Wearables: Overview

JSM 2019

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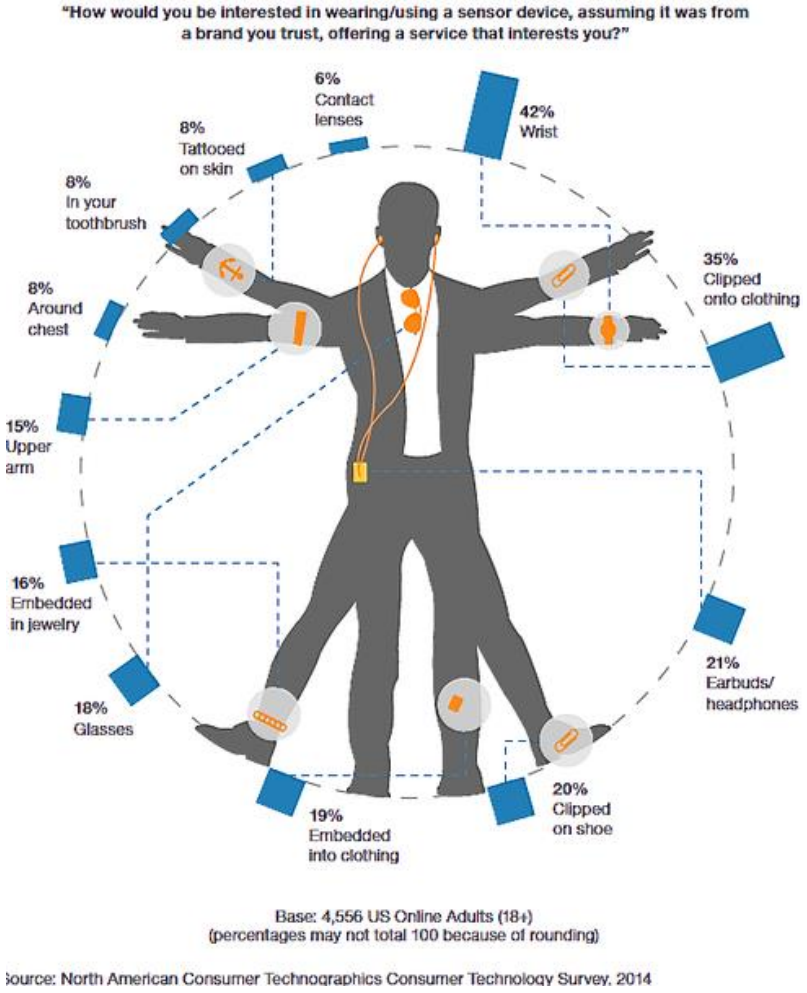
Overview of this course:

- Data and Code
- Wearables: overview
- Functional PCA
- Scalar on Function Regression
- Function on Scalar Regression
- Other Functional Approaches
- Non-functional methods

Wearables


HEADSET COMPUTER
AV GLASSES
HEALTH BRACELET
CLIP-ON SENSOR
SMART WATCH


"How would you be interested in wearing/using a sensor device, assuming it was from a brand you trust, offering a service that interests you?"
6% Contact lenses
42% Wrist
8% Tattooed on skin
8% In your toothbrush
35% Clipped onto clothing
8% Around chest
15% Upper arm
16% Embedded in jewelry
21% Earbuds/ headphones
18% Glasses
20% Clipped on shoe
19% Embedded into clothing
Base: 4,556 US Online Adults (18+)
(percentages may not total 100 because of rounding)
Source: North American Consumer Technographics Consumer Technology Survey, 2014

Wearables

Research

Consumer

What do wearables offer?

- Physical Activity
  - Steps or Activity Counts
  - Steps and Gait (temporal asymmetry, stride variability)
  - Energy Expenditure (calories, …)
- Sleep
- Circadian Rhythmicity
- Electronic Diary/Ecological Momentary Assessment (1-2-4 per day)

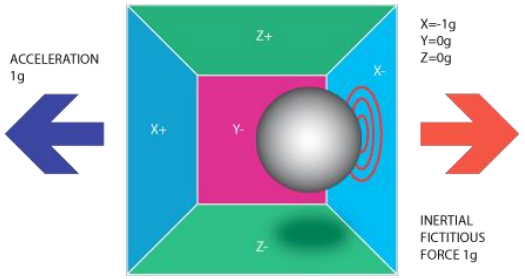
- Heart Rate (ECG, bpm)
- Blood Glucose Monitoring
- Light, Temperature (Circardian markers)
- Voice (Mood, Progression of Disease)

