Mobile Phone Sensing Based Affordable Wellness/Healthcare

Dr. Arpan Pal
Principal Scientist and Head of Research
Innovation Lab, Kolkata
Tata Consultancy Services

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**Power in the Palm of People**

**The Reach**

I think there will be a world market for about five computers
- Thomas Watson, Chairman of IBM, 1941

**The Power**

640KB of memory ought to be enough for anybody -- Bill Gates, in 1981

**The Value**

Quad Core Processor; 2048 MB RAM; Camera, Microphone, Accelerometer, Gyroscope, Magnetometer, GPS, BT, GPRS, 3G

Mobile Phones with all its sensors, compute and communication capability can be a great enabler for affordable Internet-of-Things (IoT)
Motivation in Healthcare

• Connected Health has the potential of disrupting healthcare through 24x7 monitoring of physiological parameters leading towards preventive care and newer predictive diagnosis - however cost of ownership of medical devices is an issue

• Digital India project: Government to ensure that every Indian has smartphone by 2019 – Economic Times, Aug 25 2014 (INR 3000)

• Smartphones have sensors and processing power in them to turn them into cloud-connected physiological measuring devices – no extra cost of ownership - Camera, Microphone, Accelerometer, Gyroscope, Magnetometer, GPS

Use Cases

- Elderly People Monitoring @Home
- Chronic Patient Monitoring @Home
- Rural Healthcare
- Insurance
Mobile-Health - as it is now

Health Center/Home
- ECG
- Blood Pressure Monitor
- Pulse OxyMeter

TCUP
- Web Request
- Mobile phone as medical gateway
- Healthcare Portal
- Social Network
- Patient Records
- Expert Doctor

Pilot @ Singapore
Replace Medical Sensors with Mobile Phone Sensing

Gives Rise to Interesting Distributed Computing Challenges – how much to do on mobile and how much on cloud – energy and communication cost optimization
Uses TCUP, the TCS IOT Platform
Heart Rate from PPG

- Sources of noise:
  - improper finger placement
  - imparting excessive pressure
  - finger movement
Blood Pressure from PPG

A complete PPG cycle

Peak2peak = time gap between $P_{sn}$ and $P_{sn-1}$
Pulse interval = time gap between $V_n$ and $V_{n-1}$
Crest Time = Time to reach from $V_{n-1}$ to $P_{sn}$
Diastolic Time = Falling time between $P_{sn}$ and $V_n$
Pulse Height = Amplitude of $P_{sn}$
Pulse Area = Area under the curve

2 Element Windkessel Model

Ground truth BP values

Calculate R and C

Linear regression

Models for R and C

Training Phase

PPG Features

Testing Phase

Models for R and C

Predict R and C by regression

Calculate $P_s$ and $P_d$

PPG Features

Aggregate and personalized modeling
• Stress Analysis from HRV - The sampling rate for audio is high compared to PPG, thus calculation of HRV would be more accurate. From HRV, Stress Levels can be estimated.

• Sound analysis - Analysis of normal and abnormal sounds or heart

• Fetal heart beat monitoring – The mobile phone mic is placed on lower abdomen. Simultaneous capture of mother’s PPG can be used to adaptively filter mother’s heart beat. Need to get access to hospitals for collecting data.

• Need Sophisticated Signal Processing Chain to extract signal from noise
Activity Detection

- Uses Accelerometer Data
- Gyroscope and Magnetometer for orientation correction
- Step Count, Stride Length Estimation
- Walking, Brisk Walking, Running Classification

Peak Detection and Step Validation
Calculating Step cycle lengths for all valid steps in the window

Classification of window activity using step frequencies derived from step cycle lengths

Identifying non-activity window using frequency spectrum
Some Results

Camera – Heart Rate and Blood Pressure

~2 bpm error in Heart Rate
Robust against movement, phone variation

Accelerometer - Activity Detection and Calorie Count

~80% Accuracy in Activity Classification
Accurate Calorie Count – Require no training

Microphone – Heart Sound

~92% Accuracy in Blood Pressure
No such app exists

Some Results

Best Demo Award for Blood Pressure app in Sensys 2014 at Memphis, USA
Way Forward

Field Trials

- Heart Rate and BP - Ongoing with in-house doctors
- Activity Tracking, Heart Rate for TCS Fit4Life Program
- Heart Rate, BP, HRV, Digital Stethoscope - Planned trials at rural Chhatisgarh

Work on other solutions

- Pulse Oxymetry, Fall Detection, HRV giving encouraging results
- Explore cheap mobile attachments
- Higher level diagnosis – Coronary Artery Disease? Stress?

Other System Research Problems

- Heterogeneity of mobile platforms from compute, energy and communication aspects gives rise to interesting optimization problem for distributing computing load between mobiles and cloud
- What would be the optimal protocol for sharing data between mobile and cloud for such distributed computing environments?
Published Papers

10. "Smart Phone Based Blood Pressure Indicator" MobileHealth workshop of Mobihoc 2014
Thank You

arpan.pal@tcs.com