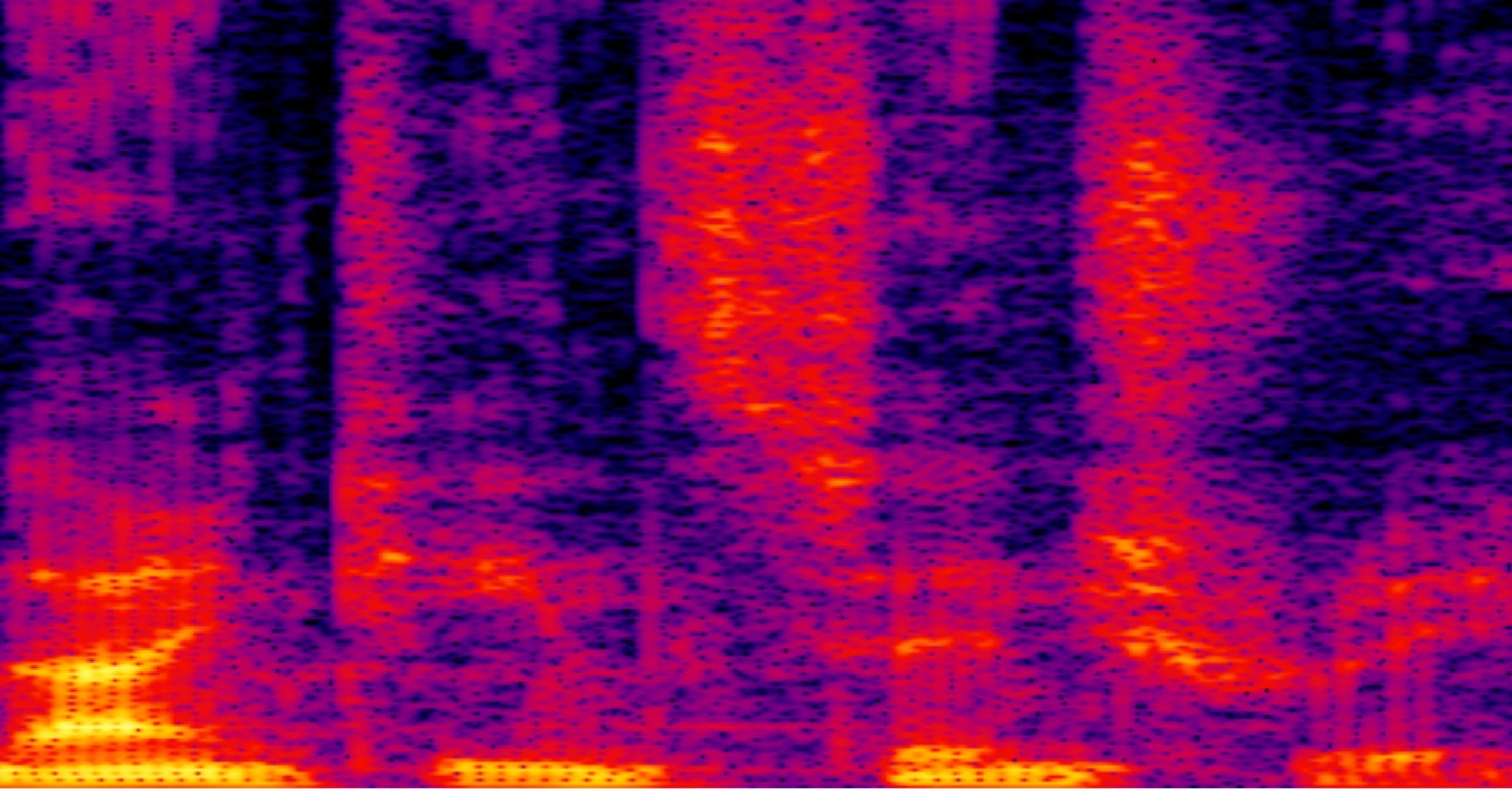


Audio Sensing

EE382V Activity Sensing and Recognition

UT Austin • Dept. Electrical and Computer Engineering • Fall 2016

Today

