



모바일 시스템 프로그래밍

01 Mobile Sensing System Overview

2017 1학기

강승우

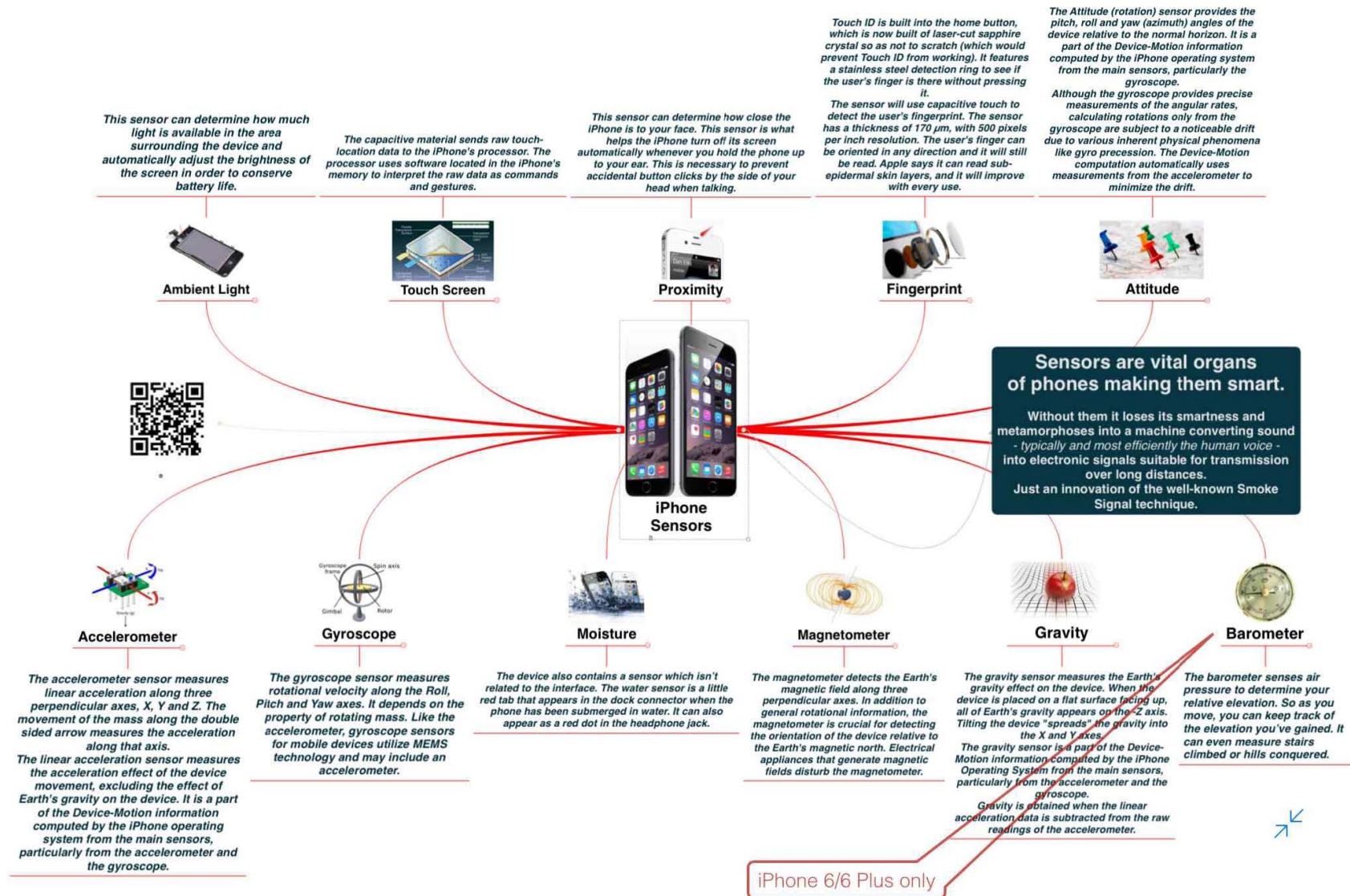
Sensors on Mobile Devices

Sensors on Mobile Devices

갤럭시S4 탑재 9대 센서



- 조도 센서
- GPS
- 마이크로폰
- Bluetooth
- WiFi
- NFC

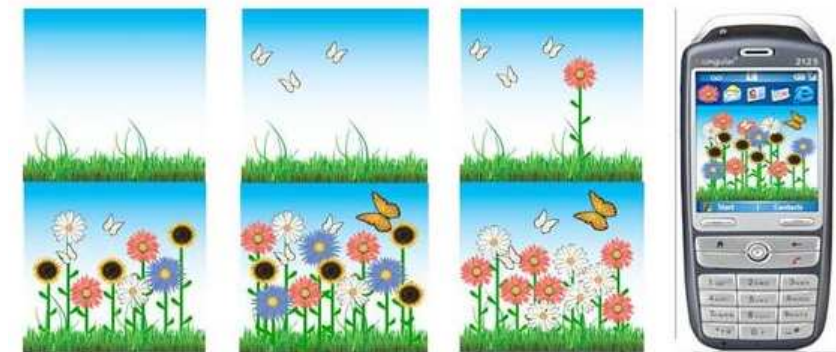
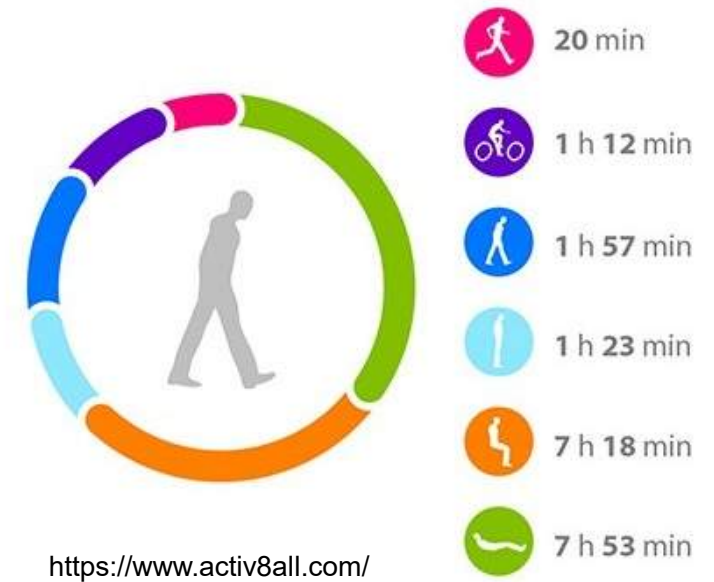


