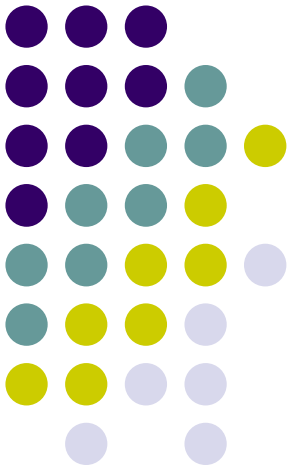
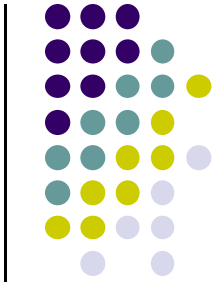
CS 525M Mobile and Ubiquitous Computing
Healthcare and Personal Assistants Intro

Emmanuel Agu

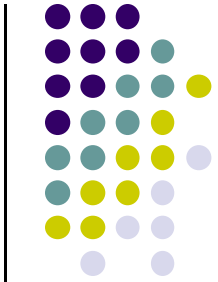


Ubicomp for Healthcare



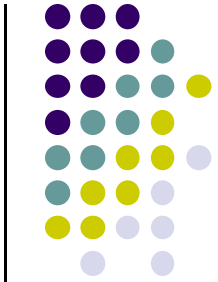
- **Currently:** Healthcare is
  - appointment-based (fixed time), infrequent
  - Specific location (hospital)
- Ubicomp can be used to provide healthcare
  - Continuously
  - Everywhere
- How?
  - Tracking wellness through phone sensors, cheap external sensors (e.g fitbit)
  - Give feedback, advise, share with support group

Wellness Tracking



- **Current healthcare system is reactive**
  - Doctors paid for treating ill patients
- Future (Obamacare)
  - Reward doctors for patients who don't get readmitted
  - Give incentives to patients with better wellness practices (e.g lower health insurance)
- Ubicomp allows easy continuous wellness logging, tracking and feedback

Smartphone as a medical Device

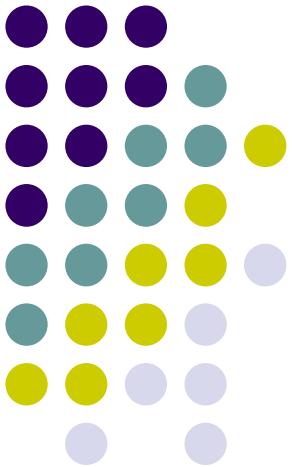


- Medical devices can be expensive
- Smartphones are quite powerful now (CPU and GPU)
- Use smartphone as a medical device
  - Implement DSP algorithms for sensing cough, asthma, etc on smartphone CPU/GPU
  - Patients download sensing app
  - Cost to patient: $0 (free download or a few dollars)

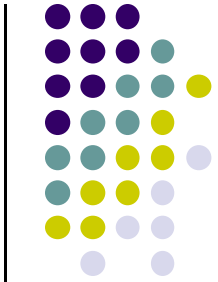
Accurate and Privacy Preserving Cough Sensing using a Low-Cost Microphone

Eric C. Larson, TienJui Lee, Sean Liu, Margaret Rosenfeld, and Shwetak N. Patel.

In Proc. UbiComp 2011

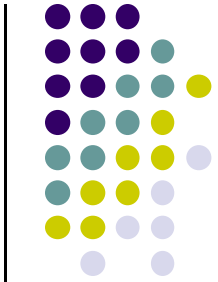


Introduction



- Cough is most common symptom of illness
- Over 40% of people have or will have chronic cough
- Cough triggers many fears:
  - Fear of illness, loss of appetite, loss of sleep, etc
- Cough detection used in diagnosis and treatment of many other ailments **(Very broad impact)**:
  - Common cold, lung cancer, tuberculosis, pneumonia, asthma, bronchitis, allergies, infection, etc

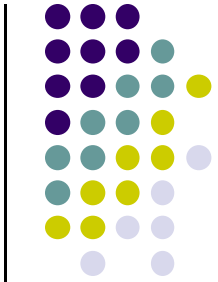
Contributions



1. Accurate cough detection
2. Method generalizes across subjects
3. Reconstructable cough audio
4. Privacy of speech (detects cough, hides speaker)
5. Leverages existing mobile phone

- **Cough detection:** over 60 years of research
- This paper generalized approach previously proposed by authors, more accurate

Related Work



- **Mobile phone health applications:** Sensing platforms for sensing health
  - Track water consumption, recognize activity levels, asthma logging
- **General cough detection:** users wear specialized sensors to detect cough, increasing cost

