Sonar-based Measurement of User Presence and Attention

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Presented at UbiComp 2009
Orlando, FL, USA
October 2, 2009

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Abstract

- Novel use of laptop's speakers and mic as a *sensor*
- In absence of HID input, we can determine whether user is
  1. still present
  2. or gone
- No new hardware required

Presence detection

Problem definition

Detect whether there is a human user present at the computer.

Motivation:

- Operating systems
- Ubiquitous computing

Goals:

- Accuracy
- Responsiveness
- Low cost

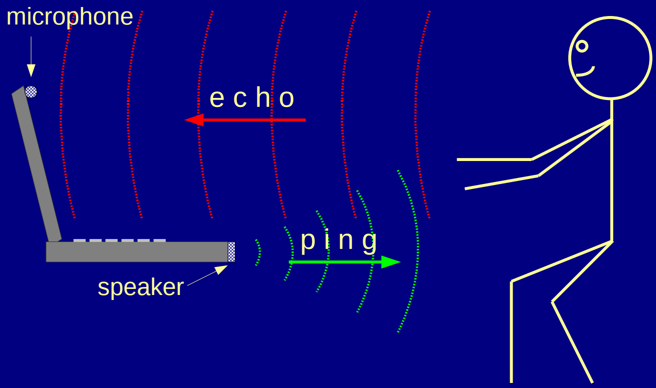
Related work

- Activity detection
- Power management
  - FaceOff - Dalton and Ellis, HotOS'03
- Ultrasonics
  - Audio networking - Madhavapeddy et al., UbiComp'03
  - Cricket localization - Priyantha et al., MobiCom'00
  - WALRUS localization - Borriello et al, MobiSys'05
  - BeepBeep acoustic ranging - Peng et al., SenSys'07

Active sonar

Our system:

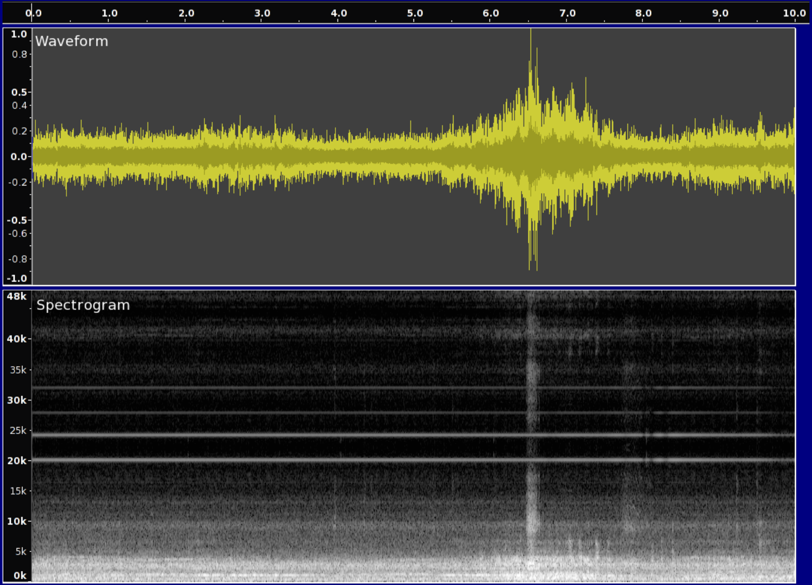
- laptop's speaker and mic
- inaudible ultrasonic tones ($\geq 20\,\text{kHz}$)
- continuous sine wave



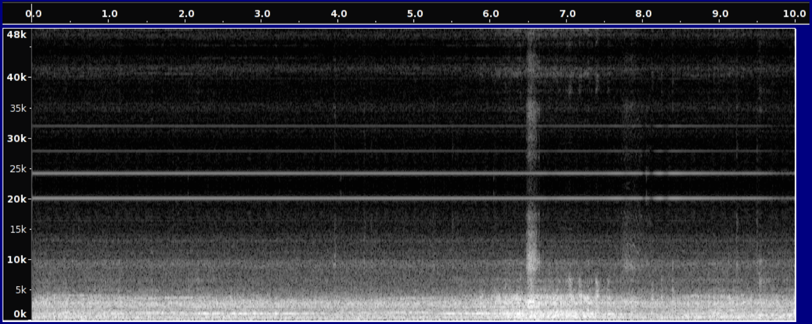
Hypothesis

- Users will reflect pings.
- Users are always moving, at least slightly.
- User movements will cause changes in echo intensity.
- *Thus, a user's presence will increase echo variance.*

An example recording



Feature extraction



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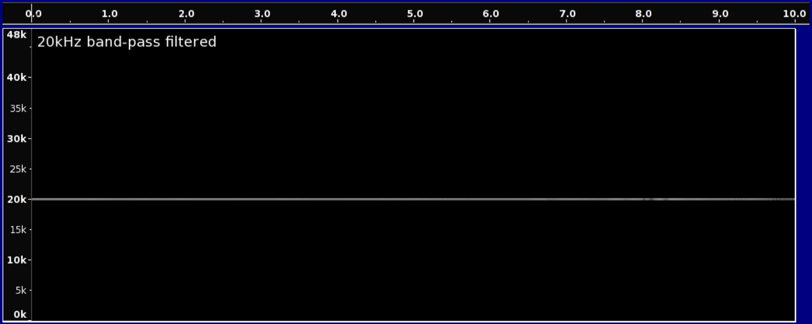

