PHONETICS: PRAAT III

MELODY: FUNDAMENTAL FREQUENCY (F0)

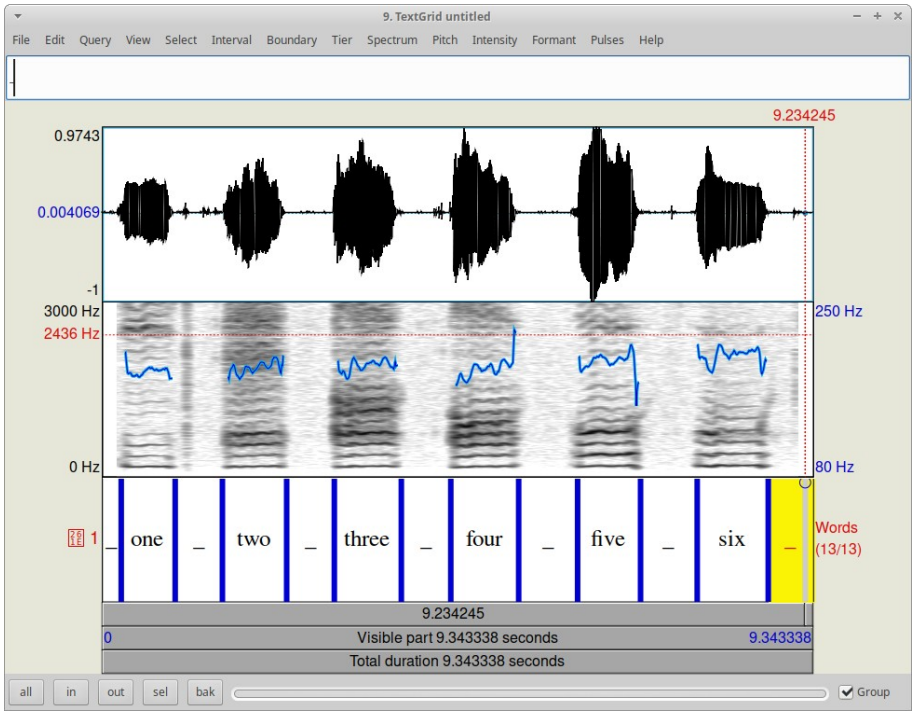
Dafydd Gibbon

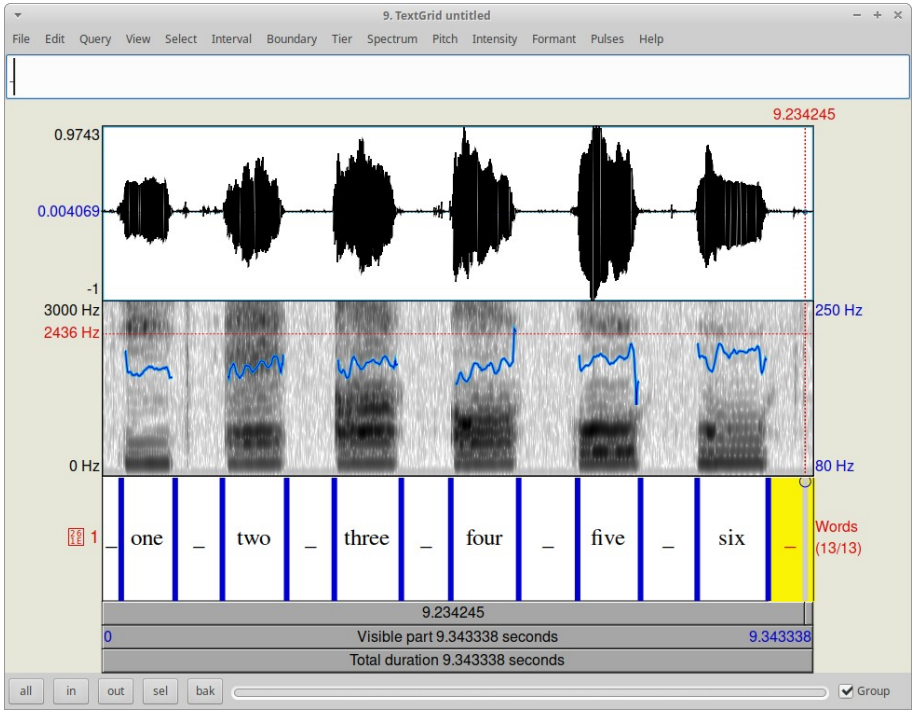
Bielefeld University, Germany

Jinan University, Guangzhou, 2022-03-07

PRAAT: BASIC FUNCTIONALITY

1. Input:
   - recording speech from microphone or other sources
   - reading from files
2. Methods:
   - waveform selection and analysis
   - spectral analysis
   - transcription and annotation of speech
   - frequency and intensity analysis
3. Output:
   - saving speech files
   - saving files with analysis results:
     - spectral information
     - annotations (TextGrid files)
     - fundamental frequency





PHONETICS: PRAAT III – 'PRACTICAL PRAAT'

The week before last:

- General introduction
- Overview of basic Praat functionality
- Creation of vowel formant charts

Last week, speech timing and rhythm:

- recording speech data
- annotating speech data
- extracting duration information from a recording, using Praat
- transferring Praat data to a spreadsheet (Excel, LibreOffice Calc, etc.)
- analysing speech timing

This week, speech melody:

- extracting fundamental frequency information from a recording
- analysing speech melody

I assume you have Praat (http://www.praat.org) and spreadsheet software.

OLD HOMEWORK ASSIGNMENT

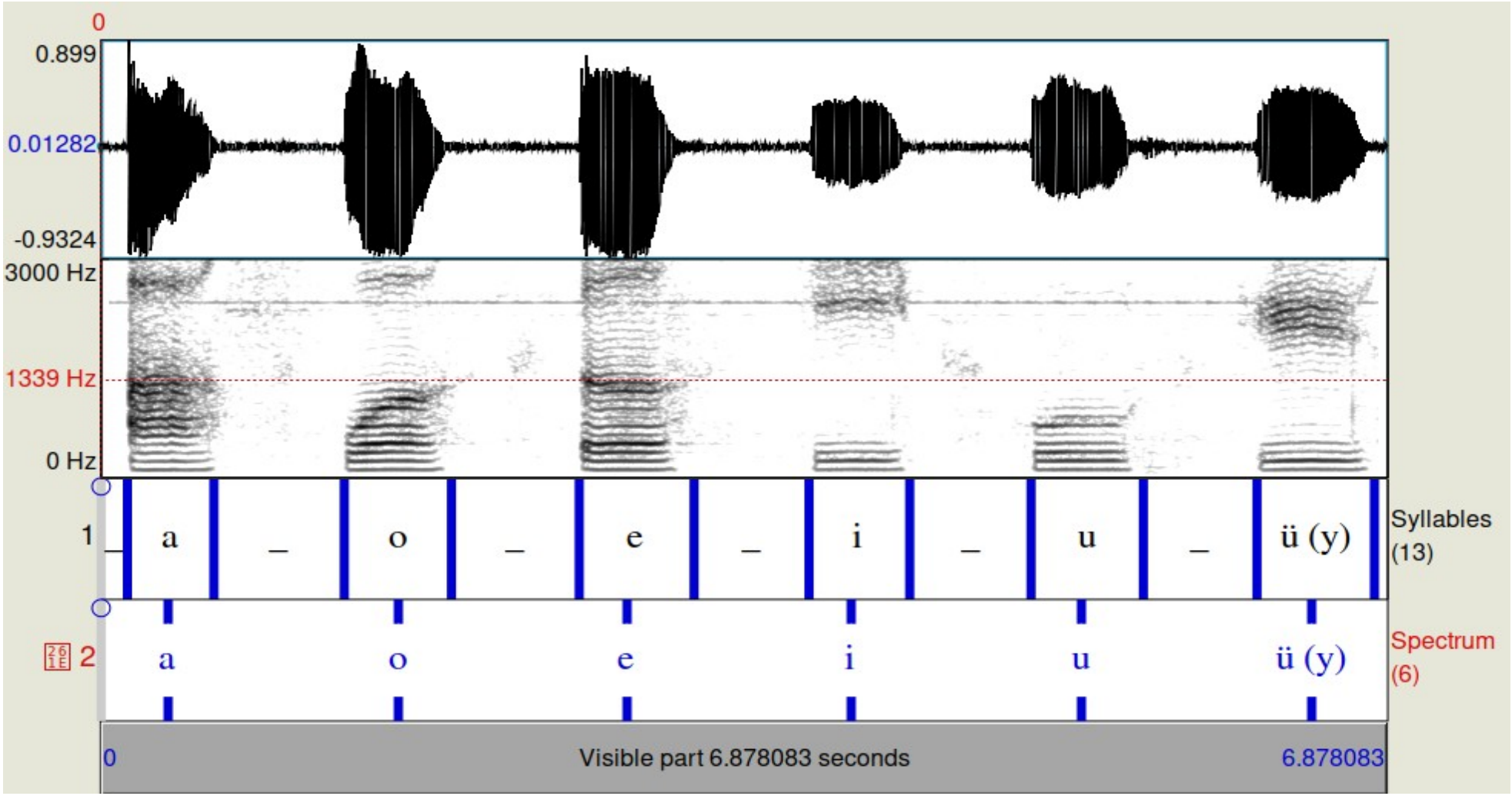
Record Chinese vowels.

Identify F1 and F2 frequencies of the vowels.

Make a spreadsheet chart of F1 X F2 for the monophthongs (simple vowels).

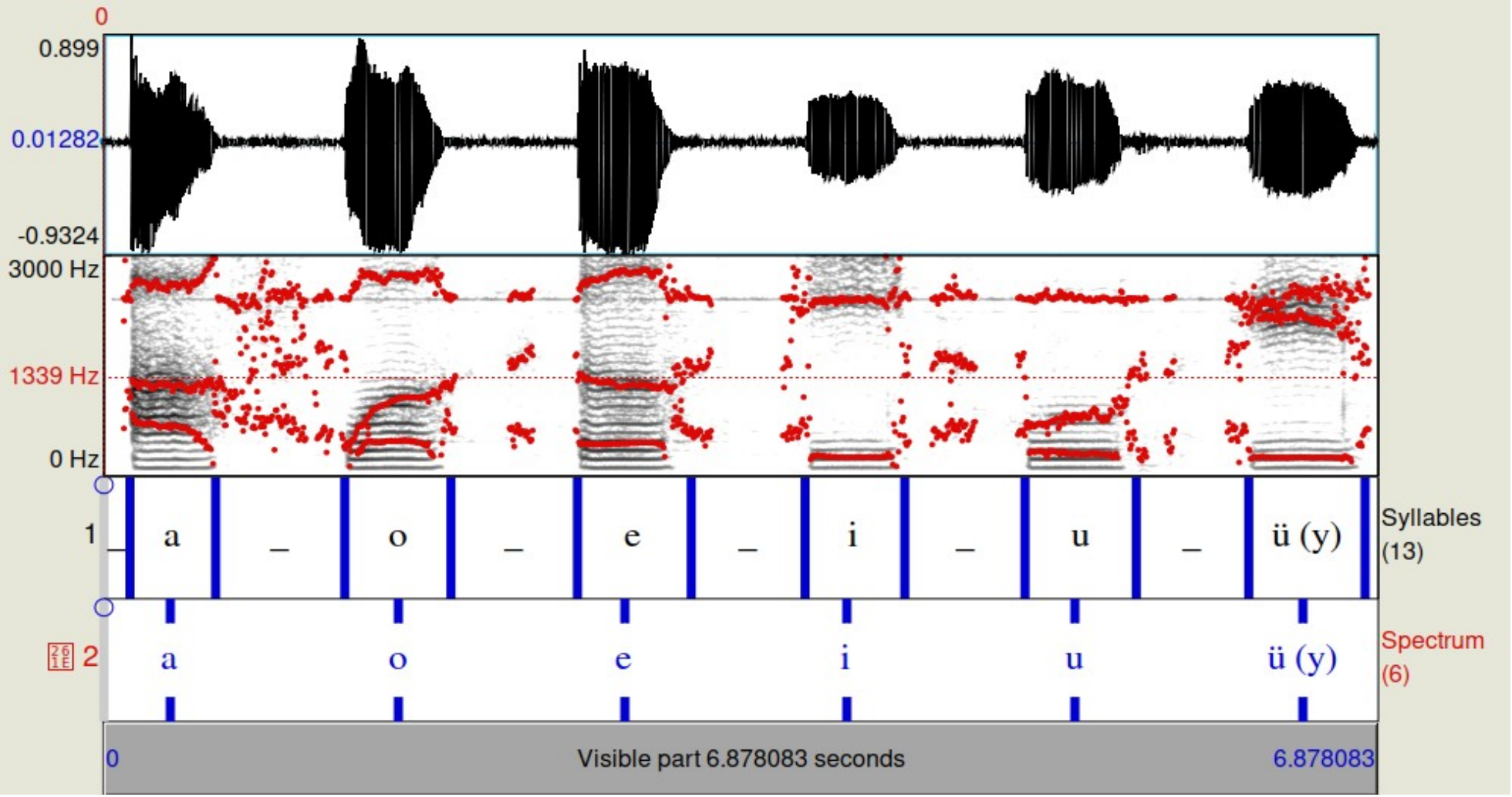
PHONETICS: PRAAT III – OLD HOMEWORK ASSIGNMENT

Method 1: locate the formants in the spectrogram.



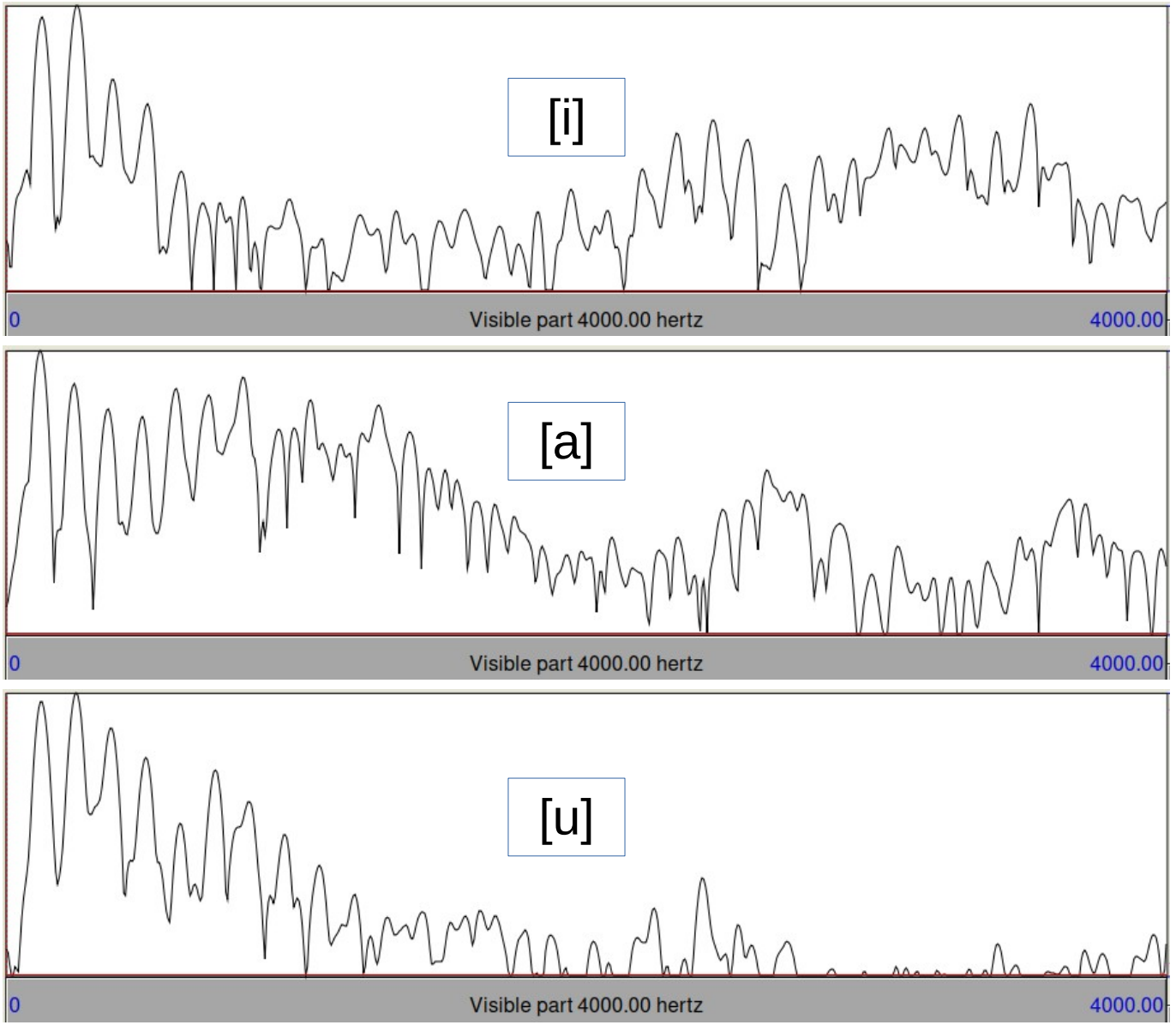
PHONETICS: PRAAT III – OLD HOMEWORK ASSIGNMENT

Method 2: show and locate the formants in the spectrogram.



PHONETICS: PRAAT III – OLD HOMEWORK ASSIGNMENT

Method 3: make a spectral slice and locate the formants.