Mobile Phone Sensing

- 스마트폰에 내장된 다양한 센서를 이용하여 각종 센싱 애플리케이션을 구동할 수 있음
 - fitness, pedometer (활동량, 만보계): Google Fit, Accupedo, S Health
 - activity/location tracking (활동량, 장소): Moves
 - transportation mode (버스/자전거/지하철/도보)
 - environment/place (주변 환경/장소 정보)
 - conversation (대화 상대/대화 상태)
 - emotion (감정 상태)
- 사람들의 다양한 활동, 상태, 상황 정보를 인지/추론/예측하여 서비스를 제공할 수 있음

Physical Activity

- activity inference 예제
 - 걷기, 달리기, 싸이클링, 계단 오르내리기, ...
- 사용 센서 예
 - accelerometer, gyroscope, compass
- 애플리케이션
 - 활동량 로그
 - Health/behavior intervention: 운동 장려



Consolvo, Sunny, et al. "Flowers or a robot army?: encouraging awareness & activity with personal, mobile displays." *Proceedings of the 10th international conference on Ubiquitous computing*. ACM, 2008.

Transportation Mode

- mode inference 예제
 - 버스, 자동차, 지하철, 자전거, ...
- 사용 센서 예
 - accelerometer, gyroscope
 - GPS, WiFi, Cell
- 애플리케이션
 - 지능형 대중 교통 시스템



http://www.123rf.com/clipart-vector/mode_of_transportation.html


Place/Environment Context

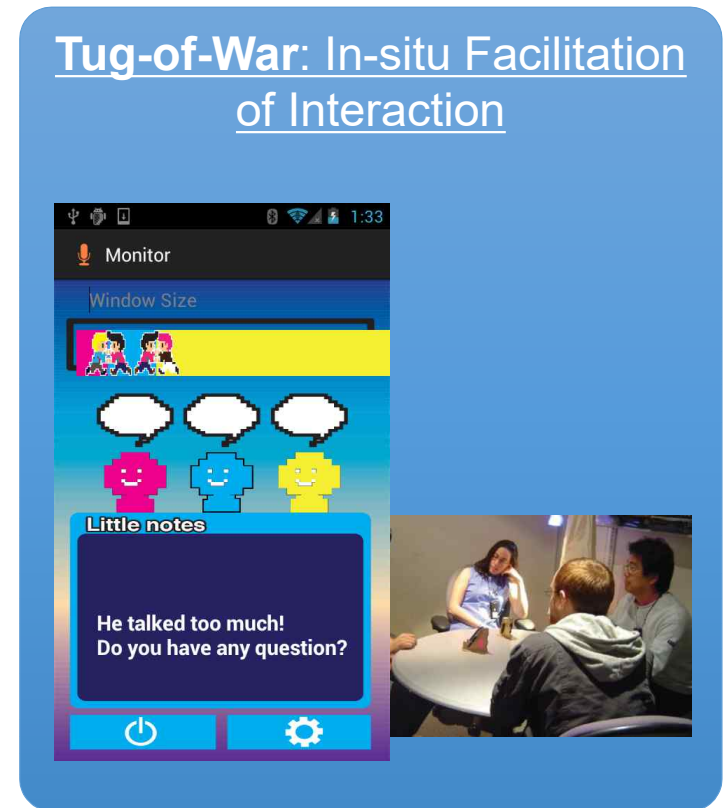
- context inference 예제
 - 대화, 음악, 파티 장소, 운전 중, ...
- 사용 센서 예
 - microphone, camera
 - accelerometer, GPS, WiFi, Cell
- 애플리케이션
 - automated diary
 - place tagging
 - health/wellness



<https://www.technologyreview.com/s/413958/cell-phones-that-listen-and-learn/>

Conversation, Human Voice

- 예제 
 - turn-taking, stress, speaker Id.
- 사용 센서 예
 - microphone
- 애플리케이션
 - 소셜 네트워크 분석
 - 대화 상대, 대화 참여도
 - 스트레스 정도

