Lecture 2-2: Fundamental Frequency Analysis

Overview

1. **Fundamental Frequency (Fx) Contours:** a graph of fundamental frequency against time is called an **Fx contour** (otherwise called a 'pitch' track); it shows how the pitch of the voice changes through an utterance which is a key aspect of its intonation. When we look at an Fx contour we can see many features: (i) changes in fundamental frequency that are associated with **pitch accents**; (ii) the **range** of Fx used by the speaker; (iii) **voiced** and **voiceless regions**; and (iv) **regular** and **irregular** phonation.
2. **Phonology of Intonation:** the phonological study of intonation leads us to ideas of **prosodic phrasing** – that utterances are broken up into rhythmic units, sometimes called intonation phrases; of **accented syllables** – that some syllables can be given prominence by means of a pitch accent; of **nuclear accent** – that the last significant pitch accent in the phrase is of particular importance in defining sentence function; and of **accent type** – that phonologically, accents fall into a small number of distinct categories (see figures 2-2.1 & 2-2.3). It is important to acknowledge individual variation in the realisation of intonation. In particular, different speakers have different Fx ranges which leads to the idea that listeners **normalise** or standardise intonation prior to phonological categorisation.
3. **Distributions of Fundamental frequency**: using the Laryngograph we can establish the durations of each individual vocal fold cycle for a phrase or passage; this data is called **fundamental period data**, or **Tx** for short (see figure 2-2.2). From this data we can calculate the **instantaneous fundamental frequency** value for each period: this is the frequency the period would have if that cycle were repeated for one second. A stream of such **Fx** values from an utterance plotted against the time at which they occur gives us an Fx contour. We can also use this stream of Fx values (from a 2 min passage, say) to calculate a **fundamental frequency distribution** or **histogram**, called **Dx** for short. From this distribution we can take measurements of central tendency (median or mode) and also measurements of range (percentiles). Typically Fx distributions are plotted on a logarithmic frequency scale, with the vertical axis indicating the amount of time spent at each frequency.
4. **Measurement of Fx Regularity**: we can also use the stream of instantaneous Fx values to make measurements of regularity. Individual Fx periods can be considered part of 'regular' voicing if they have a duration similar to their neighbours. If individual periods are dissimilar to their neighbours, then they must be part of irregular voicing. Thus we can compare a Dx plot of all periods (**Dx1**) with the Dx plot of regular periods only (**Dx2**). The difference is a measure of irregularity: if the speaker has a regular voice quality, there will be little difference between the two plots; conversely a large difference shows the use of an irregular voice quality (see figure 2-2.4). Irregularity can also be shown on a **two-period scatterplot** (**Cx**) in which adjacent periods are plotted against one another. In regular voicing, adjacent periods will have similar values and points are plotted along the diagonal of the scatterplot; in irregular voicing, adjacent periods will have different values and points are plotted off the diagonal. The percentage of period pairs plotted off the diagonal can also be used as a measure of irregularity in the voice.

Readings

At least one from:

- Abberton, Howard and Fourcin, Laryngographic assessment of normal voice: a tutorial. Clinical Linguistics and Phonetics, **3** (1989), 281-296. *Describes Dx, etc. Essential reading for report.*
- Baken, Clinical Measurement of Speech and Voice (1st edition), Chapter 5: Vocal fundamental frequency. *Technical description of Fx measurement.*

Learning Activities

You can help yourself understand and remember this week's teaching by doing the following activities before next week:

1. Write a set of definitions in your own words for the terms Lx, Tx, Fx, Dx-1, Dx-2 and Cx, explaining what each is good for.
2. Sketch a 'boxes and arrows' schematic diagram showing the chain of processes which lead from current flow across the neck to a Dx distribution.
3. Read Abberton, Howard & Fourcin (1989) and summarise in your own words what Laryngographic measures they suggest may be useful in characterising normal voices.
4. Investigate Dx from the point of view of your knowledge of statistics. Discuss the utility in this situation of different statistics commonly used to characterise non-normal distributions.

If you are unsure about any of these, make sure you ask questions in the lab or in tutorial.

