Tracking Health, Wellness & Quantified Self
Quantified Self (QS)

- QS: Community of People who want to measure, log, share metrics about various aspects of their lives. E.g.
- **Defn:** Obtaining self-knowledge through self-tracking
- Also known as personal informatics or lifelogging
  - Sleep, daily step count, food consumed, air quality, mood, etc.
- Measurements typically done using wearables/technology
  - Activity trackers, steps, sleep tracker, calories burned, etc
  - Now more available, cheaper
Why track? To figure out causes of certain behaviors, improve health/wellness
- E.g. Why do I feel tired on Friday afternoons?

Data to back up your choices/decisions
- Did that cup of coffee make you more productive?

Discover new patterns that are fixable
- Whenever I go to my mother’s house, I add at least 5 pounds on Monday morning
- Am I happier when I meet more people or when I drink more coffee?

Courtesy Melanie Swan
QS: How Popular?

- 69% of US adults already track at least 1 health metric (Pew Research)
- Local meetings, conferences, website
  - quantifiedself.com/
QS: Google Search Trends

- Google Trends displays how often a term is searched
- “Quantified Self” Searches peaked ~ 2014
- Now more popular in Europe (Netherlands = 1, USA = 8)
QS Wellness Tracking Devices

- Smart fork: eating/calories
- Sleep manager
- Bluetooth scale
- Body worn activity trackers (steps, activities, calories)
Quantified Self Big Picture

1. Track
   - Physiological
     - Eating
     - Exercise
     - Sleep
     - Weight
     - Blood pressure
     - Heart rate
     - Stress
   - + Other Context
     - Location
     - Travel
     - Calendar
     - Email
     - Lab results

2. Analyze
   - Analytics websites
     - Bodytrack.org
   - Machine Learning
     - Regression, classification, etc

3. Inform
   - Mobile App
     - Mymee.com (data-driven coaching)
   - Hire Coach/Dr
Bodytrack Project

http://www.cmucreatelab.org/projects/BodyTrack

BodyTrack chest strap:
- EKG, respiration, accelerometry;
- stress, cough/sneeze, snoring

BodyTrack Indoor Environmental station:
- Temp, humidity, barometric, sound levels, light levels;
- Sleep hygiene, air quality (with external sensor), charger and data gateway for chest strap

Actigraphy:
- Activity and energy levels

Phone:
- Pictures, GPS location, activity;
- food, events, self-reporting

Indoor air quality

Weight

Sleep logging

Quantified Self

Regional air quality:
- Particulates, other pollutants, pollen, mold
FluxStream QS Visualization

Fluxstream Unified QS Dashboard

Source: http://johnfass.wordpress.com/2012/09/06/bodytrackfluxstream/
QS: Other Personal Data Sources

- Social media: Facebook, Twitter, Foursquare
- Search engines: Google, Bing
- E-commerce sites: Amazon, Airline sites
- Entertainment/game sites: Netflix
- Email: Outlook, gmail, etc
The Future: Precision Medicine

- In future combine data from quantified self + medical data + genomics data = Precision medicine
Smartwatches + Wearables
Main Types of Wearables

- **Activity/Fitness Trackers:**
  - physiological sensing (activity, step count, sleep duration and quality, heart rate, heart rate variability, blood pressure, etc)
  - E.g. Fitbit Charge 2

- **Smartwatches**
  - Some activity/fitness tracking
  - Also programmable: notifications, receive calls, interact/control smartphone
  - E.g. Apple watch, Samsung Gear
How Popular are Smartwatches/Wearables?