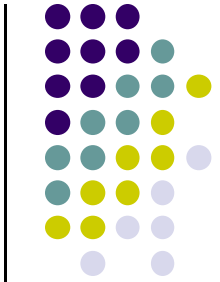
Related Work

- **Audio Based cough sensing:** Low cost but mostly proprietary algorithms

Algorithm (Author)	Sensing	Subjects	Recording Environment	Automation	Initial Calibration?	Mean True Positive Rate	Mean False Positive Rate	Mean False Alarms / Hr
LifeShirt	Throat Mic. +sensor array	N=8	Lab, 24 hours	Automatic	Yes	78%	0.4%	Not reported
VitaloJak	Piezo Sensor	N=10	Lab, 24 hours	Automatic	Yes	97.5%	2.3%	Not reported
HACC	Lapel Mic.	N=15	Clinic, 1 hour	Semi	Yes	80%	4%	Not reported
LCM (Matos)	Lapel Mic.	N=19	In Wild, 6 hours	Semi	Yes	71-82%	Not reported	13
LCM (Birring)	Lapel Mic.	N=19	In Wild, 2-6 hours	Semi	Yes	91% *	<1%	2.5‡
Our algorithm	Phone Mic. on necklace	N=17	In Wild, 2-6 hours	Automatic	No	92%	0.5%	17

Table 2. Summary of related work in audio based cough detection. *It is not clear if these rates are reported with or without a 95% energy threshold. ‡These rates are reported after review by an annotator.

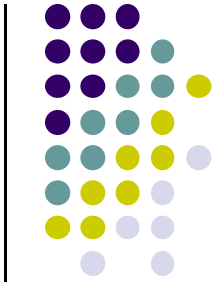
Related Work



- **Audio Privacy:**
  - Mostly work that tries to make speech undetectable
  - This work makes speech undetectable + cough reconstructable

- **Eigen Feature selection:** related to Principal Components Analysis (PCA) which authors use to classify coughs

Physiology of Cough (Cough Reflex)



1. Initial deep inspiration and glottal closure
2. Contraction of the expiratory muscles against closed glottis
3. A sudden glottis opening with an explosive expiration
4. A wheeze or “voiced” sound

- Work focussed on characterizing **exposive phase**
- Generalizes across different people

Methodology

- Subjects wear phone on neck or front pocket
  - Best audio quality but may not be most comfortable

Methodology

- Transformation and analysis in frequency domain
- Coughs parts had “signature” in frequency domain
- Applied Principal Components Analysis (PCA) to cough on spectrogram

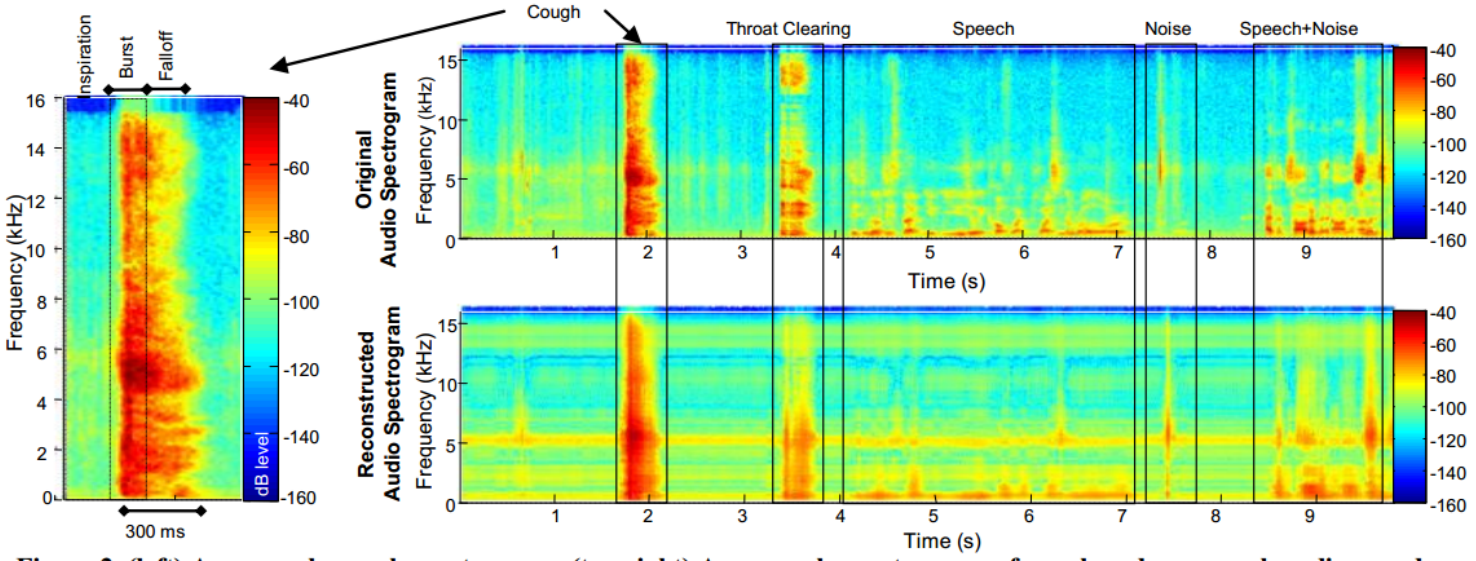
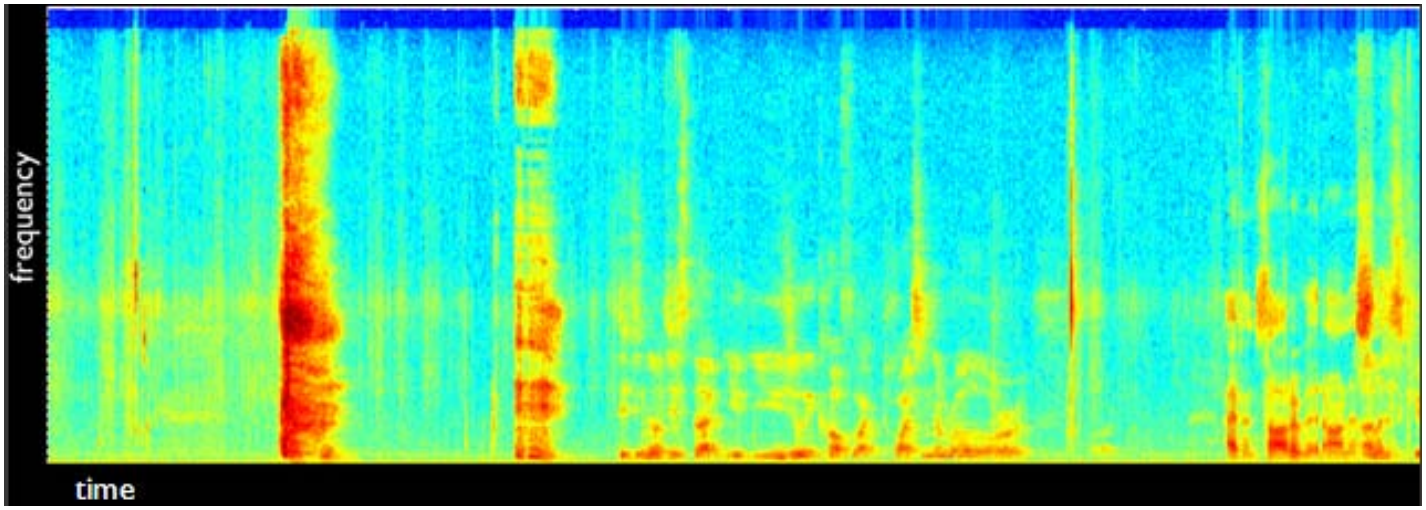