Abbreviations

Lx	Larynx excitation
Tx	Period (T) of excitation
Fx	Fundamental frequency of excitation
Dx	Distribution of fundamental frequency of excitation
Cx	Scatter ("cross") plot of fundamental frequency of excitation
Qx	Distribution of closed quotient values

Reflections

You can improve your learning by reflecting on your understanding. Here are some suggestions for questions related to this week's teaching.

1. What is the difference between a stressed syllable and an accented syllable?
2. What other differences are there between unaccented and accented syllables apart from fundamental frequency?
3. What is meant by perceptual 'normalisation' in general? Think of some examples of normalisation occurring with other human senses.
4. What are the advantages and disadvantages of mean, median and mode as measures of the central tendency of a distribution?
5. What are the advantages and disadvantages of standard deviation, inter-quartile range and total range as measures of the breadth of a distribution?
6. What requirements influence the choice of measures of average Fx or measures of Fx range for clinical use?
7. How useful do you think a Laryngograph would be in the clinic?
8. How might the choice of recording material (spoken text) affect the shape of the fundamental frequency distribution?

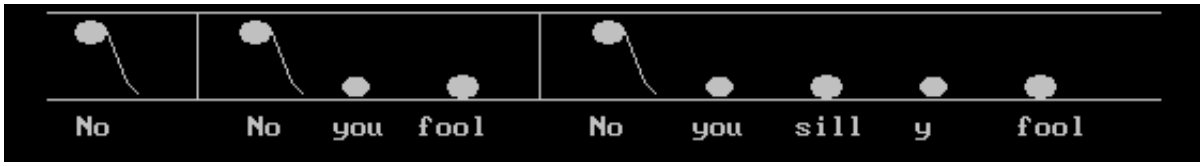
Examination Questions

These are questions from past exam papers. You may like to write outline answers to these, or to discuss them in tutorial.

1. Explain how the Laryngograph is able to provide us with information about the intonation, fundamental frequency range and regularity of a person's speech. Give one example of each type of information being used clinically. [2001/2]
2. Explain how a speaker is able to change the fundamental frequency of their voice. How can the Laryngograph be used to describe and assess their use of fundamental frequency? [2003/4]
3. Give an overview of how the Laryngograph may be used to analyse a speaker's use of fundamental frequency. Critically evaluate different measures of average fundamental frequency, range of fundamental frequency and regularity from the point of view of monitoring the progress of a client undergoing therapy. [2005/6]

