR	\mathcal{V}_+	UHr	
U.6	R	UR	\mathcal{V}_+	UHr	
U.7	D	UR	\mathcal{V}_+	UHr	
U.8	L	UR	\mathcal{V}_+	UHr	
U.9	Z	UR	\mathcal{V}_+	UHr	
U.10	N	UR	\mathcal{V}_+	UHr	
U.11	J	UR	\mathcal{V}_+	UHr	
U.12	TH	UR	\mathcal{V}_+	UHr	
U.13	CH	UR	\mathcal{V}_+	UHr	
U.14	SH	UR	\mathcal{V}_+	UHr	
U.15	\mathcal{A}	UR	\mathcal{V}_+	yUHr	

Rule	Left Context	Match	Right Context	Output	Example
U.16	\mathcal{A}	UR	\mathcal{A}	ER	
U.17	\mathcal{A}	U	\mathcal{C}_1	AH	
U.18	\mathcal{A}	$UC_1\mathcal{C}_1$	\mathcal{A}	AH	
U.19	\mathcal{A}	UY	\mathcal{A}	AY	
U.20	G	U	\mathcal{V}_+	Silent	
U.21	G	U	\mathcal{S}	Silent	
U.22	G	U	\mathcal{V}_+	w	
U.23	$\mathcal{V}_+\mathcal{N}$	U	\mathcal{A}	YUw	
U.24	T	U	\mathcal{A}	UW	
U.25	S	U	\mathcal{A}	UW	
U.26	R	U	\mathcal{A}	UW	
U.27	D	U	\mathcal{A}	UW	
U.28	L	U	\mathcal{A}	UW	
U.29	Z	U	\mathcal{A}	UW	
U.30	N	U	\mathcal{A}	UW	
U.31	J	U	\mathcal{A}	UW	
U.32	TH	U	\mathcal{A}	UW	
U.33	CH	U	\mathcal{A}	UW	
U.34	SH	U	\mathcal{A}	UW	
U.35	\mathcal{A}	U	\mathcal{A}	YUw	
V.1	\mathcal{A}	VIEW	\mathcal{A}	vYUw	
V.2	\mathcal{A}	V	\mathcal{A}	v	
W.1	\mathcal{N}	WERE	\mathcal{A}	wER	
W.2	\mathcal{A}	WA	\mathcal{S}	wAA	
W.3	\mathcal{A}	WA	T	wAA	
W.4	\mathcal{A}	WERE	\mathcal{A}	WHEHr	
W.5	\mathcal{A}	WHAT	\mathcal{A}	WHAAt	
W.6	\mathcal{A}	WHOL	\mathcal{A}	hOWl	
W.7	\mathcal{A}	WHO	\mathcal{A}	hUW	
W.8	\mathcal{A}	WH	\mathcal{A}	WH	
W.9	\mathcal{A}	WAR	\mathcal{A}	wAOOr	
W.10	\mathcal{A}	WOR	\mathcal{C}_1	wER	
W.11	\mathcal{A}	WR	\mathcal{A}	r	
W.12	\mathcal{A}	W	\mathcal{A}	w	
X.1	\mathcal{A}	X	\mathcal{A}	ks	
Y.1	\mathcal{A}	YOUNG	\mathcal{A}	yAHNG	
Y.2	\mathcal{N}	YOU	\mathcal{A}	yUW	
Y.3	\mathcal{N}	YES	\mathcal{A}	yEHs	
Y.4	\mathcal{N}	Y	\mathcal{A}	y	
Y.5	$\mathcal{V}_+\mathcal{C}_1\mathcal{C}_*$	Y	\mathcal{N}	IY	
Y.6	$\mathcal{V}_+\mathcal{C}_1\mathcal{C}_*$	Y	I	IY	
Y.7	\mathcal{C}_*	Y	\mathcal{N}	AY	
Y.8	\mathcal{C}_*	Y	\mathcal{V}_+	AY	
Y.9	\mathcal{C}_*	Y	$\mathcal{C}_1\mathcal{F}\mathcal{C}_*\mathcal{V}_+$	IH	
Y.10	\mathcal{C}_*	Y	$\mathcal{C}_1\mathcal{V}_+$	AY	
Y.11	\mathcal{A}	Y	\mathcal{A}	IH	
Z.1	\mathcal{A}	Z	\mathcal{A}	z	