Trends in Sensors, IoT and Wearable Devices

Walt Maclay
President, Voler Systems
Product Development

11 September 2018

IEEE-CNSV
Consultants' Network of Silicon Valley

Voler SYSTEMS

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

PAST

Is it a fad?

PRESENT

Evolutionary change

- Well adopted
  - Jewelry
  - Watches
  - Eyeglasses
  - Hearing aides
  - Smart phones
  - Activity tracking

FUTURE

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

Scanadu

Agenda

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

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

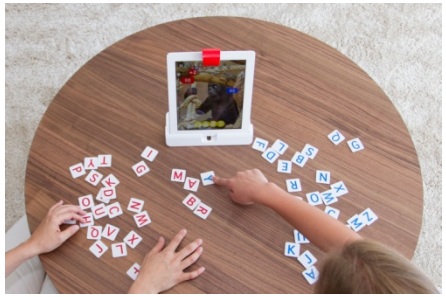
Home Security

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

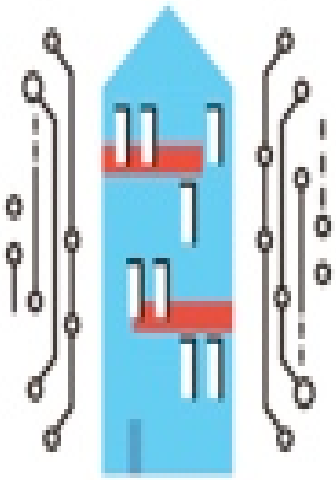
Software
- Collection
- Alerts

Data Analysis
- Aggregation
- Insight

Scale of IoT Innovation

Device

Vehicle



Building

City

Agenda

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

Innovations in Home Health

Elder monitor

FitBit
Activity Monitor

AR glasses

Sleep analysis

Eye care

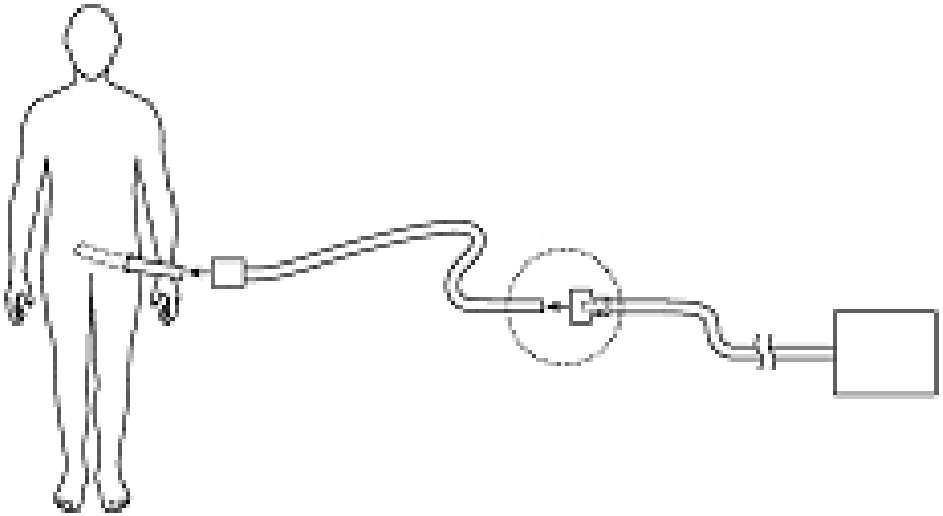
Bluetooth hearing aid

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

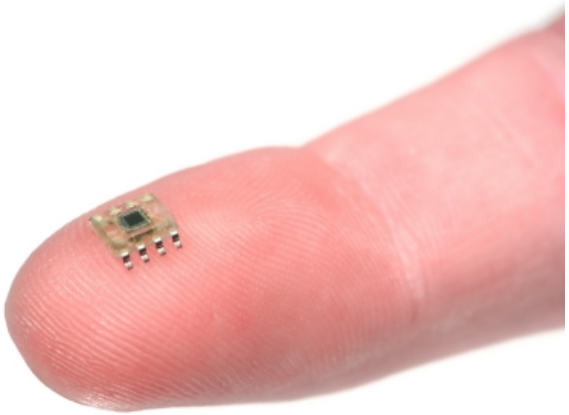
Agenda

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

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

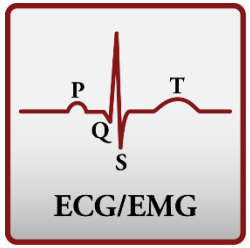
PRESENT

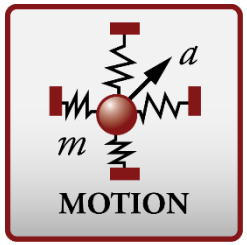
Smart Phones
- Last 10 years smart phones make sensors wearable