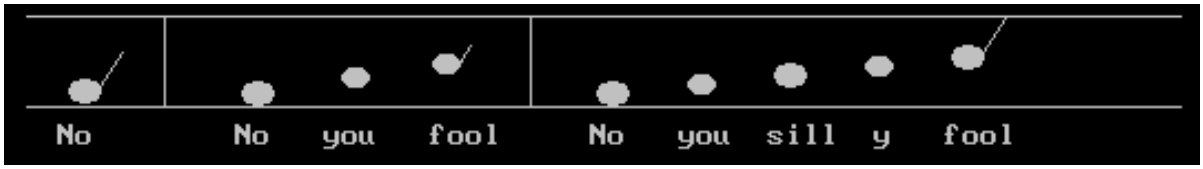
Figure 2-2.1 Nuclear tones

High fall

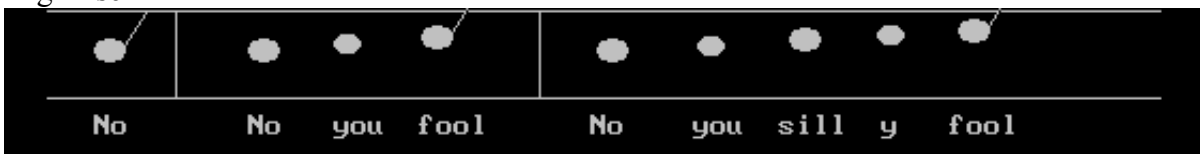


Low fall

Low rise



High rise



Fall rise

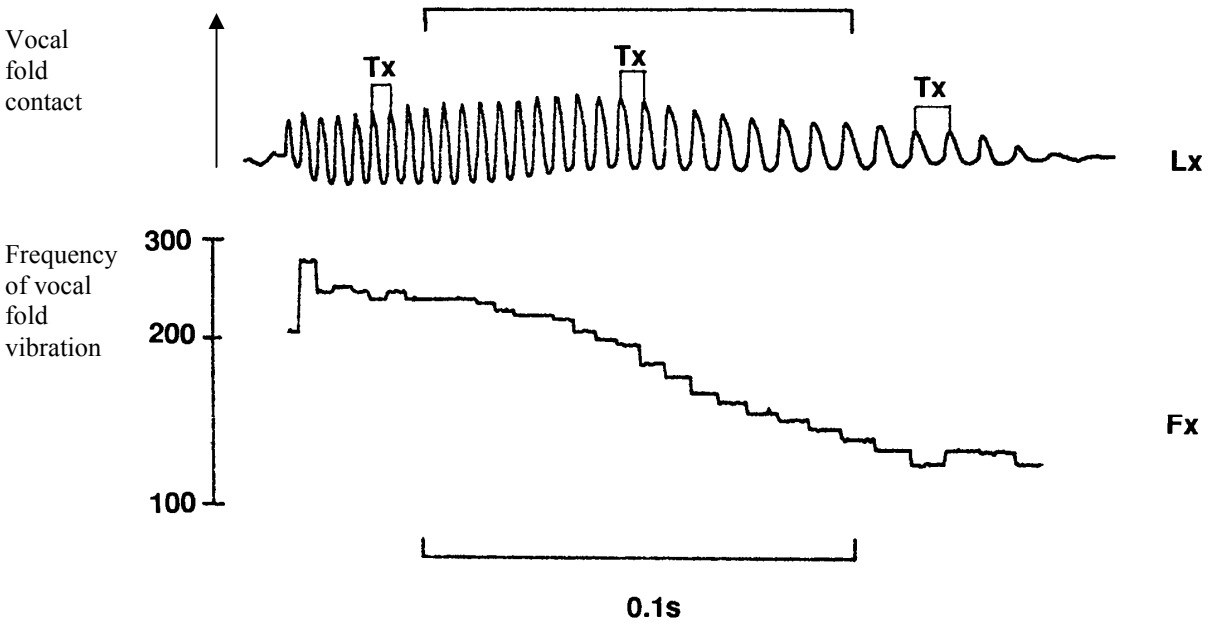
Rise fall

Figure 2-2.2 Conversion of Lx to Tx to Fx

Each vocal fold vibration has a rapid closure which is easy to locate in the Lx waveform. The time interval between successive closure instants is the excitation period or Tx.

Each excitation period is associated with an instantaneous fundamental frequency estimate Fx, where

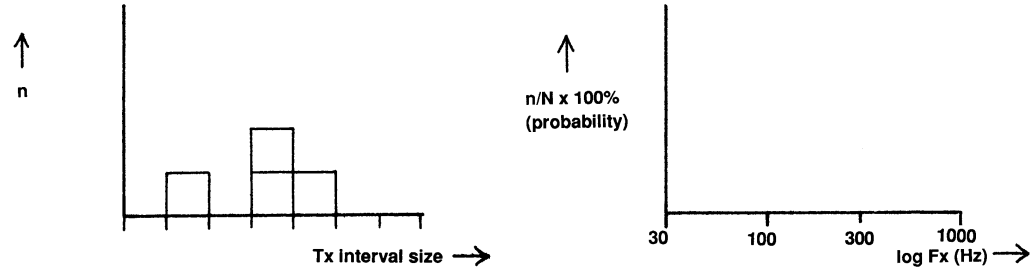
$$Fx = \frac{1}{Tx}$$



A graph of fundamental frequency against time can be obtained by plotting the instantaneous fundamental frequency value against the time at which the period took place.

A logarithmic scale is used to display Fx because it gives an approximate representation of the way in which we perceive pitch.