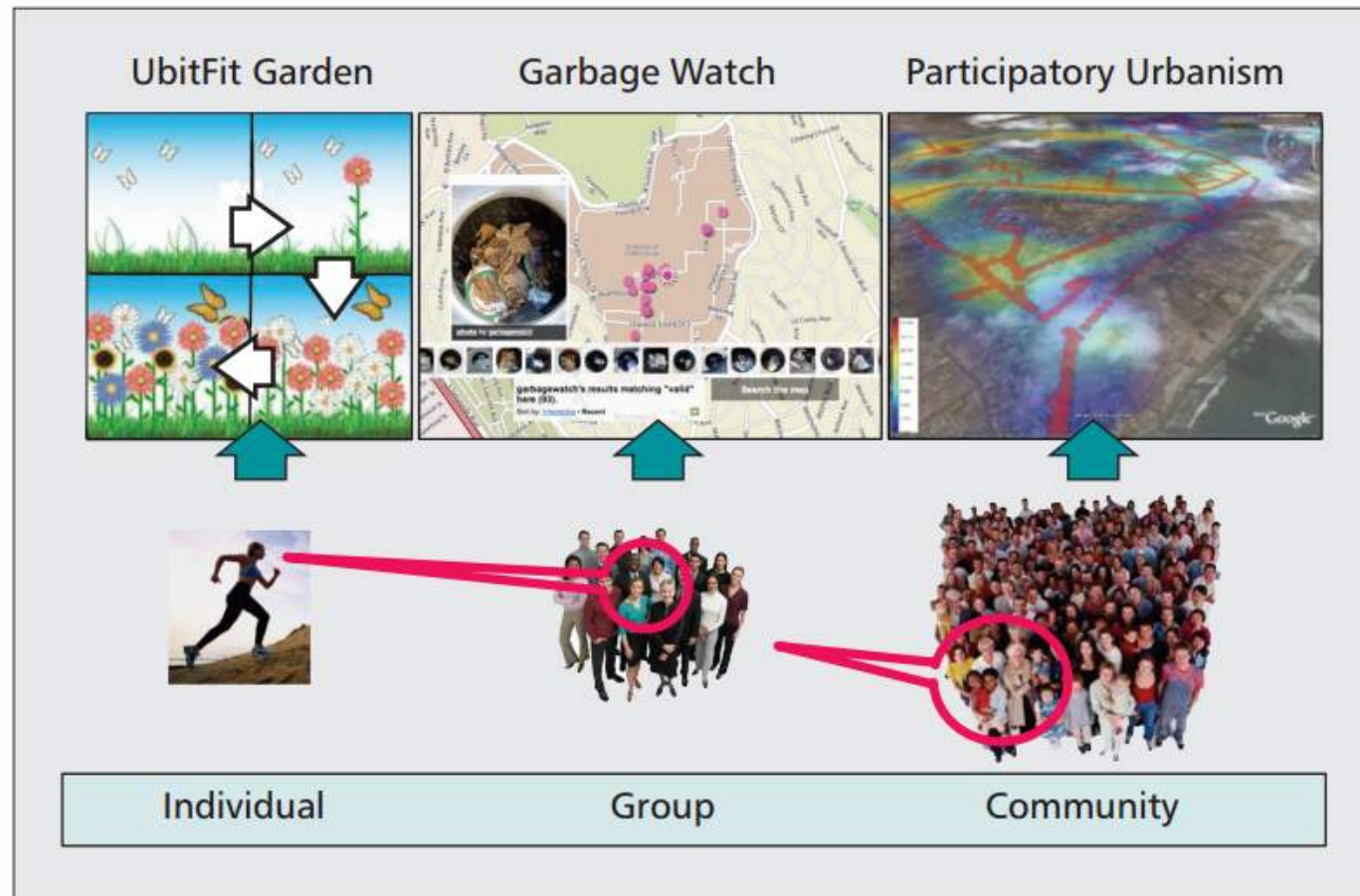


Lee, Youngki, et al. "Sociophone: Everyday face-to-face interaction monitoring platform using multi-phone sensor fusion." *Proceeding of the 11th annual international conference on Mobile systems, applications, and services*. ACM, 2013.

Mobile Sensing Applications

- Individual sensing (개인 차원)
 - fitness, activity tracking
 - behavior/health intervention
- Group/community sensing (그룹 차원)
 - interaction monitoring
 - environmental sensing
- Urban-scale sensing (도시 차원)
 - congestion/pollution monitoring in a city

Scale of Mobile Sensing



N.D. Lane, E. Miluzzo, H. Lu, D. Peebles, T. Choudhury, A. Campbell. A survey of mobile phone sensing. IEEE Computer Magazine. Vol. 48. No 9. September 2010.