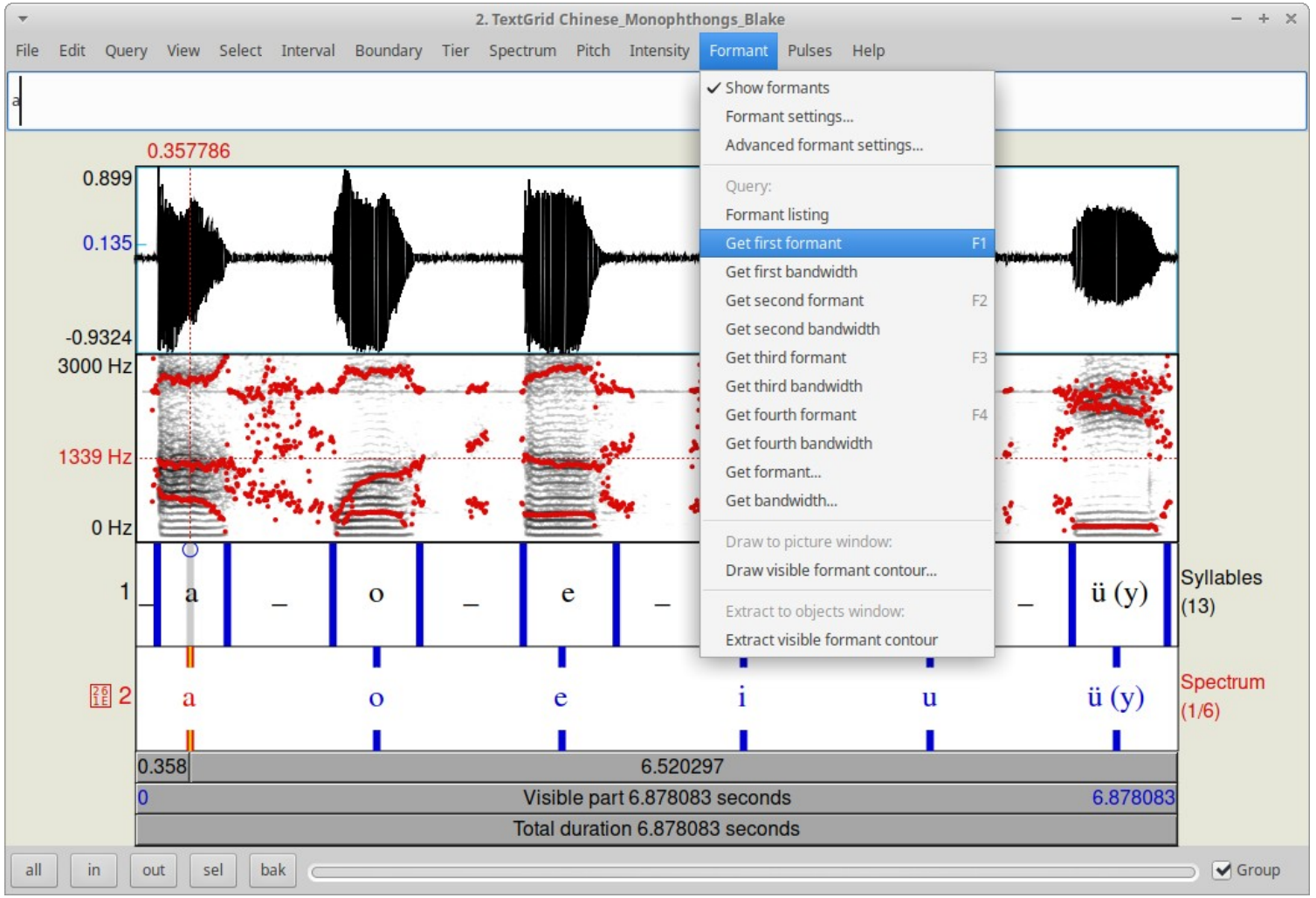
Classwork:

In each spectrum,

1. identify the fundamental frequency,
2. identify the frequency of F1,
3. identify the frequency of F2,

PHONETICS: PRAAT III – OLD HOMEWORK ASSIGNMENT

Method 4: use the Praat formant frequency functions.



Classwork:

In each spectrum,

1. identify the fundamental frequency,
2. identify the frequency of F1,
3. identify the frequency of F2,

PHONETICS: PRAAT III – OLD HOMEWORK ASSIGNMENT

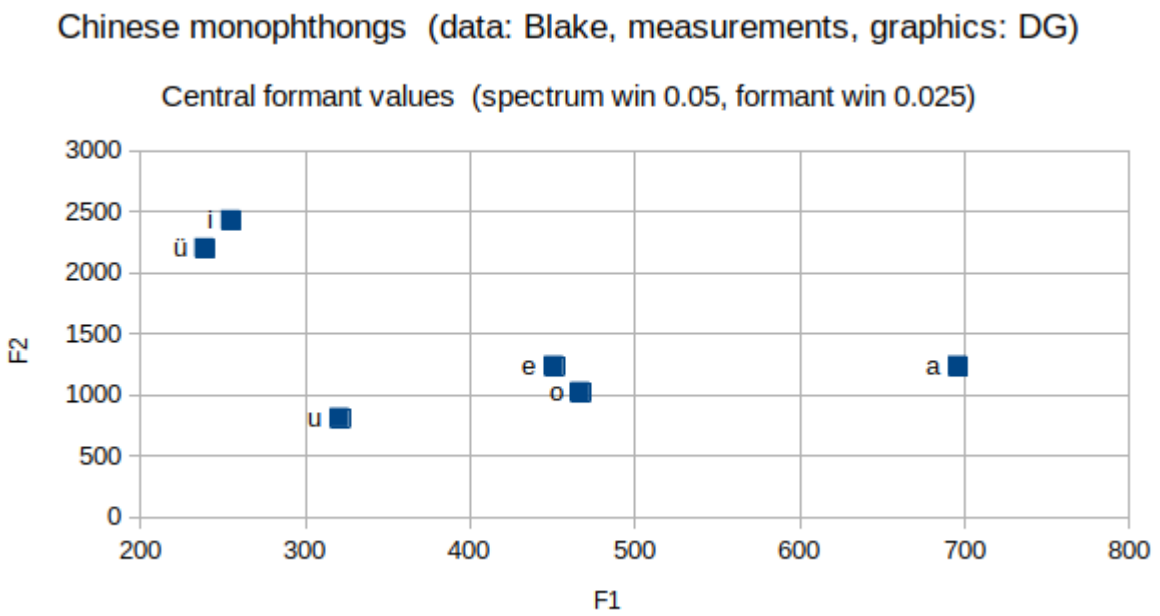
Chinese Monophthongs: measurements

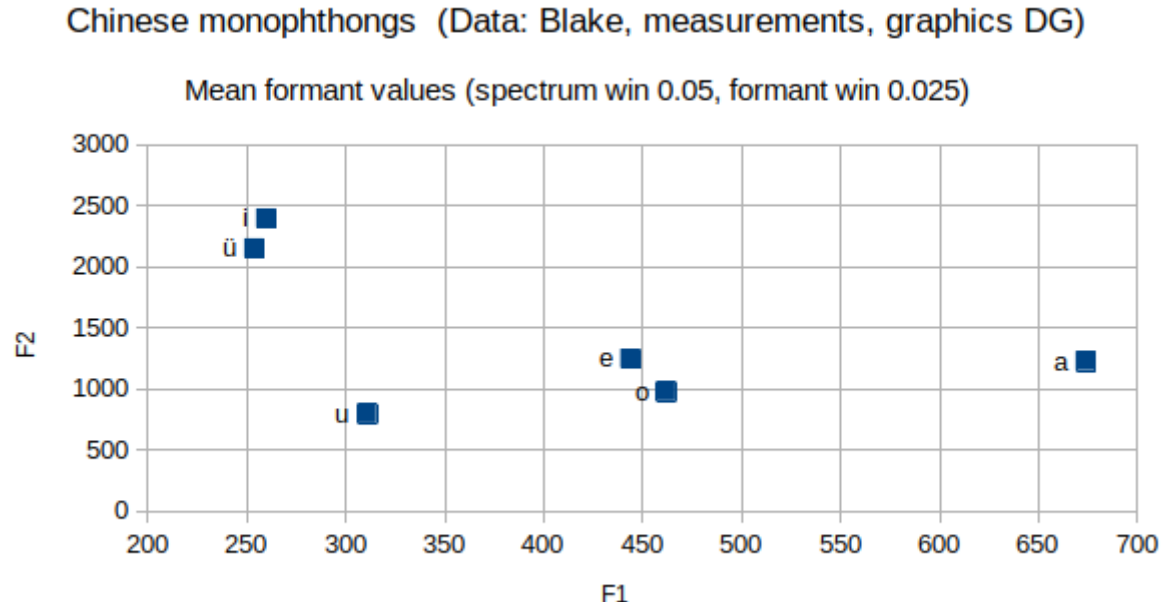
	Mid formant values			Mean formant values	
Labels	**F1**	**F2**	**Labels**	**F1**	**F2**
a	696	1236	**a**	674	1225
o	467	1023	**o**	462	978
e	451	1236	**e**	444	1245
i	255	2428	**i**	260	2392
u	321	811	**u**	311	796
ü (y)	239	2199	**ü**	254	2148

Hint: Look at the Formant menu in the Praat Edit window.

PHONETICS: PRAAT III – OLD HOMEWORK ASSIGNMENT

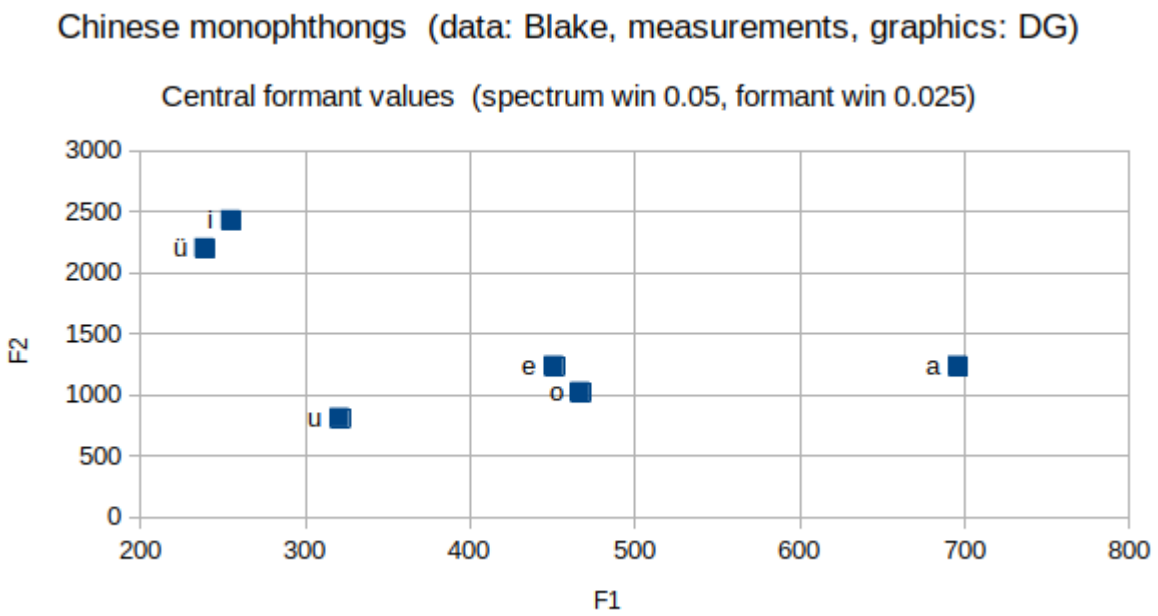
Chinese Monophthongs: visualisation

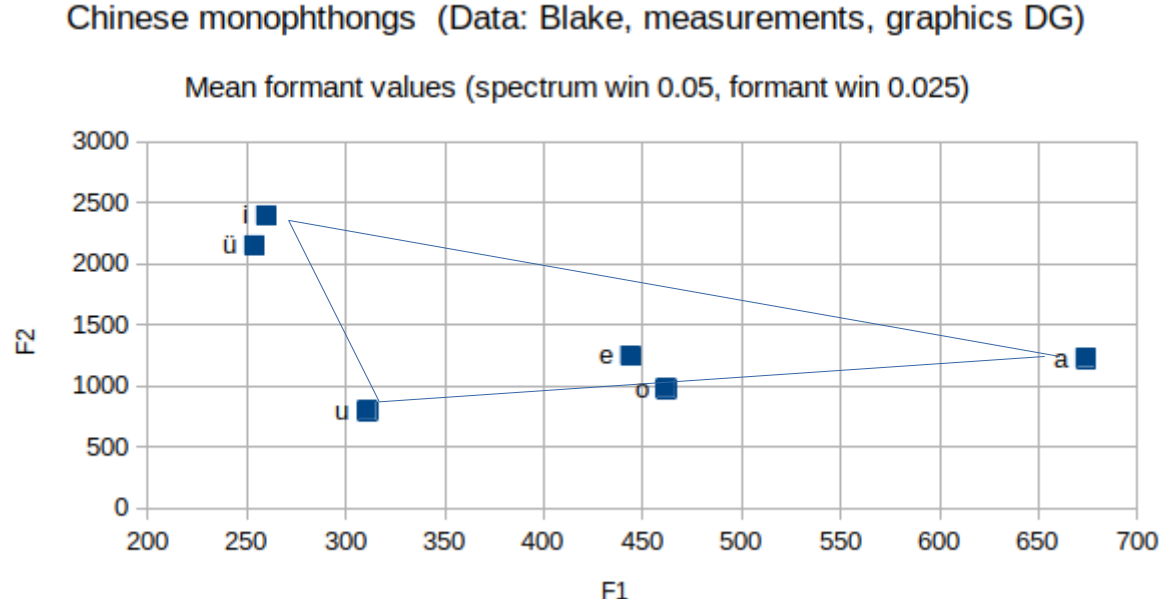




PHONETICS: PRAAT III – OLD HOMEWORK ASSIGNMENT

Chinese Monophthongs: visualisation



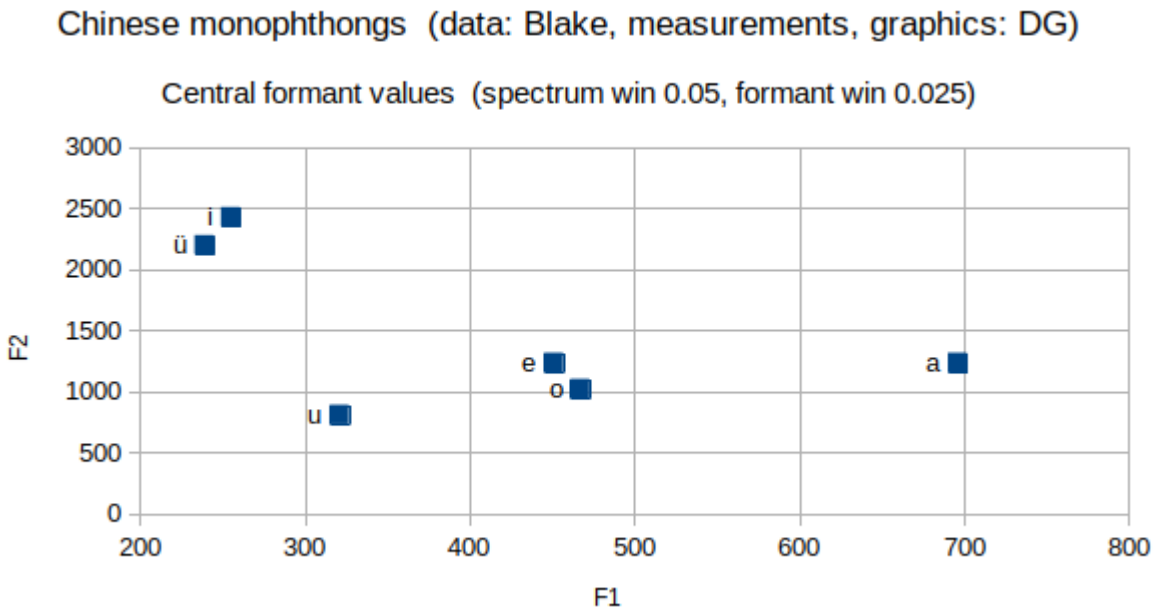


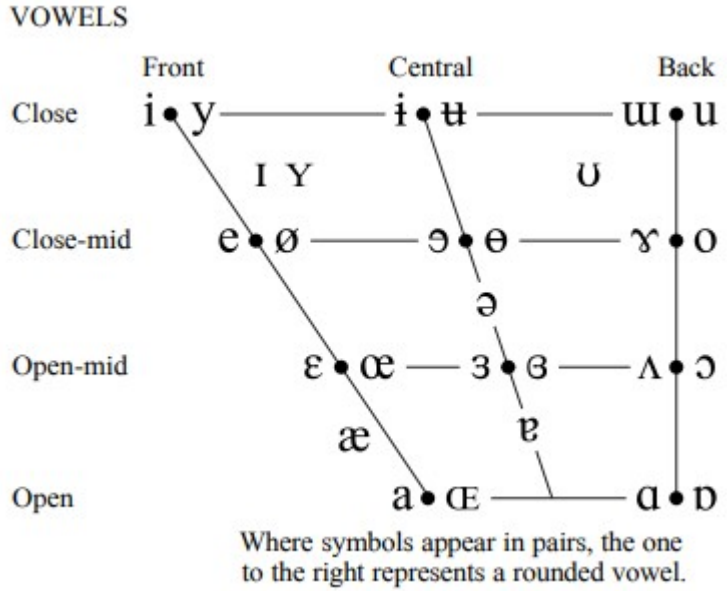
The F1-F2 formant triangle corresponds approximately to the shape of the IPA vowel chart:

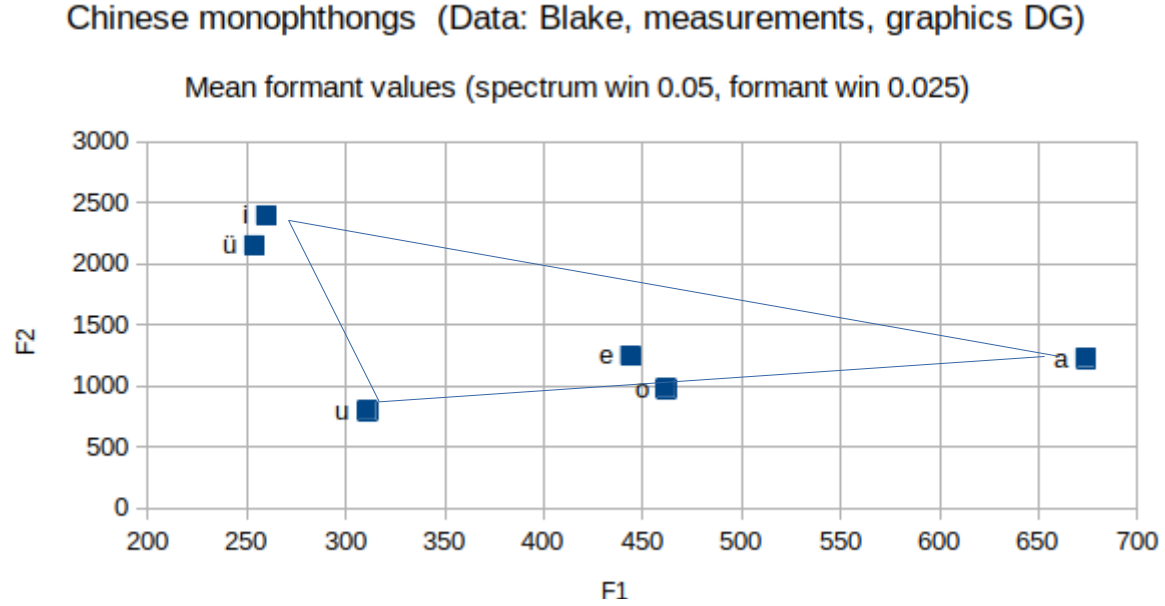
- F1: high-low
- F2: front-back

PHONETICS: PRAAT III – OLD HOMEWORK ASSIGNMENT

Chinese Monophthongs: visualisation, similarity to IPA vowel chart





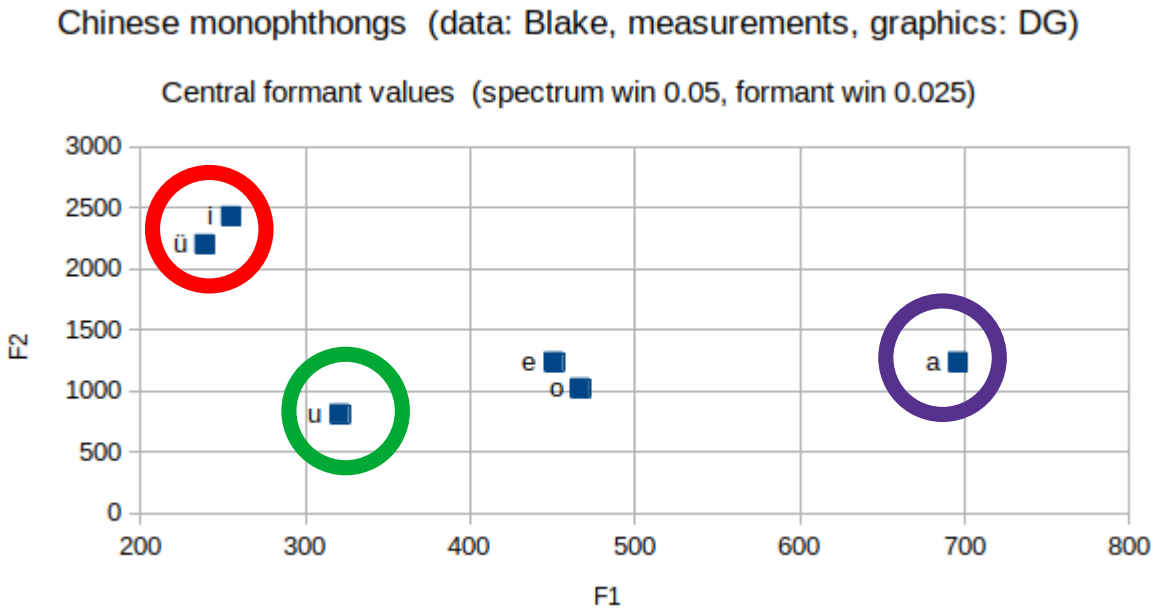


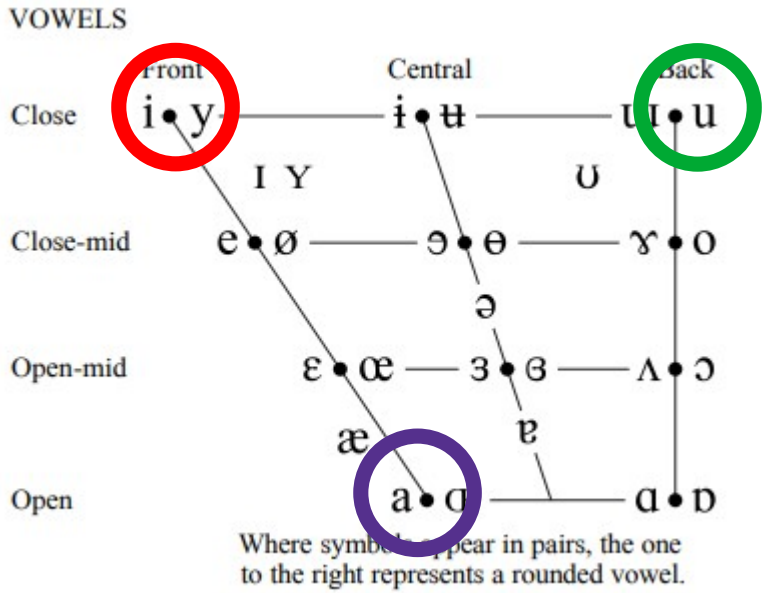
The F1-F2 formant triangle corresponds approximately to the shape of the IPA vowel chart:

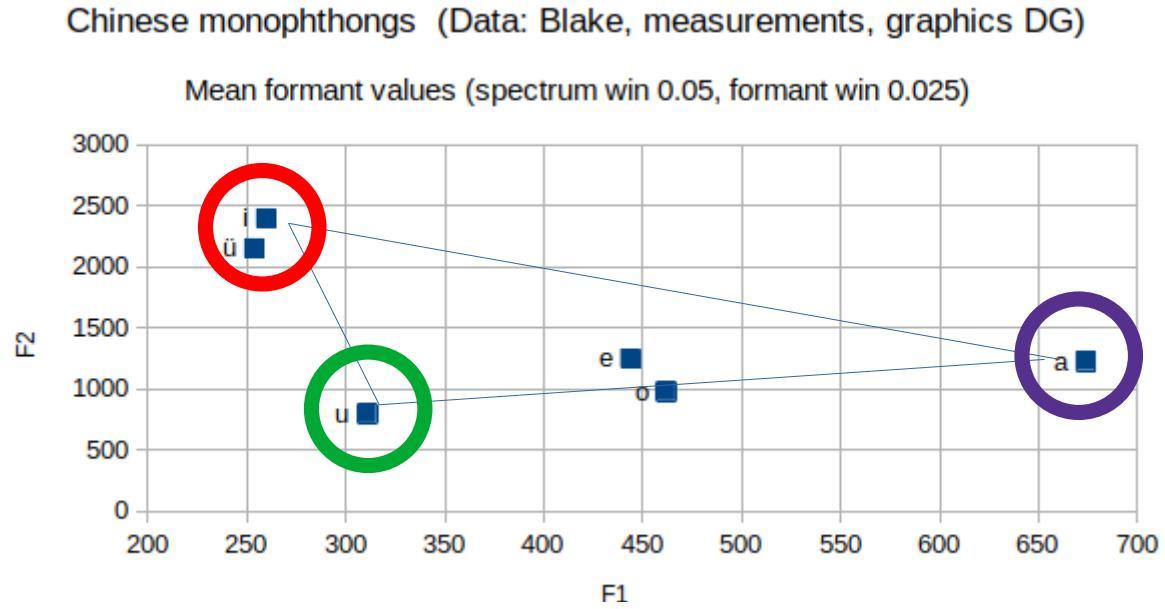
- F1: high-low
- F2: front-back

PHONETICS: PRAAT III – OLD HOMEWORK ASSIGNMENT

Chinese Monophthongs: visualisation, similarity to IPA vowel chart





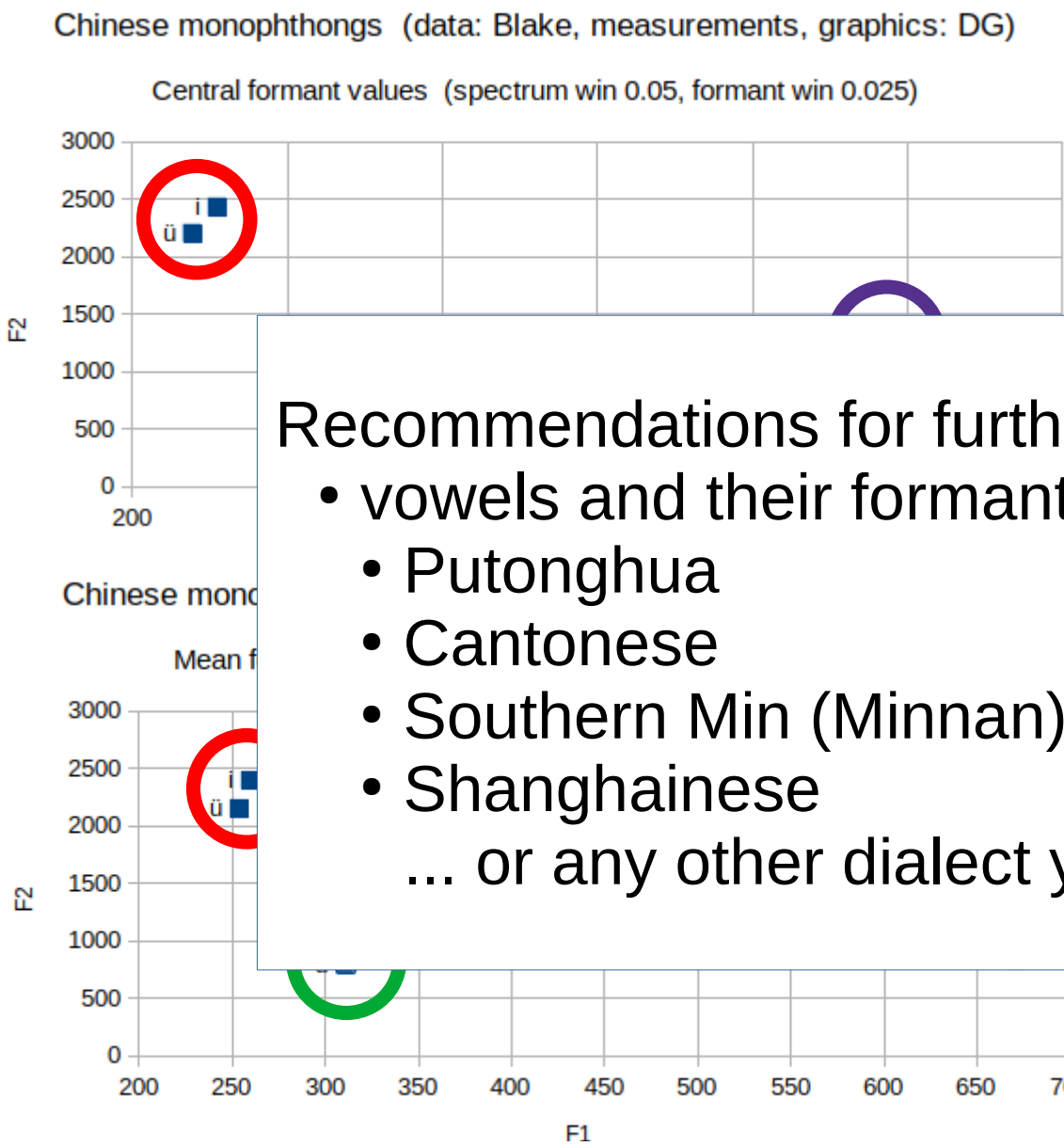


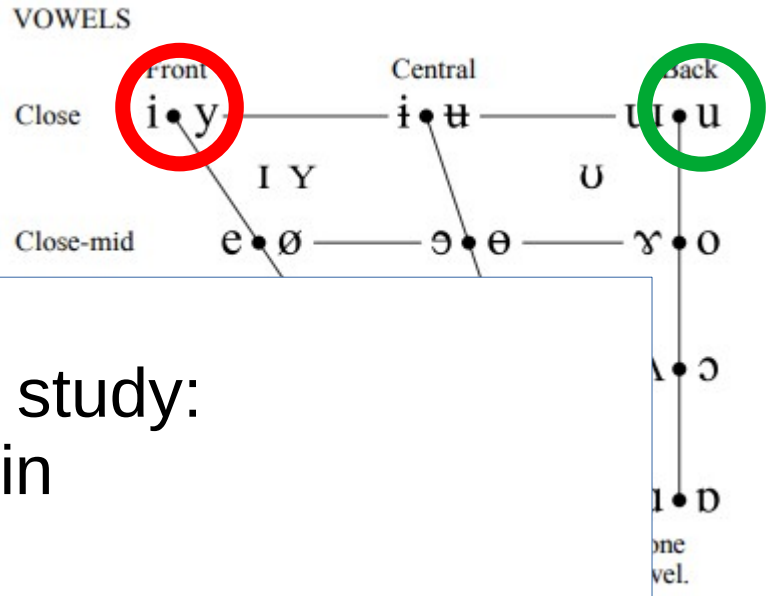
The F1-F2 formant triangle corresponds approximately to the shape of the IPA vowel chart:

- F1: high-low
- F2: front-back

PHONETICS: PRAAT III – OLD HOMEWORK ASSIGNMENT

Chinese Monophthongs: visualisation, similarity to IPA vowel chart





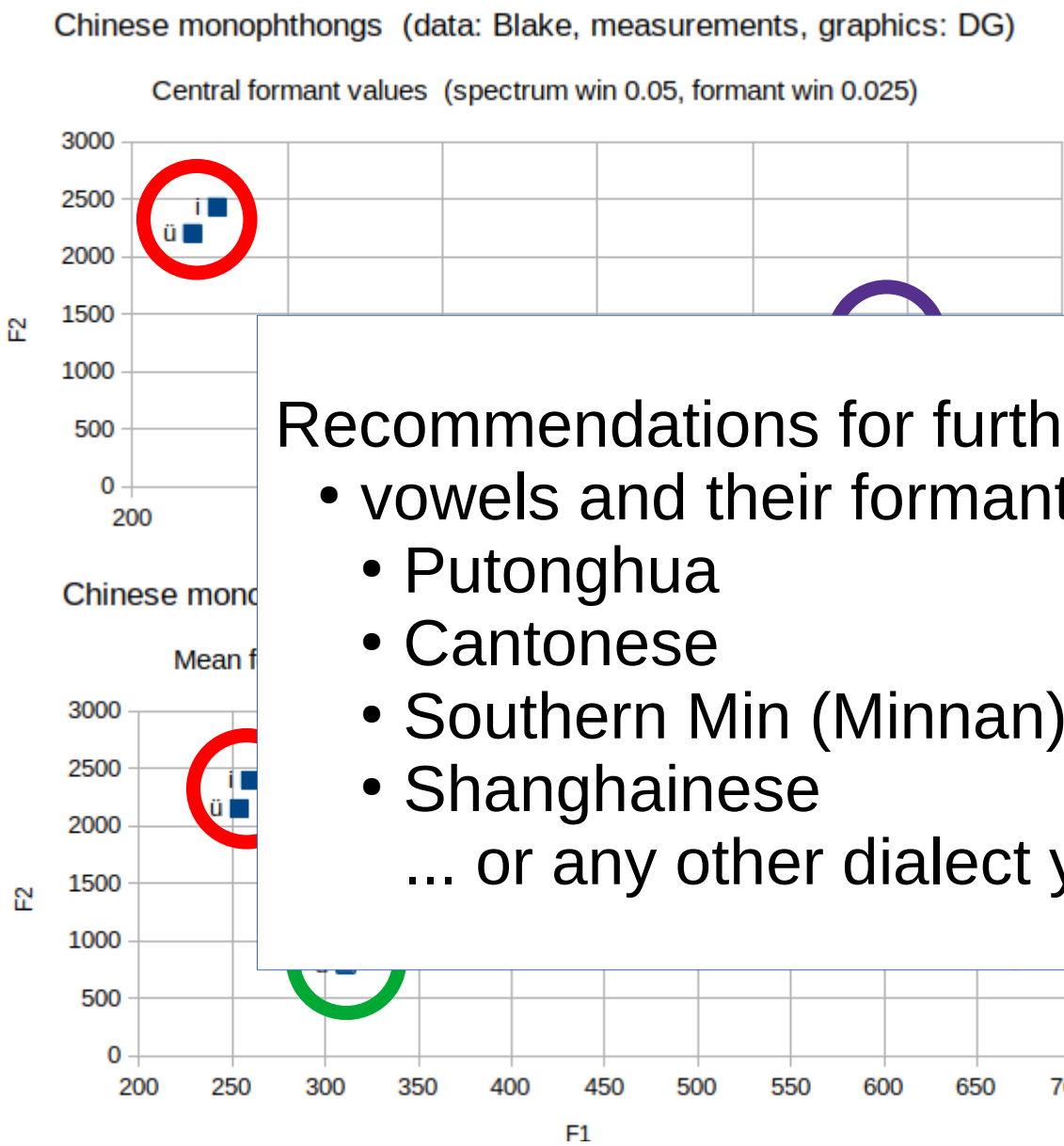
Recommendations for further study:

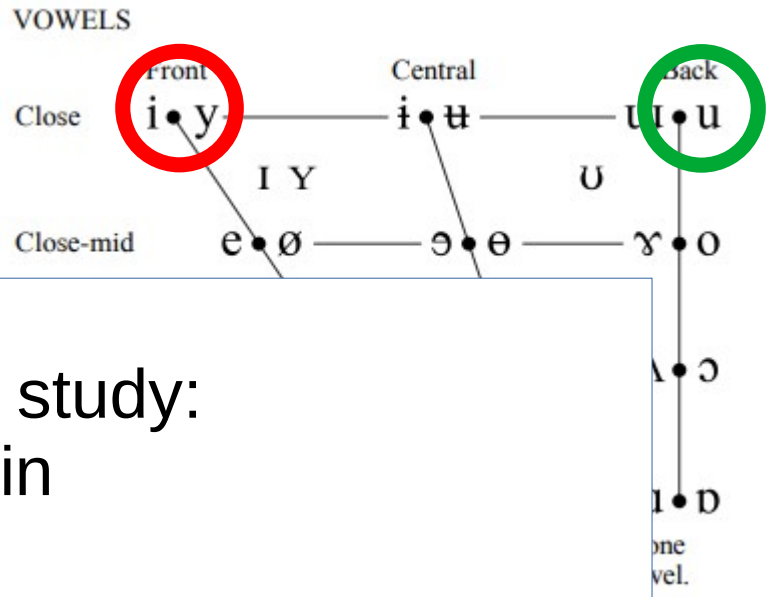
- vowels and their formants in
  - Putonghua
  - Cantonese
  - Southern Min (Minnan)
  - Shanghainese
    ... or any other dialect you speak

F1: high-low
F2: front-back

PHONETICS: PRAAT III – NEW HOMEWORK ASSIGNMENT

Chinese Monophthongs: visualisation, similarity to IPA vowel chart





Recommendations for further study:

- vowels and their formants in
  - Putonghua
  - Cantonese
  - Southern Min (Minnan)
  - Shanghainese
    ... or any other dialect you speak

F1: high-low
F2: front-back

NEW HOMEWORK ASSIGNMENT

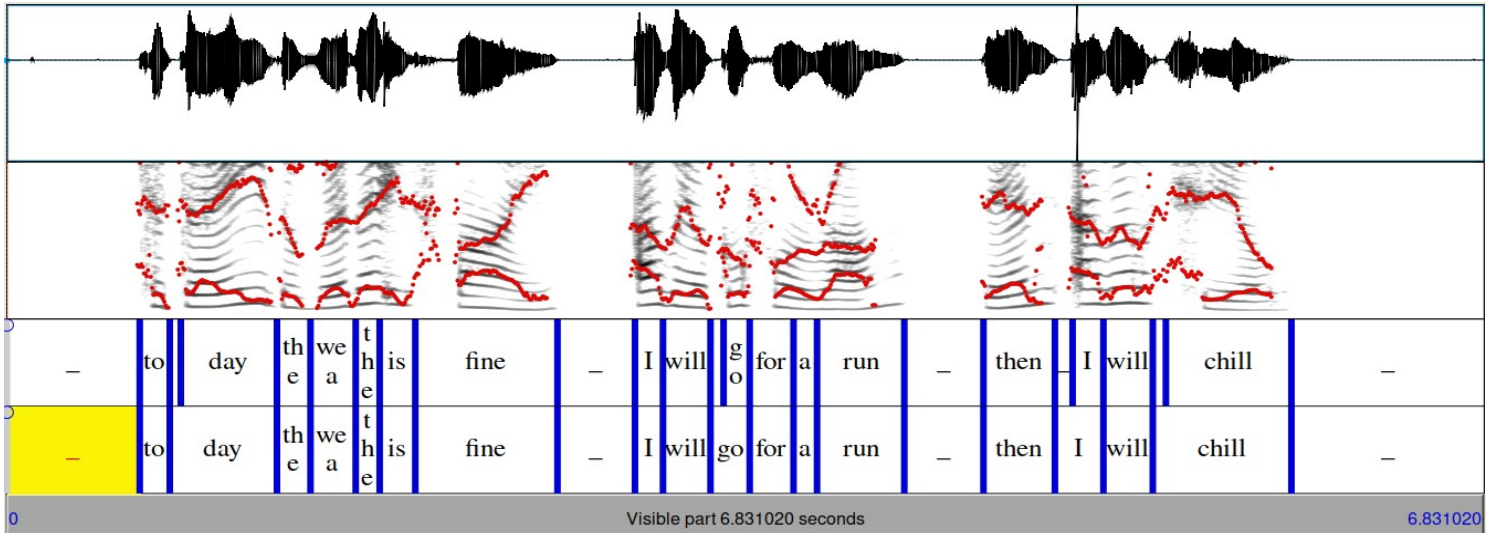
Today the weather is fine. I will go for a run. Then I will chill.

