

Real-time Physiological and Contextual Monitoring on the Smartphone

**Nuria Oliver, PhD
Microsoft Research**

Introduction

- **Mobile phones, watches, etc... are pervasive, have increasing computation and communication power**
- **Pervasive non-intrusive physiological and environmental sensors**

**New opportunities for
wearable
health and wellness
continuous
monitoring devices**



- **Continuous real-time monitoring and understanding of multiple physiological and environmental signals**
- **Finding correlations between lifestyle and health**
- **Identifying trends and deviations from those trends**
- **Developing new interesting and fun applications**
- **Empowering users**
- **Enhancing sense of connectedness with loved ones**

Two Exemplary Projects

- **Smartphone is the central processing unit (Audiovox SMT5600)**
 - Personal Computer for millions of people
 - Communication capabilities (GPRS, etc)
 - Multimodal: camera, microphone, etc
- **Wireless connection to physiological and environmental sensors**
- **Health and wellness applications**
 - HealthGear
 - MPTrain

HealthGear: Goals & Motivation

- Real-time, wearable physiological monitoring system on a mobile phone
- *Physiological sensors wirelessly* connected via Bluetooth to a mobile phone
- Continuous recording of blood oximetry, heart-rate and plethysmographic signal
- Real-time *analysis* and *presentation* of physiological data to the user
- **Usage scenario:** Sleep monitoring and automatic sleep apnea detection

Application: Sleep Apnea

- **Underdiagnosed but common condition**
 - **Affects children and adults**
 - **4% in men and 2% in women (higher for elderly)**
 - **Untreated causes \$3.4 billion of medical costs**
 - **40 million undiagnosed Americans**
- **Periods of interrupted breathing (apnea) and periods of reduced breathing (hypoapnea)**
- **Leads to:**
 - **Hypoxia, asphyxia and awakenings**
 - **Increased heart-rate, high blood pressure**
 - **Extreme fatigue, poor concentration**
 - **Compromised immune system**
 - **Cardio/cerebrovascular problems**

Sleep Apnea: Diagnosis

- **Nocturnal Polysomnography (PSG):**



manual scoring and human error ☹

- **Pulse oximetry:**

- Useful as screening tool
- One simple, light-weight sensor on finger, toe or earlobe