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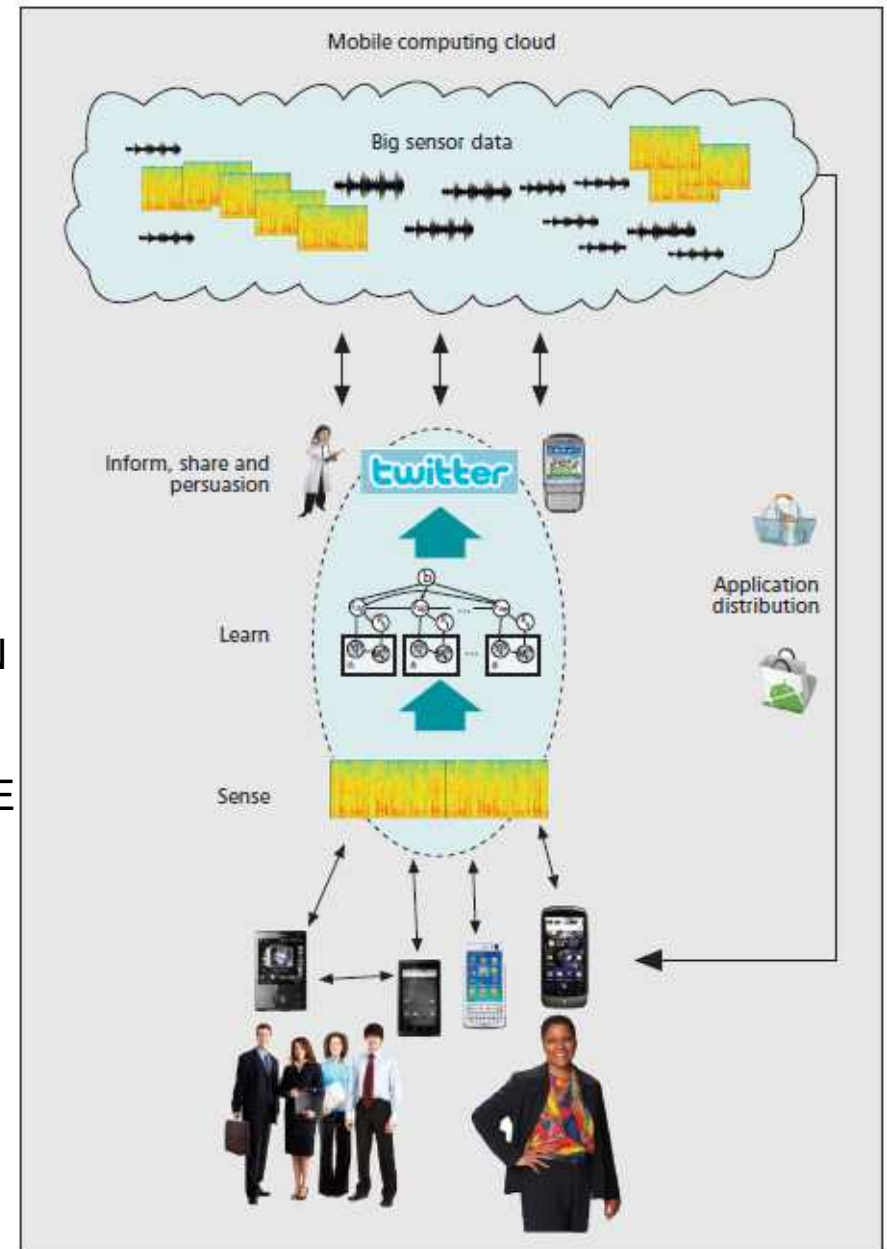
Mobile Sensing Architecture

- Sense – Raw sensor data collected from device by app
- Learn – Data filtering and machine learning used
- Inform – Deliver feedback to users, aggregate results

INFORM, SHARE,
PERSUASION

LEARN

SENSE



Example Case (Pothole Patrol)

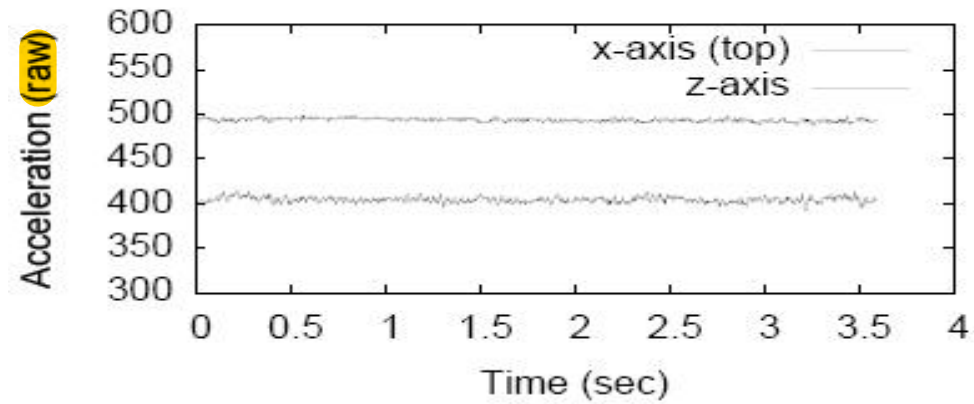


- 도로 교통 안전을 위해서 도로 상의 pothole을 찾고 보수 공사를 해야 함
- 도로 관리를 담당하는 사람들이 이러한 작업을 지속적으로 해야 하는데 인력 및 비용 소모
- 이를 모바일 센싱 기술/시스템을 이용하여 효율적으로 할 수 있을까?

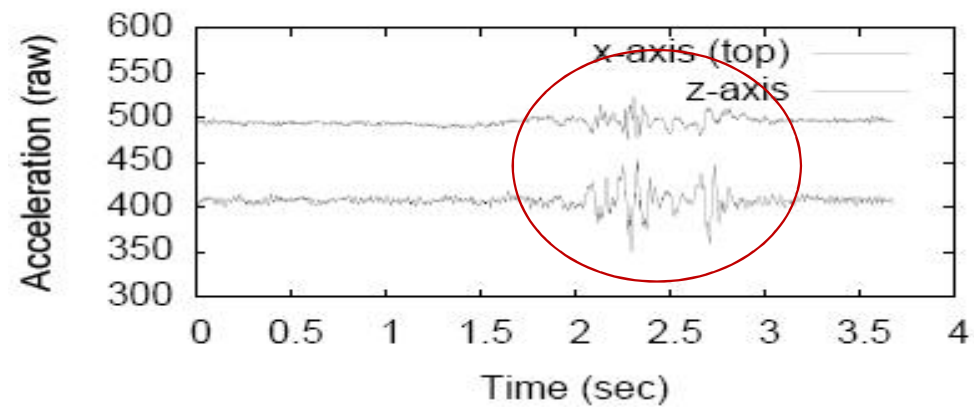
Example Case (Pothole Patrol)