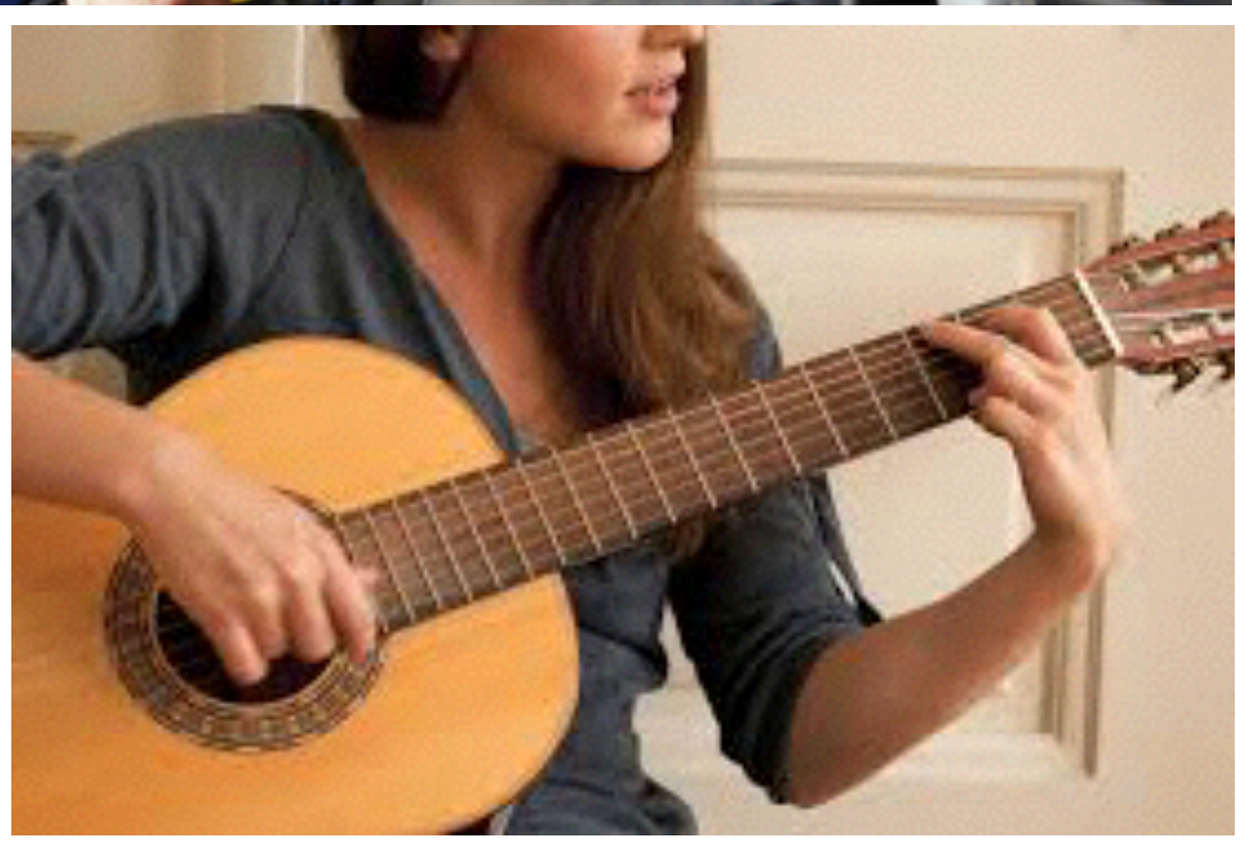
Texas Wireless Summit

Audio Sensing

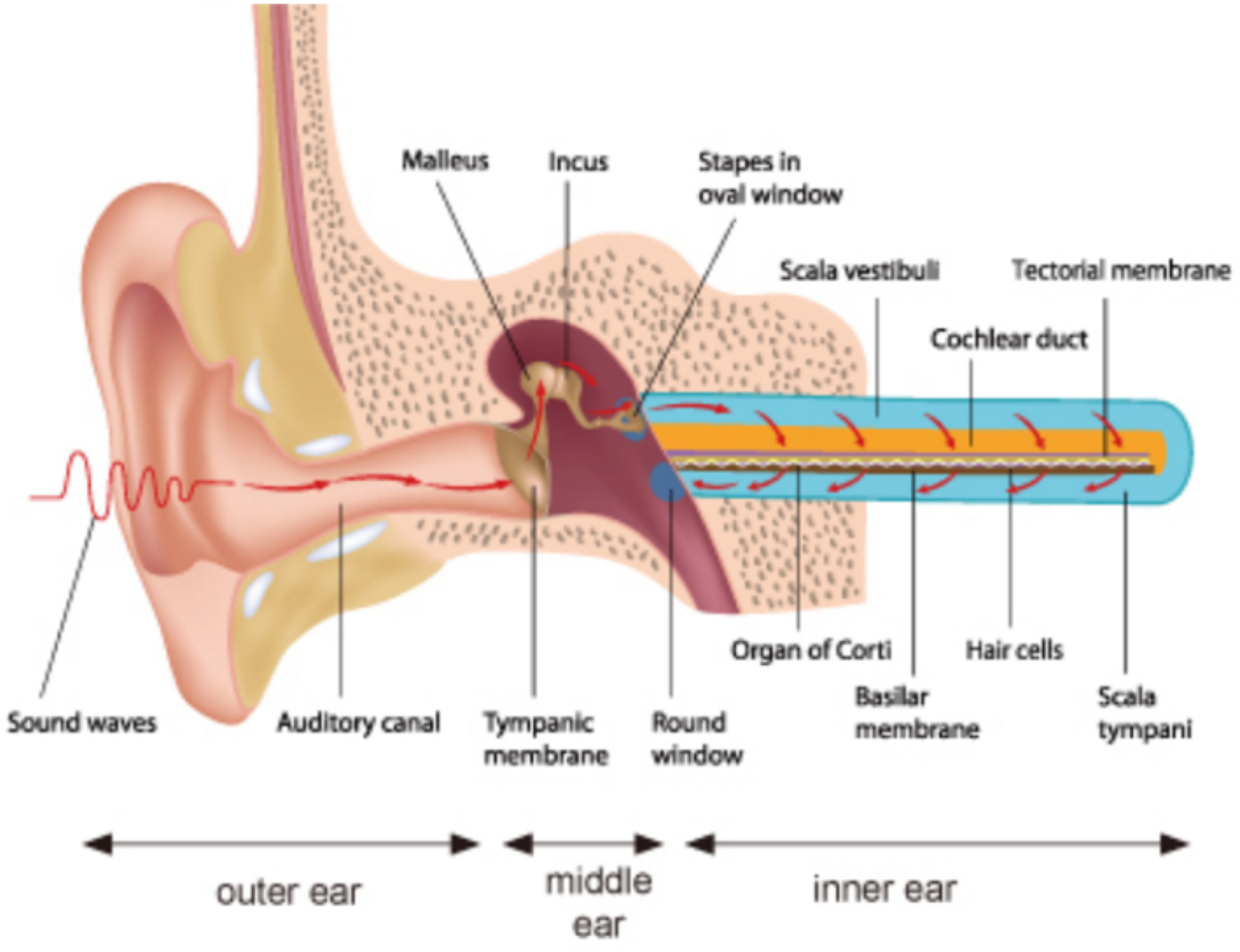
- Human Hearing
- Applications
- Features
- Tools