1. English:
    1. Record the short English passage shown above.
    2. Annotate the syllables.
    3. Convert the TextGrid to CSV and find the nPVI using TGA.
2. Translate the passage into Chinese.
    1. Record the passage.
    2. Annotate the syllables.
    3. Convert the TextGrid to CSV and find the nPVI using TGA.
3. What conclusions do you draw from the nPVI values?

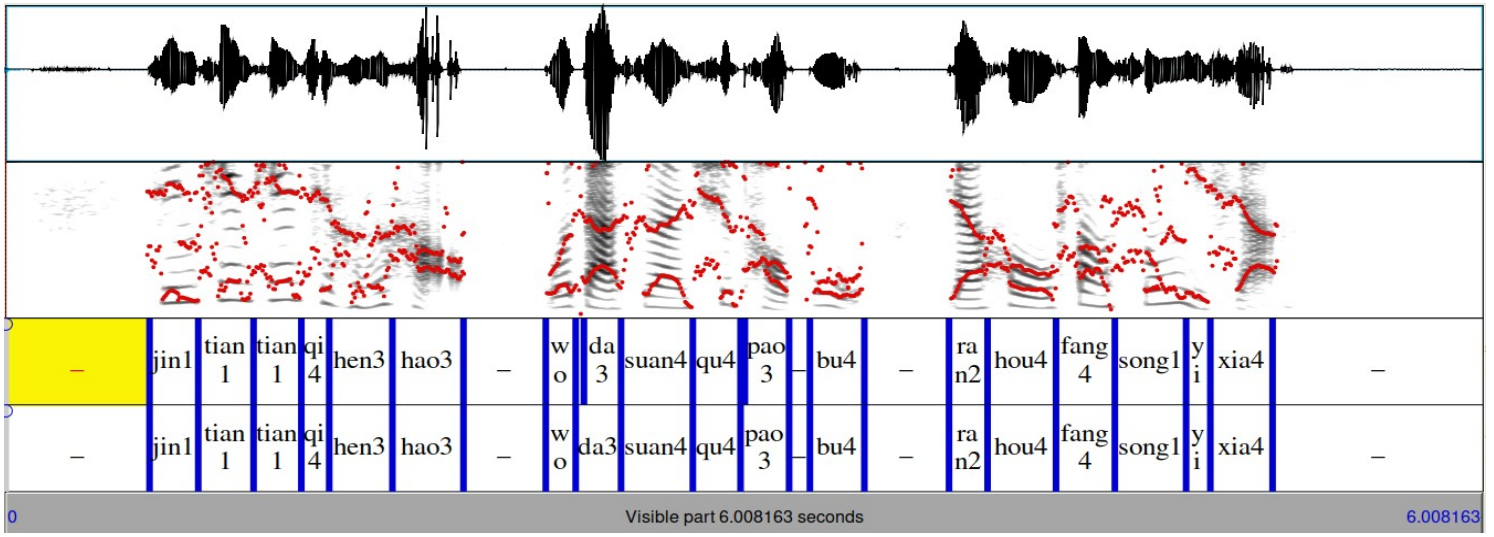
NEW HOMEWORK ASSIGNMENT

Today the weather is fine. I will go for a run. Then I will chill.

English



Chinese



NEW HOMEWORK ASSIGNMENT

```
intervals [1]:
        xmin = 0
        xmax =
0.6143557529147997
        text = "_"
    intervals [2]:
        xmin =
0.6143557529147997
        xmax =
0.7534295766109449
        text = "to"
    intervals [3]:
        xmin =
0.7534295766109449
        xmax =
1.2489799828845654
        text = "day"
    intervals [4]:
        xmin =
1.2489799828845654
        xmax =
1.404039303557279
        text = "the"
    intervals [5]:
        xmin =
1.404039303557279
        xmax =
1.6128433687831145
        text = "wea"
    intervals [6]:
        xmin =
1.6128433687831145
        xmax =
1.7239425727702649
        text = "ther"
    intervals [7]:
        xmin =
1.7239425727702649
        xmax =
1.888553391684702
        text = "is"
    intervals [8]:
        xmin =
1.888553391684702
        xmax =
2.545889627984778
        text = "fine"
    intervals [9]:
        xmin =
2.545889627984778
        xmax =
2.904153769613651
        text = "_"
```

```
intervals [10]:
        xmin = 2.904153769613651
        xmax = 3.0337623013596824
        text = "I"
    intervals [11]:
        xmin = 3.0337623013596824
        xmax = 3.2535628847874984
        text = "will"
    intervals [12]:
        xmin = 3.2535628847874984
        xmax = 3.4347289680263495
        text = "go"
    intervals [13]:
        xmin = 3.4347289680263495
        xmax = 3.6373408184609684
        text = "for"
    intervals [14]:
        xmin = 3.6373408184609684
        xmax = 3.7460421979016334
        text = "a"
    intervals [15]:
        xmin = 3.7460421979016334
        xmax = 4.1495326953506115
        text = "run"
    intervals [16]:
        xmin = 4.1495326953506115
        xmax = 4.515600576114026
        text = "_"
```

```
intervals [17]:
        xmin =
4.515600576114026
        xmax =
4.846024751756507
        text = "then"
    intervals [18]:
        xmin =
4.846024751756507
        xmax =
5.070082369386892
        text = "I"
    intervals [19]:
        xmin =
5.070082369386892
        xmax =
5.298674976151819
        text = "will"
    intervals [20]:
        xmin =
5.298674976151819
        xmax =
5.939352446862325
        text = "chill"
    intervals [21]:
        xmin =
5.939352446862325
        xmax =
6.8310204081632655
        text = "_"
```

Praat TextGrid file format

```
to      0.614   0.753
day     0.804   1.248
the     1.248   1.404
wea     1.404   1.612
ther    1.612   1.723
is      1.723   1.888
fine    1.888   2.545
_       2.545   2.904
I       2.904   3.033
will    3.033   3.253
_       3.253   3.314
go      3.314   3.434
for     3.434   3.637
a       3.637   3.746
run     3.746   4.149
_       4.149   4.515
then    4.515   4.846
_       4.846   4.927
I       4.927   5.07
will    5.07    5.298
_       5.298   5.358
chill   5.358   5.939
```

CSV (character separated values) spreadsheet and database format

In this case, TSV (tab separated values)

NEW HOMEWORK ASSIGNMENT

English: Duration properties (without pauses)

Attributes	Values	Attributes	Values
***n*:**	**17**	intercept:	203.863
min:	**109**	**slope:**	**6.48**
max:	**657**	**std:**	**164.172**
mean:	**255.71**	coeff var (%):	64.204
median:	**203.0**	**nPVI:**	**72**
mean rate:	**3.91**	rPVI:	199
median rate:	**4.93**	100*rPVI/med:	98
total:	**4347**	nPVI*med/100:	146
range:	**548**		

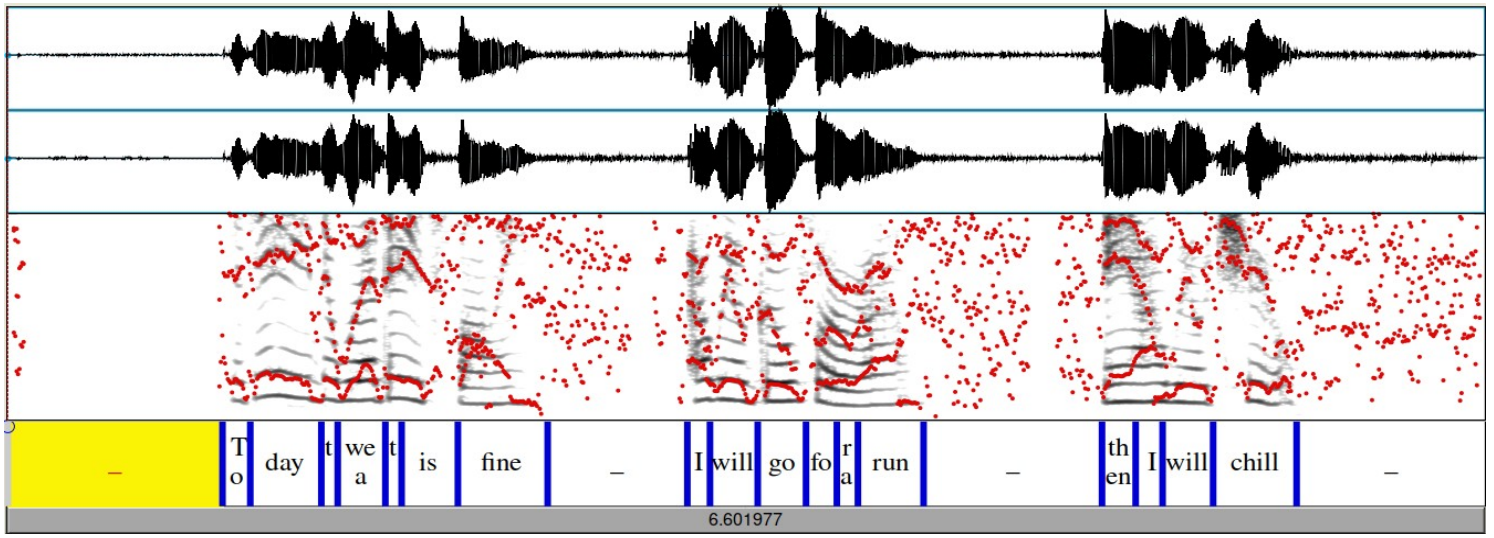
Chinese: Duration properties (without pauses)

Attributes	Values	Attributes	Values
***n*:**	**18**	intercept:	199.345
min:	**98**	**slope:**	**1.397**
max:	**292**	**std:**	**59.396**
mean:	**211.22**	coeff var (%):	28.12
median:	**210.0**	**nPVI:**	**41**
mean rate:	**4.73**	rPVI:	82
median rate:	**4.76**	100*rPVI/med:	39
total:	**3802**	nPVI*med/100:	86
range:	**194**		

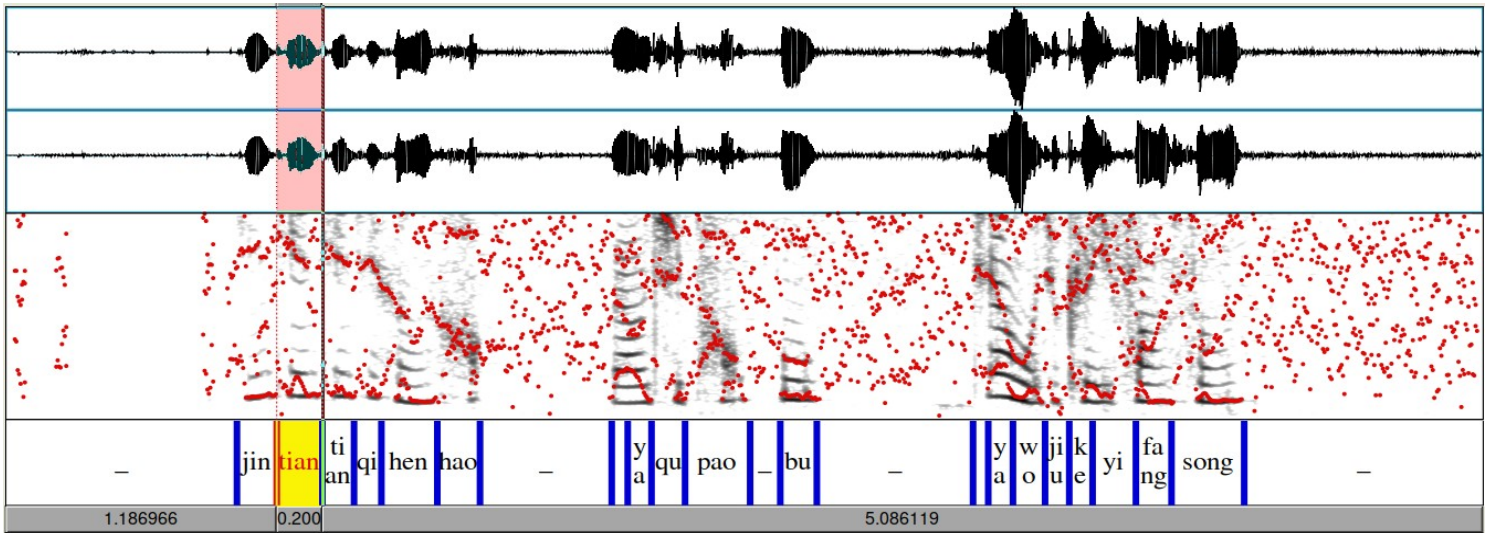
NEW HOMEWORK ASSIGNMENT

Today the weather is fine. I will go for a run. Then I will chill.

English



Chinese



NEW HOMEWORK ASSIGNMENT

```
intervals [1]:
        xmin = 0
        xmax =
0.6143557529147997
        text = "_"
    intervals [2]:
        xmin =
0.6143557529147997
        xmax =
0.7534295766109449
        text = "to"
    intervals [3]:
        xmin =
0.7534295766109449
        xmax =
1.2489799828845654
        text = "day"
    intervals [4]:
        xmin =
1.2489799828845654
        xmax =
1.404039303557279
        text = "the"
    intervals [5]:
        xmin =
1.404039303557279
        xmax =
1.6128433687831145
        text = "wea"
    intervals [6]:
        xmin =
1.6128433687831145
        xmax =
1.7239425727702649
        text = "ther"
    intervals [7]:
        xmin =
1.7239425727702649
        xmax =
1.888553391684702
        text = "is"
    intervals [8]:
        xmin =
1.888553391684702
        xmax =
2.545889627984778
        text = "fine"
    intervals [9]:
        xmin =
2.545889627984778
        xmax =
2.904153769613651
        text = "_"
```

```
intervals [10]:
        xmin = 2.904153769613651
        xmax = 3.0337623013596824
        text = "I"
    intervals [11]:
        xmin = 3.0337623013596824
        xmax = 3.2535628847874984
        text = "will"
    intervals [12]:
        xmin = 3.2535628847874984
        xmax = 3.4347289680263495
        text = "go"
    intervals [13]:
        xmin = 3.4347289680263495
        xmax = 3.6373408184609684
        text = "for"
    intervals [14]:
        xmin = 3.6373408184609684
        xmax = 3.7460421979016334
        text = "a"
    intervals [15]:
        xmin = 3.7460421979016334
        xmax = 4.1495326953506115
        text = "run"
    intervals [16]:
        xmin = 4.1495326953506115
        xmax = 4.515600576114026
        text = "_"
```

```
intervals [17]:
        xmin =
4.515600576114026
        xmax =
4.846024751756507
        text = "then"
    intervals [18]:
        xmin =
4.846024751756507
        xmax =
5.070082369386892
        text = "I"
    intervals [19]:
        xmin =
5.070082369386892
        xmax =
5.298674976151819
        text = "will"
    intervals [20]:
        xmin =
5.298674976151819
        xmax =
5.939352446862325
        text = "chill"
    intervals [21]:
        xmin =
5.939352446862325
        xmax =
6.8310204081632655
        text = "_"
```

Praat TextGrid file format

```
to      0.614   0.753
day     0.804   1.248
the     1.248   1.404
wea     1.404   1.612
ther    1.612   1.723
is      1.723   1.888
fine    1.888   2.545
_       2.545   2.904
I       2.904   3.033
will    3.033   3.253
_       3.253   3.314
go      3.314   3.434
for     3.434   3.637
a       3.637   3.746
run     3.746   4.149
_       4.149   4.515
then    4.515   4.846
_       4.846   4.927
I       4.927   5.07
will    5.07    5.298
_       5.298   5.358
chill   5.358   5.939
```

CSV (character separated values) spreadsheet and database format

In this case, TSV (tab separated values)

NEW HOMEWORK ASSIGNMENT

English: Duration properties (without pauses)

Attributes	Values	Attributes	Values
n:	17	intercept:	172.843
min:	72	slope:	3.24
max:	401	std:	99.572
mean:	198.76	coeff var (%):	50.095
median:	213.0	nPVI:	71
mean rate:	5.03	rPVI:	138
median rate:	4.69	100*rPVI/med:	65
total:	3379	nPVI*med/100:	151
range:	32		

Chinese: Duration properties (without pauses)

Attributes	Values	Attributes	Values
n:	19	intercept:	153.132
min:	67	slope:	0.64
max:	318	std:	65.903
mean:	158.89	coeff var (%):	41.476
median:	148.0	nPVI:	43
mean rate:	6.29	rPVI:	69
median rate:	6.76	100*rPVI/med:	47
total:	3019	nPVI*med/100:	64
range:	251		

NEW HOMEWORK ASSIGNMENT

1. The mean rate of the Chinese version (4.8) is higher than that of the English version (3.91), which indicates that the fluency if higher when I speak Chinese.

