Agenda

- Trends
  - Wearable devices
  - IoT
  - Digital & home health
- Common physiological measurements
- Sensor innovation
- Current challenges
Trends - Growing Markets

1. Wearable devices
2. Internet of Things (IoT)
3. Digital & home health

• This talk: My perspectives from what people are designing and investing in
Wearable Devices Trends

Is it a fad?

Evolutionary change
• Well adopted
  • Jewelry
  • Watches
  • Eyeglasses
  • Hearing aides
  • Smart phones
  • Activity tracking

Explosive growth?
• Driven by Data
• Interconnected data will make them smarter
Wearable Device Innovation

- Watch
  - Apple Watch

- Eyeglasses
  - Snapchat Spectacles

- Hearing Aid
  - Sonitus in the Mouth Hearing Aid
  - FitBit Activity Monitor

- Detection
  - Scanadu Tricorder
Example: “Tricoder”

- Temperature sensing
- Heart rate sensing
- ECG
  - Heart rate variability
  - Pulse wave transit time (blood pressure)
- Oximetry (blood oxygen level)
- Urine analysis
- Stress
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IoT Innovation

Connected Pet
Whistle

Connected Home
Roost

Connected Life
Apple Watch

Connected Baby
Hatch Baby

Connected Health
FitBit

Connected Game
Active Mind Golf Tracker
IoT Innovation

- Agriculture
- Drones
- Tractor Guidance
- Auto Backup Camera
- Home Security
- Air Quality Monitor
IoT Innovation

- Smart Outlets
- Smart Locks
- IoT games
- Fall Monitoring for Seniors
- Hearing Aide with Bluetooth
- Game Controller
3 Pillars of IoT

**Hardware**
- Sensors
- Wireless
- Battery

**Software**
- Collection
- Alerts

**Data Analysis**
- Aggregation
- Insight
Scale of IoT Innovation

- Device
- Vehicle
- Building
- City
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Innovations in Home Health

- Elder monitor
- FitBit Activity Monitor
- AR glasses
- Sleep analysis
- Eye care
- Bluetooth hearing aid
Future Home Health

• Better function
  • Smart fall monitors for elderly
  • Better passive activity tracking – Is Mom OK?
    • Alzheimer’s tracking
  • Better medication adherence monitoring
• Medical sensors in smart phones will lead to:
  • More medical apps
• Remote health monitoring – growing
• Sterilization – growing
• Implanted sensors – for hearing, now available
Example: Home Dialysis

- Ultraviolet light sterilization of connections
- Connects implanted peritoneal dialysis tube to dialysate bag and drain Bag
- Sensors
  - UV light
  - Enclosure open
What is Holding Back Home Health?

• Elderly Market is Difficult
  • Distribution
  • Ease of Use
  • Acceptance by the Elderly or their children – few early adopters
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Sensors Critical To Advances
Rapid Innovation In Sensors

- Growth of sensors and electronics
  - Miniaturization
  - Lower cost
  - Smarter systems
- Advances create new markets which drives more sensor innovation
Market Drivers for Sensors

**PAST**
- **Automobiles**
  - Since 1980s
  - Cars are full of sensors

**PRESENT**
- **Smart Phones**
  - Last 10 years
  - Smart phones make sensors wearable

**FUTURE**
- **Wearable devices**
- **IoT**
- **Home health**
Common physiological measurements

- ECG/EMG
- Heart Rate
- Motion
- Respiration
- Leg Swell
- Blood Pressure
- Body Temperature
- Blood Sugar
- Blood Oxygen
EKG / EMG / EEG

- Measure of electrical and muscle activity
- EKG measurement points have to be rather far apart
  - At least one and a half inches – larger devices needed
  - More leads is better (up to 12 for standard ECG)
- EMG requires accurate placement (millimeters)
  - Measure the wrong muscle
- EEG must use electrodes on the head
Uses of EEG

- Disease diagnosis
- Sleep diagnosis
- Detect mood
- Brain control of devices
Heart Rate

- Measured by
  - ECG electrodes – two are sufficient
  - Pulse oximeter sensing – reflected
    - Transmitted works on finger and ear
  - Pressure sensing of the pulse in the wrist
- Wrist measurement works well for Heart Rate, but not for ECG
Motion

- The most studied and used parameter
- Step counts
- Gait analysis (illness)
- Types of motion (walking, standing, sitting)
- Dead reckoning (9-axis motion)
- Works on wrist, ankle, torso, etc.
  - Different algorithms at different locations
- Motion sensor manufacturers provide advanced software algorithms
Respiration Rate

• Number of breaths per minute
  • Few good locations to measure
• Movement of chest
  • Chest strap
  • Not convenient for a wearable device except shirt
• Thoracic Impedance eliminates chest strap
  • Difficult on wrist
• EKG signal – retain lower frequency
Swelling of Leg