Papers + Panel of Experts

Human Hearing

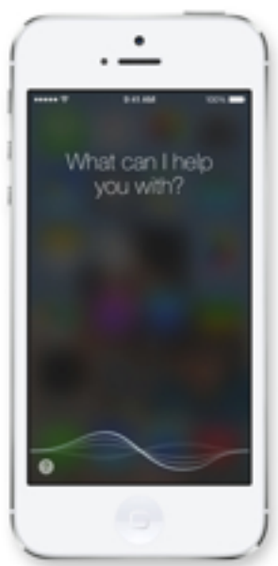


The Human Auditory System



Source: http://www.yamahaproaudio.com/global/en/training_support/selftraining/audio_quality/chapter4/01_ear_anatomy/

Consumer Electronics



Health

SpiroSmart: Using a Microphone to Measure Lung Function on a Mobile Phone

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ABSTRACT

Home spirometry is gaining acceptance in the medical community because of its ability to detect pulmonary exacerbations and improve outcomes of chronic lung ailments. However, cost and usability are significant barriers to its widespread adoption. To this end, we present SpiroSmart, a low-cost mobile phone application that performs spirometry sensing using the built-in microphone. We evaluate SpiroSmart on 52 subjects, showing that the mean error when compared to a clinical spirometer is 5.1% for common measures of lung function. Finally, we show that pulmonologists can use SpiroSmart to diagnose varying degrees of obstructive lung ailments.

Author Keywords

Health sensing, spirometry, mobile phones, signal processing, machine learning.

ACM Classification Keywords

H5.m. Information interfaces and presentation (*e.g.*, HCI): Miscellaneous.

INTRODUCTION

Spirometry is the most widely employed objective measure of lung function [37] and is central to the diagnosis and management of chronic lung diseases, such as asthma, chronic obstructive pulmonary disease (COPD), and cystic fibrosis. During a spirometry test, a patient forcefully exhales through a flow-monitoring device (a tube or mouthpiece), which measures instantaneous flow and cumulative exhaled volume (Figure 1). Spirometry is generally performed in medical offices and clinics using conventional spirometers, but home spirometry with portable devices is slowly gaining acceptance [6,26]. Measurement of spirometry at home allows patients and physicians to more regularly monitor for trends and detect changes in lung function that may need evaluation and/or treatment. Home spirometry has the potential to result in earlier treatment of exacerbations, more rapid recovery, reduced health care costs, and improved outcomes [15,23,34,35]. However, challenges currently faced by home spirometry are cost, patient compliance and usability, and an integrated method for uploading results to physicians [9,12]. Importantly, while office-based spirometry is coached by a trained technician, current home spirometers have no coaching, feedback, or quality control mechanisms to ensure acceptable measurements.

