Activity Level Estimator on a Commercial Mobile Phone

feasibility study

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IWFAR2011 at PERVASIVE – 12th June 2011
Motivation

• Lack of physical activity which is increasing the risk of chronic diseases
  – How to unobtrusively monitor the physical activity of people?
  – How to ensure that user carries the designated device continuously?
• How to motivate people to be more active daily?
  – Preventive care
• How to present the physical activity to the user?
  – Intensity levels?
  – Energy expenditure (EE) and burned calories estimation?
  – Counting steps?

Foerster and Fahrenberg 2000; Fogg 2002; Barralon, Vuillerme et al. 2006; Connelly, Faber et al. 2006
The Smartphone Factor

• Unobtrusive – carried around along the day
  – 3D accelerometer and other built-in sensors
  – Possible continuously running background services

• Activity Level Estimator (ALE)
  – Android-based software
  – Physical activity level duration, EE estimation
  – Assumes that the phone is in the person’s pocket

http://www.android.com
Activity Level Estimator (ALE)

• Estimation of the calories burned
  – Per activity level
  – Overall estimation for 24 hours
  – 5 activity levels, from sedentary to vigorous

• Estimation based on
  – Metabolic Equivalent Task (MET) table
  – Resting Metabolic Rate (RMR)

Harris and Benedict 1918; Ainsworth, Haskell et al. 2000; Byrne, Hills et al. 2005
Prototype
Algorithm: Raw Data & Sample Median

- **Signals from the accelerometer with gravity compensation → acceleration vector**
  - Sample: 1.5 seconds time window (~60 data points)
- **Filtering**
  - Keeps the high values of the sample
  - Smooth the signal
- **Sample median value**
  - Median compared to thresholds that matching to a MET value
Algorithm: Thresholds & MET

- Threshold defined via user study
  - 15 participants
  - 30 steps at 3 levels
- 5 thresholds corresponding to 5 activities levels
  - Sedentary = 1 MET
  - Very low = 2.5 MET
  - Low = 4.5 MET
  - Moderate = 6 MET
  - Vigorous = 9 MET

- Influence of height, weight and gender?
  - Main variable: gender
- Other variables
  - Clothes
  - Shoes
First ALE Validation

- SenseWear from BodyMedia
  - MET values calibrated

- Study Design
  - Short terms study
    - 7 participants walk at least 15 minutes
  - Long term study
    - 1 participant for 3 days, daily activities

Jakicic, Marcus et al. 2004; St-Onge, Mignault et al. 2007; BodyMedia Inc 2010
Results

Short term study
• Average 14% MET difference per minute
• Overestimation 7% of MET for the whole test duration

Long term study
• Average 23.4% MET difference per minute for all kinds of activity levels
• Underestimation of calories by 27.9%
• Driving a car or working on a computer not detected by ALE

Wac and Hausmann 2011
Example Result

- 42 minutes walk on a road forest with small hills and irregular ground, user stopped several times
Results Discussion

• ALE
  – on average 86% accurate for walking
  – more sensitive for body movements than SenseWear
    • ALE granularity: 2 seconds vs SenseWear: 1 minute
  – unable to detect physical activities like working on a computer, driving a car
Second ALE Validation: In Progress

- Institute of Science of Movement and Sports Medicine at University of Geneva
- Indirect Calorimetry and treadmill
- Study Design
  - 12 participants
  - Walk on a treadmill
  - 4 thresholds speed (3 – 6 km/h)
  - 5 minutes per threshold speed
Preliminary Results

**Participants MET error per minute**

<table>
<thead>
<tr>
<th>Participants</th>
<th>MET error per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>N = 12</td>
<td></td>
</tr>
<tr>
<td>3 km/h</td>
<td>10.01%</td>
</tr>
<tr>
<td>4 km/h</td>
<td>7.81%</td>
</tr>
<tr>
<td>5 km/h</td>
<td>9.15%</td>
</tr>
<tr>
<td>6 km/h</td>
<td>12.10%</td>
</tr>
<tr>
<td>Average</td>
<td>9.77%</td>
</tr>
</tbody>
</table>
Conclusion and Future Work

• Work in progress with promising results
  – Accurate EE estimation with a commercial mobile phone
    • Avg accuracy 86% with BodyMedia
    • Avg accuracy 90.3% with Indirect Calorimetry (in progress)
  – Ongoing user study and a new one in real terrain conditions (September)

• Future Work
  – Add GPS to get altitude (e.g., hill) and other forms of transport (bike)
  – User interface design and feedback to user
  – Social network factor

• Overall goal
  – behavioral change for sedentary people
Questions?

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