An Algorithm for Determining the Endpoints for Isolated Utterances

L.R. Rabiner and M.R. Sambur

The Bell System Technical Journal, Vol. 54, No. 2, Feb. 1975, pp. 297-315

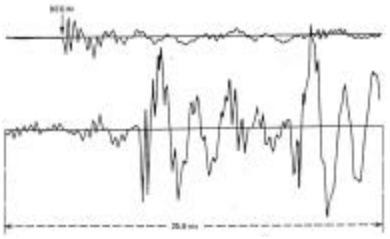
Outline

- 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

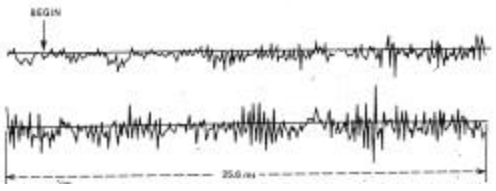
Visual Recognition



"Eight"

- Easy
- Note how quiet beginning is (tape)

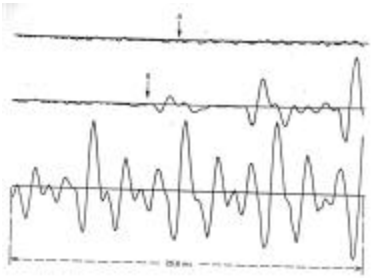
Slightly Tougher Visual Recognition



"Six"

- "sss" starts crossing the 'zero' line, so can still detect

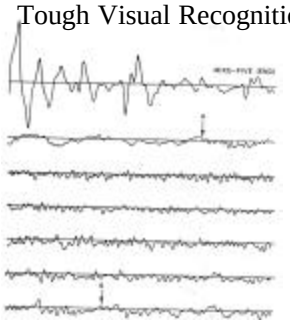
Tough Visual Recognition



"Four"

- Eye picks 'B', but 'A' is real start
  - /f/ is a *weak fricative*

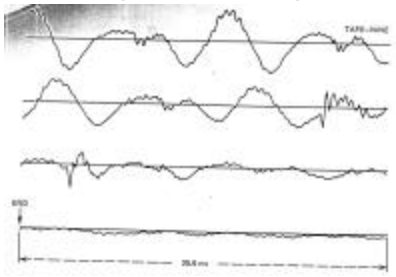
Tough Visual Recognition



"Five"

- Eye picks 'A', but 'B' is real endpoint
  - V becomes *devoiced*

Tough Visual Recognition



"Nine"

- Difficult to say where final trailing off ends

The Problem

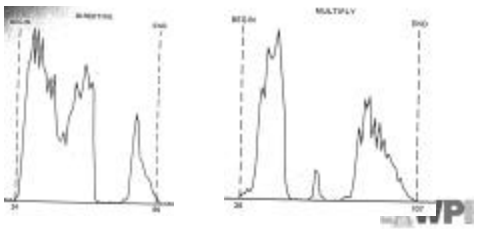
- Noisy computer room with background noise
  - Weak fricatives: /f, th, h/
  - Weak plosive bursts: /p, t, k/
  - Final nasals
  - Voiced fricatives becoming devoiced
  - Trailing off of sounds (ex: binary, three)
- Simple, efficient processing
  - Avoid hardware costs

The Solution

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

Energy

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



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 σ)

The Algorithm: Thresholds

- Compute energy, *E*(*n*), for interval
  - Get max, IMX
  - Have silence, IMN

    *I*1 = 0.03 * (IMX – IMN) + IMN

    (3% of peak energy)

    *I*2 = 4 * IMN

    (4x silent energy)
- Get energy thresholds
  - ITL = MIN(*I*1, *I*2)
  - ITU = 5 * ITL

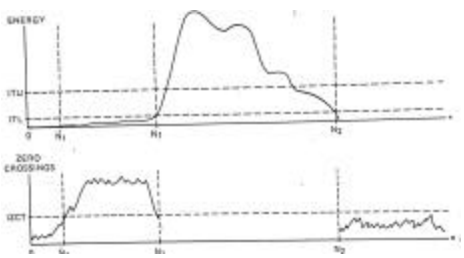
The Algorithm: Energy Computation

- 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

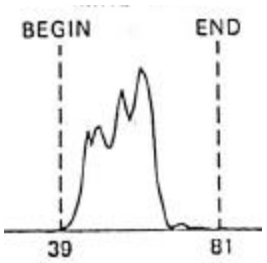
- Search back 250 ms
  - Count number of intervals where rate exceeds IZCT
    - If 3+, set starting point, *s*, to first time
    - Else *s* remains the same
- Do similar search after end

The Algorithm: Example



(Word begins with strong fricative)

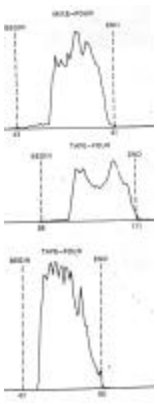
Algorithm: Examples



"Half"

- 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