Smooth Road

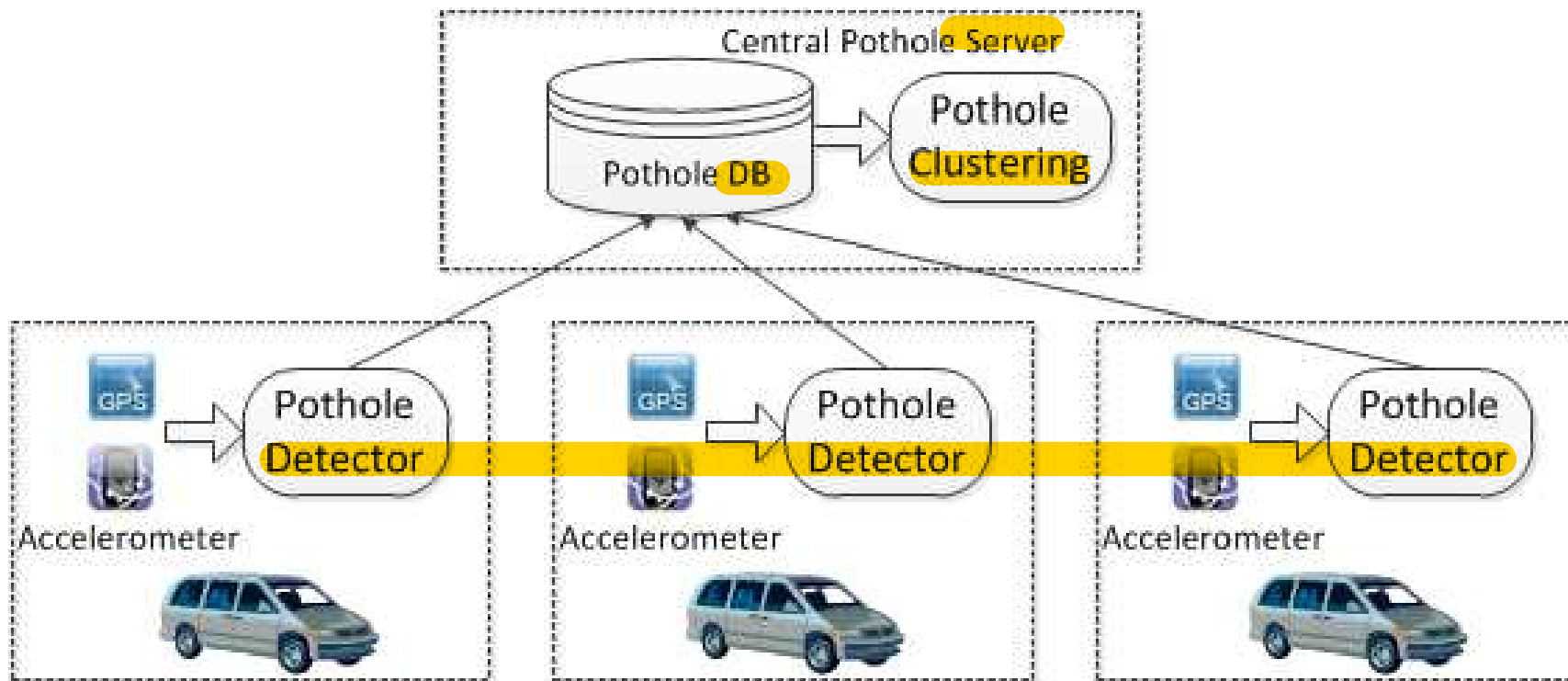


Pothole



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Example Case (Pothole Patrol)

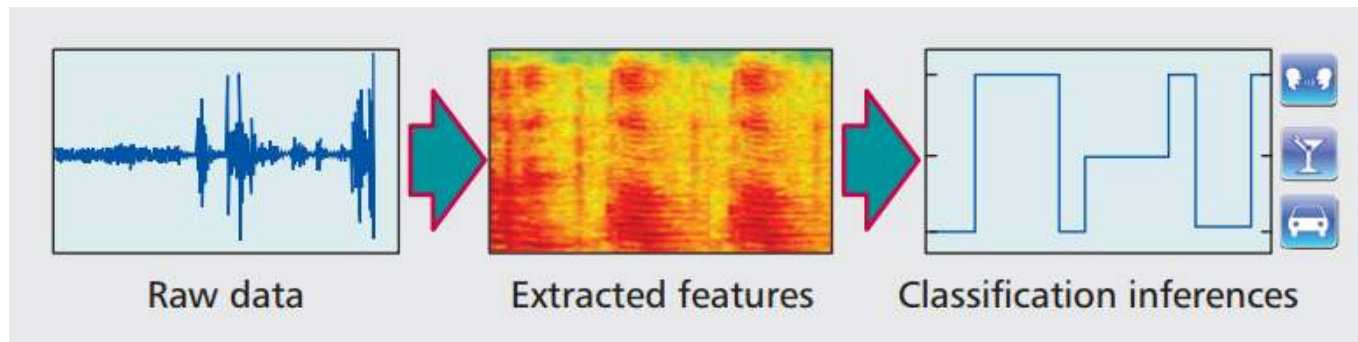


Eriksson et al, The Pothole Patrol: Using a Mobile Sensor Network for Road Surface Monitoring, MobiSys, 2008

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Common Mobile Sensing Design Pattern