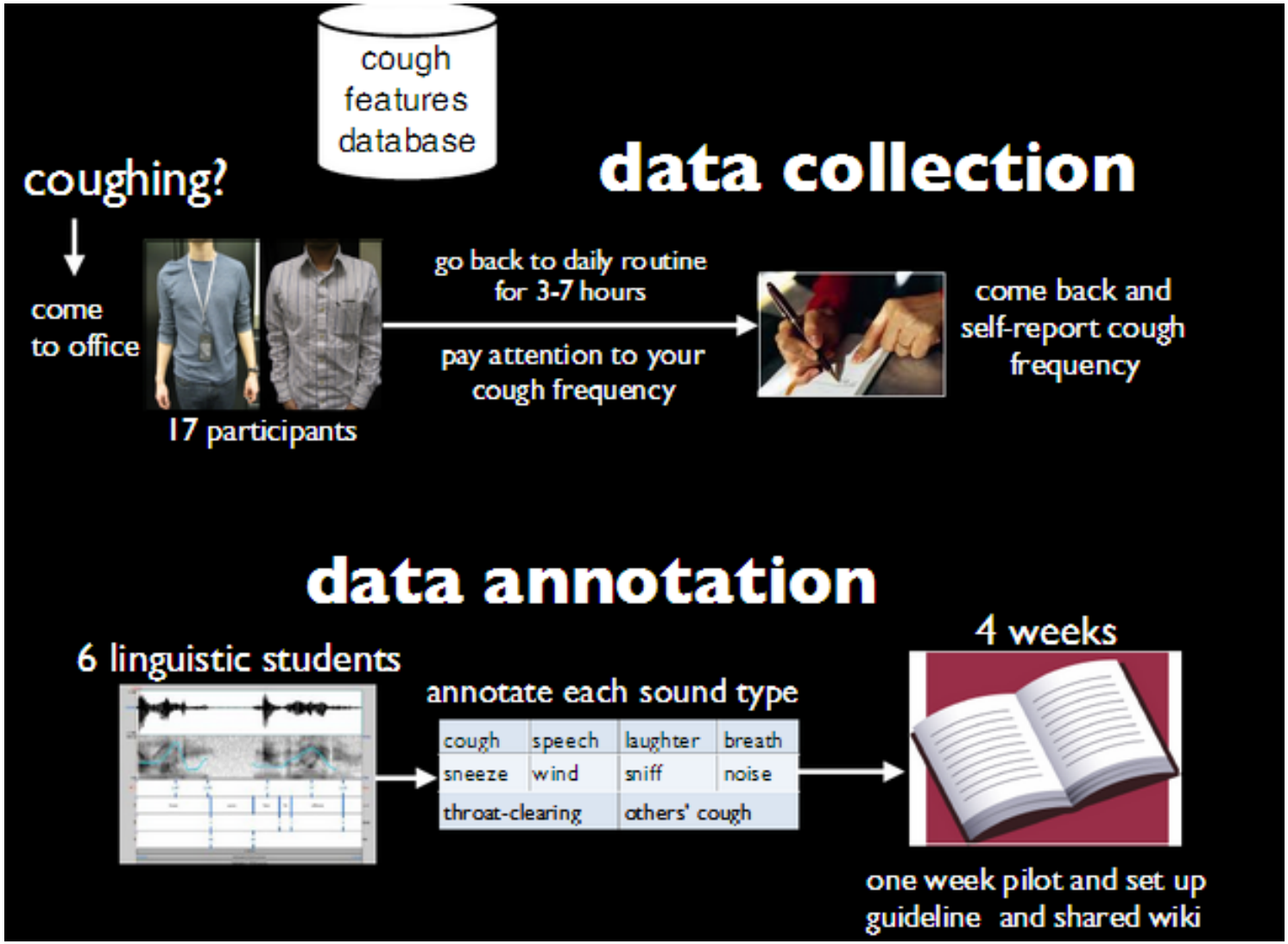
Figure 2. (left) An example cough spectrogram. (top right) An example spectrogram of cough and non-cough audio sounds. (bottom left) An example of the reconstructed spectrogram using principal components analysis.

