Fo contours as strings of syllabic pulses

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Sources of inspiration

Where do Swedish tonal accents come from?
- The ‘stress clash’ theory
- Danish stød, the ‘curl’

How is F0 lowered?
- The AES model of laryngeal mechanisms.
- F0 lowering, creaky voice, glottal stop, Danish stød

(Tomas Riad)  (Jan Gauffin)

Learn more about F0 contours in 2010 CS!
(present project)
Outline

1. Revisit the classics

2. Present a numerical model that generates Fo contours from a string of syllabic pulses.

3. It works but what does it mean?
Stetson’s chest pulse theory

- Every syllable is characterized by a ‘ballistic chest pulse’.

(based on measurements of rib cage movements, tracheal and pulmonary pressure, some EMG);

**Stetson R H (1951): Motor Phonetics**
Ladefoged’s criticism

- Stetson’s work not technically reliable.

"In our opinion there is certainly insufficient basis for a chest pulse theory of the syllable in normal speech"...

Ladefoged P (1967): Three areas of experimental phonetics
Subglottal pressure & stress
Ladefoged (1967)

Fo

Subglottal pressure

(That's a) [d ai d3 est]

(Hedidn't) [d ai d3 est]

(That's a) [s3 vei]

(He didn't) [s3 vei]

digest

survey
EMG from expiratory muscle fiber

Ladefoged (1967)

Time

EMG

Sound

The old man doddered along the road

Impulses per sec

old man dodd- road
Clues from singing & stage speech
(Sundberg 1995, 2007)

Barytone singing
Ps higher
1st beat of bar

Stage speech
Ps higher
stressed syll’s

Reading
Ps higher
on V’s A2 word

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Ladefoged (2005)

"Concluding ..., we note that stressed syllables may or may not have a greater intensity or a higher pitch, and they may or may not have bursts of internal intercostostals activity. However, they always use greater respiratory energy."

A compromise
‘Stetson light’

Let us abandon chest pulses for stress pulses
Stress
Jespersen’s view

”Akzent (Druck) ist Energie, intensive Muskeltätigkeit, die nicht an ein einzelnes Organ gebunden ist, sondern der gesamten Artikulation ihr Gepräge gibt.”

”Druck als Gesamtenergie”

Modeling Fo contours using stress pulses

Assumptions

- *Stress* involves a strengthening of all the physiological activities (respiratory, phonatory and articulatory) that the production of a *syllable* gives rise to;
- Every syllable is produced with a certain physiological ‘gain’, in other words a *quantum of energy* injected into the motoric systems of respiration phonation and articulation
- The input is idealized as an instantaneous event, a *pulse*.
- The output of is a smooth *bell-shaped curve* reflecting sluggish response characteristics.
Can Fo contours be analyzed as a summation of a string of syllabic pulses?
Speech samples and measurements
Prosodic syllable types (SAOB)

- **Stressed**
  - **Main stress**
    - “3”
  - **Secondary stress**
    - “2”
- **Unstressed**
  - “0, 1”
Words with accent I

- stressed
  - main stress
    - “4”
  - secondary stress
- unstressed
  - “0, 1”
Words with accent II

- stressed
  - main stress
    - “3”
  - secondary stress
    - “2”
- unstressed
  - “0, 1”

in compounds
# Some words & phrases

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<td>Katrin vet</td>
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<td>Ted muckar gräl</td>
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<td>Per leker polis</td>
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Speech samples

- **Words** 1-3 syllables long
- **Accent 1 & Accent 2**
- **2\text{ary stress}**
- **Unstressed** syllables
- **Phrases** 2-6 syllables long by combining the word forms.
Fo data

- Male speakers
- Central Swedish (Stockholm)
- 3-5 rep’s of each test item
- Wavesurfer pitch tracker
- Fo curves synchronized @ vowel onsets and averaged.
The declination component

\[ y = -36t + 123 \]
Raw data
Rotate & translate!
Pulse analysis
Sum the pulses,
Undo translation & rotation!
Ground rules

- Shape of pulse: Gaussian
  \[ f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left( -\frac{(x - \mu)^2}{2\sigma^2} \right) \]

- Parameters:
  - Time of peak
  - Amplitude
  - Fall & rise of slopes
Comparing accent I and II

“grå ben”

“gråben”
Emphatic stress

"Per går"

Emphasis on
1st syllable

equal stress

Emphasis on
2nd syllable
Observations

- Numerically accurate descriptions
- 1 pulse per syllable
- Pulse amplitudes correlate with 2 degrees of lexical stress
- Distinct representations of Accent I & II
Mere curve fitting?
A model for speech tech?

Syllable strings with lexical prosody $\rightarrow$ Algorithm $\rightarrow$ Fo(t)
The explanatory claim

Fo contours of Central Swedish tonal accents

... are the way they are because they are close to the unmarked (default) response of the pitch system to the Swedish form of syllabic stress.
The pulse theory account

- **Fo properties of SC tonal accents**
  - Tonal accents occur only in stressed syllables
  - They derive from stress pulses
  - They form bell-shaped curves

- **Fo properties of unstressed syllables**
  - Also derive from stress pulses (but with lower amplitudes)

- **Fo time properties** (digital to analog conversion)
  - The details of their temporal integration arise from summation of pulses.
Any problems?
What about ‘peak delay’ effects?
Smooth and seamless yet pulsed?

Q: How come a continuous curve like $F_0$ can be credibly be parsed into a series of discrete pulses?

$$\underbrace{\text{}} = \Sigma \begin{array}{c} + \end{array} \begin{array}{c} - \end{array}$$

Clue: 2 sine waves added = horizontal line

*Stetson lives again!*
*There is more than meets the eye!*
Any problems?
What about ‘peak delay’ effects?

![Graph showing vowel onset and Fo over time for 4, 40, 400 words]

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What about laryngeal pitch control?

- Default case: If the tonal accent contours get their properties from "the default response of the pitch system to syllabic stress", we should expect a tight time locking between pulses and the segmental events (vowel onsets).

- In fact, although the Fo mechanism is here assumed to get such a contribution from syllable production, it must also be expected to be able to work independently on top of that input.

- The thing to be surprised about in the case of Swedish tonal accents is this: the default model seems to do pretty well without such contributions. No extra curlicues and wiggles!
Canonical pulse shapes
Comparing 4’s and 3’s

Difference curve
low tone for accent II?
Canonical pulse shapes
Comparing (non-final) 4’s with (final) 2’s

Difference curve
low tone
for terminal juncure?
3 and final 2 are very similar

Hardly any difference!

Can they be switched with impunity?
Some samples 🎈

**Recorded (32 pattern)**

"Lundberg"

"matpersonal"

"sportbil"

"miljöakademi"

"blågrå"

**After tape splicing**

"Berglund"

"personalmat"

"bilsport"

"akademimiljö"

"gråblå"
Samples of ‘stress clash’
(Tomas Riad)

Old Norse

sammansättning 'land bói
csólichvarf
avledning 'sjuk dömrr
klók skapr
mann likr
vík ingr
stamsuffix 'tung o:
'drup an
bøjning 'herði o:z
domi de:

Difference curve
low tone
for terminal juncture?
Progress report

Where do Swedish tonal accents come from?

- Accent 2 HL pattern may arise from re-use of laryngeal gesture already in place in final main stress syllables (terminal juncture).

How is Fo lowered?

- The AES laryngeal mechanism of Fo lowering [and creaky voice, glottal stop, Danish stød]
Game plan and challenges

- Pitch patterns as deviations from stress-based default contours.
- Apply to historical and typological data
- Extend beyond Swedish
Thank you!