HealthGear

Bluetooth Module

Your text here

Cell Phone

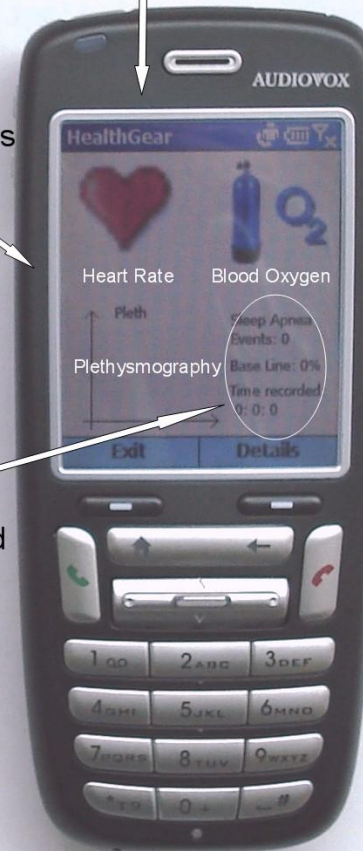
DSP Unit

HealthGear's
Interface

Oximeter

Batteries

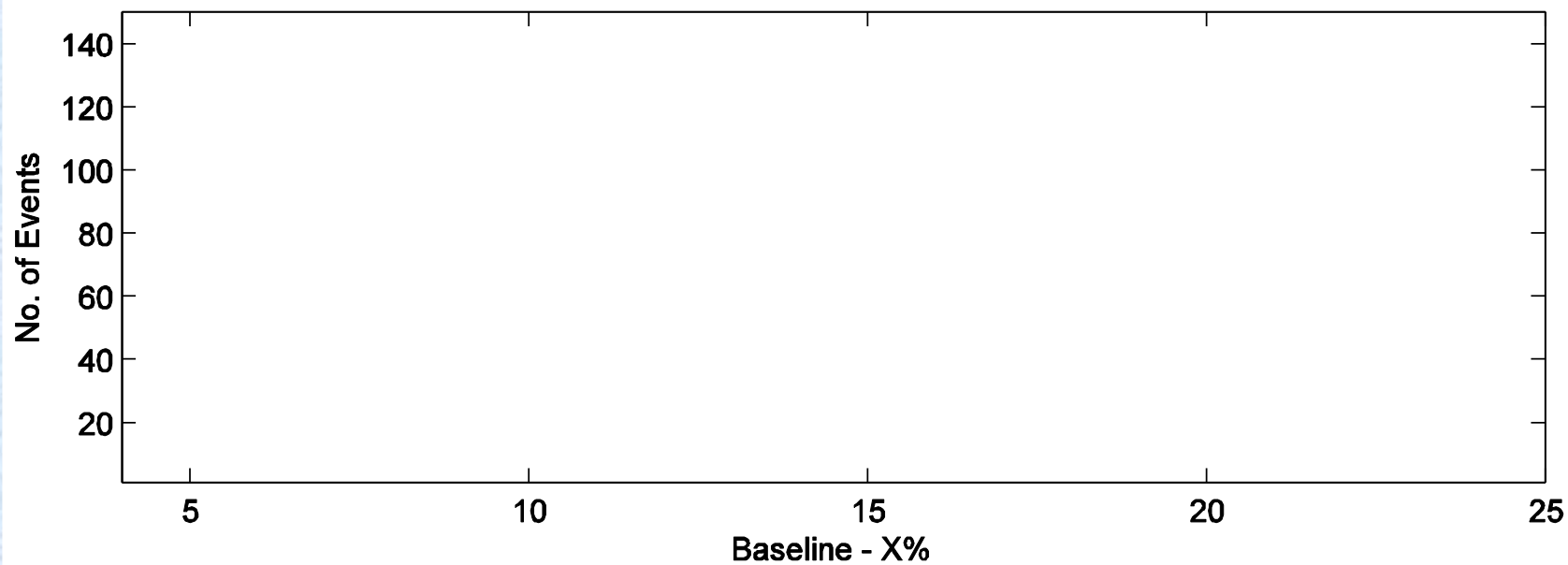
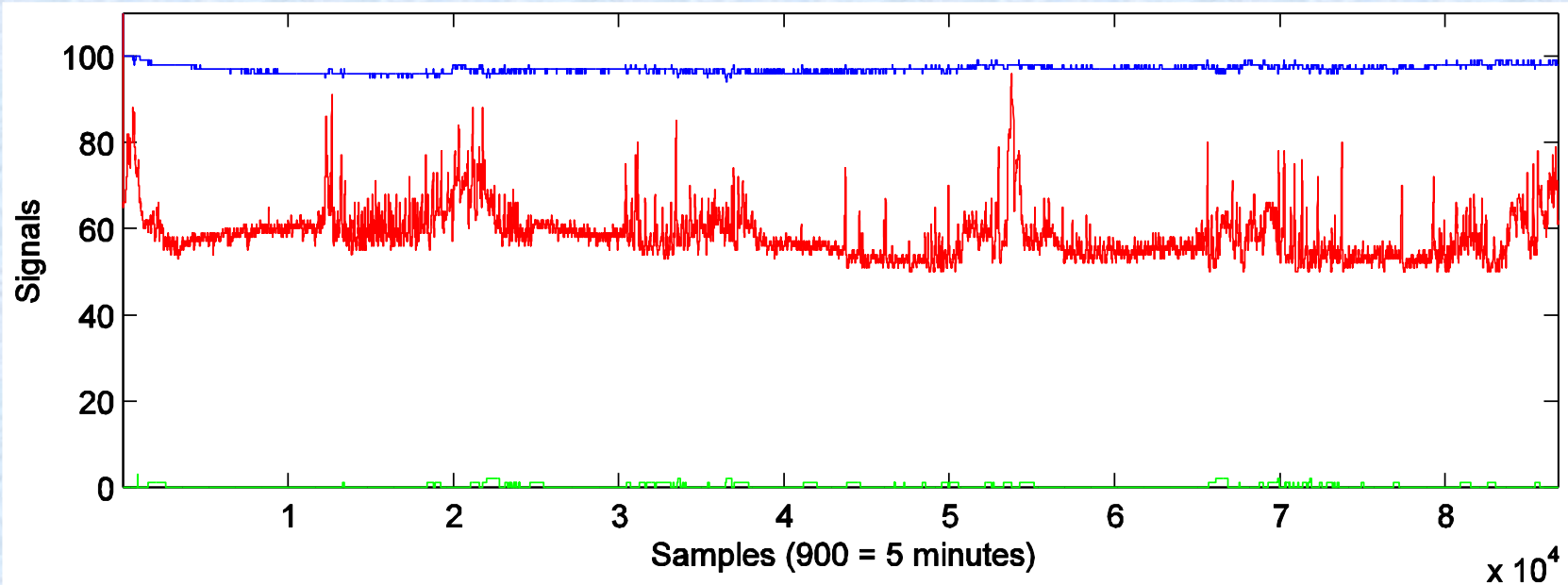
Automatic
Sleep Apnea
Detection and
Analysis