Methodology

- PCA components used as features to capture cough signature for machine learning
- **Goal:** ML Classifier able to reconstruct coughs but not speech



Methodology

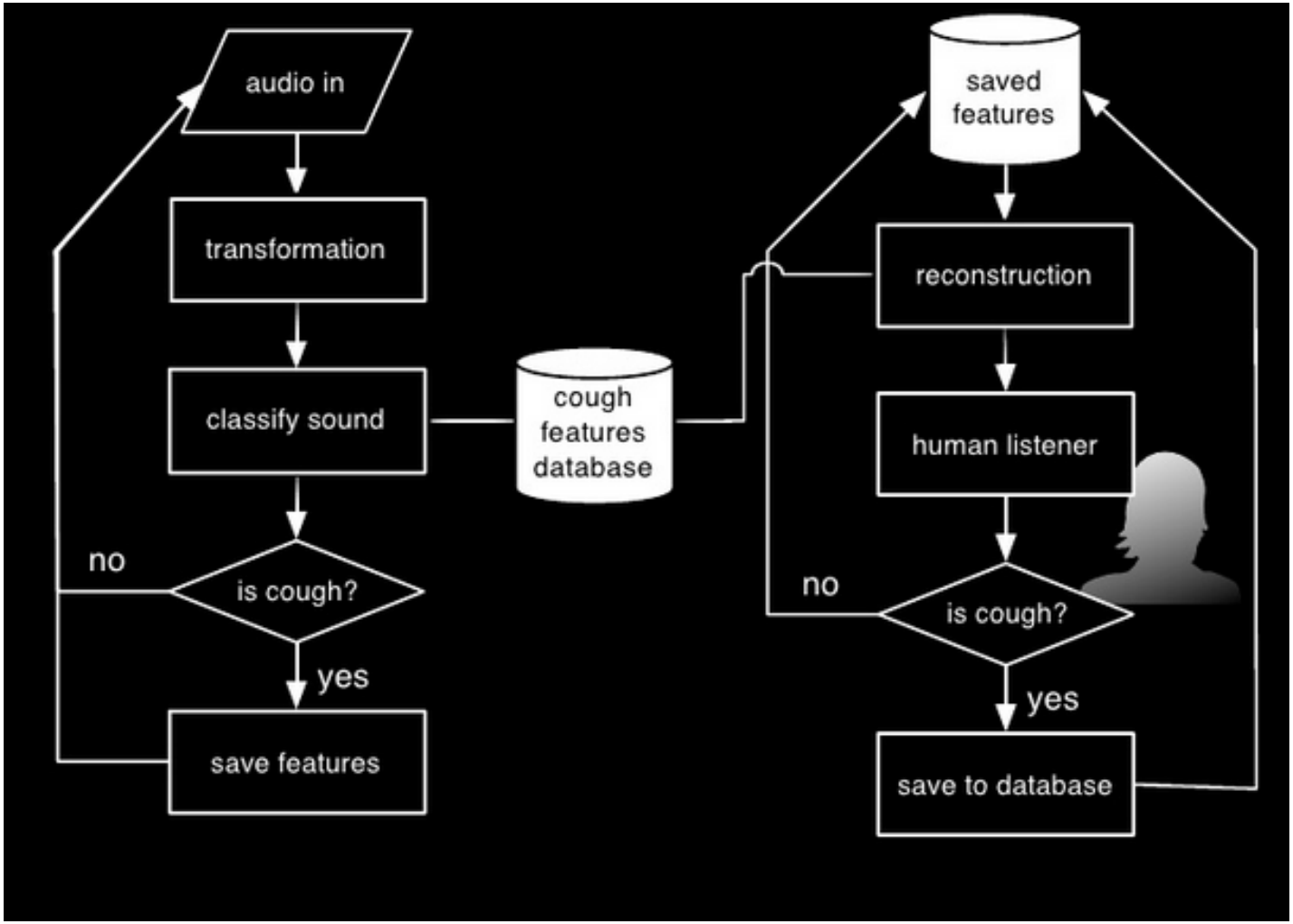


Demographics of Subjects

Subject Demographics and Dataset		
# Subjects	17	7 Female,10 male
Age Range	18 – 60,	μ.=27, *mode*=25
Diagnosis	3 Asthma, 5 Chronic, 8 Cold, 1 Allergy	
Audio Recorded per Subject	3 – 6.5 hrs	μ =4.2, *mode*=3
Coughs per Subject	33 – 894,	μ =150, *mode*=79
Coughs/Hour	10 – 178,	μ =33, *mode*=15
Difference from Self Report	6 – 139 cough/hr	μ =22.8, *mode*=20
Total Coughs	2558 coughs	1016 epochs