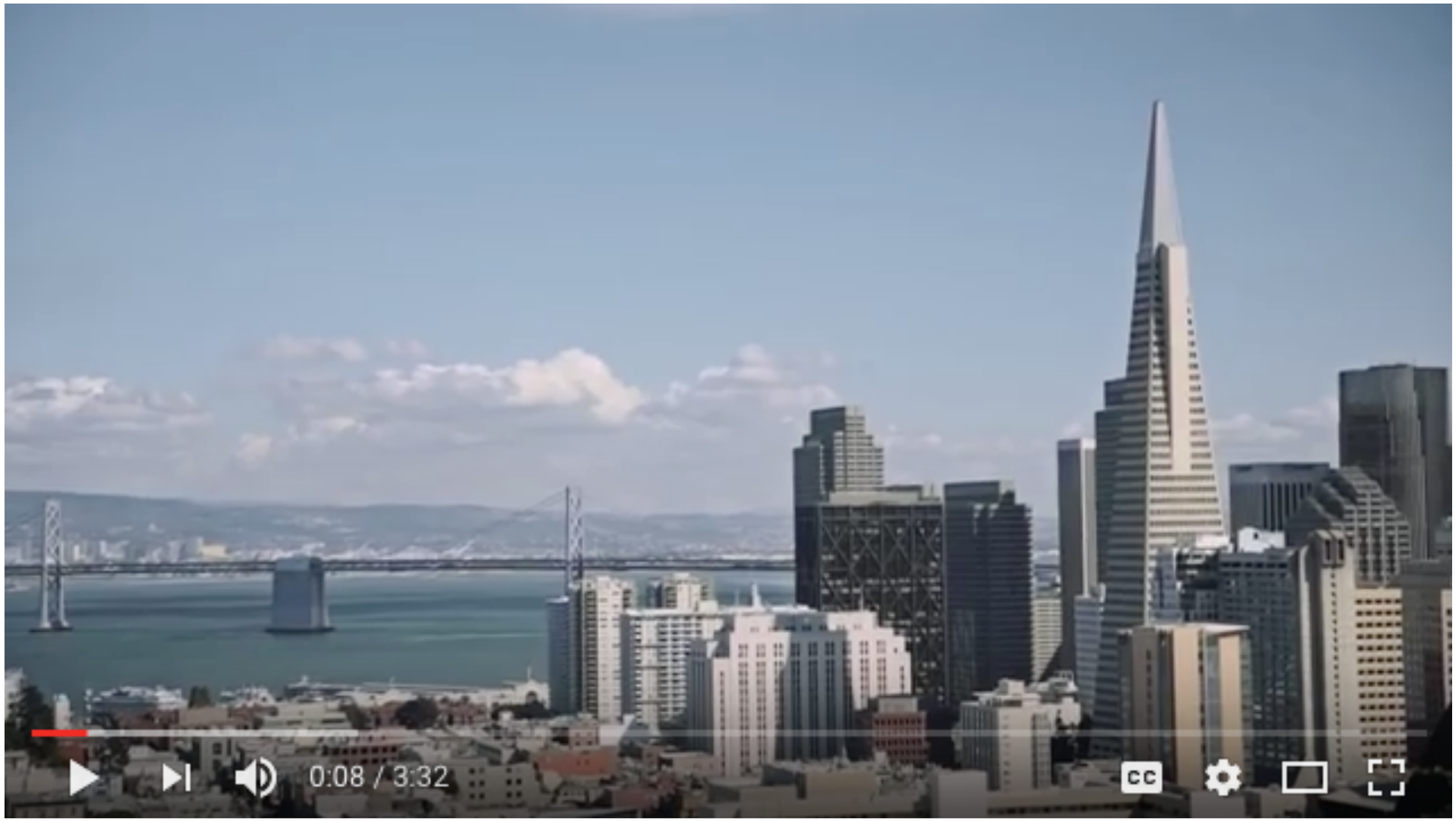
Figure 1. Subjects using SpiroSmart (left) and a clinical spirometer (right) and example curves from each device.

In this paper, we present *SpiroSmart*, a smartphone-based approach that measures lung function using the phone's built-in microphone (*i.e.*, a complete software-enabled solution). SpiroSmart requires the user to hold the smartphone at approximately arm's length, breathe in their full lung volume, and forcefully exhale at the screen of the phone until the entire lung volume is expelled. The phone's microphone records the exhalation and sends the audio data to a server, which calculates the exhaled flow rate by estimating models of the user's vocal tract and the reverberation of sound around the user's head. Flow rate is estimated by calculating the envelope of the sound in the time domain; performing resonance tracking in the frequency domain; while measuring white noise gain through linear prediction. SpiroSmart is able to compute and provide flow rates and graphs similar to those found in home or clinical spirometers (Figure 1).

UbiComp '12, Sep 5 – Sep 8, 2012, Pittsburgh, USA.

[1] The first two authors are equal contributors to this work.

Public Safety



Microphone

Inexpensive

Compare Parts		Image	Digi-Key Part Number	Manufacturer Part Number	Manufacturer	Description	Quantity Available	Unit Price USD
☐								
☐			102-1721-ND	CMA-4544PF-W	CUI Inc.	MIC COND ANALOG OMNI -44DB	40,949 - Immediate	0.96000