Clinical applications

- Aging (BLSA, Health ABC, NHANES, UKBiobank, WHI)
- Dementia and AD (Sleep & Agitation)
- Cardiovascular: CHF, Afib, and post-surgery
- Multiple Sclerosis (Disability & Sleep)
- Mood Disorders
- Cancer: Fatigue and Sleep
- Diabetes (T2)
- Diabetes in babies (Nurture)
- Rehabilitation (METRC)

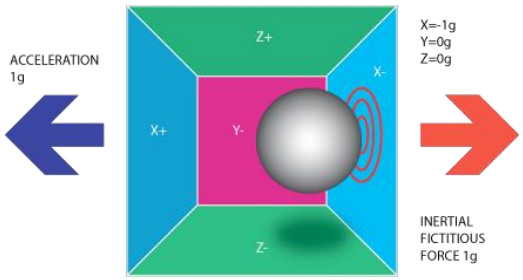
Accelerometers

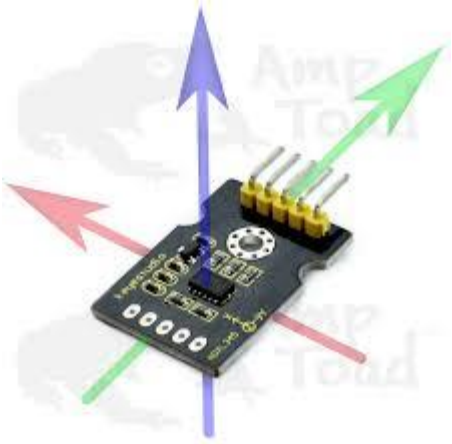
- Use sensors to detect accelerations in one-to-three orthogonal planes

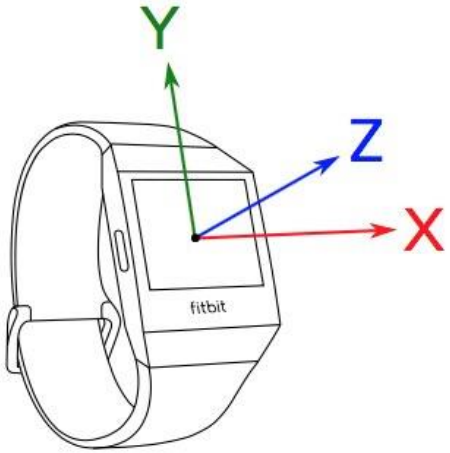


- Small sensor, non-invasive measurement
- Long battery life (tiny energy consumption)
- Inexpensive: ~$10 if you want to build your own device