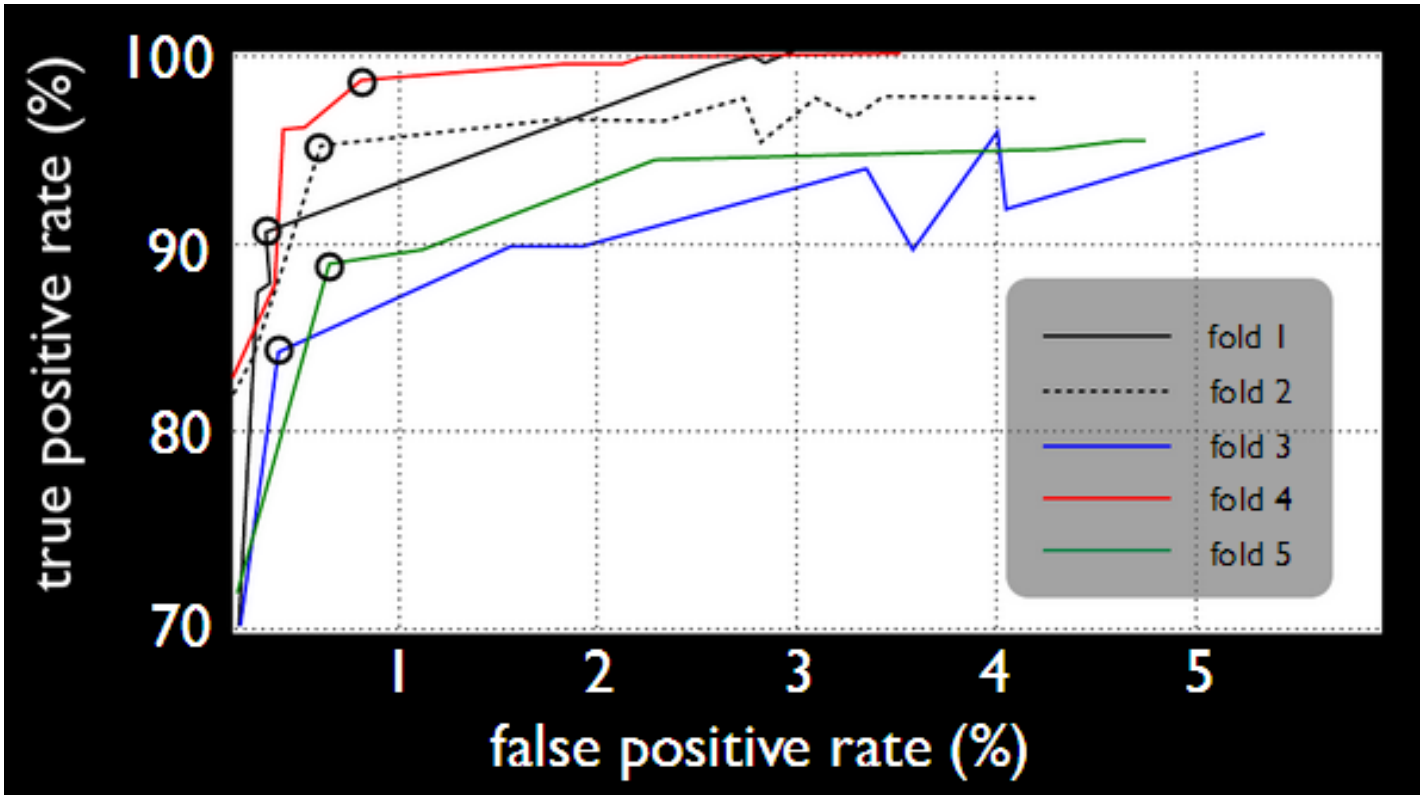
Table 3. Demographic information and number of coughs collected of all the participants.