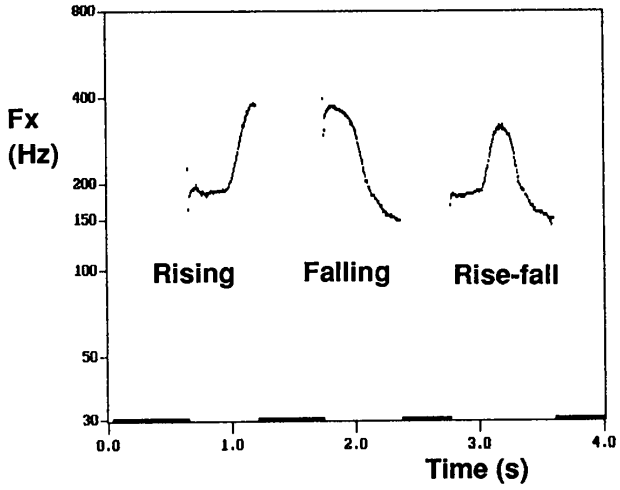
Distributions of fundamental frequency use can be calculated by building a histogram of excitation periods.



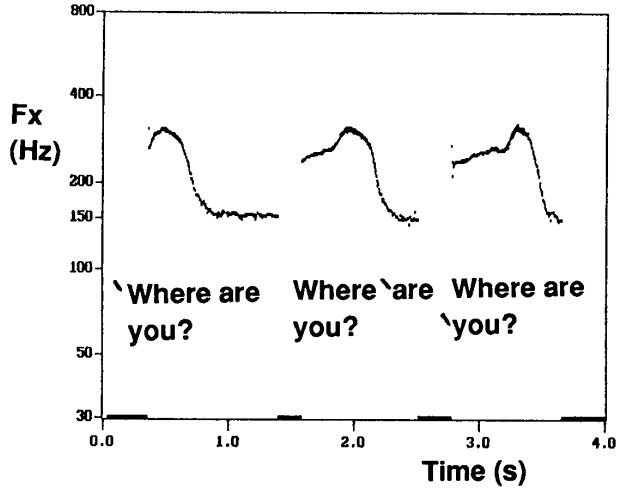
However, we prefer to plot histograms against Fundamental frequency rather than period, and frequently choose to normalise the histogram count to the amount of time spent at each frequency

Figure 2-2.3 Example Fundamental Frequency (Fx) Contours

Kinds of nuclear accents



Shift in position of nuclear accent



Interrupted voicing

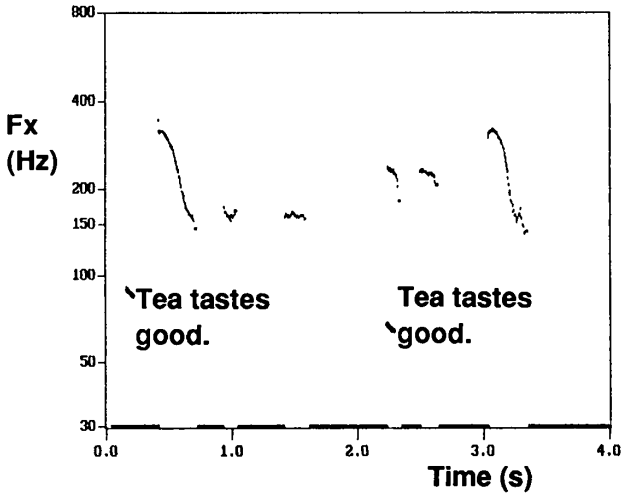
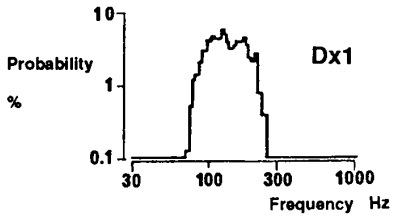
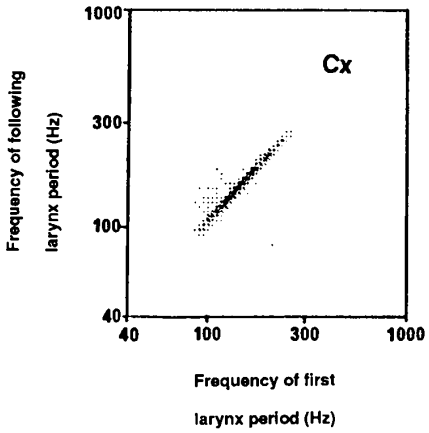