Accelerometers



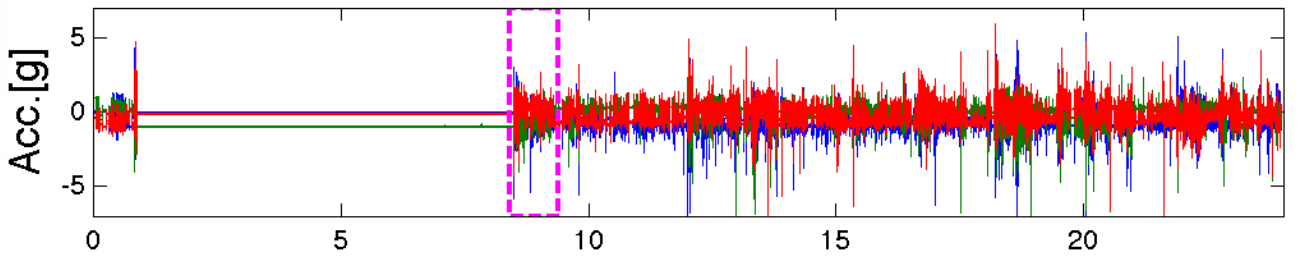


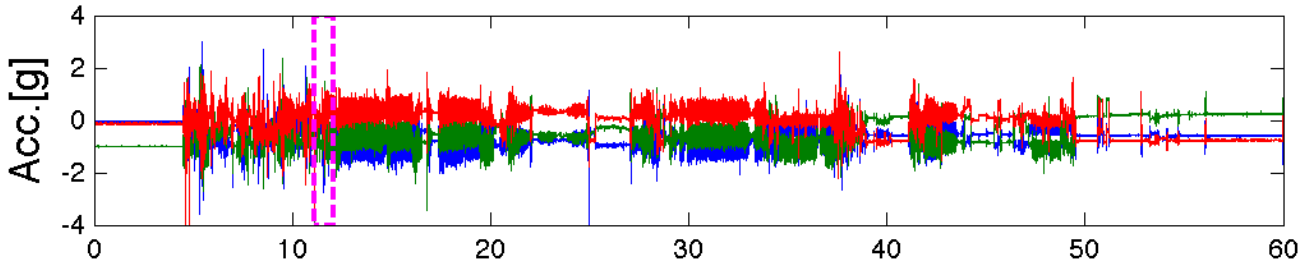


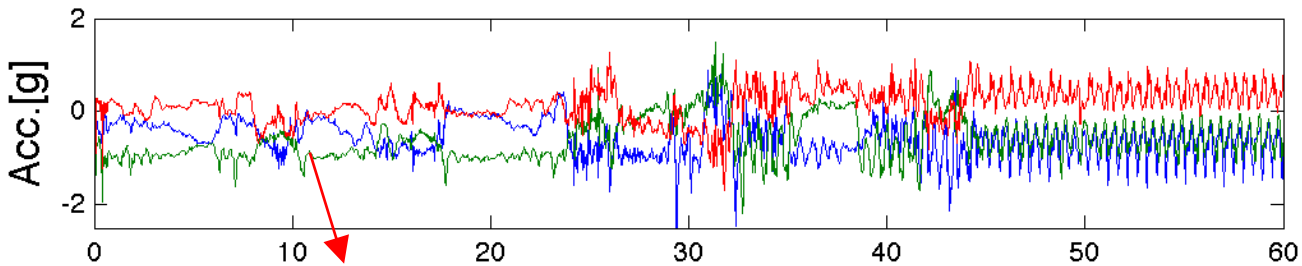
- Detects acceleration in three orthogonal planes