Methodology



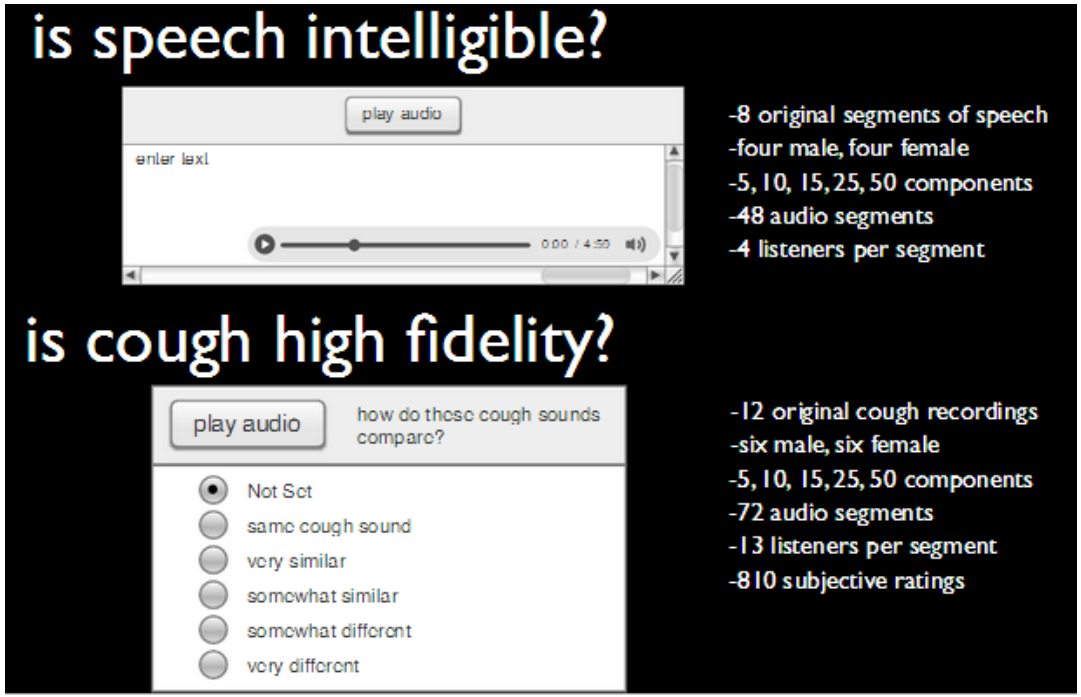
Results of Sound Classification

- High rate of true positives
- Low rate of false positives

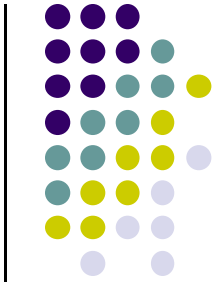


Reconstruction Design

- If cough needs to be replayed reconstruct from PCA components corresponding to coughs
- Tested by playing back speech to humans.
  - Good enough?



Conclusions and Future Work

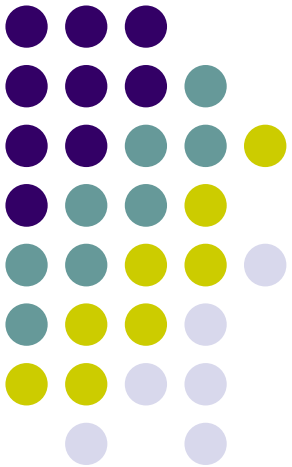


1. Accurate cough detection
2. Method generalizes across subjects
3. Reconstructable cough audio
4. Privacy of speech
5. Leverages existing mobile phone

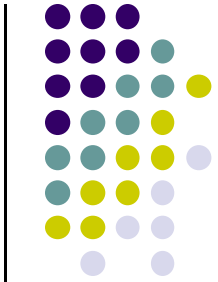
- Future work
  - Extend battery life to 24 hours
  - Increase accuracy

CS 525M Mobile and Ubiquitous Computing Discussion Points

Emmanuel Agu



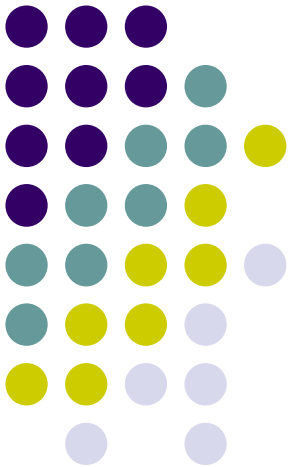
Discussion Points



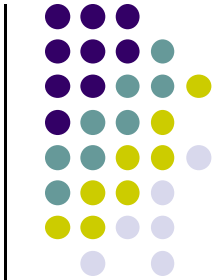
- Evaluation: Were their claims backed up well by numbers?
- Will their solution work well in practice? Will it scale up well?
- What did you like about the paper?
- What did you dislike about this paper?
- Ideas for improvement/extension? Project ideas?

Tapping into the Vibe of the City using VibN, a Continuous Sensing App for Smartphones

Emiliano Miluzzo, Michela Papandrea, Nicholas Lane, Andy Sarroff, Silvia Giodano, Andrew Campbell

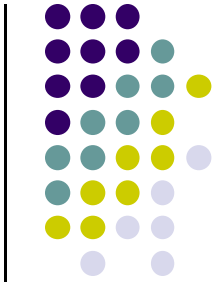


Introduction/Motivation



- Humans at would like to know ongoing events at other parts of their city
- Sample questions:
  - What music being played at a given club?
  - How many people are in the club? Demographics?
  - What is the quietest place in the city to read book?
  - How many people are jogging in the park right now?
- Characterize events in city spaces
- Dynamic: time-varying + location-dependent info