2. When speaking English, the syllable duration seems to vary more drastically, while in Chinese, every syllable duration varies within a range without too drastic change.

   To some extent this can be explained by the prosodic feature of English and Chinese: Chinese is a syllable-timed language, where each syllable has a roughly same duration, and each character is an independent syllable which enjoys a high degree of individuality. ...

   English is a stress-timed language, where syllables between each stress have a roughly same duration. In English each word or syllable is at the disposal of the whole sentence, and it is in this way that various weakening and liaison come into being.

Additional comments:

- English also has a distinction between strong syllables, with complex structure (*streets*, /stri:ts/, 6 phonemes, and weak syllables (*walking*, *unde**cid**ed*)
- The strong syllables may have lexical stress.
- Any syllable, including lexically unstressed syllables, strong or weak, may be stressed in a contrastive or emphatic context.
- This distinction determines a rhythmic alternation between stressed strong syllables and unstressed weak syllables.

NEW HOMEWORK ASSIGNMENT

$$nPVI(D) = 100 * \sum_{i=2}^{n} \left| \frac{(d_i - d_{i-1})}{(d_i + d_{i-1})/2} \right| / n, for\ D = (d_1, \ldots, d_n)$$

Description:

100 multiplied by the average normalised duration difference between two neighbouring durations (for example, of syllables).

The duration difference is the difference between two neighbouring durations.

The duration difference divided by the average of the two durations is the normalised duration difference.

A spreadsheet file with examples of calculations with durations, including the nPVI (normalised Pairwise Variability Interval) is on the class website.

You can find out more in my open access article in JIPA (the Journal of the International Phonetic Association):
https://www.cambridge.org/core/journals/journal-of-the-international-phonetic-association/article/rhythms-of-rhythm/320466201A281543DA7768741DB99B7D

MODULATION

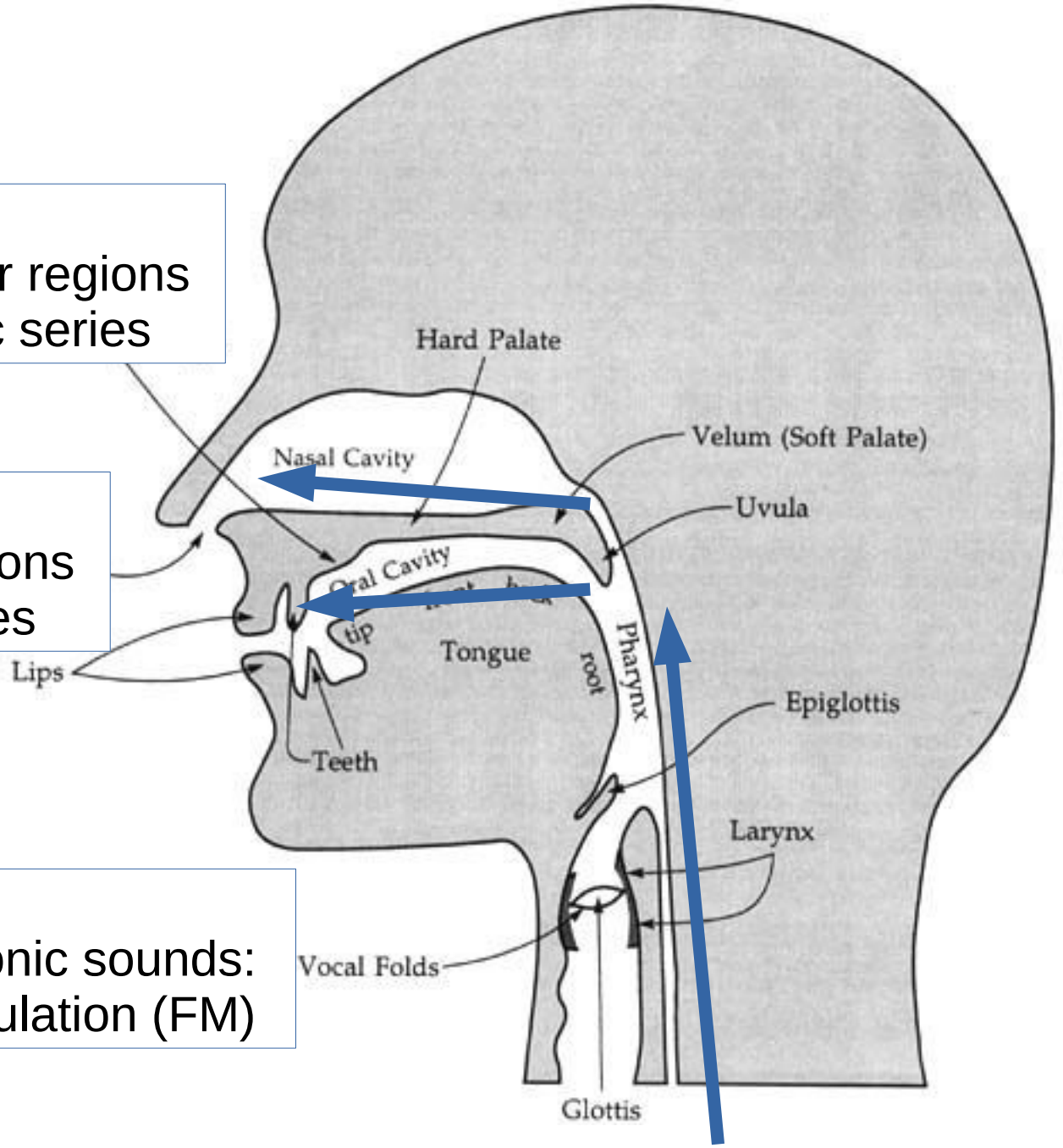
HOW INFORMATION IS CONVEYED BY SPEECH

MODULATION: THE SOURCE-FILTER MODEL OF VOWELS

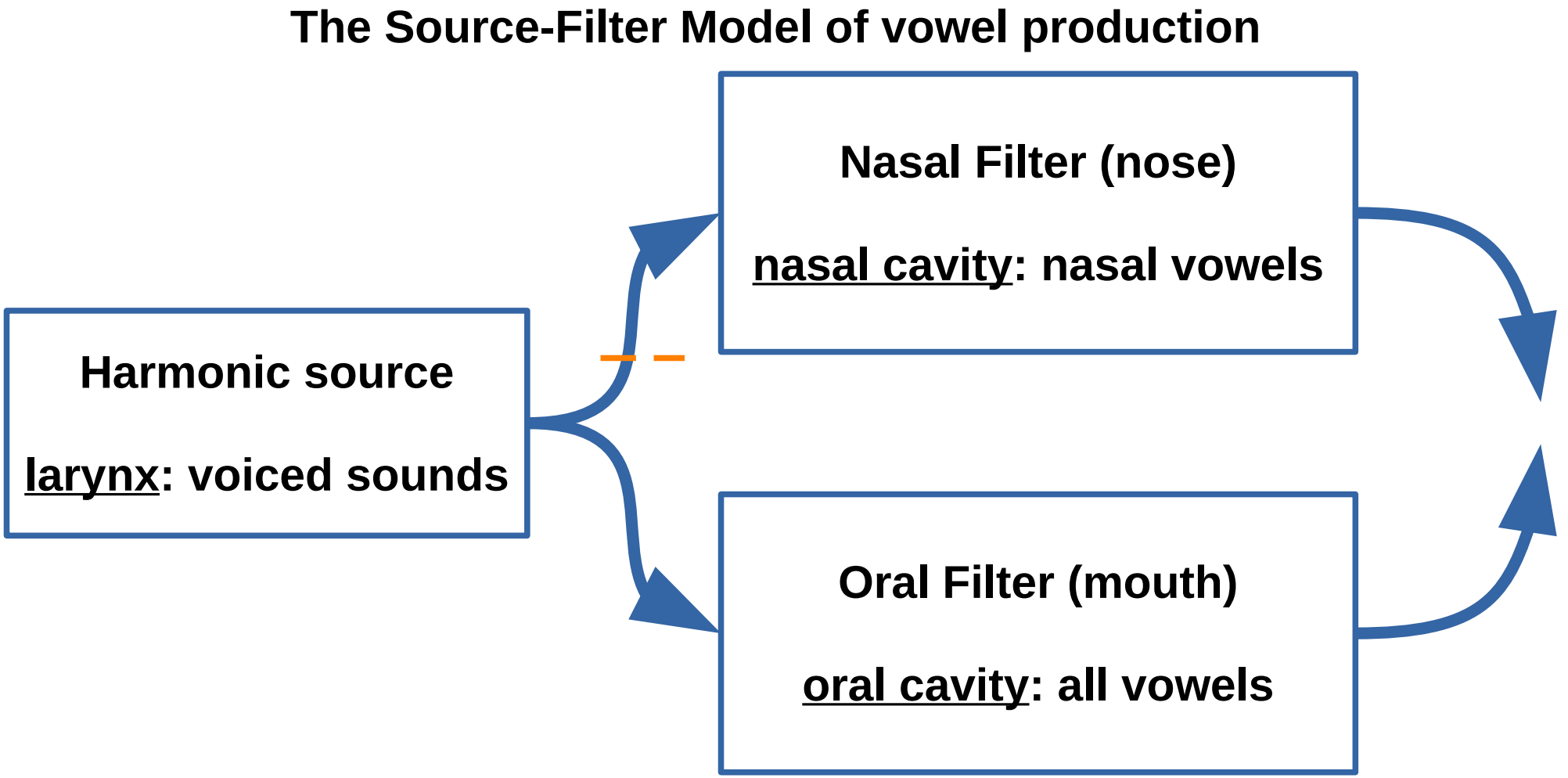
Oral Cavity:
- formant filter for regions in the harmonic series

Nasal Cavity:
- formant filter for regions in the harmonic series

Larynx:
- source of harmonic sounds:
- Frequency Modulation (FM)



MODULATION

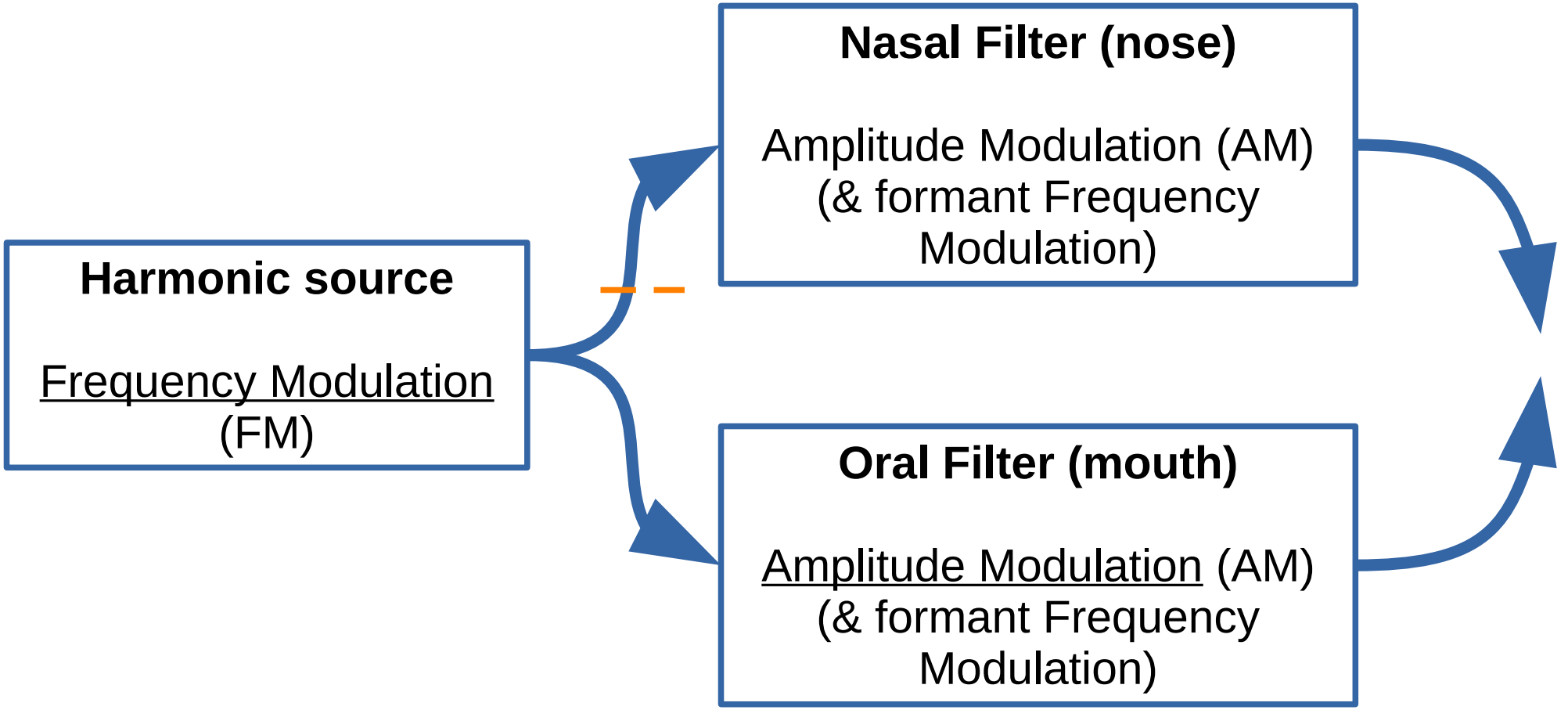


airflow

Consonants are different kinds of obstruction of the airflow.

MODULATION

The Source-Filter Model of vowel production



airflow

Consonants are different kinds of obstruction of the airflow.

FREQUENCY MODULATION: TRY IT OUT ...

1. Carrier signal in the larynx: sing “Aaaaah!”, on one note!
2. Frequency modulation: sing a melody with “Aaaaah!”

   The frequency of the carrier signal increases and decreases in order to convey information:

   - in **English**, for example:
     - pitch accent: marking stressed, contrastive, emphatic syllables
     - final rise or fall: final/non-final; asking questions; making statements
     - expressing involvement or detachment (inclination, declination; register change)
   - in **Mandarin**, for example:
     - phonemic lexical tone: *mā*, *má*, *mǎ*, *mà*
     - morphemic lexical tone: *ô*!
     - intonation: register change; change of final tone; emphasis
3. Amplitude modulation

   Consonants generally have a lower amplitude than vowels, and combine with high amplitude vowels to make syllables

   In phonology: the *sonority curve*

MODULATION: HIGH FREQUENCY AM AND FM

Amplitude modulation:

1. phonetics:
   amplitude curve, syllable,
   stress-accent
2. phonology:
   sonority curve, syllables, stress

Carrier signal:

1. larynx:
   harmonic sounds
2. constriction:
   noise sounds

FM envelope modulation signal:

1. phonetics:
   F0, pitch track
2. phonology:
   tones, pitch accents, intonation

MODULATION: LOW FREQUENCY AM AND FM

Amplitude modulation:

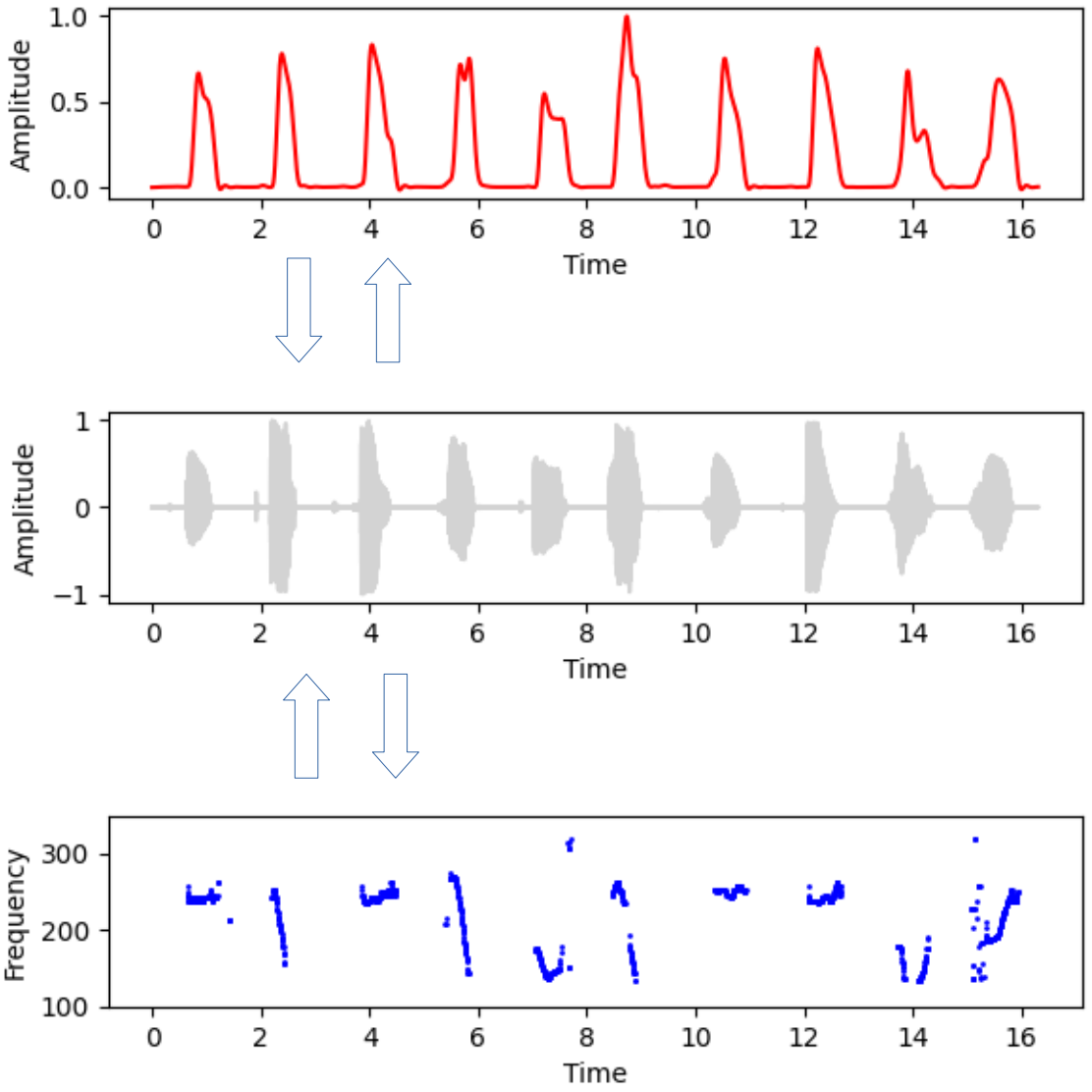
1. phonetics:
   amplitude curve, syllable, stress-accent
2. phonology:
   sonority curve, syllables, stress