Global Wearables Shipment Forecast, By Device

Source: IDC, BI Intelligence estimates
Wearables Example: Fitbit Charge 2

Fitbit Charge 2

Smartphone companion app (displays all variables tracked)
Example: Samsung Gear SmartWatch Uses

- **Home Screen**: 7:00 PM - After a long day, set your notifications to "Do not disturb".
- **Email**: 6:00 PM - Mom sends an email list of things to buy at store.
- **Phone Call**: 5:00 PM - Take dog out for walk and mom calls.
- **Music**: 4:30 PM - Take a walk and track steps home.
- **Navigation**: 4:00 PM - Listen to music on the way home.
- **Message**: 2:30 PM - Send text to friend while working out.
- **S Health**: 1:00 PM - Leave phone in your locker and go workout.
- **Alarm**: 10:00 AM - Wake up when your alarm goes off.

Image credits: Samsung
SmartPhone Vs Smartwatch

Smartphone:
- More processing power, memory, sensors
- More programming APIs

Smartphone Cons:
- Sometimes not carried (Left on table, in pocket, bag, briefcase, gym locker)
  - Smartphone within arms reach, on person ~50% of the time (Anind Dey et al, Ubicomp 2011)
- Why? Sometimes inconvenient, impossible (e.g. when swimming)
- Consequence: Missed activity (steps, activity, etc), incomplete activity picture

Smartwatch:
- Lower processing power, memory, sensors, but
- Always carried/worn
- Can sense physiological variables continuously, or require contact (e.g. skin temperature)
Programming Android Wearables

- Programmable using Android Wear (latest version is 2.0)
- Supported by Android Studio
- Needs to be connected to a smartphone (via Bluetooth)
- Architecture:
  - **Node API**: tracks all connected/disconnected nodes (E.g. wearables, smartwatches)
  - **Message API**: Used to send messages between wearable and smartphone
  - **Data API**: Used to synch data between app and smartwatch

A bit outdated, but nice overview for Android Wear for kitkat Android 4.4W
## Android Wear Evolution


<table>
<thead>
<tr>
<th>Android Wear Version</th>
<th>Android Smartphone Version</th>
<th>Release Date</th>
<th>Major New Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4W1</td>
<td>4.4</td>
<td>June 2014</td>
<td>Initial release at Google I/O 2014</td>
</tr>
<tr>
<td>4.4W2</td>
<td>4.4</td>
<td>Oct 2014</td>
<td>GPS support, music playback</td>
</tr>
<tr>
<td>1.0</td>
<td>5.0.1</td>
<td>Dec 2014</td>
<td>Watch face API (face design) Sunlight &amp; theater modes, battery stats</td>
</tr>
<tr>
<td>1.1</td>
<td>5.1.1</td>
<td>May 2015</td>
<td>WiFi, Drawable Emojis, Pattern Lock, swipe left, wrist gestures</td>
</tr>
<tr>
<td>1.3</td>
<td>5.1.1</td>
<td>Aug 2015</td>
<td>Interactive Watch Face, Google Translate</td>
</tr>
<tr>
<td>1.4</td>
<td>6.0.1</td>
<td>Feb 2016</td>
<td>Speaker support, send voice messages</td>
</tr>
<tr>
<td>1.5</td>
<td>6.0.1</td>
<td>June 2016</td>
<td>Restart watch, Android security patch</td>
</tr>
<tr>
<td>2.0</td>
<td>7.1.1</td>
<td>Feb 2017</td>
<td>UI (material design, circular faces), watch keyboard, handwriting recognition, cell supp.</td>
</tr>
</tbody>
</table>

Evolved into Google Wear OS in June 2018!!
Physiological Sensing
Wearables for Physiological Sensing

- Some wearables measure more physiological signals
  - Cardiac rhythms (heartbeat), breathing, sweating, brain waves, gestures, muscular contractions, eye movements, etc
- Basis Health tracker: heart rate, skin temperature, sleep
- Microsoft Band 2: Heart rate, UltraViolet radiation, Skin conductance
Empatica E4 WristBand

- Wristband measures physiological signals real time (PPG, EDA, accelerometer, infra-red temperature reader)
Myo Armband

- Measures muscle contraction (electromyography or EMG), to detect gestures
- EMG measures electrical activity, used to assess health of muscles
Electrocardiogram (ECG)