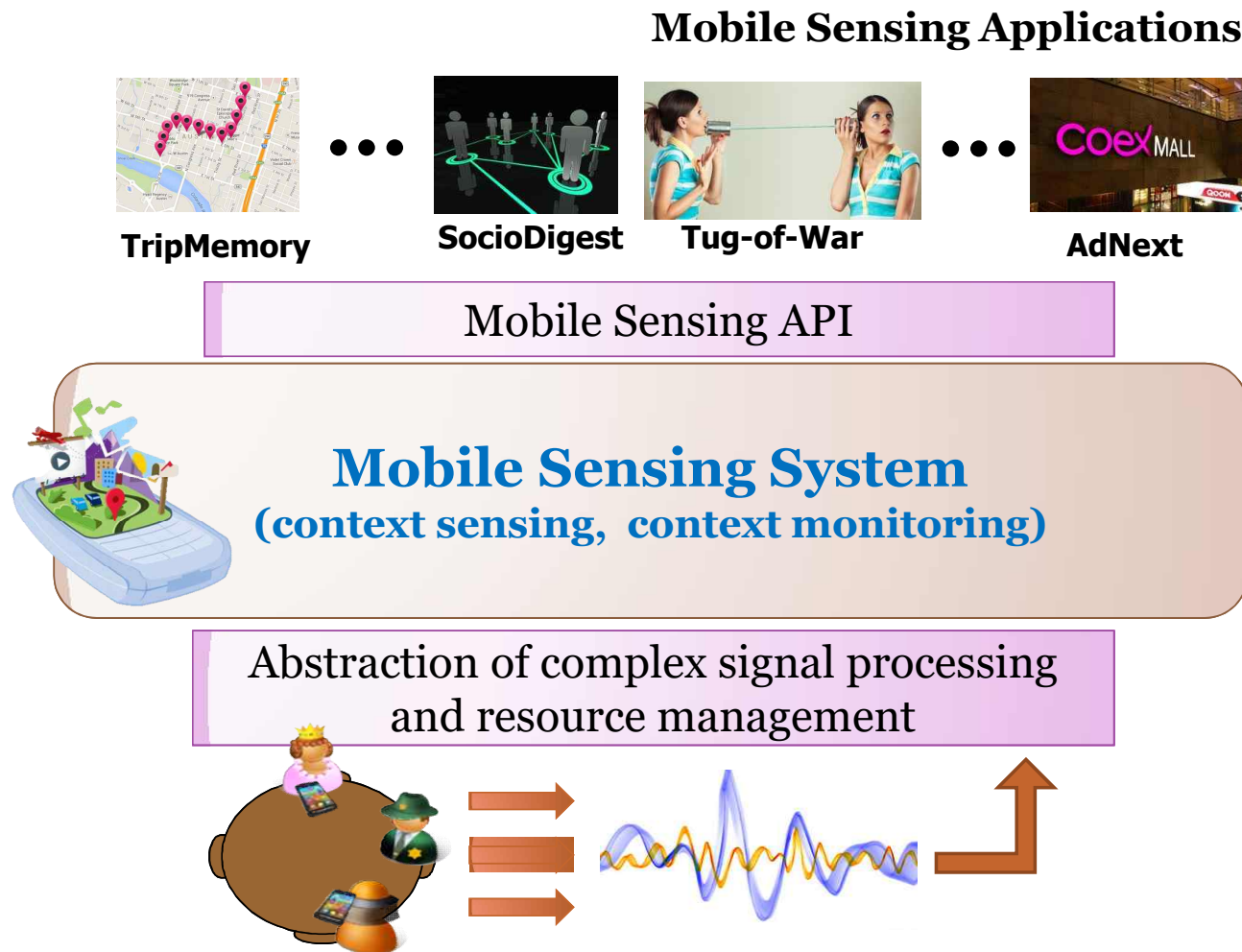
- 일반적으로 다음과 같은 작업을 공통으로 수행
 - **Collect raw** data using the sensors (mobile phone, other wearable sensors)
 - **Infer a context** (state, situation) of a user using the raw sensor data
 - physical activity: running, waking, driving?
 - conversation
 - Provide the inferred result to the user or use the result to adapt the service/information provided by the application



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Mobile Sensing System

- 여러 모바일 센싱 애플리케이션들이 공통으로 필요로 하는 작업을 수행
 - 센서 데이터 수집
 - 데이터 처리, inference
 - 자원 관리
- 애플리케이션에는 high-level API를 제공
 - application이 필요한 sensing, context 정보를 제공
- 애플리케이션 개발자는 **low-level detail**을 처리하지 않아도 되고 서비스 로직에 집중하여 구현할 수 있음



Mobile Sensing System Examples

- 다양한 research prototype

- Kang, Seungwoo, et al. "Seemon: scalable and energy-efficient context monitoring framework for sensor-rich mobile environments." Proceedings of the 6th international conference on Mobile systems, applications, and services. ACM, 2008.
- Lee, Youngki, et al. "Comon: cooperative ambience monitoring platform with continuity and benefit awareness." Proceedings of the 10th international conference on Mobile systems, applications, and services. ACM, 2012.
- Hong Lu, Jun Yang, Zhigang Liu, Nicholas D. Lane, Tanzeem Choudhury, Andrew T. Campbell. "The Jigsaw Continuous Sensing Engine for Mobile Phone Applications", 8th ACM Conference on Embedded Networked Sensor Systems (SenSys '10), November 2010.
- David Chu, Nicholas D. Lane, Ted Tsung-Te Lai, Cong Pang, Xiangying Meng, Qing Guo, Fan Li, Feng Zhao. "Balancing Energy, Latency and Accuracy for Mobile Sensor Data Classification", 9th ACM Conference on Embedded Network Sensor Systems (SenSys '11), November 2011.

