Statistical Methods for Real-Time Monitoring of Physical Disability in Multiple Sclerosis

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Actigraphy studies

- Physical Activity and Aging
- Heart Failure Hospitalizations: real-time monitoring
- Aortic Valve Replacement: pre/post-operation
- Mental Health: Mood Disorders and EMA
- Physical Activity & Location (GPS)
- Parkinson Disease: cross-species studies
- Pediatric Surgery: early dispatch
- Sleep-wake vs Brain Atrophy & \( A\beta \)-amyloid
Quantified-self (self-chronometry)

- High alertness: 10:00
- Highest testosterone secretion: 10:00
- Bowel movement likely: 08:30
- Melatonin secretion stops: 07:30
- Sharpest rise in blood pressure: 06:45
- Lowest body temperature: 04:30
- Deepest sleep: 02:00
- Midnight: 00:00
- Melatonin secretion starts: 21:00
- Highest blood pressure: 18:30
- Highest body temperature: 19:00
- Best coordination: 14:30
- Fastest reaction time: 15:30
- Greatest cardiovascular efficiency and muscle strength: 17:00
- Bowel movements suppressed: 22:30
Stability/Disruptions in Circadian Rhythms
Wearables

Research

Consumer
What do research grade sensors offer?

- Dense measurements of Physical Activity
  - G’s (mg)
  - Activity Counts (per minute)
  - Steps (per minute)
  - Gait (temporal gait asymmetry, stride variability)
  - Energy Expenditure (calories, ...)
  - Sleep (duration, the number of wakes, ...)
- Light, Temperature, others
- Heart Rate (ECG, BPM)
- Voice (Mood, Progression of Disease)
- App-based surveys (2-4 times a day)
- GPS
Accelerometers

- Use sensors to detect accelerations in one-to-three orthogonal planes
  - Anteroposterior
  - Mediolateral
  - Vertical

- Small size: wireless, non-invasive
- Long battery life, can record activity for up to 45 days (and down to 14 days)
- Provides an objective, comprehensive assessment of free-living physical activity
Value of the Raw data

- 400m walk: currently only time (gait speed)
Temporal Gait Parameters

- quality of steps (AM vs PM)
- temporal gait parameters:
  - step asymmetry
  - stride variability
  - instantaneous walking speed

Urbanek, et al, arxiv.org
Minute-level activity count
Minute-level activity profiles
Epidemiological Studies and Clinical/Interventional Trials

• Epidemiological studies:
  – Cross-sectional/one visit: 7 -14 days per visit
  – Age, Sex, BMI,...
  – Nutrition, Heart Diseases, Mood Disorders, ...

• Clinical trials:
  – two visits, multiple visits, continuous monitoring
  – mobile monitoring:
    • comparative effectiveness, pre-/post- intervention
    • progression, recovery
    • early detection (Congestive Heart Failure, Multiple Sclerosis)
  – part of the treatment
  – compliance to treatment
  – FDA: to define endpoints at Clinical Trial of 2020
Multiple Sclerosis (MS)

• Multiple Sclerosis
  – affects physical and cognitive function
  – slow accumulation of physical disability
• Expanded Disability Status Scale (EDSS)
  – non-linear scale
  – poor reliability and poor responsiveness
• Our proposal:
  – normalized physical disability score (real-life, accelerometry-based)
Preliminary Data

• Collected data on 10 subjects (1-7 days)
• Patient 1 (red) is a 61 year old female with an EDSS of 6.0
• Patient 2 (blue) is a 54 year old male with an EDSS of 4.0
Preliminary Data

- Accelerometry vs EDSS

- Accelerometry vs t25fw
Preliminary Data

- Slow t25fw (red) vs Fast t25fw (blue)
Our approach

Step 1: Feature Extraction
Step 2: Feature Selection
Step 3: Creating normalized physical-disability score
Step 1: Feature Extraction

- Traditional time-invariant summaries (# of active minutes, total activity, max10, etc.)
- Time-dependent summaries (multiresolution: minute, hour)
- Temporal modeling of activity bouts (duration, frequency, magnitude), switching, fragmentation, stability/variability
- Temporal architecture of PA (functional PCs, landmarks of daily profiles)
Step 2: Feature Selection
Step 3: Creating normalized physical-disability score

Zipunnikov, et al, unpublished data
Challenges

• Main Challenge: Steps 2 and 3
  - identifying features responsive to disability
  - no well-defined “events” (surgery/treatment, hospitalization)
Next Steps

• Collection data on 20 subjects (different levels of disability, 2 weeks each)

• Working out the main challenge