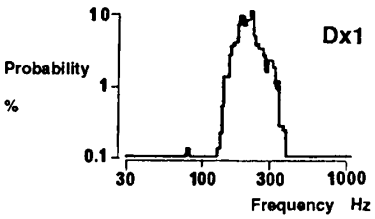
Figure 2-2.4 Example Fundamental Frequency Distributions

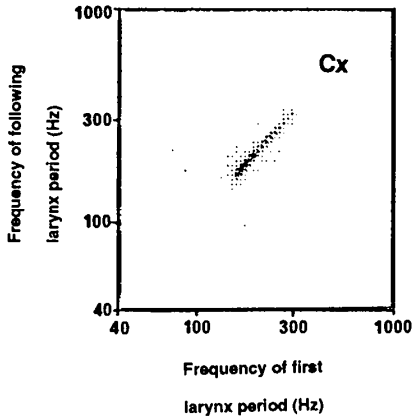
Normal male



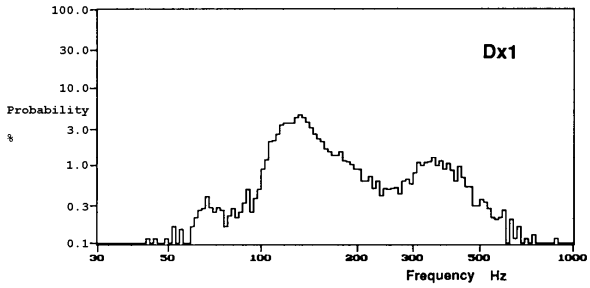


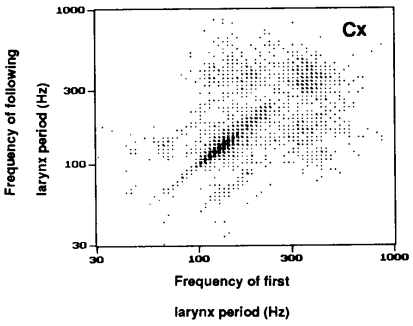
Normal female



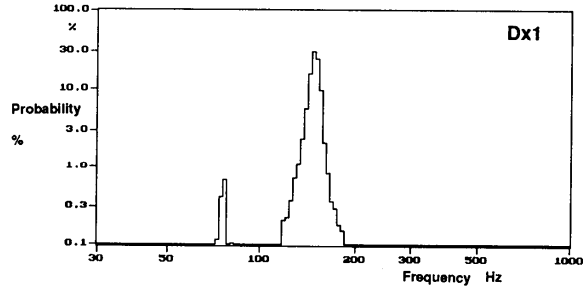


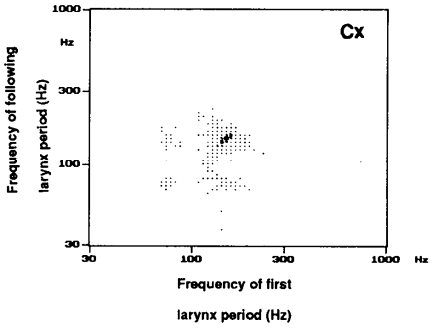
Unilateral paralysis





Problem of neurological origin





Lab 2-2: Distributions of Fundamental Frequency

Introduction

Laryngographic signals (Lx) can be automatically processed into a stream of fundamental period values (Tx) which in turn can be converted to instantaneous estimates of fundamental frequency (Fx). In this experiment, you shall look at fundamental frequency contours for a contrasting pair of sentences, and fundamental frequency histograms (Dx) for a short passage.

Scientific Objectives

- to investigate how intonation patterns used in a statement and a question relate to the distribution of fundamental frequency used when reading a passage