- https://www.youtube.com/watch?v=irjG9Y4NGnE

Data





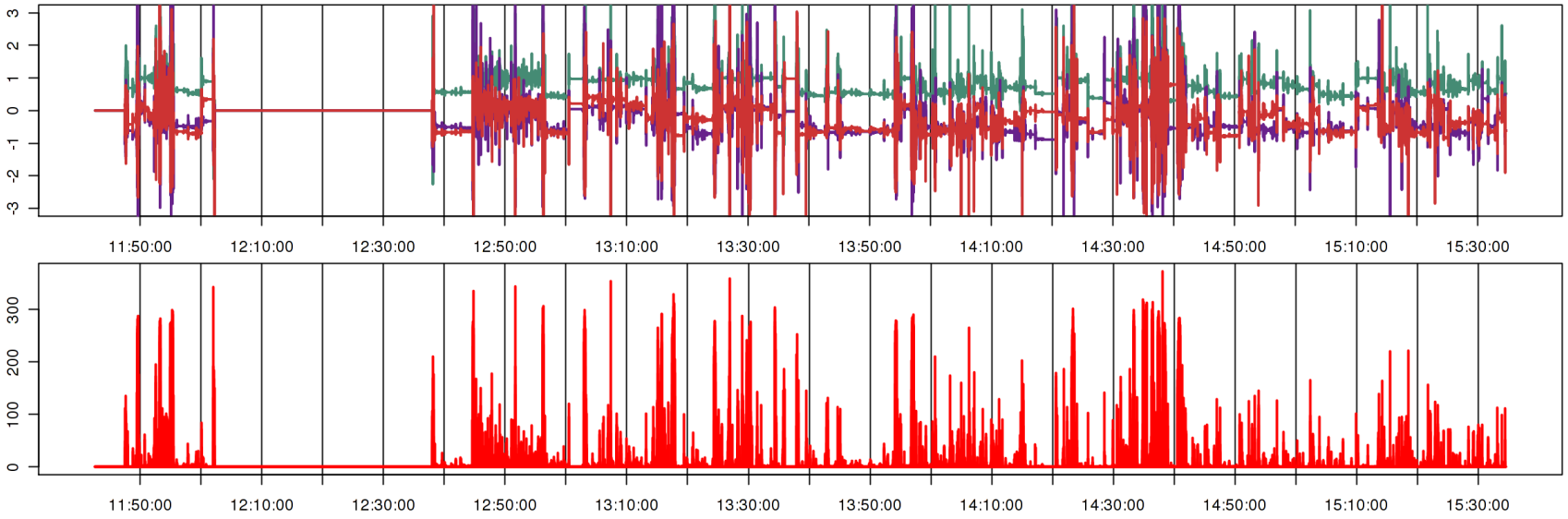


50.4

Activity Count

Raw (Hz) vs Activity Counts (minute)

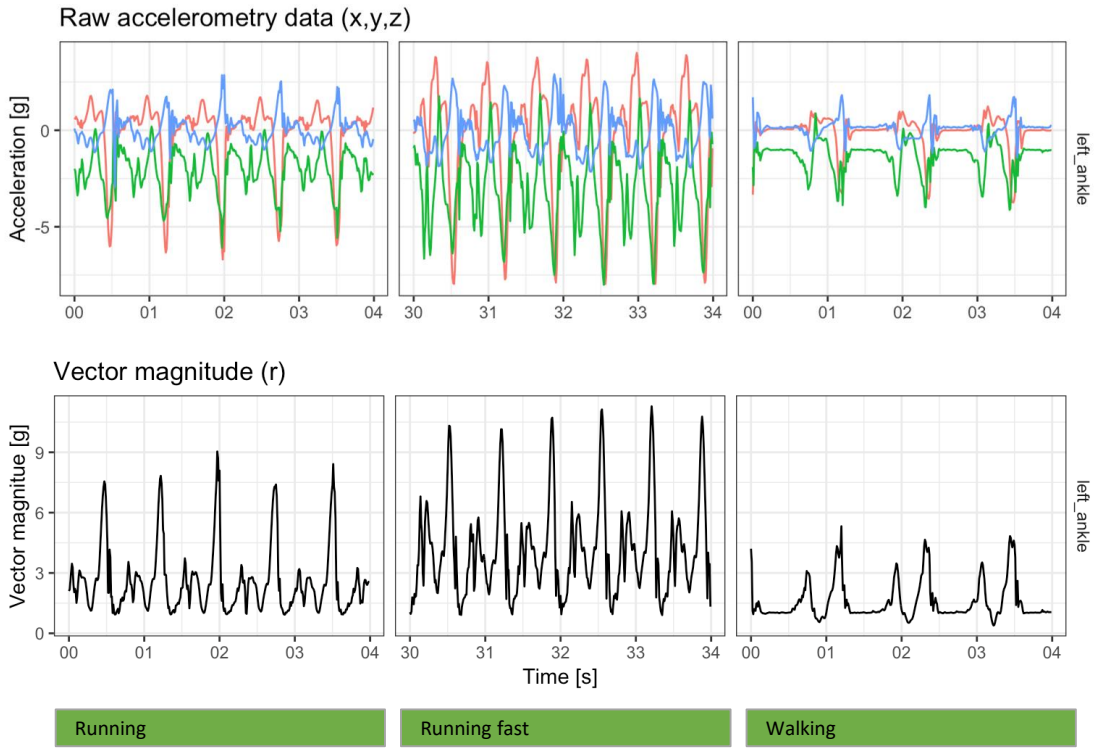
- Top: raw accelerometry data at 80Hz
- Bottom: Activity Count at minute level



Subsecond-level accelerometry data analysis

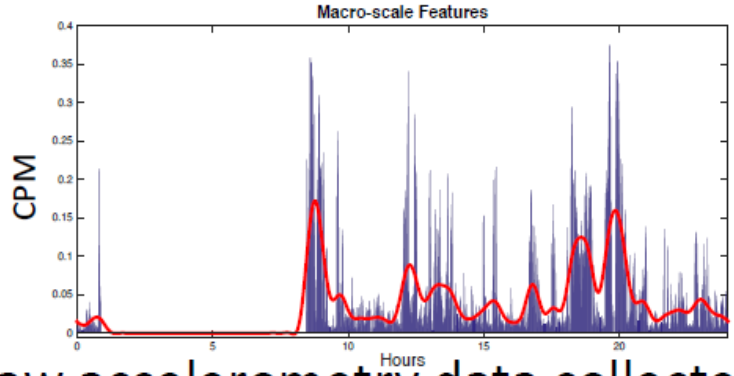
- **Vector Magnitude (VM)**: 1-dimensional summary of 3-dimensional time-series