Types of Sounds

Noise

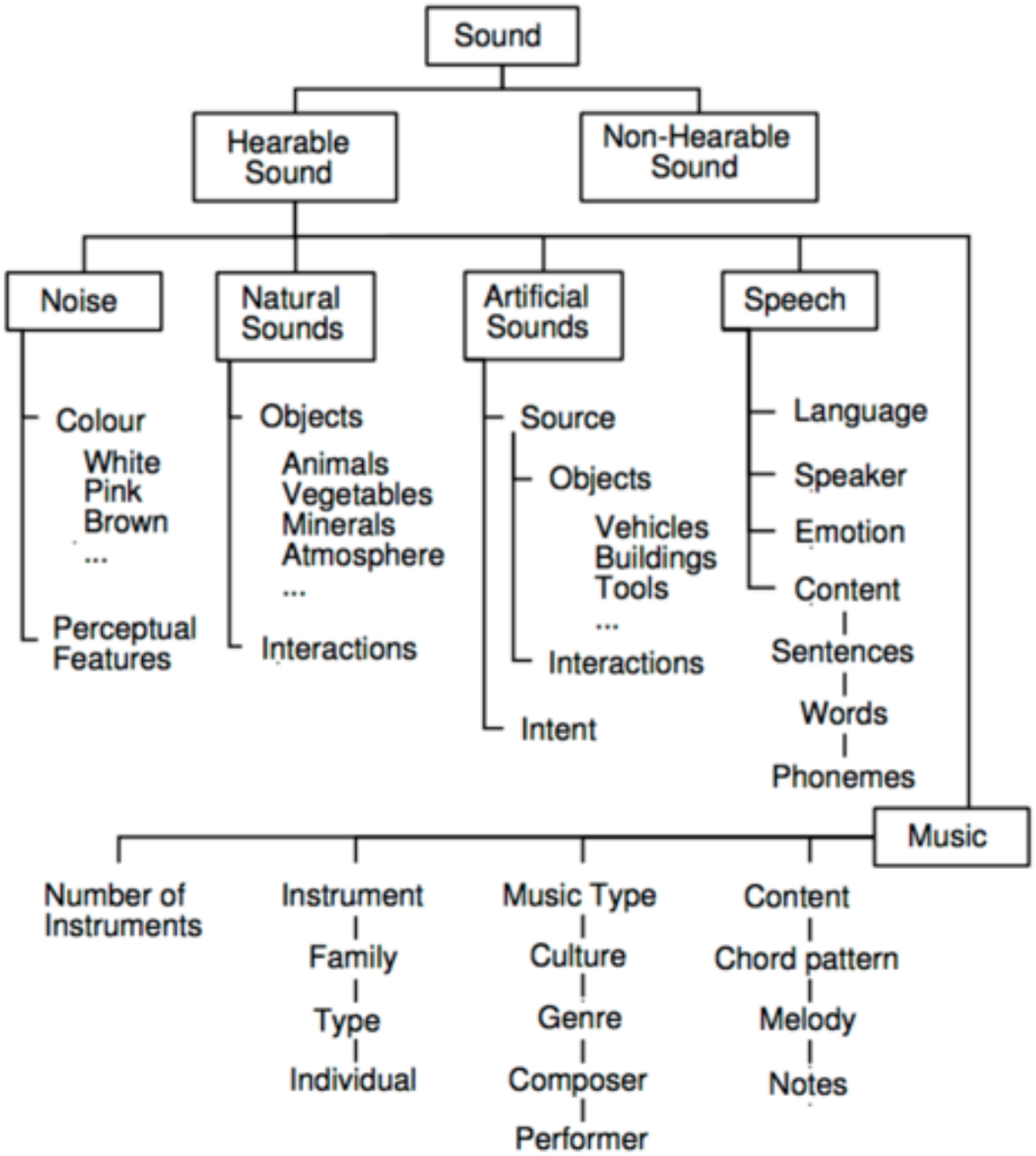
Natural Sounds (Nature and natural world)

Artificial Sounds (Machines, Cars)