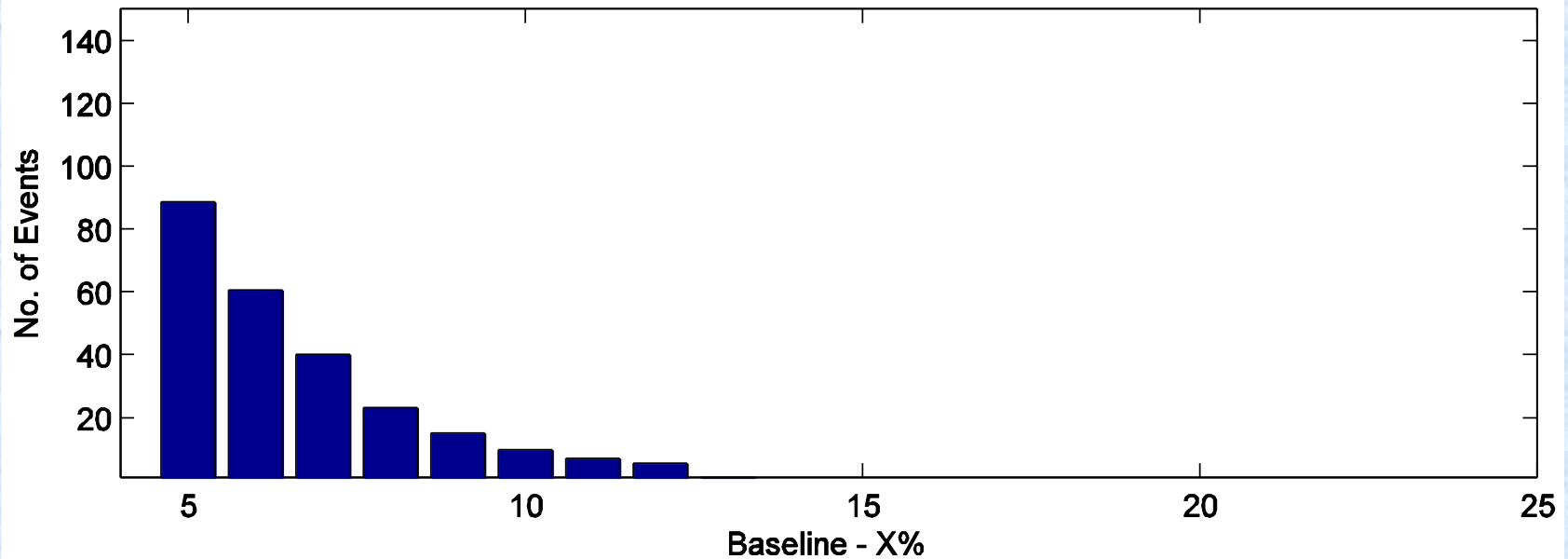
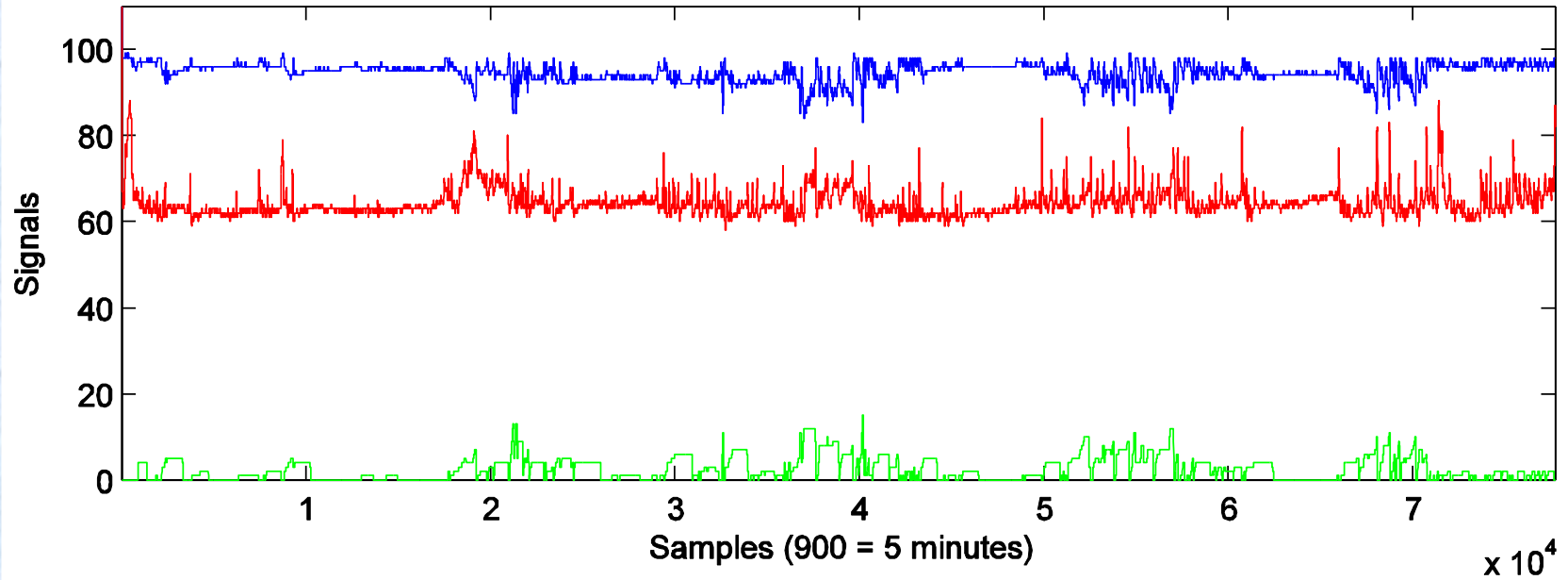
Sleep Study

- **21 volunteers:**
 - **80% male, ages 25-65**
 - **30% healthy, 70% with sleep apnea or suspected**
- **Wore HealthGear for one full night in their own homes**
- **Very successful on multiple fronts**
 - **Correctly identified all known cases of sleep apnea**
 - **Identified a few cases of apnea of ‘suspected’ individuals**
 - **Very highly rated by the users**