$$r(t) = \sqrt{x_1^2(t) + x_2^2(t) + x_3^2(t)}$$

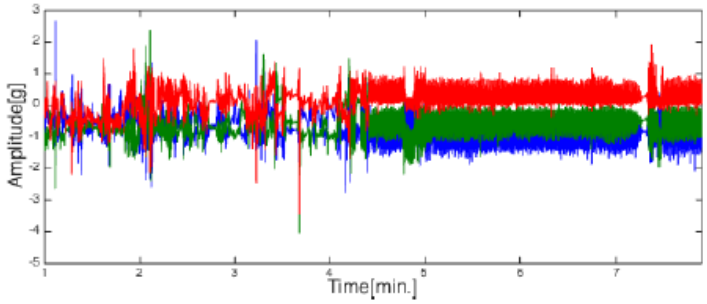


Macro- and Micro-scale

- **Macro-scale** – summarized data (1 minute intervals)

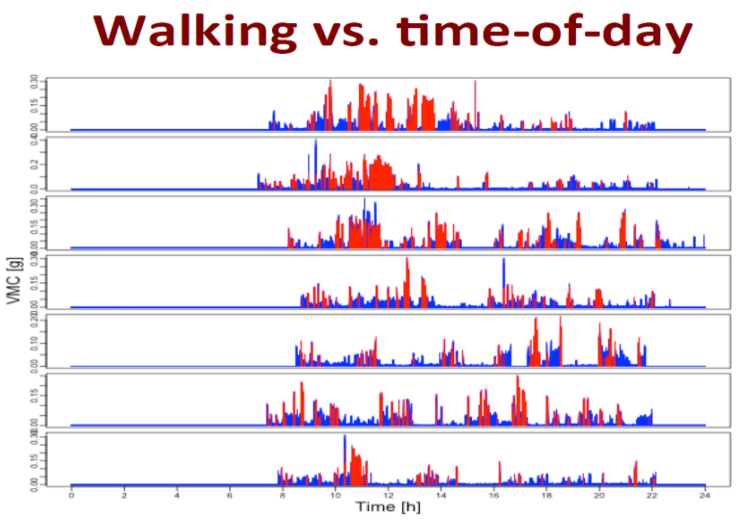


- **Micro-scale** – raw accelerometry data collected (10Hz+)



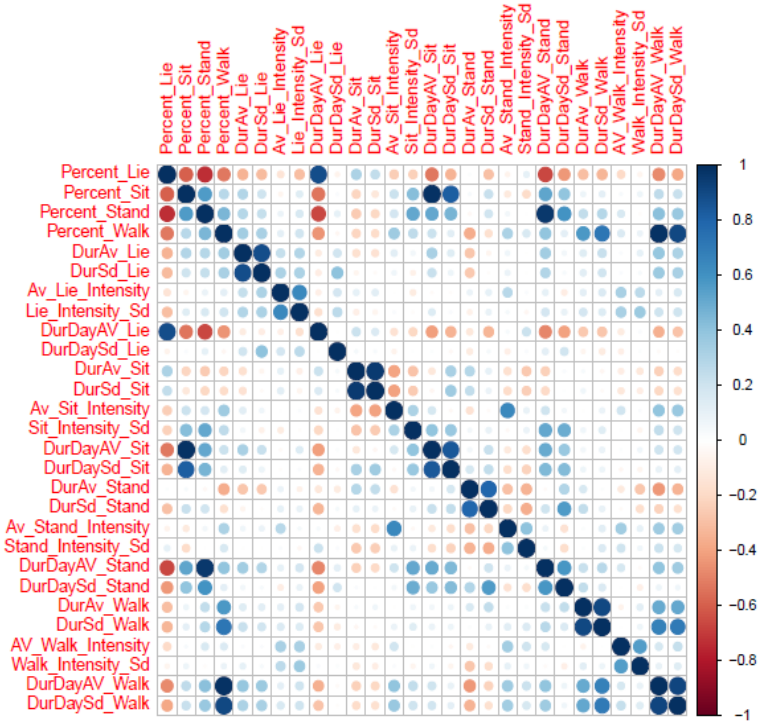
Stage 1: Episode Detection

- Non-wear time
- Posture: sitting, lying, standing, driving, stairs climbing, …
- Activity: walking, running, driving, …
- Sleep: rest/wake, in/out of bed, …