Carrier signal:

1. larynx:
   harmonic sounds
2. constriction:
   noise sounds

FM envelope modulation signal:

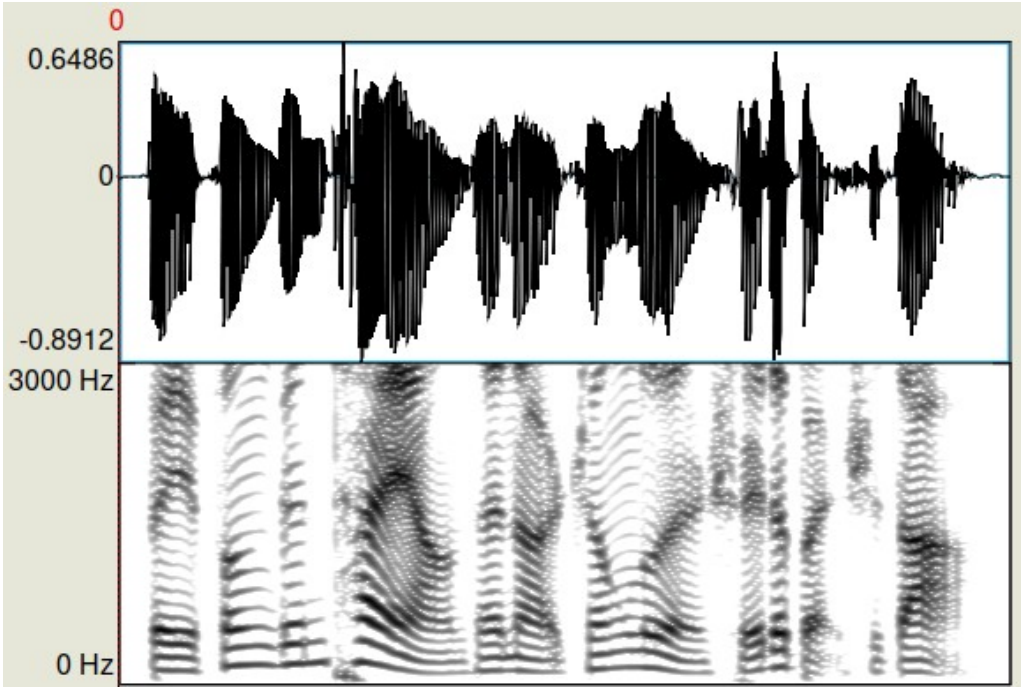
1. phonetics:
   F0, pitch track
2. phonology:
   tones, pitch accents, intonation



