KNOWME: Exploring the Role of Mobile Devices in Health Care

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Computing in 2020

• Computing 2020: Yet another paradigm shift
  • Interfacing computing with physical world
    • societal challenges: Health, Infrastructure Efficiency.....

• Vision enabled by three layers of computing
  • On Body Computing Devices
    • Environmental and body sensors, mobile devices
  • Cloud Network
  • Datacenters
    • Resource to synthesize useful info from volumes of data
Mobile Social Networks

- Enabled by advancing capabilities of mobile devices
  - Innumerable sensors, reliable and relatively low cost communication
- Features of this class of applications
  - Each user in a social group contributes their knowledge about their surrounding environments
  - The collective knowledge can be exploited by the community members for personal or social benefit
Body Sensing and Processing Systems
Enabling new directions for evidence driven health care

• Efficient, Just in time information and intervention possibility
• Can help motivate, and facilitate self awareness
• Data from real life conditions, not just lab tests
• New research capabilities
• An interdisciplinary enterprise: medicine, public health, technology, policy and society
KNOWME for Obesity

• Pediatric Obesity and Metabolic Health: A compelling use domain
  • 33.6% of children above normal weight
  • Overall increase of 5.4% from 2000 to 2004
  • Only 35.8% of HS Students meet suggested daily physical activity rate
  • Estimated Annual Pediatric Obesity Costs
    • $14B, US [cdc.gov], £3.3B, UK [www.nao.org.uk] and between 3.58% - 8.73% of GNP in China, 2000-05

Ogden et al, JAMA, 2006; YRBS, 2005; Popkin, 2006; Metz-Spruijt 2009
Wireless Body Area Networks (WBANs)
  • An incarnation of people-centric sensing

KNOWME WBAN
  • Integrates external body sensors with mobile phone
  • Measures bio-sensor signals continuously and in real time
  • Classification algorithms to detect user states
    • Simple classification on phone
    • Complex classification on backend
  • Data transmitted to backend for classification
• Combine health sensors with mobile (N95)
  • Metabolic data: ECG, ACC, OXI
  • Emotional data: GSR
  • User initiated data: SMS, speech notes, images/ videos, Tweet Feeds
  • Location data: GPS
KNOWME Mobile Client: Software Overview

Client Software role: Sensor, aggregator, analyzer, transmitter & on body compute.

Free living studies for 9 months with ~0 crashes!
• Few domains of interest: chronic obstructive pulmonary disease (COPD), diabetes, post injury rehabilitation
• COPD: Integrating new sensors for measuring air quality, spirometry (peak flow), ... into KNOWME-like infrastructure
• Run new class classification and correlation algorithms on the mobile phone for auto-detection of disease severity
• Pinning the context with the disease
Mobile as a Center Piece

- As we bring KNOWME to new domains, mobile is the center piece
  - Data aggregation, data analysis, automatic user feedback, data communication

- Interdisciplinary research
  - Work with KECK medical team to understand the domain and apply existing standards for data collection
  - Work with signal processing and communication researchers to analyze signals
  - Build new interfaces to improve mobile phone’s usability as a medical monitoring device
Challenges on Mobile Device Front

- Mobile devices are battery limited
  - Cannot consume too much energy for analysis and sensing
- Health monitoring cannot impact user’s ability to interact with the device for other purposes
  - Reduce monitoring demands in terms of computation and communication
- User friendly application designs
  - Understanding societal demands and change interfaces
- Integration of monitoring into social networks
  - Particularly useful for positive reinforcement, interaction with domain-specific support groups
- Dealing with privacy
Lessons From Free Living Trials

- Application robustness is key to successful WBAN usage
  - End user compliance depends on robustness and ease of use

- Energy efficiency must be dealt with in all aspects of the WBAN design
  - Choice of programming language to sensor sampling
  - Energy efficiency plays major role in robustness

- Finally, all effort must be transparent to the user
  - User does not care about what is under the hood
• Some data generated from KNOWME experiments
  • Focused on energy efficiency issues in mobile phone
  • Solutions currently being developed to tackle this problem
Good Choices and Bad Choices

- Many choices at each WBAN design stage
  - Initial Dev: Efficiency vs. programming simplicity
  - Sense: Sampling rate vs. accuracy
  - Xmit: Signal quality, ZIP & encryption
  - Local vs. remote compute
- Each choice has dramatic impact on power consumption
- Designer has little knowledge of the energy impact of their choice
- Energy impact varies dynamically
  - Signal quality for data transmission,
    Indoor/Outdoor GPS, Compression factors
• 3 WBAN functions + 3 languages + 3 models
  • QDA: QRS Detection, AES: Encryption, ZIP: 10 min data (180KB)
• PyS60 Energy >> J2ME > C++
  • Runtime environment overheads, memory management
• Programmer efficiency vs. WBANs battery
  • Easy to program most often conflicts with energy efficiency
  • Resource constrained environment & unlikely to improve
  • Tradeoffs tilt toward energy efficiency
Energy Challenge - Sensing

- Dramatic battery drain on N95
  - 200 hours standby time reduced to 5 hours
- Even without external sensors the in-built sensors drain battery
  - GPS reading = 6.6 Joules
One Example: GPS Sensing

- Power consumption varies significantly with the type of GPS
  - Nearly 2X more power for A-GPS over N-GPS
  - A-GPS is accurate within meter
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Compute vs. Communicate

• WBAN data is analyzed for state detection, anomaly detection,…

• Two Choices:
  • Analyze locally on mobile phone and send only interesting events to backend server
    • What is interesting is user/scenario-defined
  • Do nothing on phone and send everything to backend
    • Backend transmits anomaly data to mobile phone

• Trading local compute cost with communication cost
  • Selection must be dynamic for optimal energy consumption
Local Vs Remote Compute: QDA

- **J2ME**: Local 19J, WiFi XMIT: 1J, ZIP EDGE:24J, EDGE: 16J
- WiFi is preferable BUT uncommon scenario in free-living WBAN
- Else remote compute on EDGE (& no ZIP) better for small pkts
- Even a simple example has no clear choice
  - Signal quality issues make choices even more uncertain
  - Computational demands differ per WBAN & even vary dynamically
Active Energy API

- Provide a set of API for designers to obtain system services at the lowest energy cost, such as GPS, data transmission
- API automatically selects the best implementation
  - Implementation relies on Active Energy Profiling framework
- Current APIs:
  - Initialize()
  - StartMonitoring()
  - StopMonitoring()
  - GetPosition()
  - MakeDecision()
  - SendData()
Active Energy API

- Initialize (Sample Sensor Data, *Anal Func)
  - Called on system start with sampled data and analysis function ptr
  - Collects position-independent configuration parameters
    - Compression cost, ratio
    - Local computation cost on sampled data
    - Store in Config DB
- MakeDecision (Sample Data, Destination IP)
  - Scan WiFi Aps
  - Check config DB for position-dependent params
  - If no match then use Active Energy Profiling
    - Transmission costs for each network interface (scan WiFi Aps)
    - Store profile data in DB (indexed by GPS)
  - Compute local & remote costs
- GetPosition
  - Calls GPS only if WiFi scan is 20% changed
• KNOWME Operation
  • Sense continuously
  • Find state every min
  • Get position
  • Xmit after 1 min
AEP in Action

Power (mW)

Time (Minutes)

Bluetooth Communication with Two Alive Heart Rate Monitors

- Energy Profiling
- Positioning
- Energy Profiling
- WiFi Upload data w/o Gzip
- 3G Upload data w/ Gzip
- Local Computation & Gzip (Initialization)
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