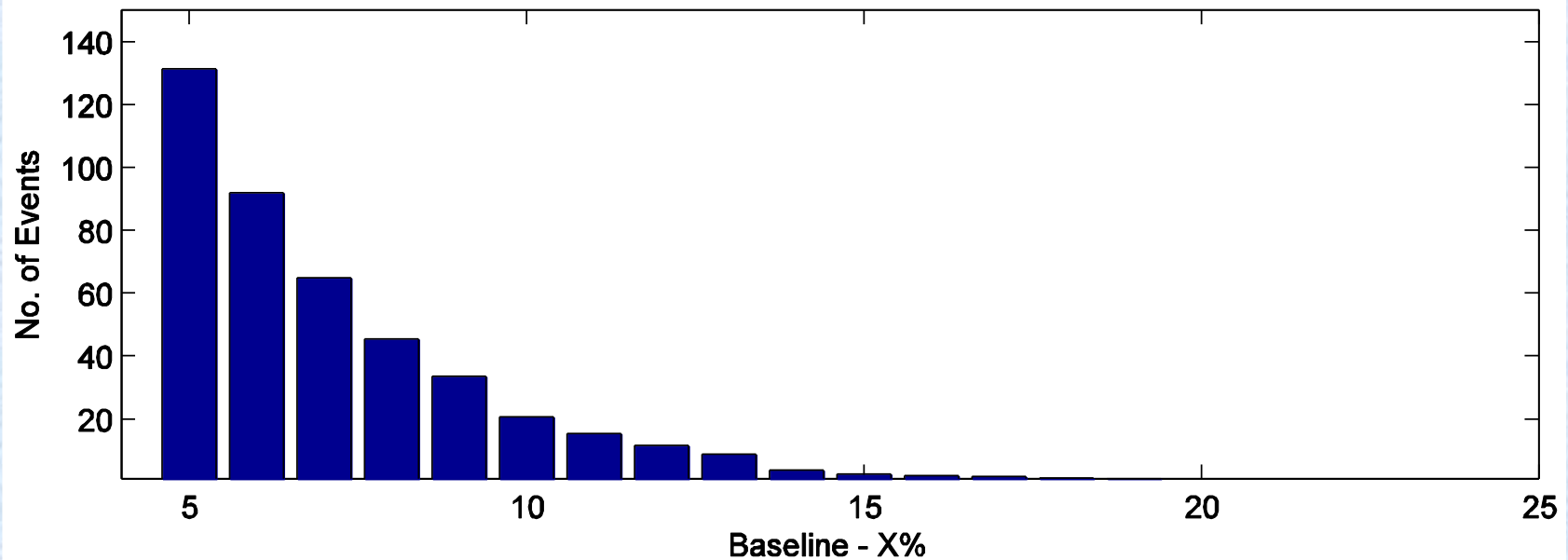
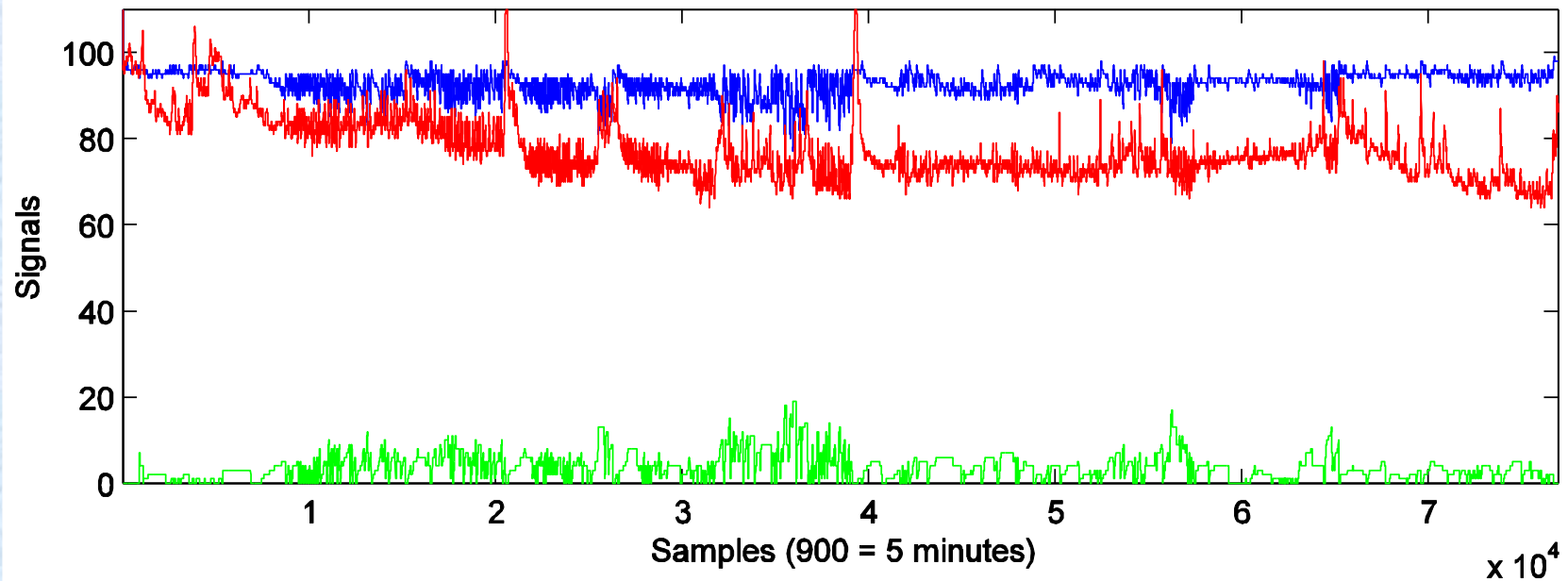
No Apnea



Mild-Severe Apnea



Severe Apnea



Video

Long term sleep studies

- **3 long-term (2-3 weeks at a time) sleep studies**
- **Investigated correlations between quality of sleep and lifestyle factors:**
 - **Alcohol intake**
 - **Diet**
 - **Exercise**
 - **Stress level**
- **Very interesting conclusions!**
- **Information never gathered and investigated before!!**

Conclusions & Future Work

- **Accurate sleep apnea monitoring**
- **Light-weight sleep monitoring system**
- **High acceptance rates**

- **More Long-term sleep studies**
- **Sleep study with Swedish Sleep Center**
- **Sleep study with MIT's House_N project**
- **Further collaboration with doctors**
- **Identifying correlations between lifestyle, environmental factors and physiology**
- **Application to other domains**

MPTrain

- **Personal trainer on a Smartphone**
- **Exploit the influence of music on exercise performance**
- **Real-time monitoring of ECG (heart-rate) and acceleration (pace)**
- **MP3 player**
- **Real-time selection of the right music to play to encourage users to achieve their exercise goals**



Gear Up | Run | Sync

Get in gear.