- Detection of water retention – congestive heart failure
- Detection of swelling due to injury
- Detection of problems following knee surgery or knee replacement
- Sense stretching of band around leg
  - Similar to chest strap for respiration
Blood Pressure

• Measure of systolic and diastolic pressure
• Accurate measurement requires pressure cuff that is compressed and released
  • Works on wrist, but inconvenient
• Pulse Transit Time – measure at wrist or elsewhere
  • Currently not medically accurate
• EKG – is it medically accurate?
Body Temperature

• Few good locations to measure core temperature
  • Axilla (under arm) or forehead are best locations
  • Not convenient for a wearable device
• Extremeties (eg wrist) have variable temperature
• Algorithms can partially adjust over time
• Good contact is important – heat flow causes errors
Blood Sugar (Glucose)

- Measure of glucose level in blood sample
- Widely used
- Non-invasive measurement has failed
- Now available as a wearable patch
- Frequent calibration required
- Attempts to not use finger tip – less accurate
- Not accurate on wrist
- Closed loop system replaces the pancreas
  - Control glucose with a pump
Blood Oxygen

- Oxygen saturation in blood
- Measured by pulse oximeter (infra-red) technology
  - Measure loss through body of 2 IR wavelengths
  - Separates changes in blood from other changes
  - Measure pulse at the same time
- Transmissive or reflective measurement
- Reflective for wrist and other places
  - Less accurate, difficult to get a reading
- Transmissive – on finger or ear only
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Future Of Sensors

• Chemical sensors
  • Gene detection chips – getting better
  • Lab on a chip – for fluids
  • Liquid Biopsy – detect disease from DNA fragments
  • Paper based - disposable

• Fiber optic sensors
  • Pressure, temperature, strain, force, displacement

• Non-invasive glucose sensor?

• Big data to analyze sensor data
  • Make sensors smarter with software
Fiber Optic Sensors

• **Advantages**
  • Safe – no wires, biocompatible
  • Small – 0.25 mm diameter
  • Operate in harsh Environments, no EMI
  • Use in MRI Machines
  • Multiplex sensors on one fiber
    • Pressure, Strain, Bending, Motion, Temperature
    • Respiration, Heart Rate

• **Disadvantages**
  • Support electronics still expensive
  • Electronics can get cheap in volume
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Current Challenges

• Wearables – batteries a major limitation
• Limitations in sensors
• Are you making a medical device?
• Security
Battery Limitations

• Slow pace of improvement
  If improved like semiconductors:
  Size of a pin head, could power your car, cost 1 cent
• Must always work around limitations
  • Long time between charging vs small size
5 Areas That Impact Power

- Wireless transmission
- Displays
- Sensors
- Microprocessors
- Software
Common Ways to Get Data Into the Cloud

1. Device directly to cloud

2. Sensor to gateway to cloud

3. Sensor to cell phone to cloud
# Power - How Much? How Far?

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<tr>
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<td>120</td>
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Power in milliWatts
How Much Power Do Sensors Use?

- **Camera chip**: 300mW
- **Illumination for camera at night**: 200mW
- **GPS (Position)**: 20mW
- **Load cell (Weight)**: 10mW
- **Pulse Oximeter (Blood Oxygen)**: 10mW
- **EKG/Heart Rate**: 1mW
- **9-axis Motion Sensor**: 0.5mW
- **Microphone**: 0.1 to 10mW
- **Light Intensity**: 0.1 to 10mW
- **3-axis Accelerometer**: 0.01 to 0.1mW
Are You Making a Medical Device?

- Cell Phone App Can Be A Medical Device
  - FDA Issued Guidelines for Mobile Apps in October 2013
  - FDA Can Force A Company Out of Business for Violating Regulations
- Changing the “Instructions For Use” May Make It Not a Medical Device
  - Pulse Oximeter Example
Consider Whether the Device Is Medical

- Does it sense data or only transmit data?
- Does it diagnose disease or only report data?
- What is the risk of error?
  - Fever thermometer is class I
  - ECG for diagnosis is class II
- Instructions for use may determine if it is a medical device
- Phone apps have special exemptions
Data Security

• The FDA issued a guidance document at the end of 2016 regarding end-to-end security for medical devices.

• End-to-end security requires:
  • Detect a device that is not authorized
  • Ensure the data is valid when received in the cloud
    • From a known device
    • The right data – right time, right user, etc
    • Accurate
  • Store data in the cloud securely
  • Ensure software updates come from right source
Data Security Solutions from Third Parties

- SecureRF Corporation has an encryption algorithm that runs on processors as small as 8 bits.
  - Most algorithms too slow, need powerful processors
- Intrinsic ID Corporation generates secret key from random SRAM power-up state
  - Provides authentication device to cloud
- SecurePush Corporation provides end-to-end solution with
  - System on a chip
  - Mobile app
  - Cloud service
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Quality Electronic Design & Software
Wearable Devices
Sensor Interfaces
Wireless
Motion Control
Medical Devices