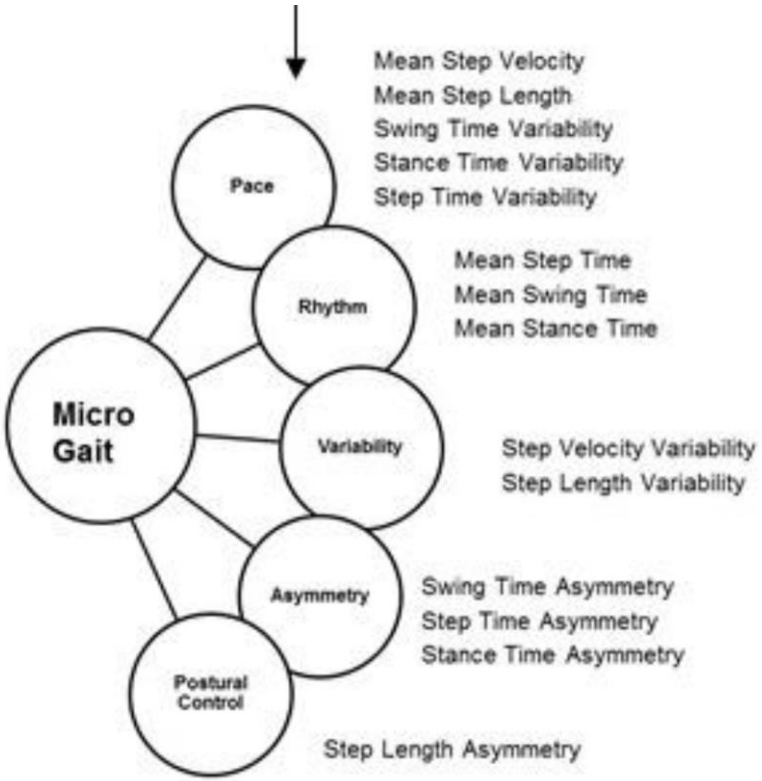
Stage 2: Feature extraction

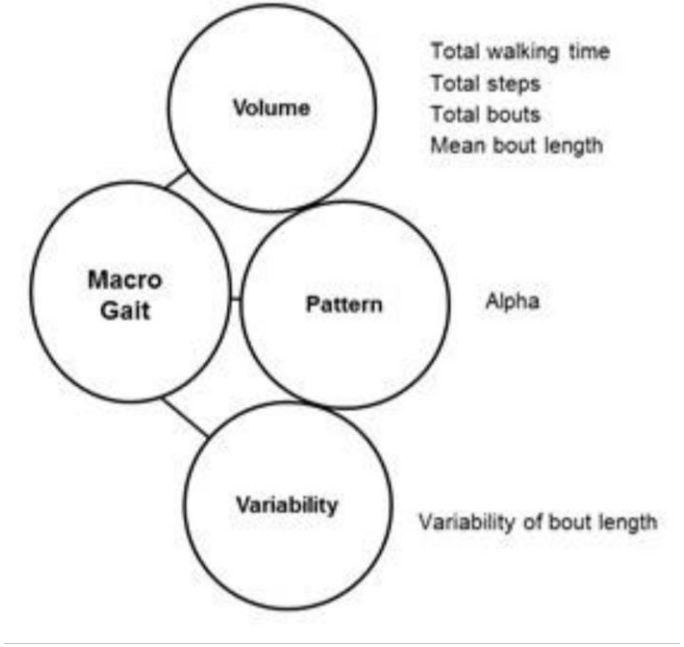
- Walking: cadence, stride-variability, asymmetry, …
- Sleeping: time in bed, fragmentation, variability, …