Meet the must-haves for the ultimate synthesis of sport and music: a pair of Nike+ shoes, an iPod nano, and the Nike + iPod Sport Kit. Find out what happens when the leading name in sports and the leading name in digital music team up to take on your workout.



Get a pair of Nike+ shoes

Only Nike+ shoes feature a built-in pocket under the insole specially engineered for the Nike + iPod sensor. For seamless, stylish integration, add



Get an iPod nano

Skip-free playback, a brilliant display, and up to 1,000 songs⁽¹⁾ in an impossibly small iPod keep you light on your feet. And only iPod nano syncs

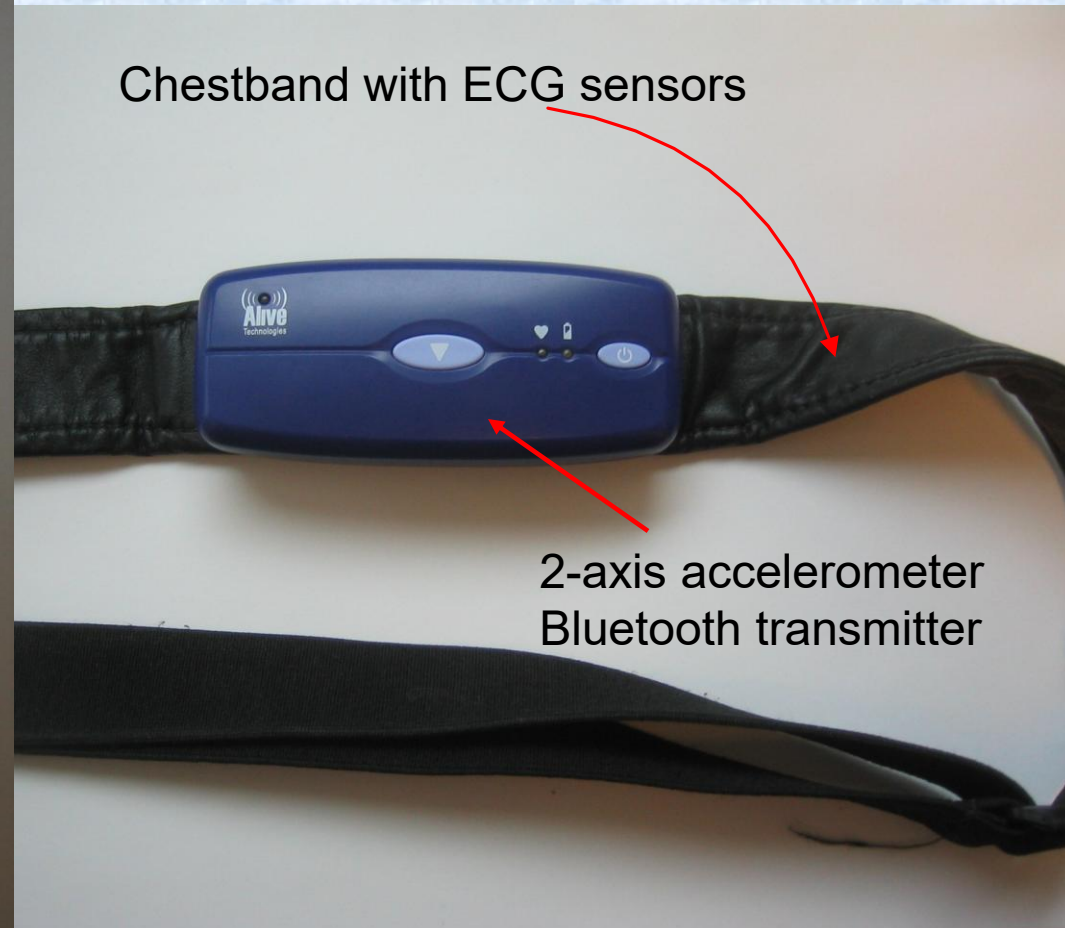
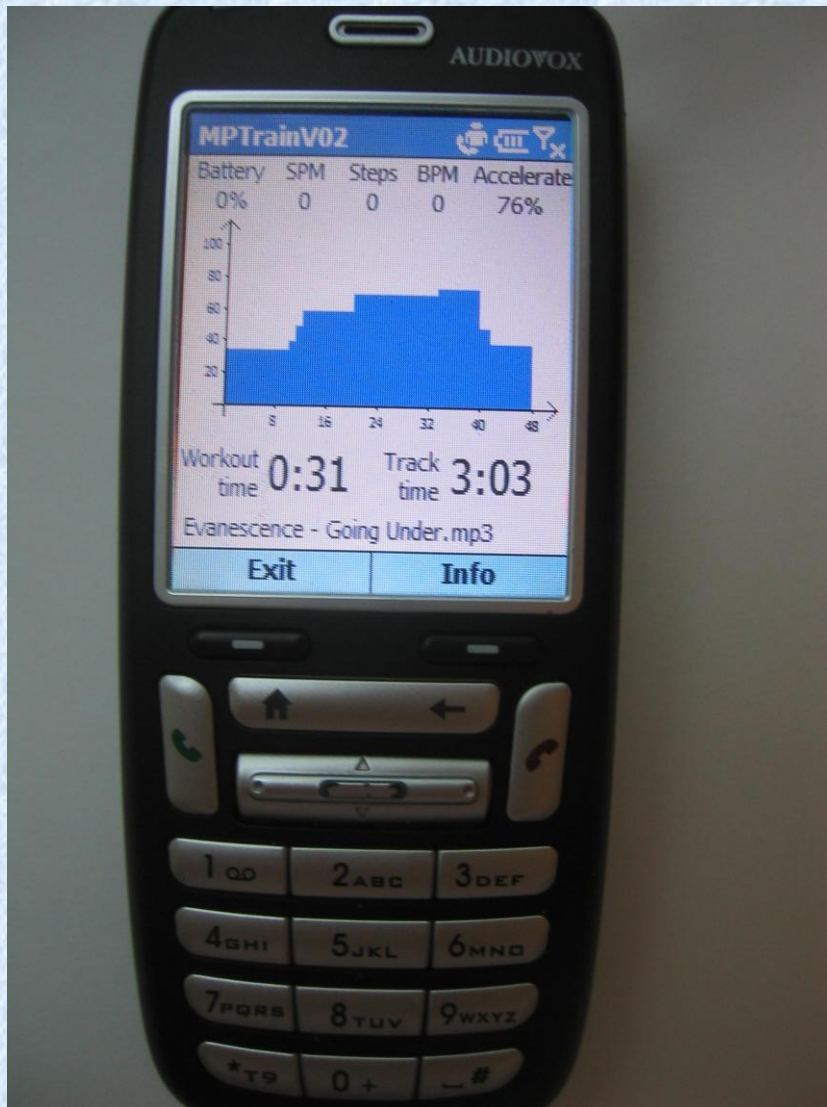