Speech

Music

Taxonomy of Sounds



Source: http://www.cs.uregina.ca/Research/Techreports/2003-07.pdf

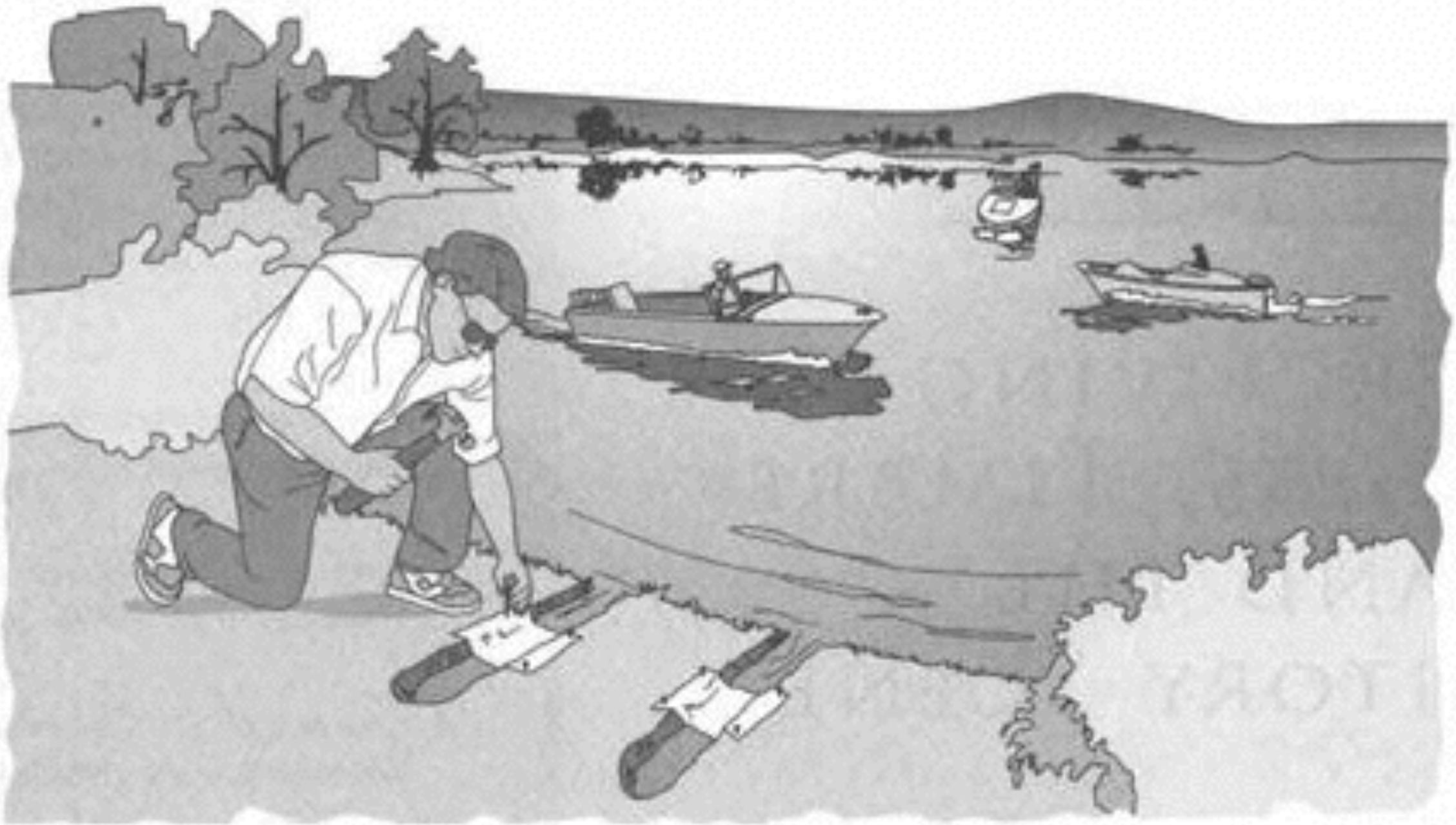
An Auditory Picture

An Auditory Picture

An Auditory Scene (Analysis)

Cocktail Party (Source Separation)

Lake Analogy



Source: http://gureckislab.org/courses/spring13/robots/materials/Slide6.jpg

Audio Signal Processing

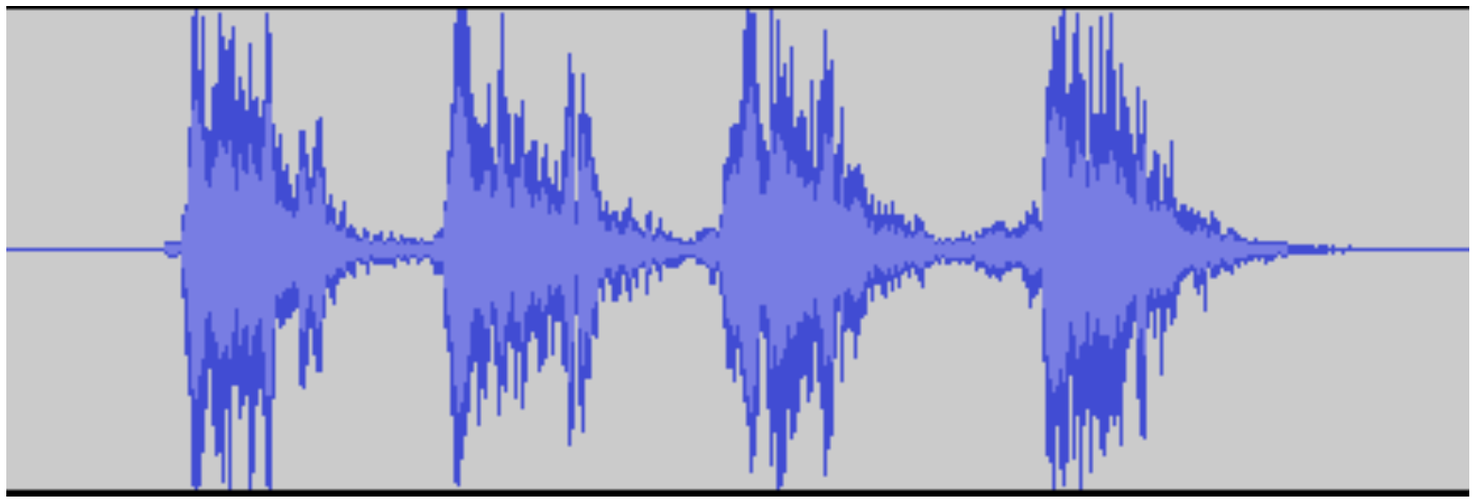
Harry Nyquist (1889-1976)