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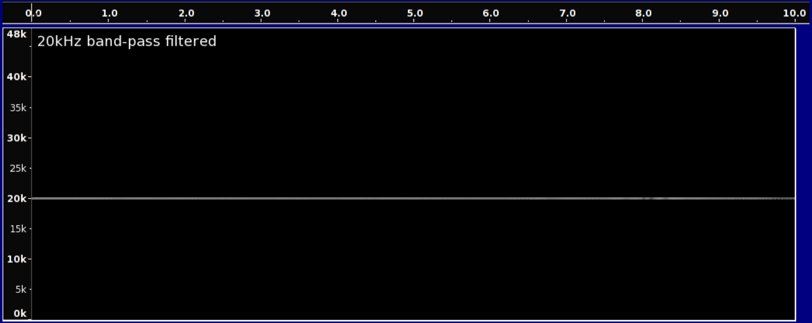

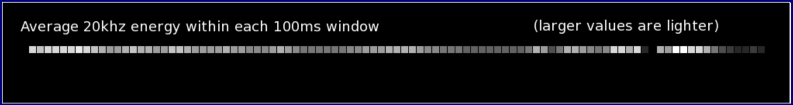

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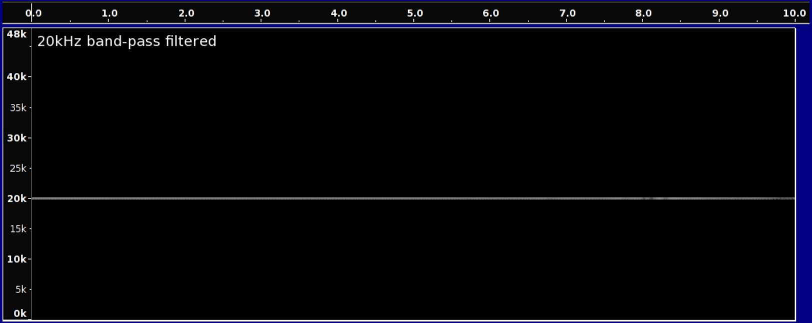

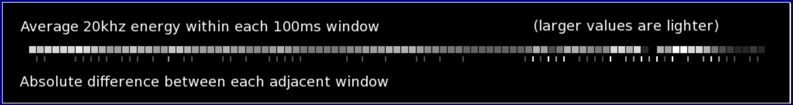

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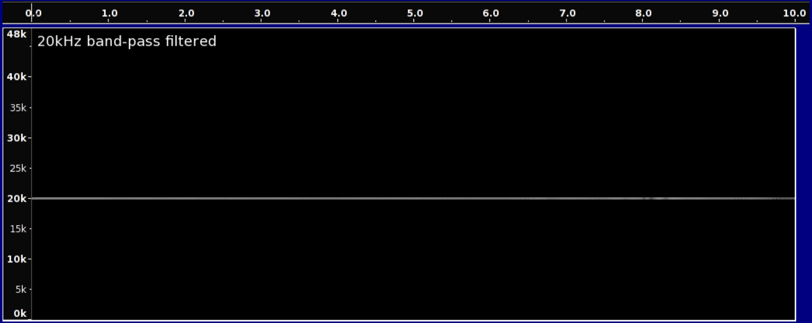
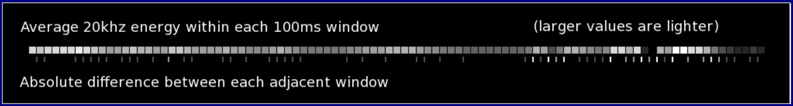




Echo Delta is the sum of these absolute differences.

User study goals

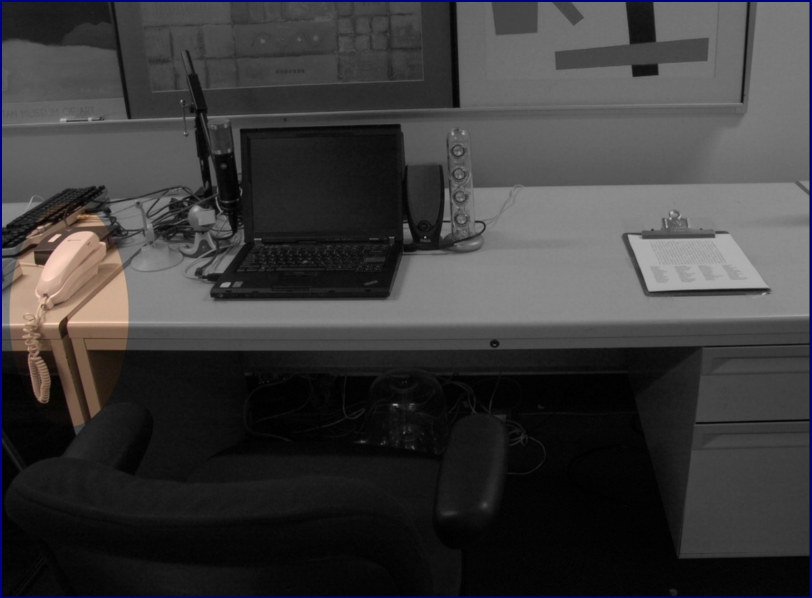
- Test hypothesis
- Carefully guide users through several states
- Mimic real usage scenarios
- Evaluate suitability of various microphones and speakers