Get the Nike + iPod Sport Kit

The Sport Kit⁽²⁾ allows your Nike+ shoe to talk to your iPod nano. The sensor uses a sensitive accelerometer to measure your activity, then

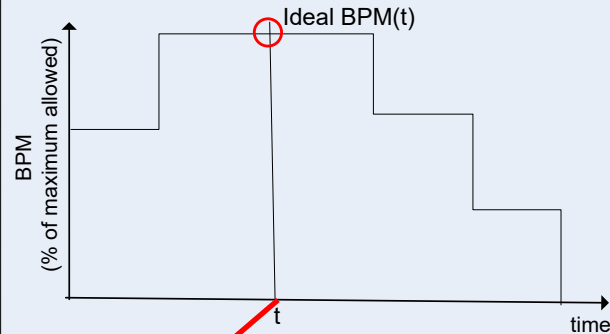
Sorry Apple, looks like this time you're the one copying Microsoft. Your iPod Sport Kit? Microsoft Research did it already.

MPTrain's Hardware



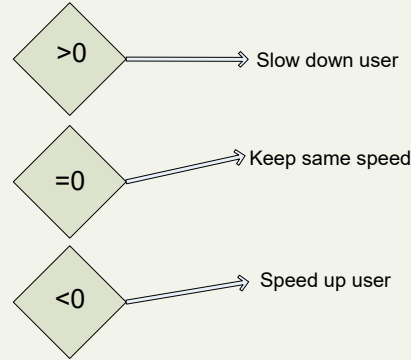
Desired Workout

(in BPM with respect to maximum allowed heart rate)



$$dBPM(t) = \text{Current BPM}(t) - \text{Ideal BPM}(t)$$

Current heart-rate (BPM(t)) and speed (SPM(t))