MODULATION THEORY OF SPEECH

OVERVIEW USING PRAAT

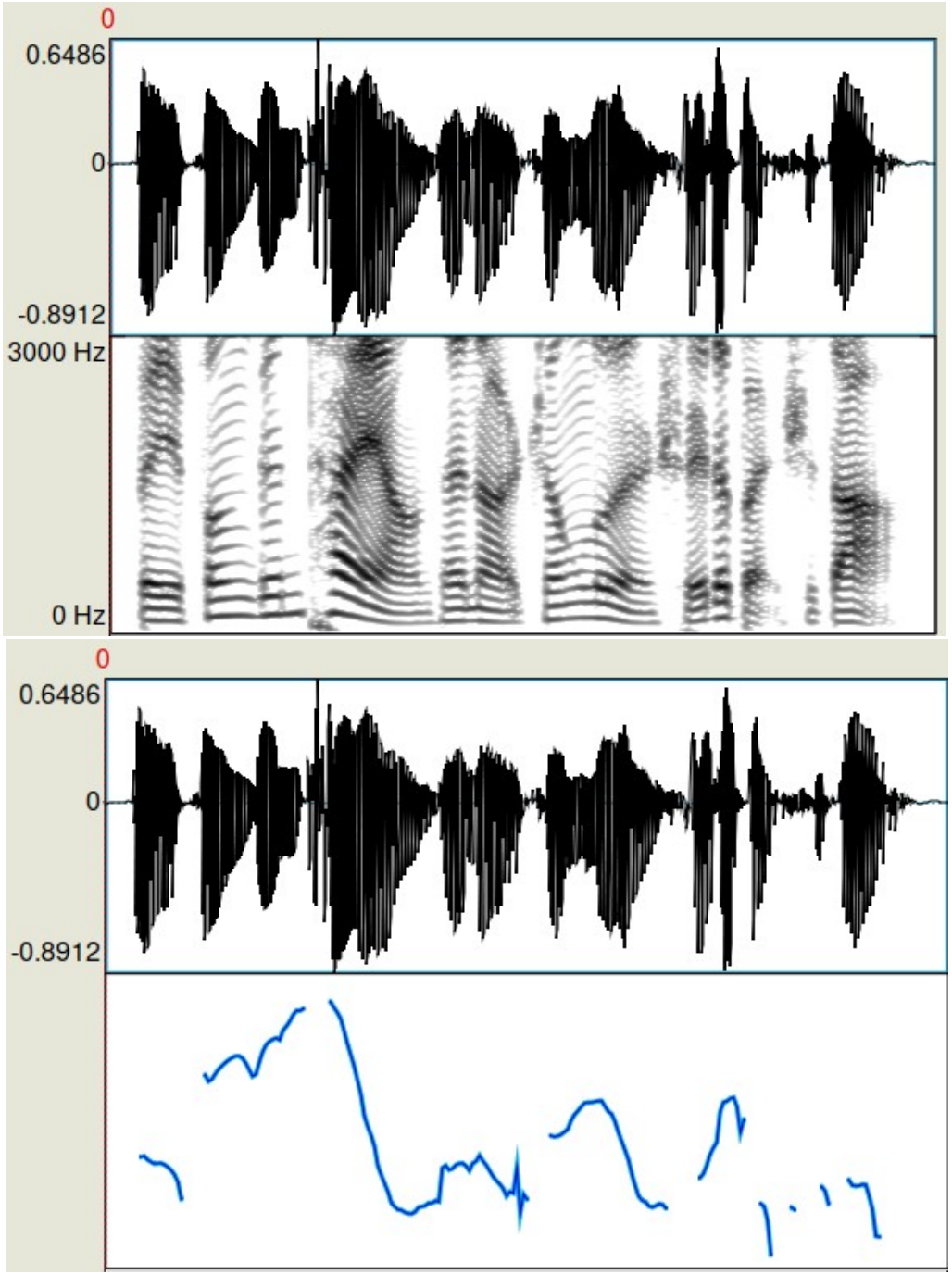
THE FREQUENCIES OF SPEECH



Waveform, oscillogram

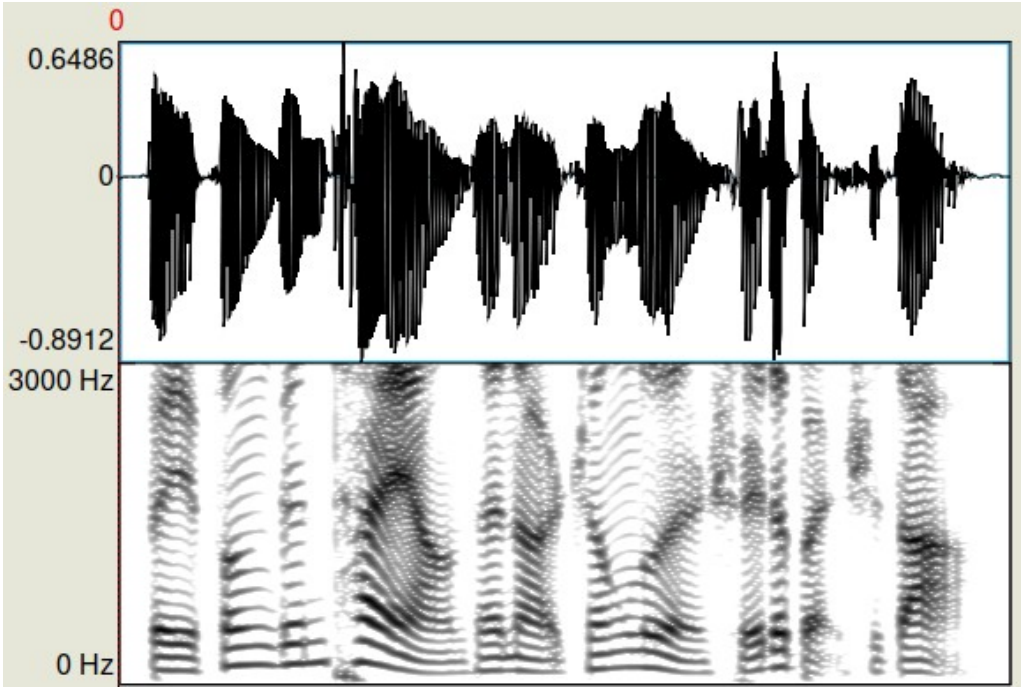
Spectrogram

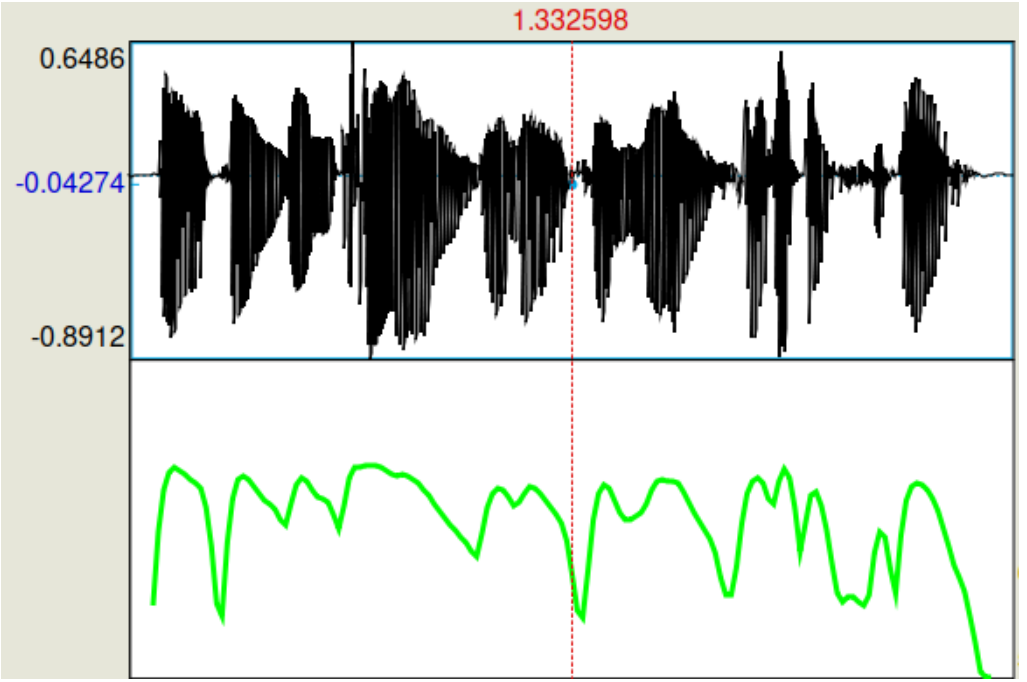
THE FREQUENCIES OF SPEECH



FM, frequency modulation

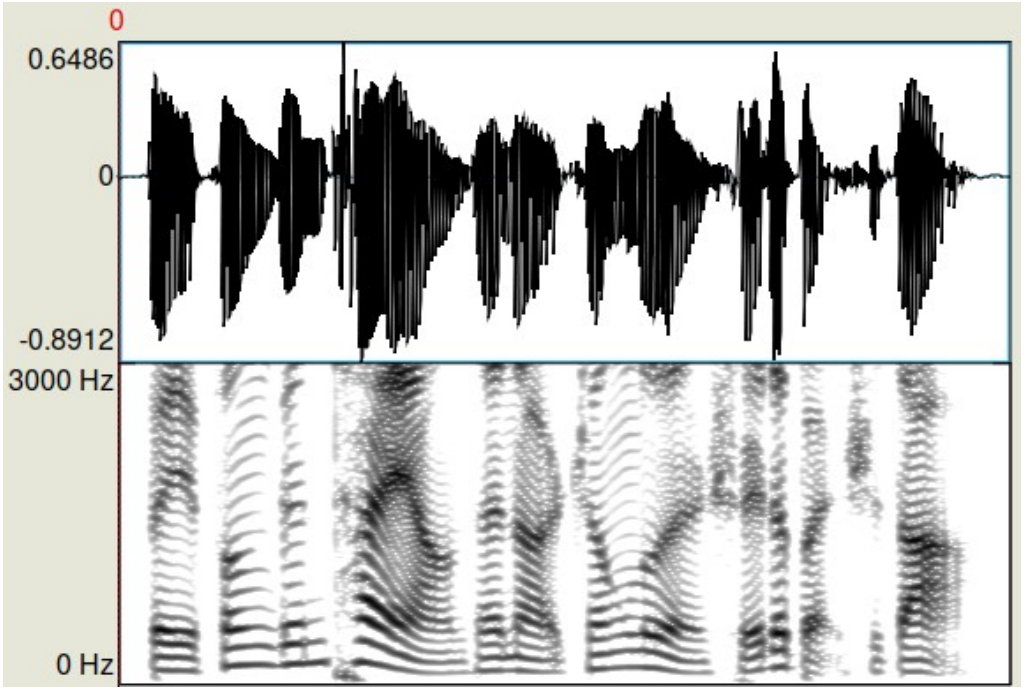
THE FREQUENCIES OF SPEECH

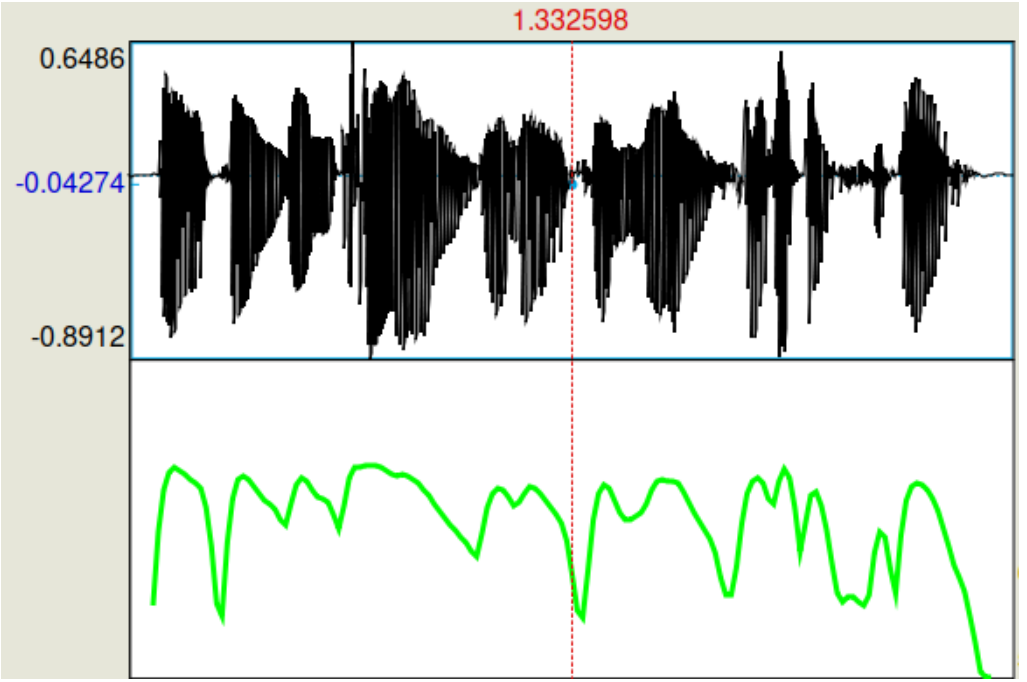




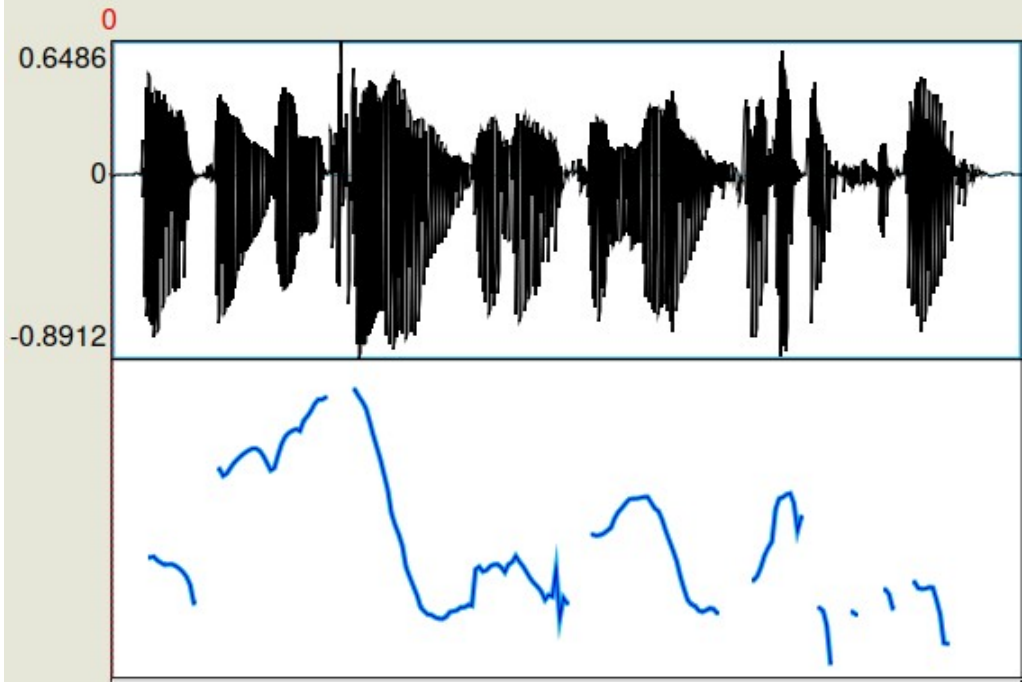
AM: amplitude modulation

THE FREQUENCIES OF SPEECH



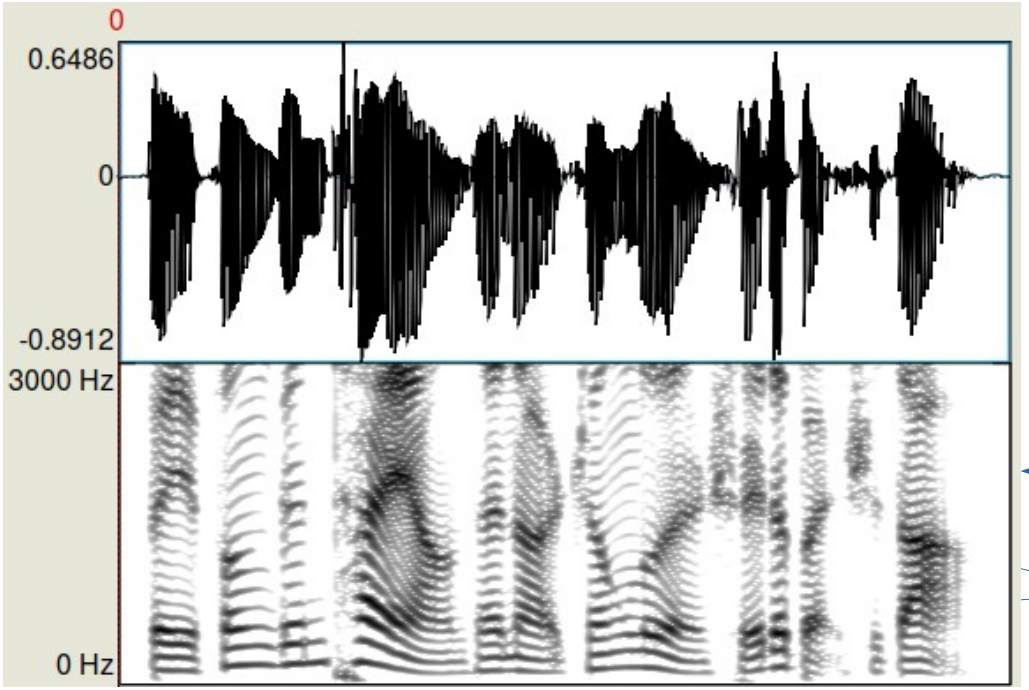


Low frequency AM



Low frequency FM

THE FREQUENCIES OF SPEECH



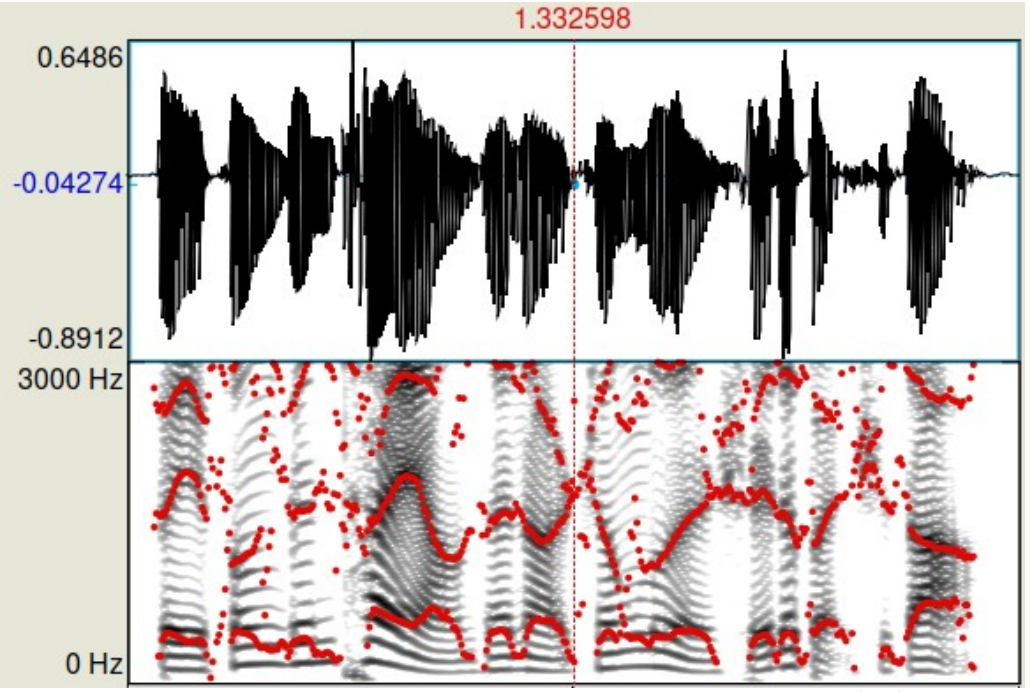
Harmonics: multiples of F0

Formants: stronger harmonic regions

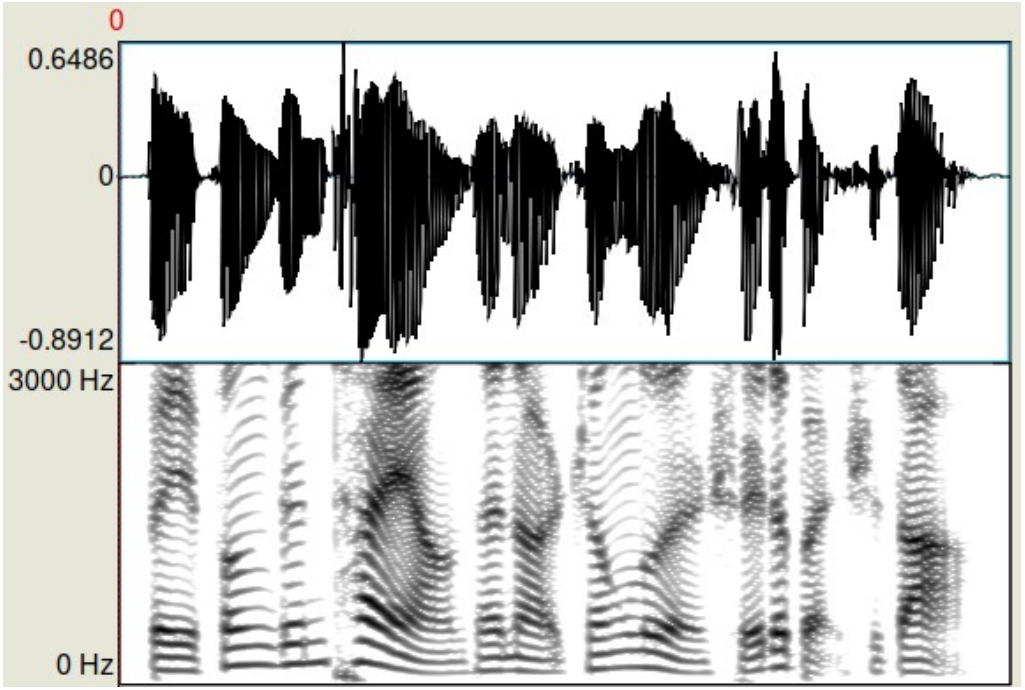
High frequency modulation, phone (consonant and vowel) modulation:

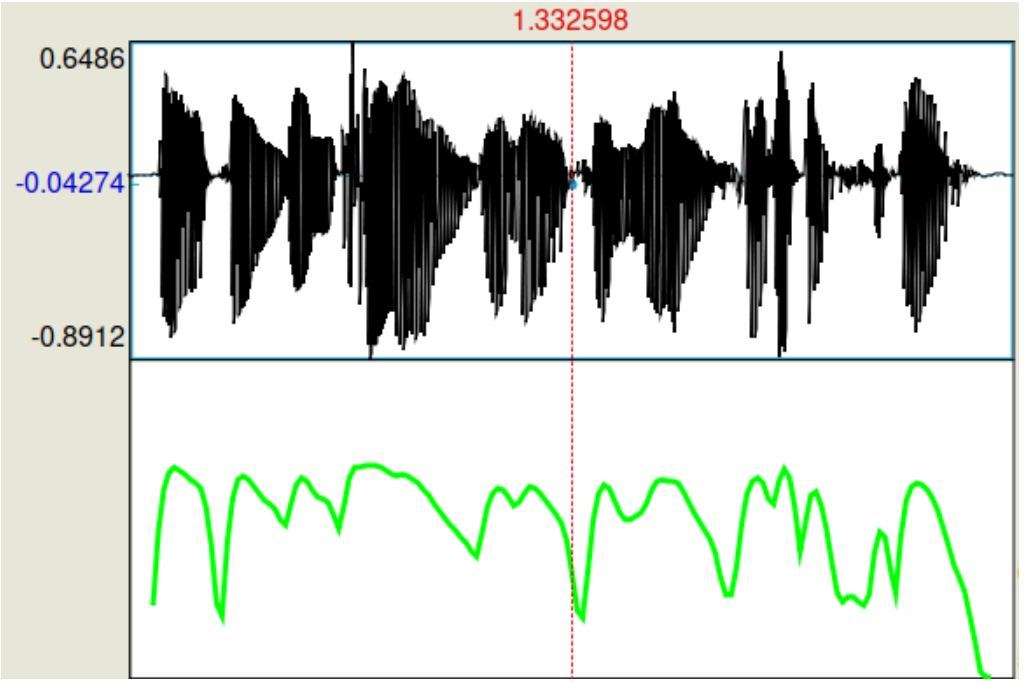
1. High frequency amplitude modulation of the harmonics by the formants

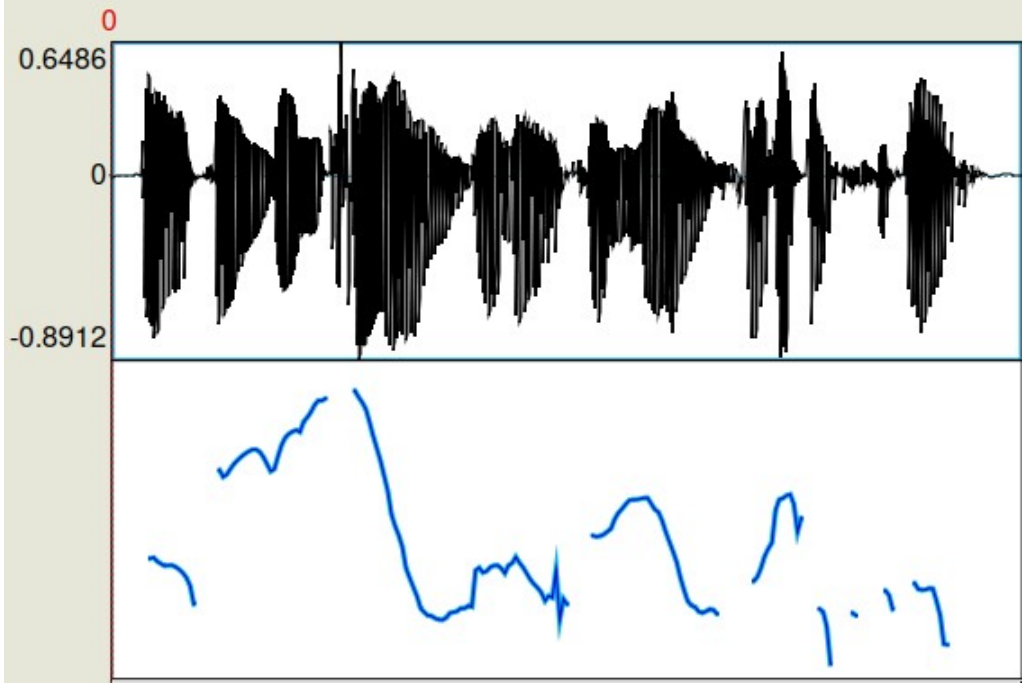
2. High frequency frequency modulation of the formants