Stage 3: Feature Grouping

- Example: grouping of gait characteristics



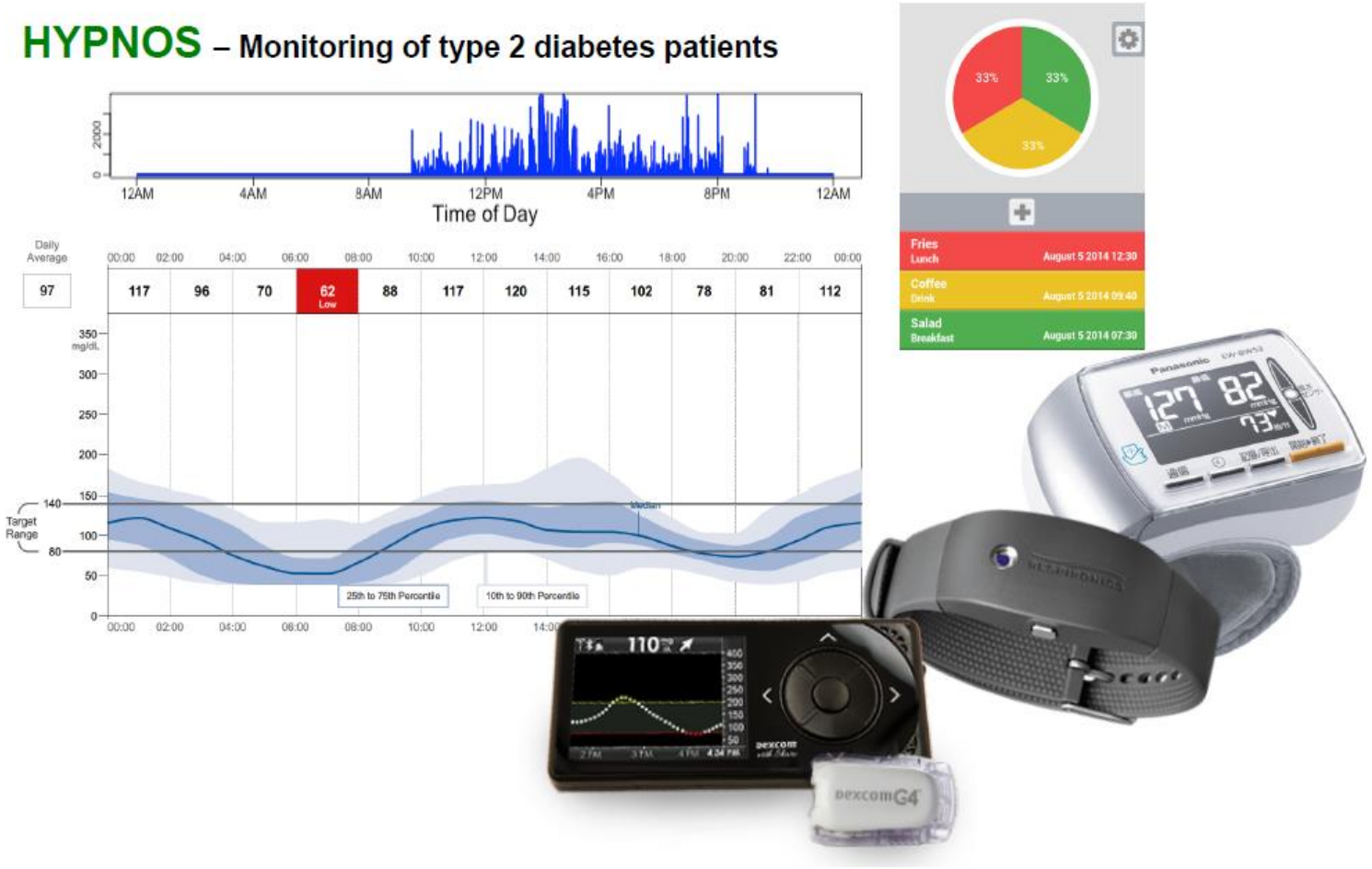


Gait in Mild Alzheimer's Disease.
Feasibility of Multi-Center Measurement
in the Clinic and Home with Body-Worn Sensors.
A Pilot Study, Zetterberg et al, 2019, JAD

Challenges

- Need **new** methods that can be applied to:
  - thousands of subjects
  - very large data sets (10 Tb+)
  - free-living environment
  - no visual labeling(camera or person);
  - large between- and within- person variability

Sensors fusion



Functional Methods

- Physical activity trackers
- Heart rate monitors
- Blood glucose monitors
- Blood pressure monitors

- All devices record **signal over 24 hour periods** – the exact focus of Functional Data Analysis (FDA).