Next Action Module

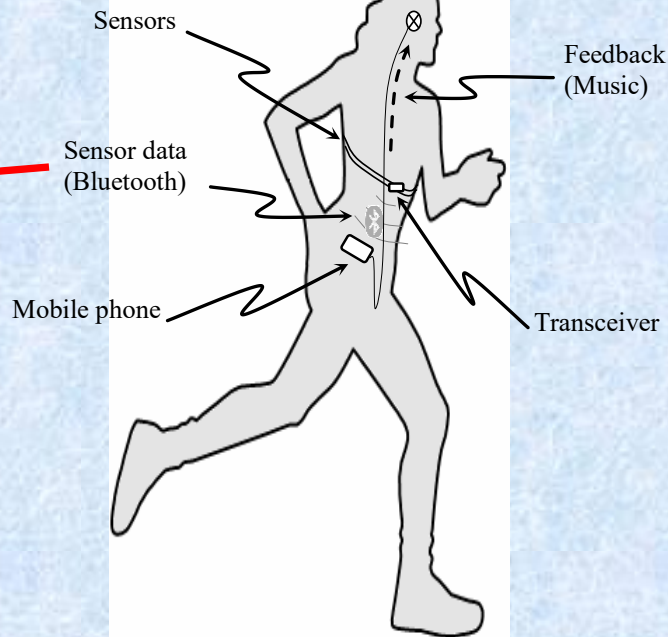
Digital Music Database

Find optimal slower song in beats per minute

Find optimal similar song in beats per minute

Find optimal faster song in beats per minute

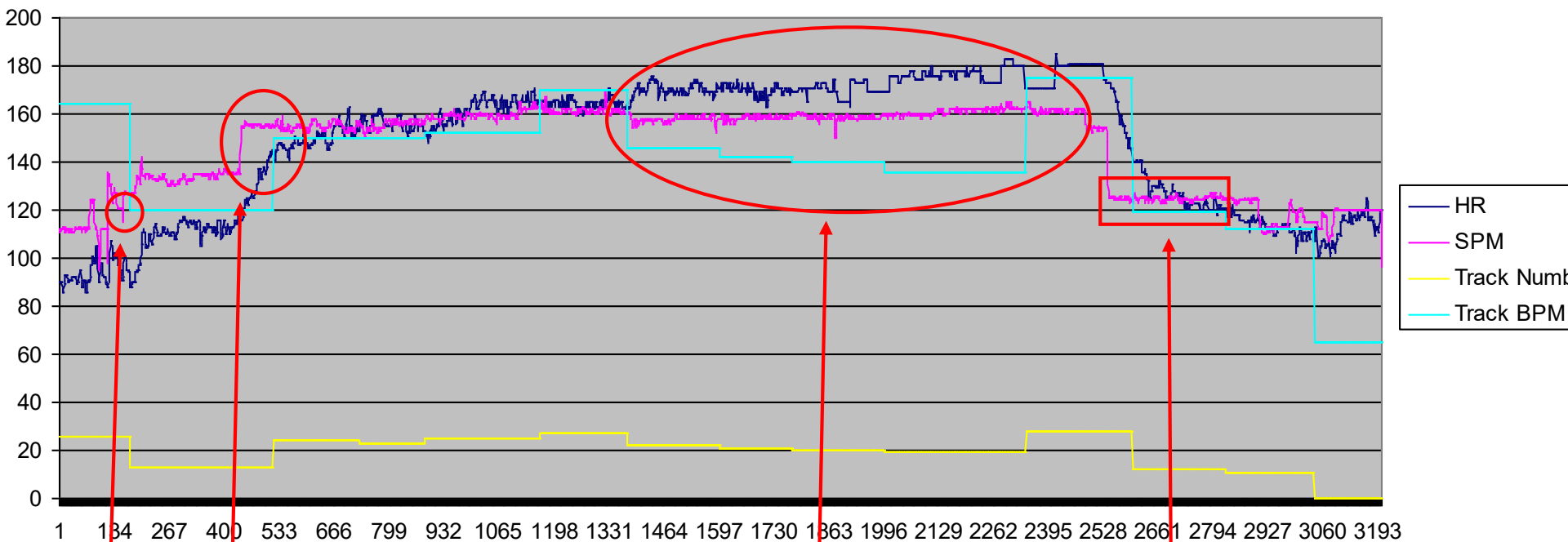
Music Finding Module



Next song to be played

Video

Results on a Treadmill



1

First song selection according to SPM

2

Increase of the Treadmill speed, a few seconds later the next song tracks the SPM

3

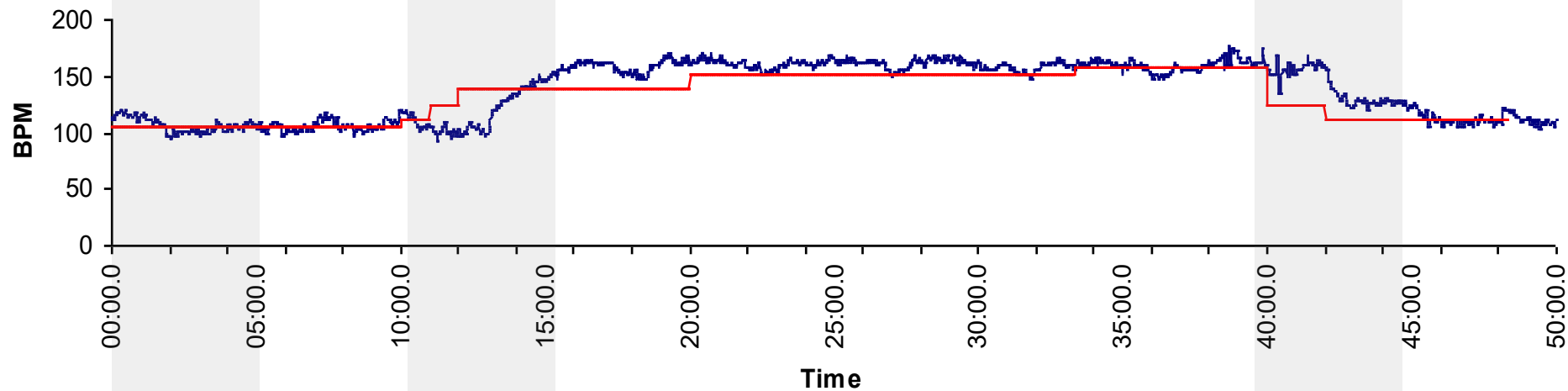
The songs with the closest BPM have already been played, therefore MPTrain chooses the best from the pool of songs that haven't been played yet