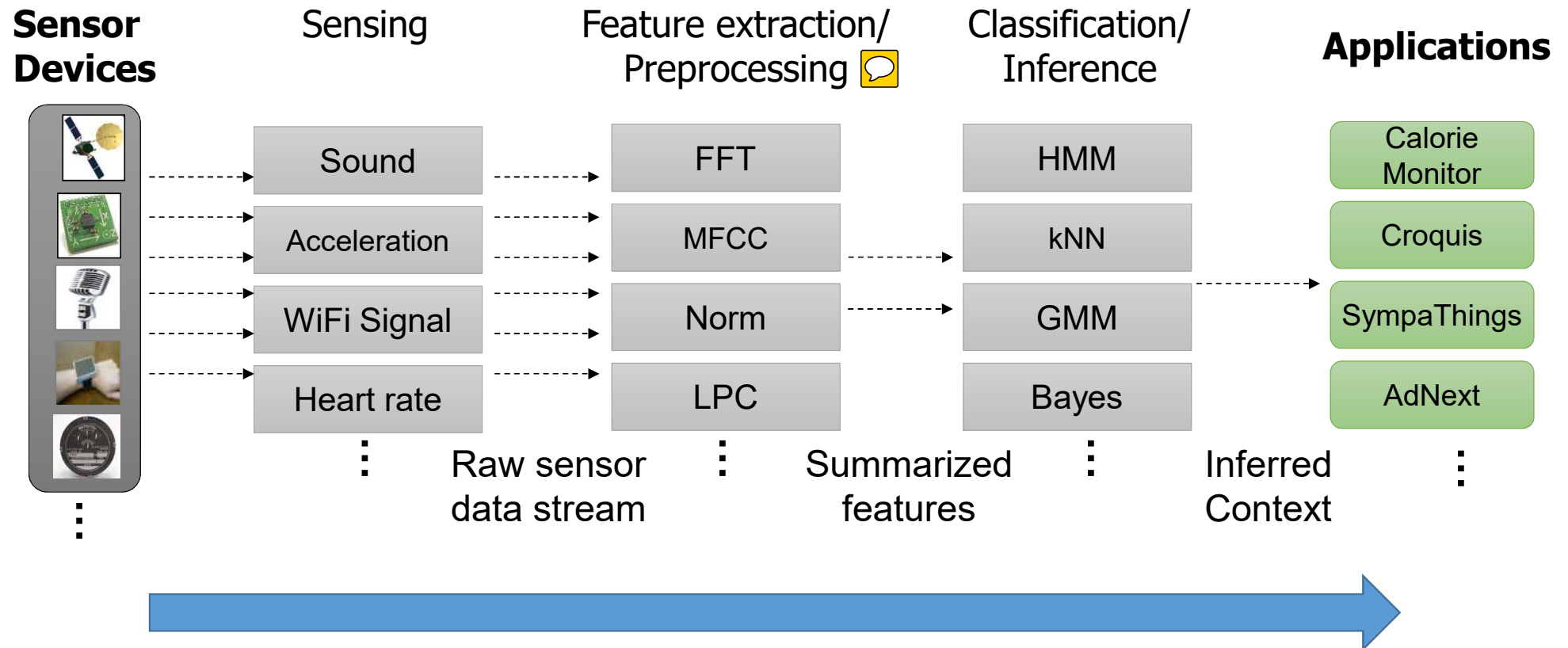
- Commercial product



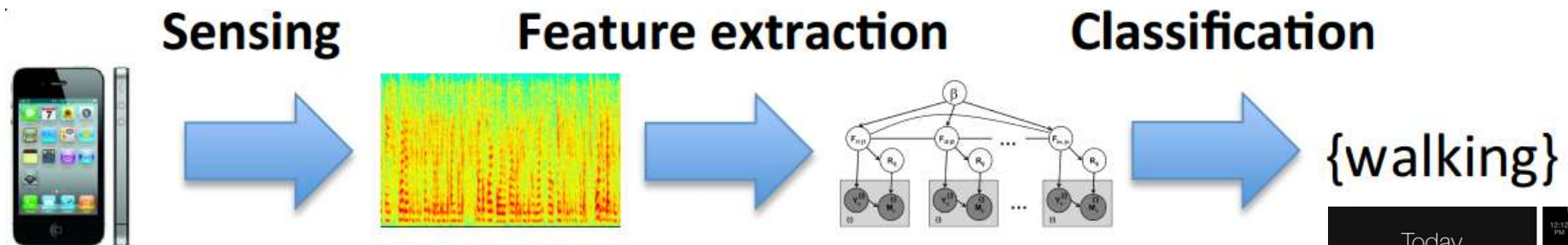
- M7(M8, M9) motion co-processor / iOS Core Motion Framework (introduced in iOS 7)
 - M7: Apple iPhone 5S에 처음 탑재된 motion sensing 을 위한 co-processor (2013)
 - CM Framework: Application에서 (raw or processed) motion data를 받을 수 있게 하는 API 제공
- Google Android smartphone에도 비슷한 기능 탑재 (Nexus 5 이후)