- ECG (or EKG): recording of electrical activity of the heart
- Each heartbeat causes electrical signal to spread from top to bottom of heart
- Electric Signal
  - is rhythmic, causes heart to contract and pump blood
  - Can be measured electric activity between 2 electrodes placed on chest
Electrocardiogram (ECG)

- ECG shows:
  - How fast the heart is beating
  - Rhythm of heartbeat (steady vs irregular)
  - Strength and timing of electrical signals

- Arrhythmia: fast or irregular heartbeat, can cause stroke or heart failure
Electrocardiogram (ECG)

- ECG waveform comprises sequence of peaks and trough (P,Q,R,S,T), which repeats
  - Occasionally a U wave after T
ECG Features for Classification

- From a waveform with at least 5 peaks, can extract as features for classification, the following timing intervals:
  - RR interval
  - PR interval
  - QRS interval
  - QT interval, etc

- Heart rate is number of RR intervals/min = $60 / RR$

- Note: RR is in seconds
Trends: Mobile ECG

- E.g. AliveCor kardia ECG
  - Hold 2 fingers on metal plates (ECG recorder) for at least 30 seconds
Photoplethysmography (PPG)

- **PPG:** Non-invasive technique for measuring blood volumes in blood vessels close to skin
- Now popular non-invasive method of extracting physiological measurements e.g. heart rate or oxygen saturation
- Traditional device for PPG is pulse oximeter
  - Measures concentration of oxygen in the blood
  - Low oxygen levels (< 80%) can compromise organs, lead to heart attack, etc
Pulse Oximeter PPG

- Amount of oxygen in the blood determines how much infrared light absorbed, scattered, passes through (from LED to photodiode)

Image credit: Deepak Ganesan
Smartphone/Smartwatch PPG: Estimating HR

- **Principle:**
  - Blood absorbs green light
  - LED shines green light unto skin (back of wrist)
  - Blood pumping changes blood flow and hence absorption rhythmically
  - Photodiode measures rhythmic changes in green light absorption => HR

Image credit: Deepak Ganesan
Smartphone PPG: Heart Rate Detection

- Like smartwatch, use camera flash (emitter), camera as detector
- Place finger over smartphone’s camera, shine light unto finger tip
- Heart pumps blood in and out of blood vessels on finger tip
  - Changes how much light is absorbed (especially green channel in RGB)
  - Causes rhythmic changes of reflected light

Smartphone PPG: Heart Rate Detection

- **Idea:**
  - Color expressed as (R G B)
  - Track intensity of Green channel of Camera response
  - Use peak finding algorithm (similar to step counter)
  - Time between peak is 1 cycle
  - Heart rate = cycles per minute = 60 / time for 1 cycles

- Can also extract breathing rate, heart rate variability
PPG: Final Words

- PPG (or similar ideas) have been attempted:
  - on other body parts (ear lobes, face)
  - from video frames (detect, magnify small changes in facial color 100x)
  - Using other ubiquitous devices (e.g. Medical Mirror, Poh et al)


MZ Poh, D McDuff, R Picard A medical mirror for non-contact health monitoring, ACM SIGGRAPH 2011 Emergin
Electrodermal Activity (EDA)

- When people experience emotional arousal (e.g. danger), stress, cognitive load or physical exertion => increased sweating
- Increased sweating changes electrical conductance of skin
- Sometimes called Galvanic Skin Response (GSR)
- This response cannot be controlled by person
  - Hence, widely used in emotion/lie detection
EDA Features

- Features useful for classifying measured human EDA response
  - **Latency**: time between stimulus and response
  - **Rise time**: time for skin conductance to peak
  - **Amplitude**: Height of conductance signal
  - **Half recovery time**: Time for conductance signal to lose half of its peak value

Figure 5. Graphical representation of principal EDA components.
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  http://www.slideshare.net/ramykhuffash/the-ultimate-guide-to-the-quantified-self