Sampling Theorem

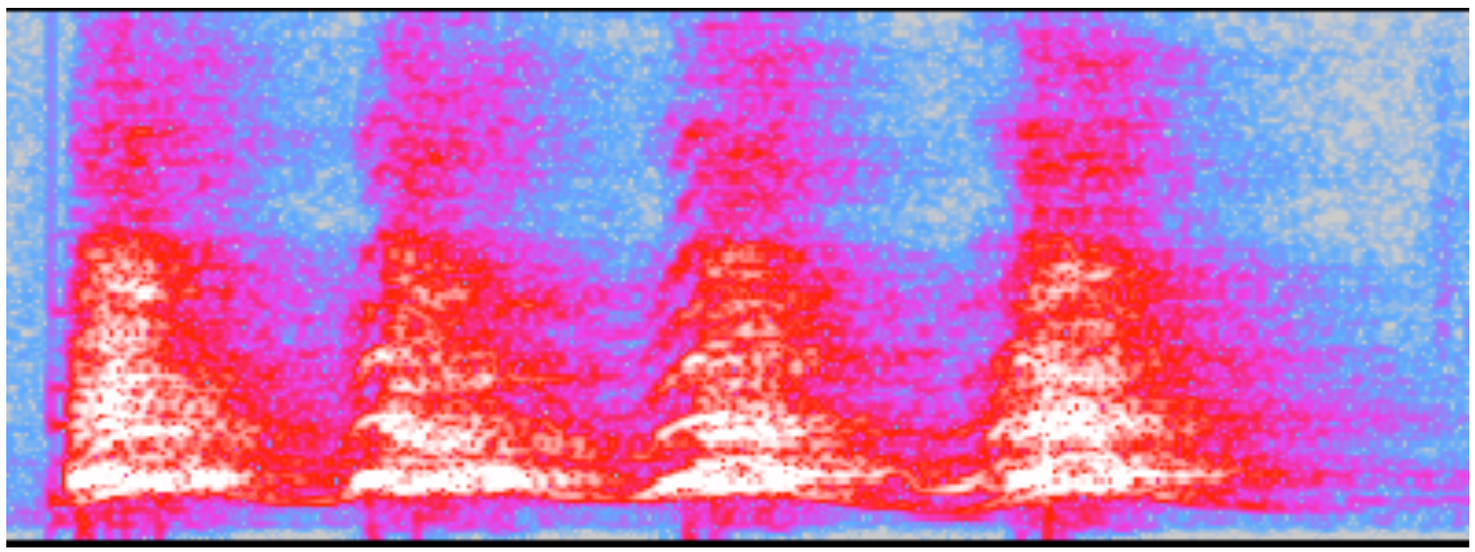
Analog to Digital Conversion

Audio Signal Processing

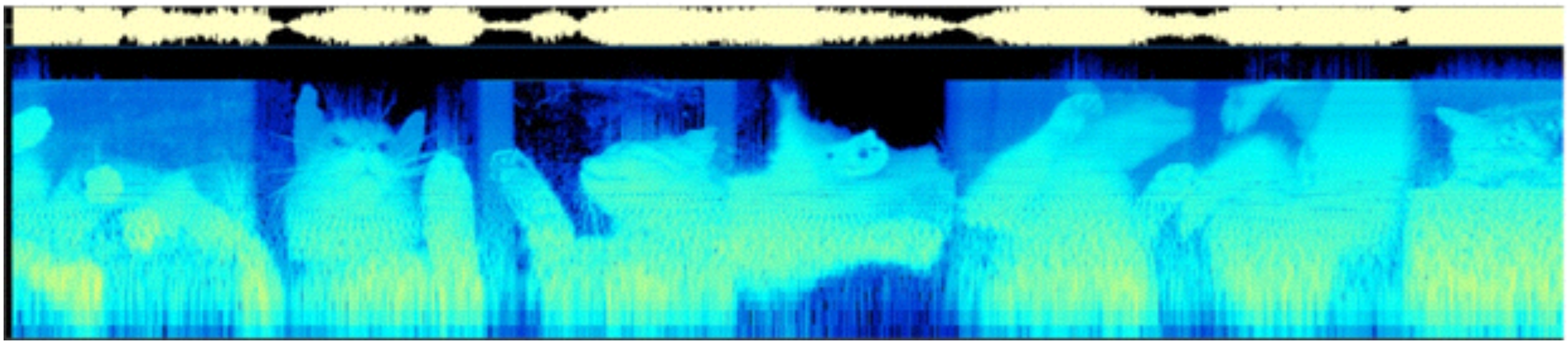
Temporal Domain

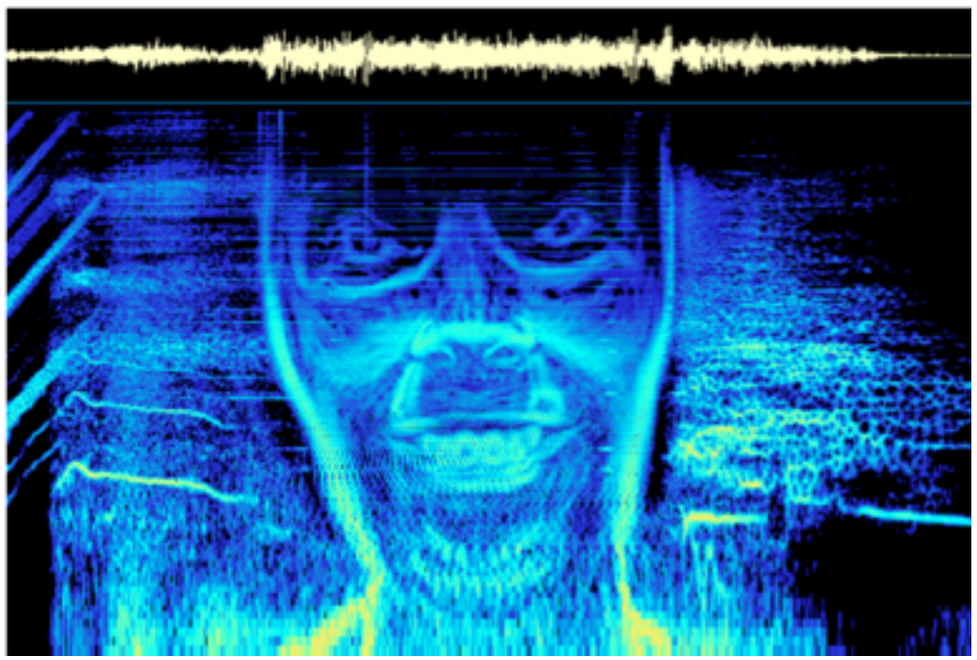


Frequency Domain



Spectrogram Pictures





Artists use synthesizers that converge images into sound

Audio Features (Perceptual vs. Physical)