Mobile Sensing Pipeline



Example for Physical Activity Inference




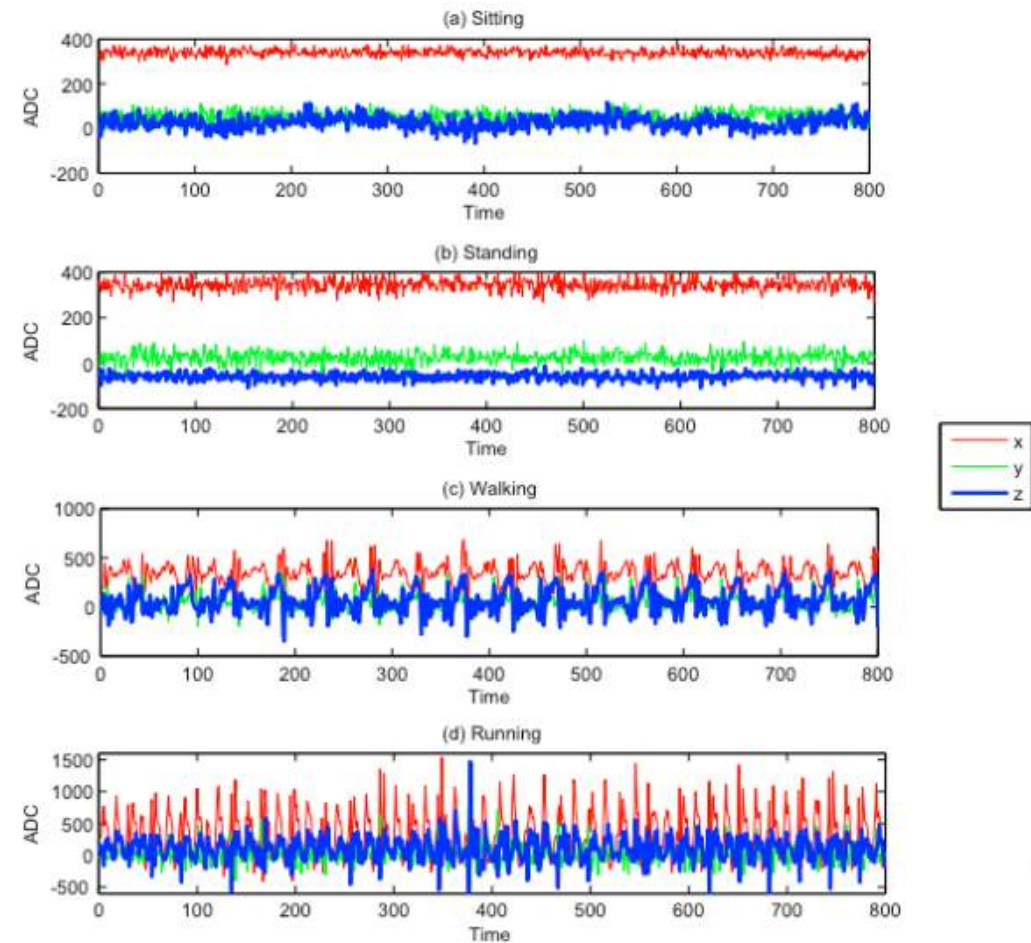
- Physical activity inference를 위해 필요한 사전 과정

- sensor data 수집
- context labeling(tagging) – 어떤 상황에서 수집된 데이터인지 표기 (예: 걷기/달리기)
- Classifier training – machine learning 알고리즘 이용



Physical Activity Example

- Activities
 - sitting, standing, walking, running
- Sensor
 - accelerometer
- Features 
 - Mean
 - Standard deviation
 - Number of peaks
 - FFT-derived features (spectrum peak, sub-band energy, spectral entropy, ...)
- Classification
 - Decision Trees
 - Hidden Markov Models
 - Naïve Bayes



Activity에 따른 가속도 센서 데이터의 변화


Challenge of Mobile Sensing System



- Mobile sensing은 자원을 많이 소모하는 작업
 - 지속적인 센서 데이터 수집: Sensor/GPS/Mic., CPU, Memory, Storage
 - 지속적인 데이터 처리: CPU, Memory, Storage, (Network)

→ **Battery!!!**
- 스마트폰은 여러 애플리케이션이 실행되어야 하는 범용 플랫폼
 - 모바일 센싱 애플리케이션을 위한 작업을 수행하는 데에 무한정 자원을 사용할 수는 없음
 - 모바일 센싱 애플리케이션이 작동하는데 필요한 자원의 양과 애플리케이션이 요구하는 적정 수준의 context inference 정확도 사이에 균형을 맞추어야 함

What to learn

- 모바일 센싱 기능 구현을 위한 안드로이드 Application Framework의 각종 시스템 서비스 API 활용
 - SensorManager
 - LocationManager 
 - WiFiManager
 - BluetoothManager
 - PowerManager
- 모바일 센싱 애플리케이션 구현
- 효율적인 모바일 센싱 시스템 구현을 위한 디자인 방법

References

- Mobile and Sensor Systems Lecture Material (Lecture 7: Mobile Phone Sensing)
 - <http://www.cl.cam.ac.uk/teaching/1415/MobSensSys/materials.html>
- N.D. Lane, E. Miluzzo, H. Lu, D. Peebles, T. Choudhury, A. Campbell. A survey of mobile phone sensing. *IEEE Computer Magazine*. Vol. 48. No 9. September 2010.
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- Lu, H., Pan, W., Lane, N. D., Choundhury, T., and Campbell, A. T. SoundSense: Scalable Sound Sensing for People-Centric Application on Mobile Phones. In *MobiSys*, 2009.
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