Related Work

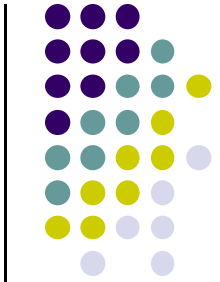


- Other frameworks for continuous sensing at scale
  - Tracking bikes
  - Audio noise mapping, etc
- Related Apps (manual user input)
  - Apps to promote awareness of city events
  - Apps to connect people socially (e.g FourSquare)
  - **TwitMic:** associates audio clips to twitter accounts
- Techniques proposed to optimize smartphone resources while continuously sensing

VibN Smartphone App

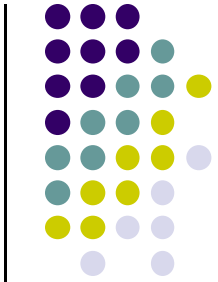
- Continuously running opportunistic sensing mobile application
  - Collects smartphone sensor data
  - Executes inferences
  - Presents results to user
- Real-time info on city hotspots
  - **Live Points of Interest (LPOIs)**
- **LPOIs:** Anywhere people spend a lot of time (work, home, fun)

Live Points of Interest (LPOIs)



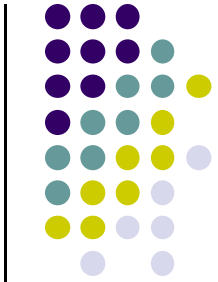
- Information provided on LPOIs include
  - Demographics of its inhabitants (avg. age, ratio of men/women, relationship status)
  - **Historical LPOIs:** Replay of past demographics of LPOIs
  - Novel *vibe it* feature: audio recordings that can be played back
    - Privacy: segments with voice are filtered out
- Complete working app, deployed on Apple and Android app store
  - Released Nov 18, 2010, 1000 users in 6 months

VibN Client



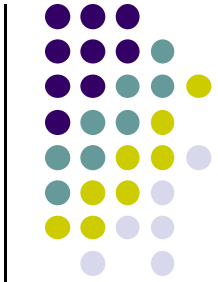
- Consists of smartphone client + backend server
- Client may run on iOS or Android. Components
  - **Sensing:** Capture accelerometer, audio and location data
    - Data captured for:
      - **Personal diary:** personal POIs
      - **Communications manager:** communicates with VibN server
  - **Duty Cycling Manager:** reduce sampling to save resources
    - GPS + Record data only after user at location for 30 minutes
- **Personal Data Manager:** Determines importance of a location by analyzing duration of user's visit
  - 2 hours used as threshold for importance

VibN Client



- **LPOI Manager:** maintains up-to-date live and historical LPOI info on phone
  - Information partitioned by time windows
  - Demographic information manually entered by users
  - Future: sensors to auto-infer demographics
  - Historical LPOI stored for a month
- **User Feedback Manager:** Questions directly presented to users on client

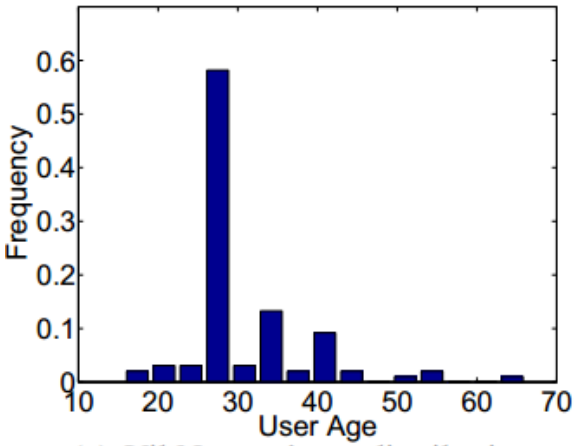
VibN Backend



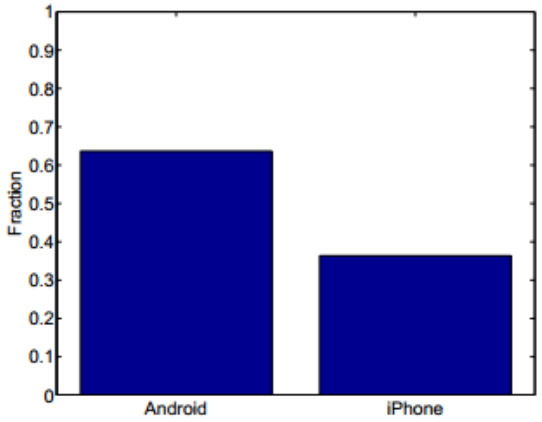
- Standard web service + python framework on Linux
- Anonymize audio data by randomly deleting short segments so conversations cannot be reconstructed
- Runs density-based spatial clustering (DBSCAN) algorithm to determine LPOIs

Evaluation

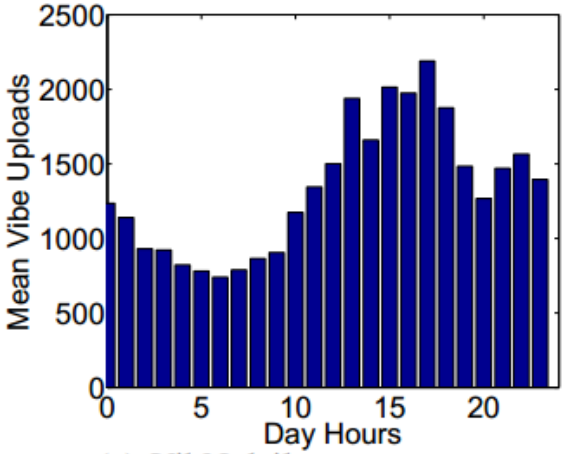
- Battery lasted 25 hrs on iPhone, 30hrs on Nexus One



(a) VibN users' age distribution.

