An Algorithm for Determining the Endpoints for Isolated Utterances

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**Outline**
- Intro to problem
- Solution
- Algorithm
- Summary

**Motivation**
- Word recognition needs to detect word boundaries in speech
- Recognizing silence can reduce:
  - Processing load
  - (Network not identified as savings source)
- Easy in sound proof room, with digitized tape

**Visual Recognition**
- Easy
- Note how quiet beginning is (tape)

**Slightly Tougher Visual Recognition**
- “sss” starts crossing the ‘zero’ line, so can still detect

**Tough Visual Recognition**
- Eye picks ‘B’, but ‘A’ is real start
  - “ff” is a weak fricative
Tough Visual Recognition

“Five”

- Eye picks ‘A’, but ‘B’ is real endpoint
  - V becomes devoiced

“Nine”

- Difficult to say where final trailing off ends

The Problem

- Noisy computer room with background noise
  - Weak fricatives: /f, th, h/
  - Weak plosive bursts: /p, t, k/
  - Final nasals
  - Voiced fricatives becoming devoiced
  - Trailing off of sounds (ex: binary, three)
- Simple, efficient processing
  - Avoid hardware costs

The Solution

- Two measurements:
  - Energy
  - Zero crossing rate
- Simple, fast, accurate

Energy

- Sum of magnitudes of 10 ms of sound, centered on interval:
  \[ E(n) = \sum_{i=-50}^{50} |s(n + i)| \]

Zero (Level) Crossing Rate

- Number of zero crossings per 10 ms
  - Normal number of cross-overs during silence
  - Increase in cross-overs during speech
The Algorithm: Startup

- At initialization, record sound for 100ms
  - Assume ‘silence’
  - Measure background noise
- Compute average (IZC’) and std dev (σ) of zero crossing rate
- Choose IZCT (zero-crossing threshold)
  - Threshold for unvoiced speech
- IZCT = \min (25 / 10ms, IZC’ * 2 \sigma)

The Algorithm: Thresholds

- Compute energy, \( E(n) \), for interval
  - Get max, IMX
  - Have silence, IMN
  \[
  I_1 = 0.03 \times (IMX - IMN) + IMN \\
  I_2 = 4 \times IMN
  \]
  (3% of peak energy)
  (4x silent energy)
- Get energy thresholds
  - ITL = \min (I_1, I_2)
  - ITU = 5 * ITL

The Algorithm: Energy Computation

- Search sample for energy greater than ITL
  - Save as start, say s
- Search for energy greater than ITU
  - s becomes start
  - If energy falls below ITL, restart
- Results in conservative estimates
  - Endpoints may be outside

The Algorithm: Zero Crossing Computation

- Search back 250 ms
  - Count number of intervals where rate exceeds IZCT
  - If 3+, set starting point, s, to first time
  - Else s remains the same
- Do similar search after end

The Algorithm: Example

- (Word begins with strong fricative)

Algorithm: Examples

- Caught trailing /f/
Algorithm: Examples

“Four”

Notice how different each “four” is

Evaluation: Part 1

• 54-word vocabulary
• Read by 2 males, 2 females
• No gross errors (off by more than 50ms)
• Some small errors
  – Losing weak fricatives
  – None affected recognition

Evaluation: Part 2

• 10 speakers
• Count 0 to 9
• No errors at all

Evaluation 3: Your Project 1

Future Work

• Three classes of speech:
  – Silence
  – Unvoiced speech
  – Voiced speech
• May be more computationally intensive solutions that are more effective