4

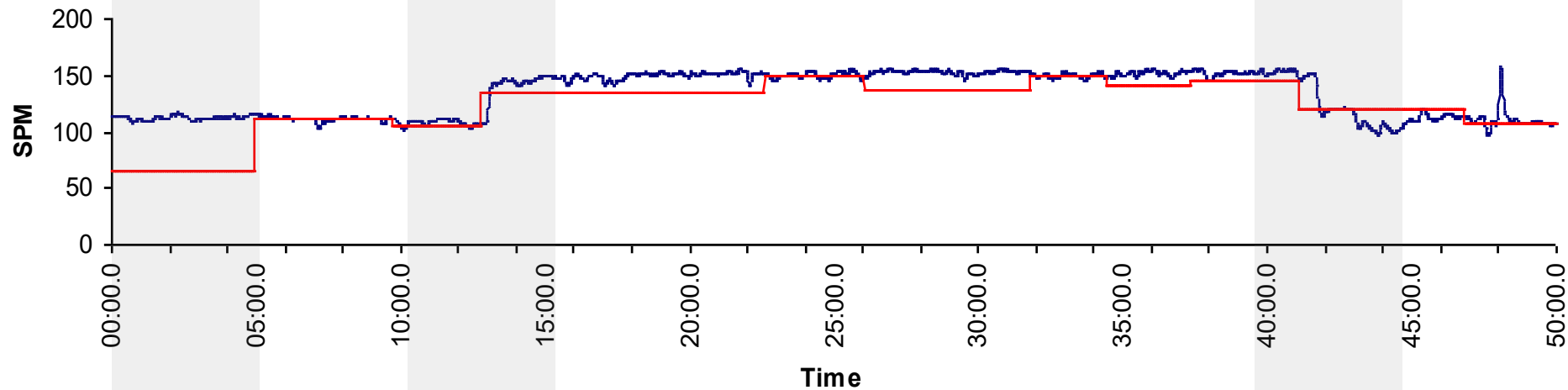
Cool down starts. Music slows down too!

Results on Outdoor Running

Street run log



Street run log



a

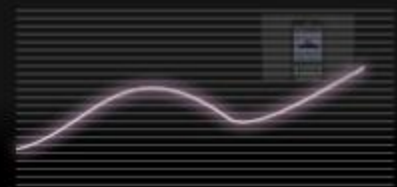
b

c





160
140
120
100
80
60



PACED AT 134 BPM

134

MPTrainer: On | Off

Standings

1. Swifty44

2. FinishLineFury

3. SarahHansen

4. Rebecca10

5. EarlyRizer



Standings

1. Swifty44
2. FinishLineFury
3. SarahHansen
4. Rebecca10
5. EarlyRizer

160

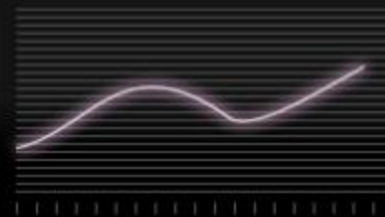
140

120

100

80

60



PACED AT 134 BPM

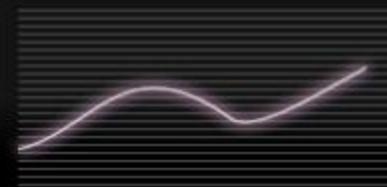
134

MPTrainer: On | Off



You have lost 1 liter of water. Drink up, water is the secret fuel."

160
140
120
100
80
60



PACED AT 134 BPM

134

MPTrainer: On | Off



Finished 34:23
New Personal Best

Unlocked: 75% Courses
Handicap: 2 Minutes



Tokyo, Japan
Schedule Race



New York City
Schedule Race



Bogota, Colombia
Schedule Race



Sarah
WellnessCenter

Overview

Body

Mind

Research

Settings

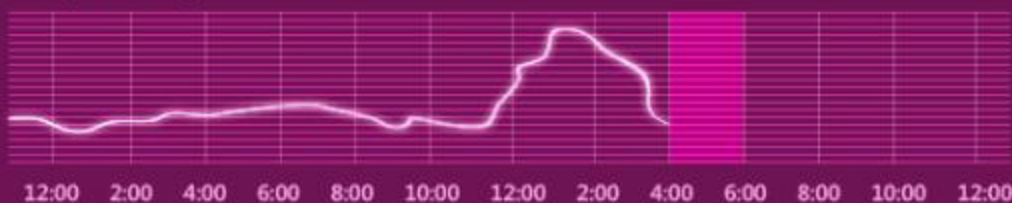
Activity Status

Activity	Today's run	Today's total
Total calories	932	2060
Aerobic Time	1 hour	1 hour 30 minutes



You're over-training. Take two days off per week.

Today's Activity



Activity



Body Fat %



01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 **18** 19 20 21 22 23 24 25 26 27 28 29 30 31

May

Next Steps

- **Large runner's study:**
 - 23 regular runners run 3 or 4 sessions of 42-min each under different conditions: mute, random, metronome and MPTrain
- **Add Bluetooth-enabled GPS for track and incline information**
- **Include information about past workouts to inform the music selection algorithm**
- **Add user rating information of particular playlists or song selections**
- **Add lifestyle variables and find correlation between them and the quality and performance of the workouts**
- **Deploy applications for sharing the data and music in real-time with friends and family**

Conclusions

- **Real-time collection and analysis of physiological and environmental signals on a mobile phone (Smartphone)**
- **Big opportunity for**
 - **Constant monitoring of users**
 - **Real-time feedback to users**
 - **Finding correlations between lifestyle and health/wellness**
 - **Identifying trends and deviations from those trends**
 - **New applications and services**
 - **Impact on society: aging, chronic disease management, EM, exercise, wellness**

Thank You!

For more information:

<http://www.nuriaoliver.com/>

<http://www.nuriaoliver.com/healthGear/healthGear.htm>

<http://www.nuriaoliver.com/MPTTrain/MPTTrain.htm>

Email : nuria@microsoft.com