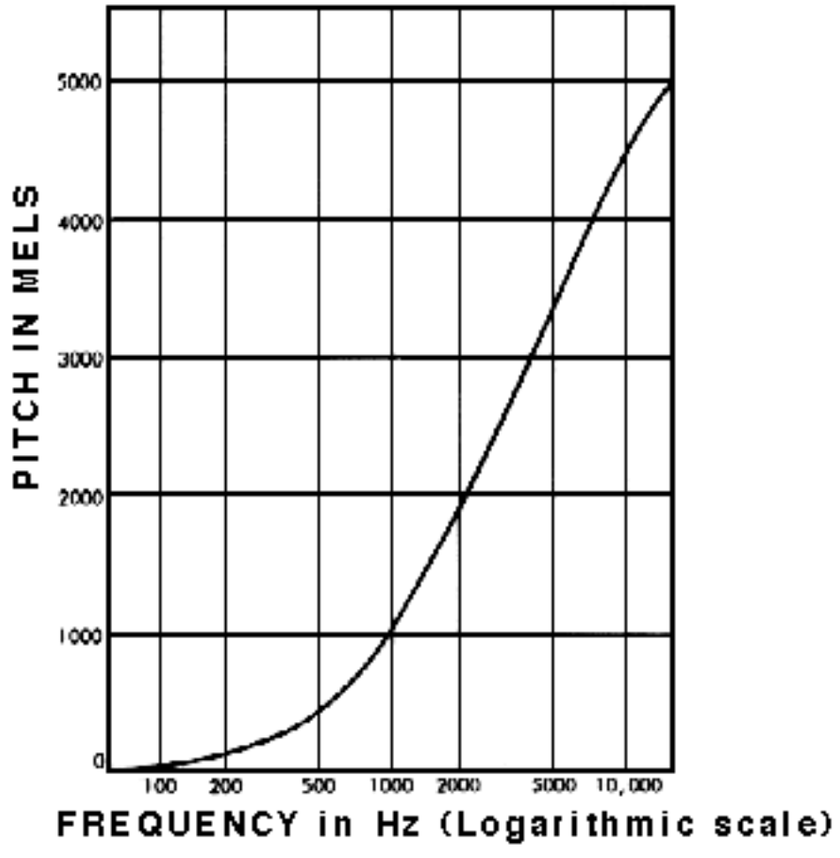
Pitch	Fundamental Frequency
ZCR	How often signal crosses zero per unit time
Energy	How much signal there is
Spectrum Flatness	Signal is noisy or harmonic

Audio Features (Perceptual vs. Physical)

Spectrum Centroid	Average frequency of the signal
Spectrum Envelope	Spectrum descriptor
Spectrum Rolloff	Frequency below which most of the spectral energy exists
Spectrum Flux	Rate of change of spectral information

Audio Features (Perceptual vs. Physical)

MFCC	Compact representation of audio spectrum taking into account non-linear human perception of pitch, as described by the mel scale



Tools

Yaafe

http://yaafe.sourceforge.net

```
> yaafe.py -l
Available features:
 - AmplitudeModulation
 - AutoCorrelation
 - ComplexDomainOnsetDetection
 - Energy
 - Envelope
 - EnvelopeShapeStatistics
 - Frames
 - LPC
 - LSF
 - Loudness
 - MFCC
 - MagnitudeSpectrum
 - OBSI
 - OBSIR
 - PerceptualSharpness
 - PerceptualSpread
 - SpectralCrestFactorPerBand
 - SpectralDecrease
 - SpectralFlatness
 - SpectralFlatnessPerBand
 - SpectralFlux
 - SpectralRolloff
 - SpectralShapeStatistics
 - SpectralSlope
 - SpectralVariation
 - TemporalShapeStatistics
 - ZCR
```

Tools

Librosa

http://librosa.github.io

`chroma_stft`	([y, sr, S, norm, n_fft, ...])
`chroma_cqt`	([y, sr, C, hop_length, fmin, ...])
`chroma_cens`	([y, sr, C, hop_length, fmin, ...])
`melspectrogram`	([y, sr, S, n_fft, hop_length])
`mfcc`	([y, sr, S, n_mfcc])
`rmse`	([y, S, n_fft, hop_length])
`spectral_centroid`	([y, sr, S, n_fft, ...])
`spectral_bandwidth`	([y, sr, S, n_fft, ...])
`spectral_contrast`	([y, sr, S, n_fft, ...])
`spectral_rolloff`	([y, sr, S, n_fft, ...])
`poly_features`	([y, sr, S, n_fft, hop_length, ...])
`tonnetz`	([y, sr, chroma])
`zero_crossing_rate`	(y[, frame_length, ...])

Panel of Experts

Next Class (Thursday)

Install either Yaafe or librosa

Bring laptop to class

We will do some audio signal analysis and feature extraction

Project Progress Report due next Tuesday