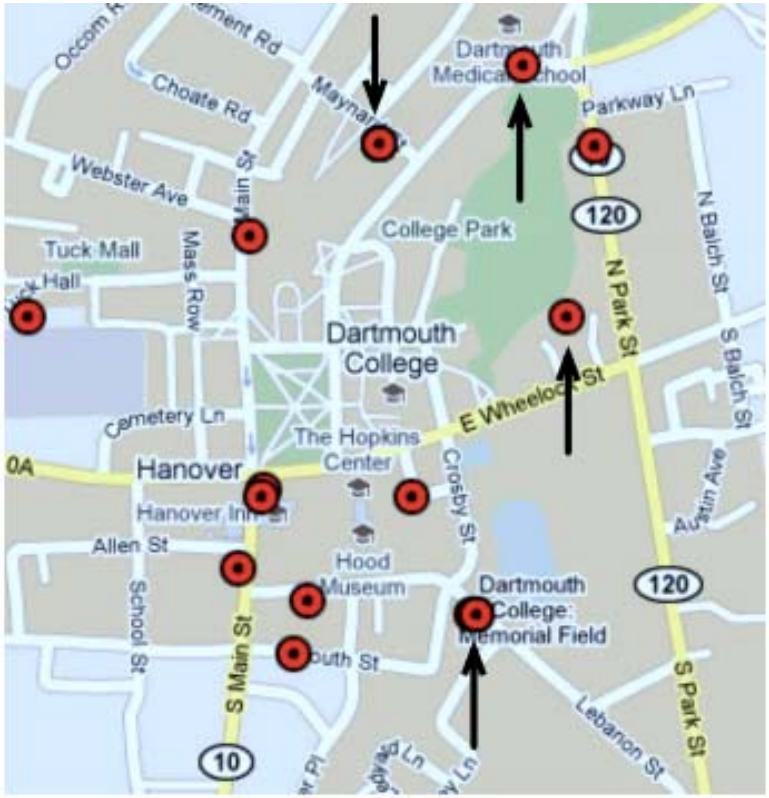


(b) Fraction of Android Vs iOS users.

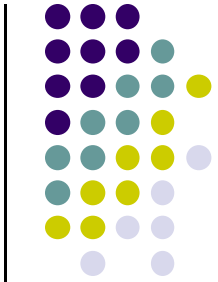


(c) VibN daily usage pattern.

Sample of Clustering algorithm

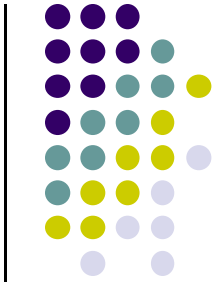


Projects



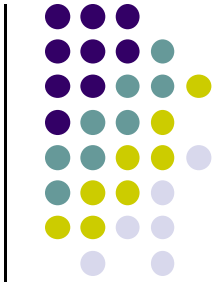
- Next, I will talk about sample projects
- Remember:
  - Focus is on **knowledge** not creating a product
  - Prototype just demonstrates an **idea**
  - Research is done by a **community of people**
  - **Quote:** Good research is built on the shoulders of giants
  - You want to contribute a piece
    - Based on/extends other work
    - Small piece but well done (sound methodology, evaluation)

Final Project Ideas (VibN extension)



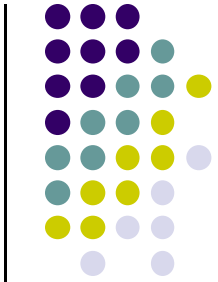
- Automatically process smartphone audio feeds
  - Classify events going on at location from audio
  - E.g. crowd noise vs conversation
  - Loud music?
  - Turn by turn (different speakers) = conversation
  - Combine with GPS lookup + pull schedule of venue from web, etc

Final Project Ideas (Healthcare Ideas)



- Detecting food I eat based on pictures taken + follow up user study
- Inferring calories of internet based recipes
- User study to compare accuracy + compliance, convenience of
  - Health worn sensors
  - Manual data input into smartphone
  - Automatic data input into smartphone (continuous sensor)

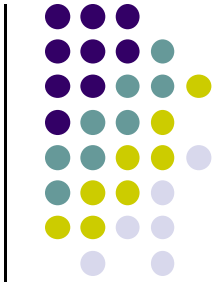
Final Project Ideas (Healthcare Ideas)



- Asthma weezing detector.
  - Asthma attach weezing has spectral signature
  - Analyze and detect
  - Requires signal processing experience

- Implement and compare various activity recognition algorithms based on accuracy, sensitivity, etc. + User studies

Final Project Ideas (Healthcare)



- Improve the efficiency of activity detection by maintaining location history + what activities at locations
  - Track what has the user done at that location before?
  - Also allow user to annotate so that system can
  - learn and get better.