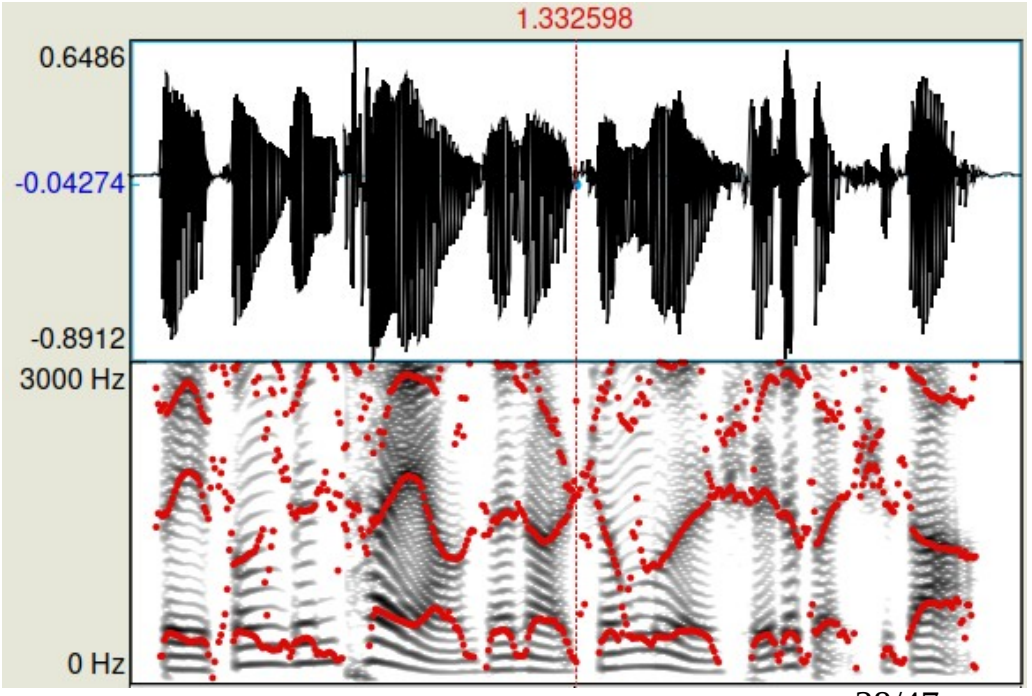


THE FREQUENCIES OF SPEECH

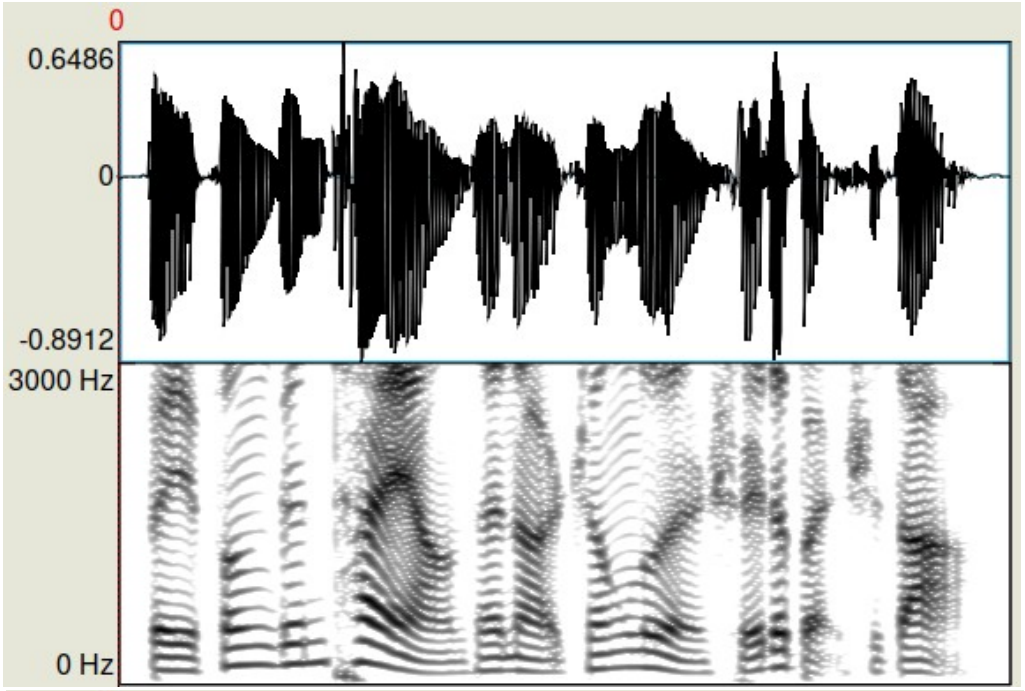


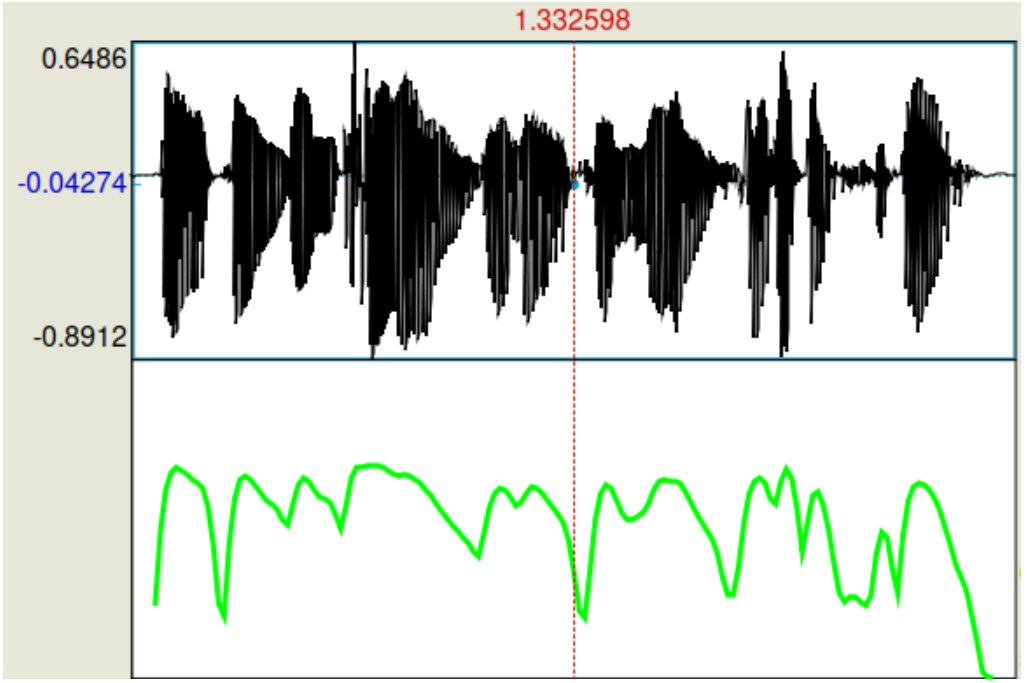


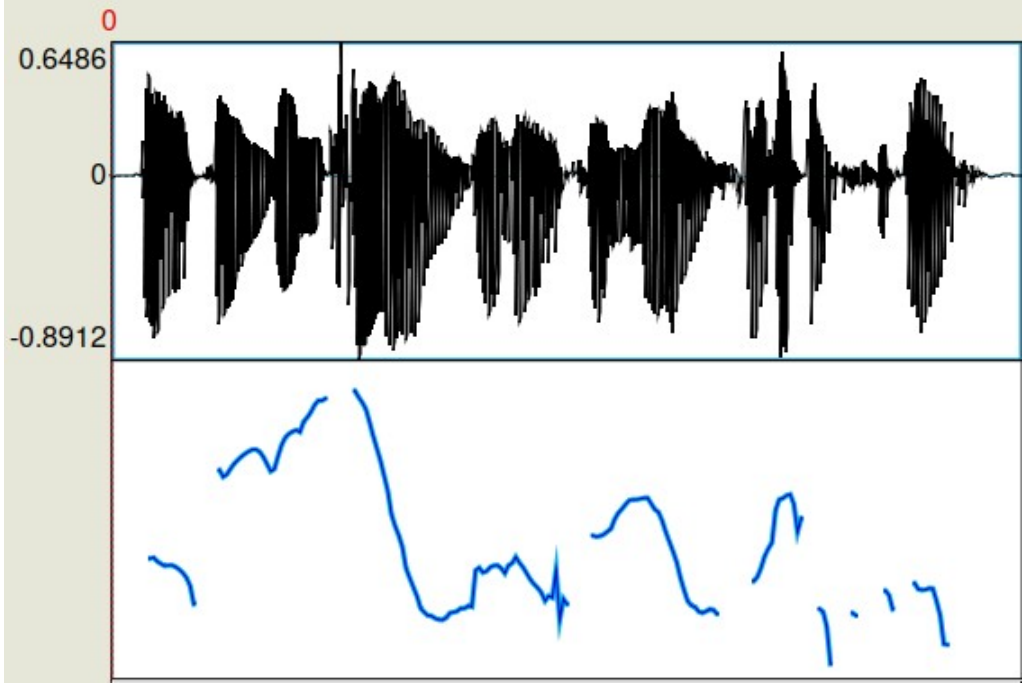


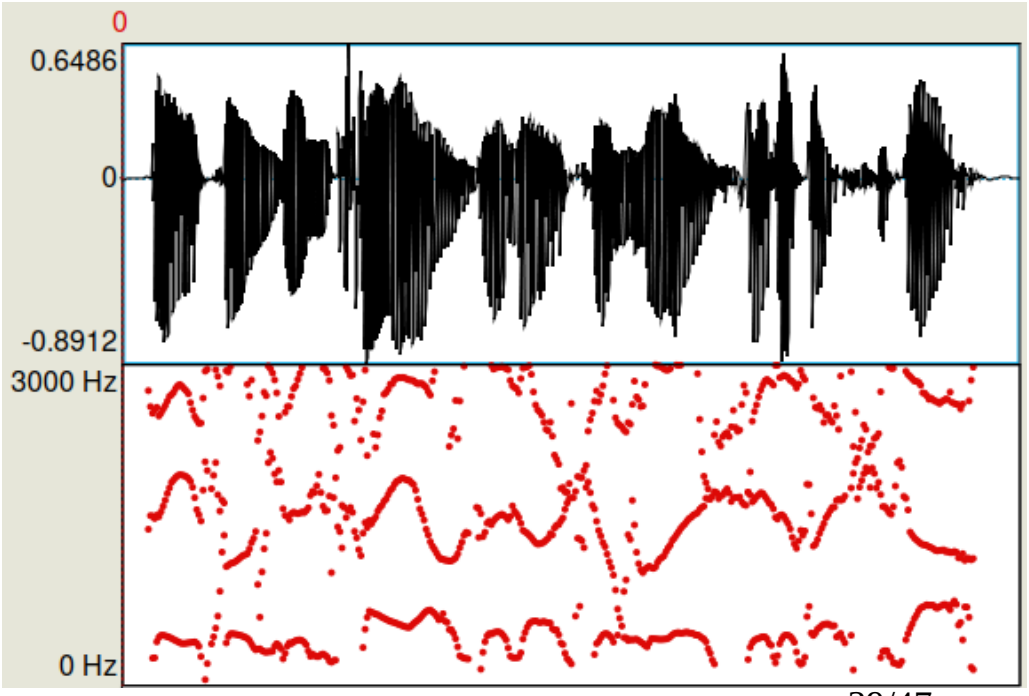


THE FREQUENCIES OF SPEECH: MODULATION



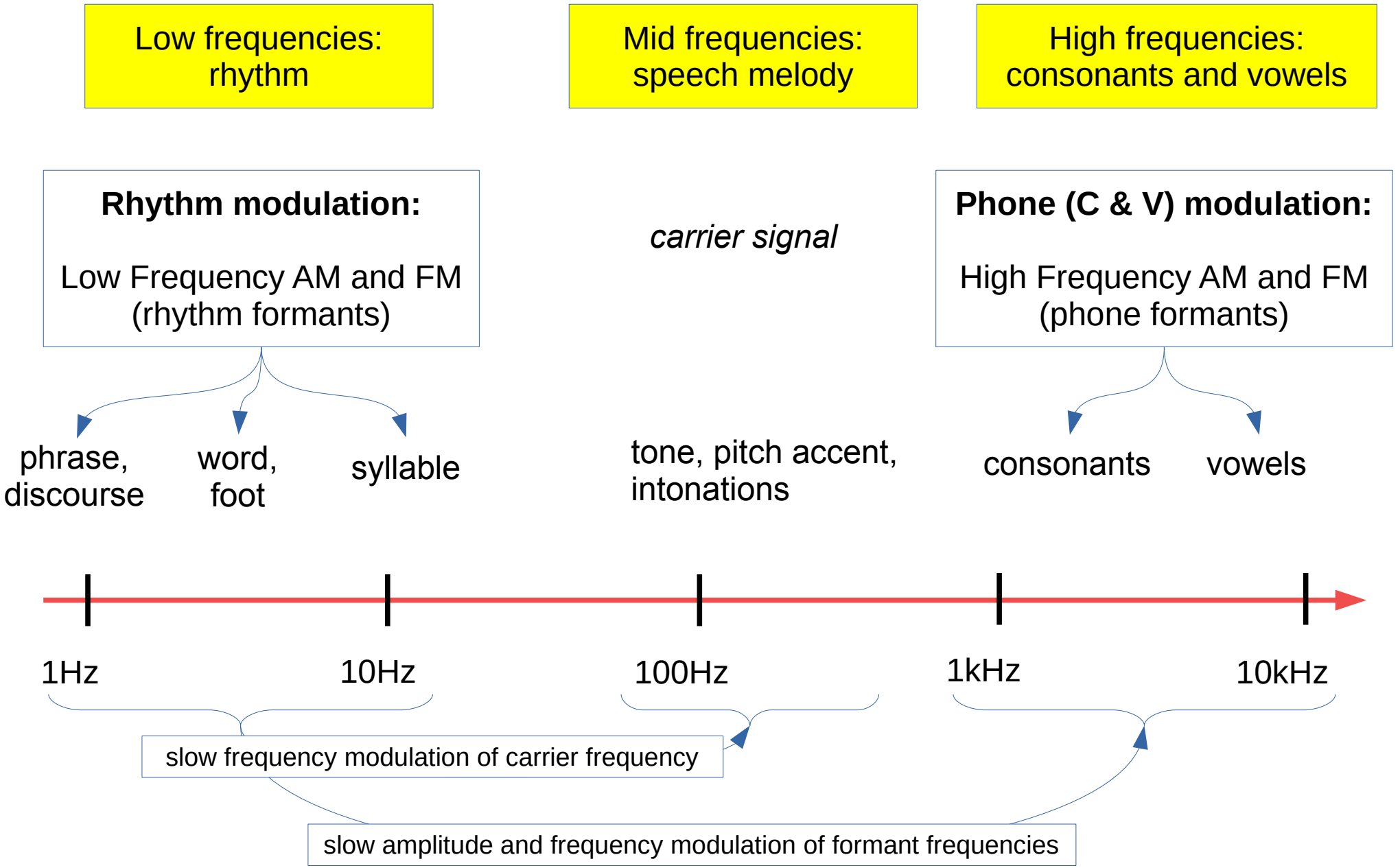






THE FREQUENCIES OF SPEECH: SUMMARY

THE FREQUENCIES OF SPEECH



FREQUENCY MODULATION (FM)

LEXICAL TONES

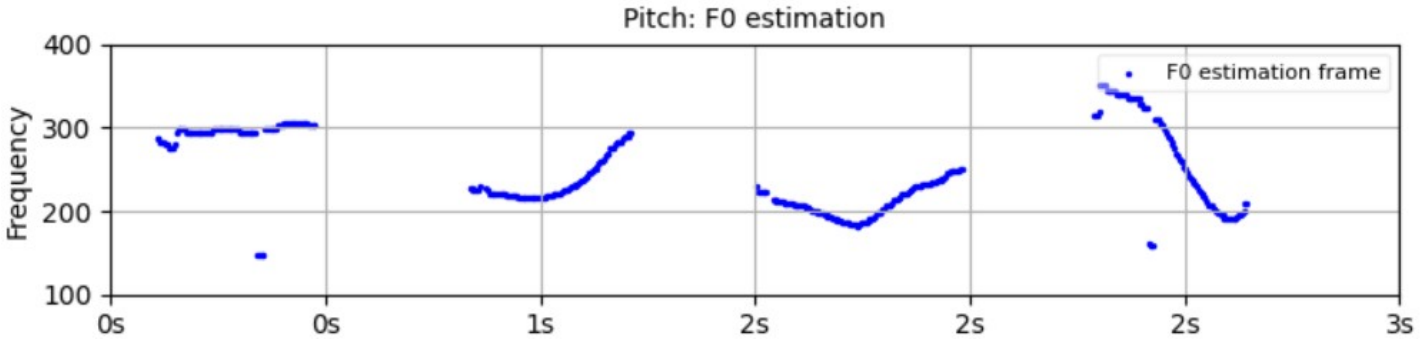
PITCH ACCENTS & PHRASAL TONES

INTONATION

FREQUENCY MODULATION: CHINESE LEXICAL TONES

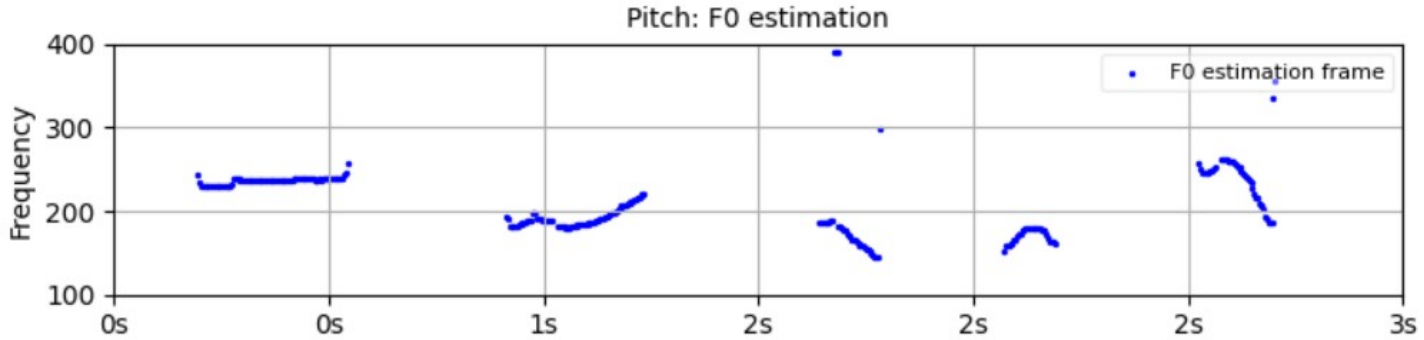
Phonemic tones
Tones 1 … 4

high female voice



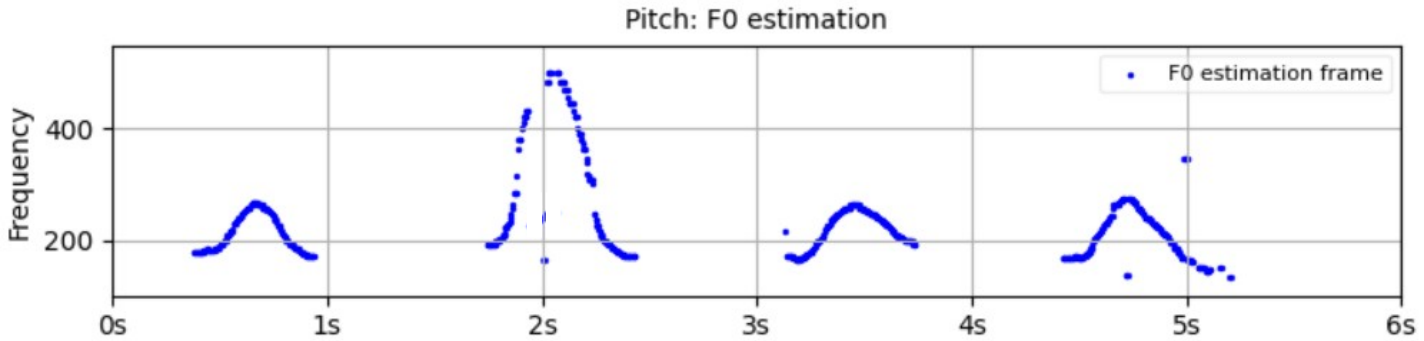
Phonemic tones
Tones 1 … 4

low female voice:
creaky Tone 3



Morphemic tone
“Tone 6” ☺

low female voice:
4 allotones

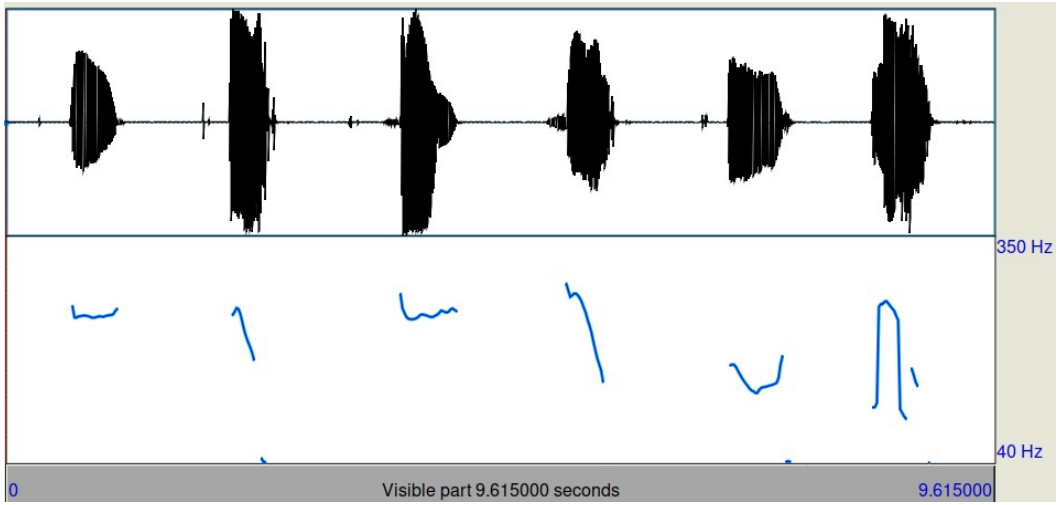


What is the meaning of this tone?

FREQUENCY MODULATION: ENGLISH PITCH ACCENTS

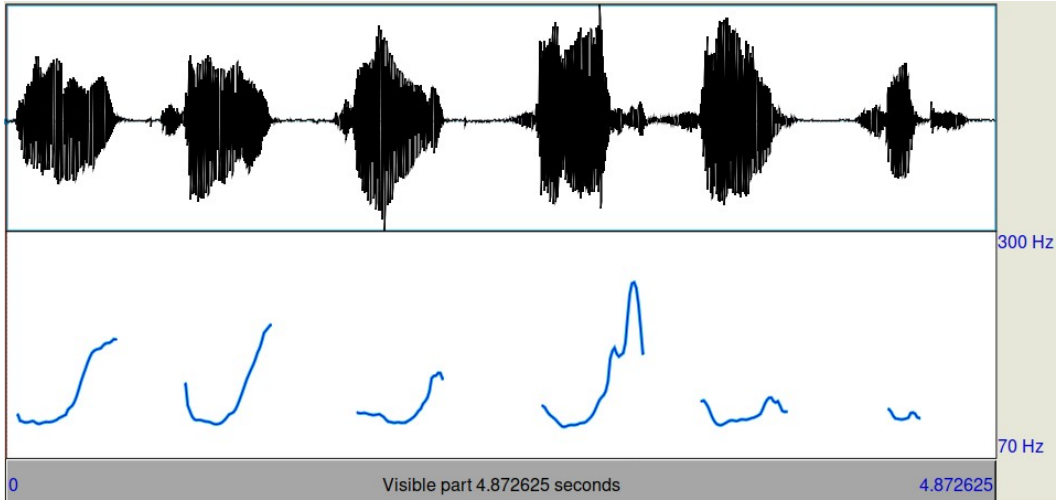
Chinese lexical tones:

function –
phonemic lexical contrast



English pitch accents:

function –
metalocutionary morphemic pointing to positions in utterances



SUMMARY

Week One:

- General introduction
- Overview of basic Praat functionality
- Creation of vowel formant charts

Week Two:

- recording speech data
- annotating speech data
- extracting duration information from a recording, using Praat
- transferring Praat data to a spreadsheet (Excel, LibreOffice Calc, etc.)
- analysing speech timing

Week Three

- Homework
- Modulation Theory
- extracting fundamental frequency information from a recording
- analysing speech melody

THANKS – NOW PLEASE PRACTICE !

And if anyone decides to write a class paper or MA thesis about a phonetic or phonological topic, do not hesitate to get in touch with me.