Experimental setup

Active state: Typing task

Passively-engaged state: Video task

Disengaged state: Phone task



Distant state: Puzzle task

Absent state

Experiment details

- Twenty grad student volunteers
- 4 minutes spent on each task
- 50 second recordings for each task
- Tasks were randomly ordered

Sonar measurements (50 s recording)

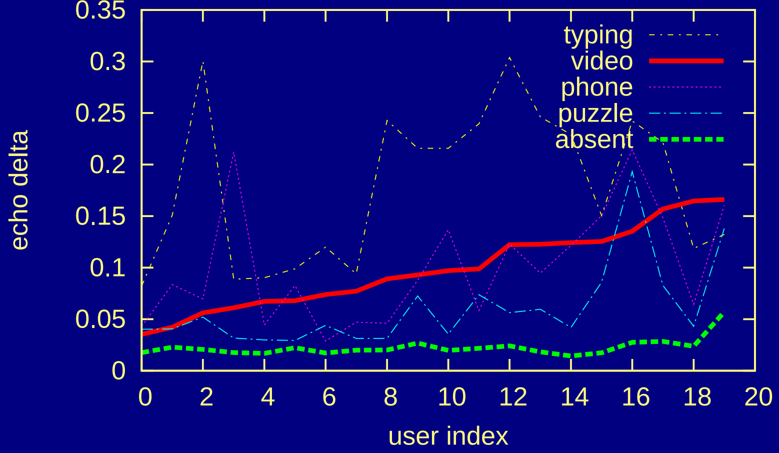


Figure: Consistent gap between video and absent states across all users

Sonar measurement ranges (10 s recordings)

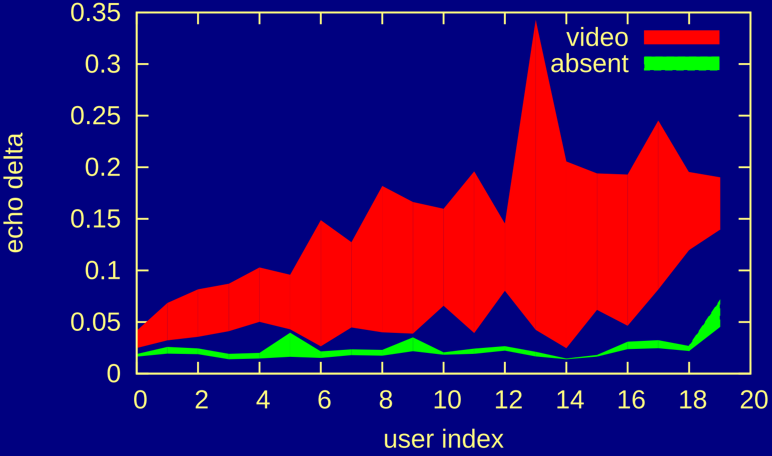


Figure: Gap remains after reducing recording length to 10 seconds

Binary state classifier

- Motivated by clear difference seen in sonar measurements
- If sonar measurement is above a certain threshold, classify as passively-engaged; otherwise absent.
- Threshold setting

$$T \equiv (\Delta_e^{passive} * (\Delta_e^{absent})^2)^{1/3}$$

Classifier confusion matrix results

- Tested the binary classifier using the user study recordings (video and absent)
- Split recordings into 10 s of training and 40 s of test data
- *Error rate less than 4%.*

	Predicted state	
Actual state	passively engaged	absent
passively engaged	0.9632	0.0368
absent	0.0248	0.9752

Conclusion

- Hypothesis supported by experimental results
  - User presence causes an increase in sonar measurement variance.
- Binary state classification for two important states was successful.
- Low computational overhead

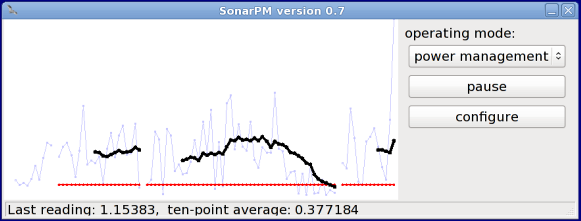
Current and future work

Open questions:

- How common is ultrasound-capable audio hardware in laptops and other electronics?
- How much power can be saved using fine-grained sonar-based power management?

Sonar Power Manager software is available:

- Windows and Linux
- Open-source



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