Learning Objectives

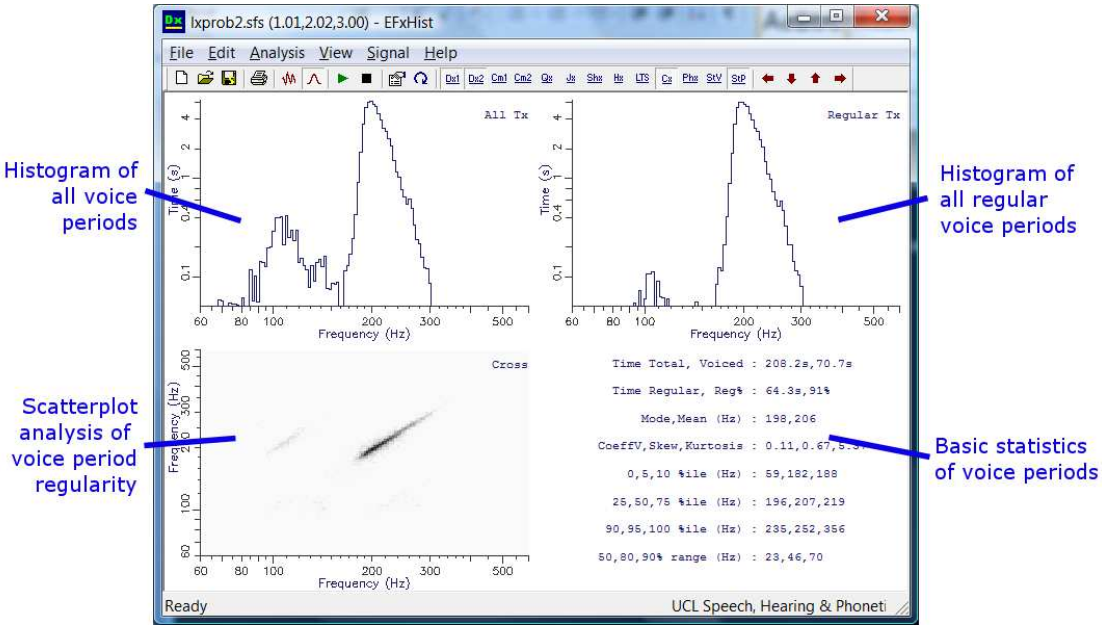
- to gain experience of how fundamental frequency changes through an utterance
- to look at long-term measures of fundamental frequency use, specifically measures of average Fx, range of Fx and regularity of Fx.
- to experience how these measures vary across a group of speakers

Apparatus

You will work in groups of three or four, but you should analyse your own recording made in week 1-9. We will use the EFxHist program that we met last week.

Method

1. Your passage and the two sentences will have been acquired for you and stored on the laboratory network. This recording will have Speech and Lx waveforms sampled at 44100Hz.
2. Open your recording in EFxHist and select the Waveforms display. Position cursors at the start and end of the passage.
3. Select the Analyses display. Ensure you show the following panels: Dx1 Histogram, Dx2 Histogram, Cx Crossplot, Stats table (Passsage). (On the View menu, ensure that "Overlay Dx1 & Dx2 is not set)



Observations

1. Analyse your recording of the 'Natural World' passage and print first and second order Dx histograms, a cross-plot and a table of statistics.

2. Use the EFxHist waveform display to print speech and Fx displays from your recordings of
   a) They saw twenty \Snowmen
   b) They saw twenty /Snowmen?

3. Annotate the print with the words in the sentences, aligned to the contour. What are the major changes in contour between the two versions? What differences do you observe between accented and unaccented syllables?

4. Compare the fundamental frequencies used in the sentences with the distribution of fundamental frequency plotted for your reading of the passage. What parts of your range did you use in what parts of your sentences? How might you use knowledge of your range to normalise your fundamental frequency contour?

5. Record the snowmen statement (or another statement of your choice) into Praat, then display and simplify the pitch contour. You will need the Praat commands:
   a) New | Record Mono Sound
   b) "To Manipulation"
   c) "Edit"
   d) Pitch | Stylise Pitch

   Use Praat to modify the pitch contour for the statement into a question using the information you obtained from your earlier analysis. How well does this work?

Concluding Remarks

1. Consider methods for measuring the **range** of fundamental frequency used by a speaker from a fundamental frequency histogram. What are their advantages and disadvantages?

2. In general, how do the two Dx histograms and the Cx plot give indications of regularity of vocal fold vibration?

Report guidelines

Imagine you are the first person to have thought about using the Laryngograph for the analysis of intonation. You'll want to tell the reader how the Laryngograph works (referencing appropriate sources), how you can use it to get information about fundamental frequency, what its strengths and weaknesses are, and to demonstrate its use. You can use the questions on this lab sheet to prompt you for things to discuss.