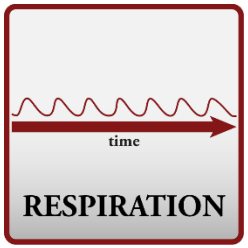
FUTURE

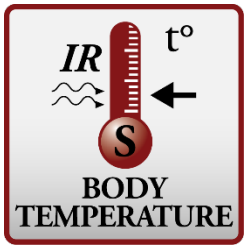
Wearable devices
IoT
Home health

Common physiological measurements

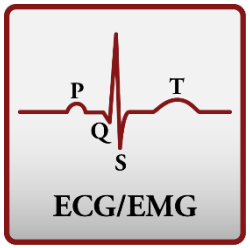








EKG / EMG / EEG

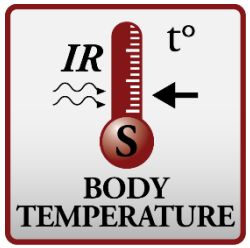


- Measure of electrical and muscle activity
- EKG measurement points have to be rather far apart
  - At least one and a half inches – larger devices needed
  - More leads is better (up to 12 for standard ECG)
- EMG requires accurate placement (millimeters)
  - Measure the wrong muscle
- EEG must use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

Uses of EEG

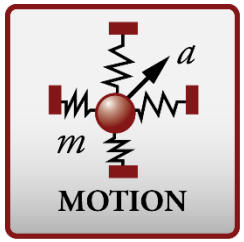
- Disease diagnosis
- Sleep diagnosis
- Detect mood
- Brain control of devices

Heart Rate



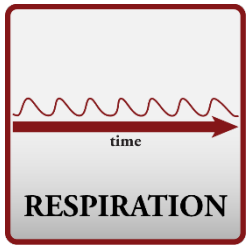
- Measured by
  - ECG electrodes – two are sufficient
  - Pulse oximeter sensing – reflected
    - Transmitted works on finger and ear
  - Pressure sensing of the pulse in the wrist
- Wrist measurement works well for Heart Rate, but not for ECG

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

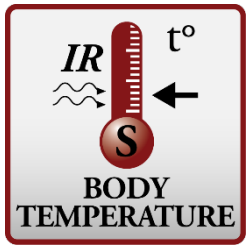
Swelling of Leg

- 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

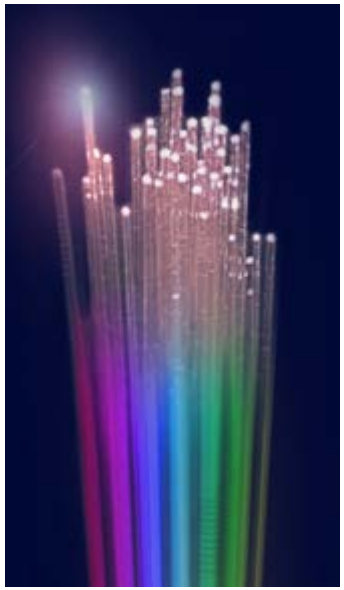
Agenda

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

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

Agenda

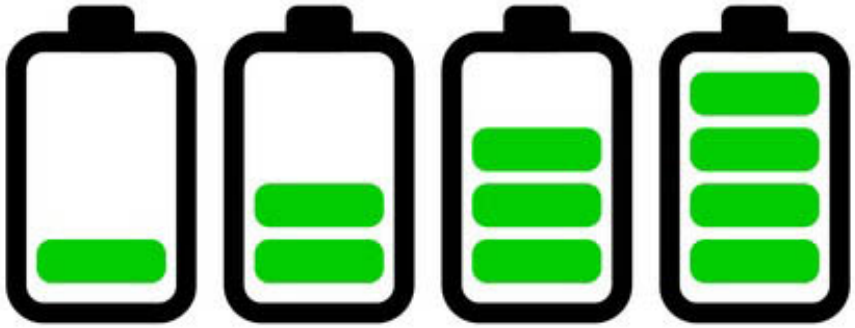
- Trends
  - Wearable devices
  - IoT
  - Digital & home health
- Common physiological measurements
- Sensor innovation
- Current challenges

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

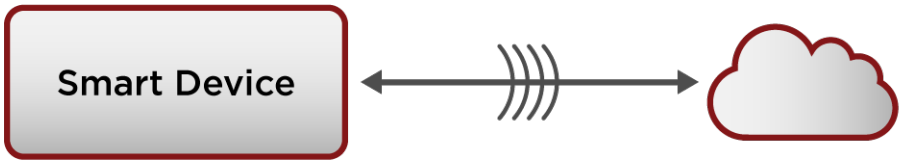


5 Areas That Impact Power

- Wireless transmission
- Displays
- Sensors
- Microprocessors
- Software

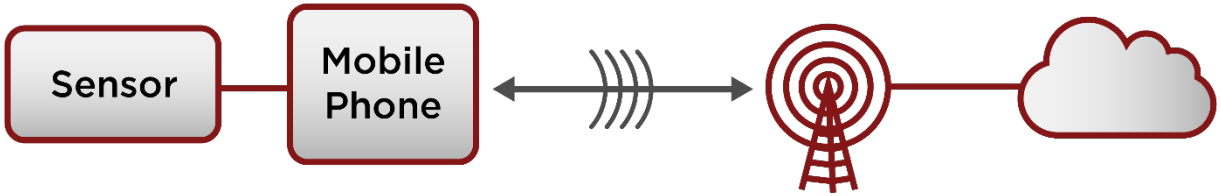
Common Ways to Get Data Into the Cloud

1. Device directly to cloud



2. Sensor to gateway to cloud

3. Sensor to cell phone to cloud



Power- How Much? How Far?

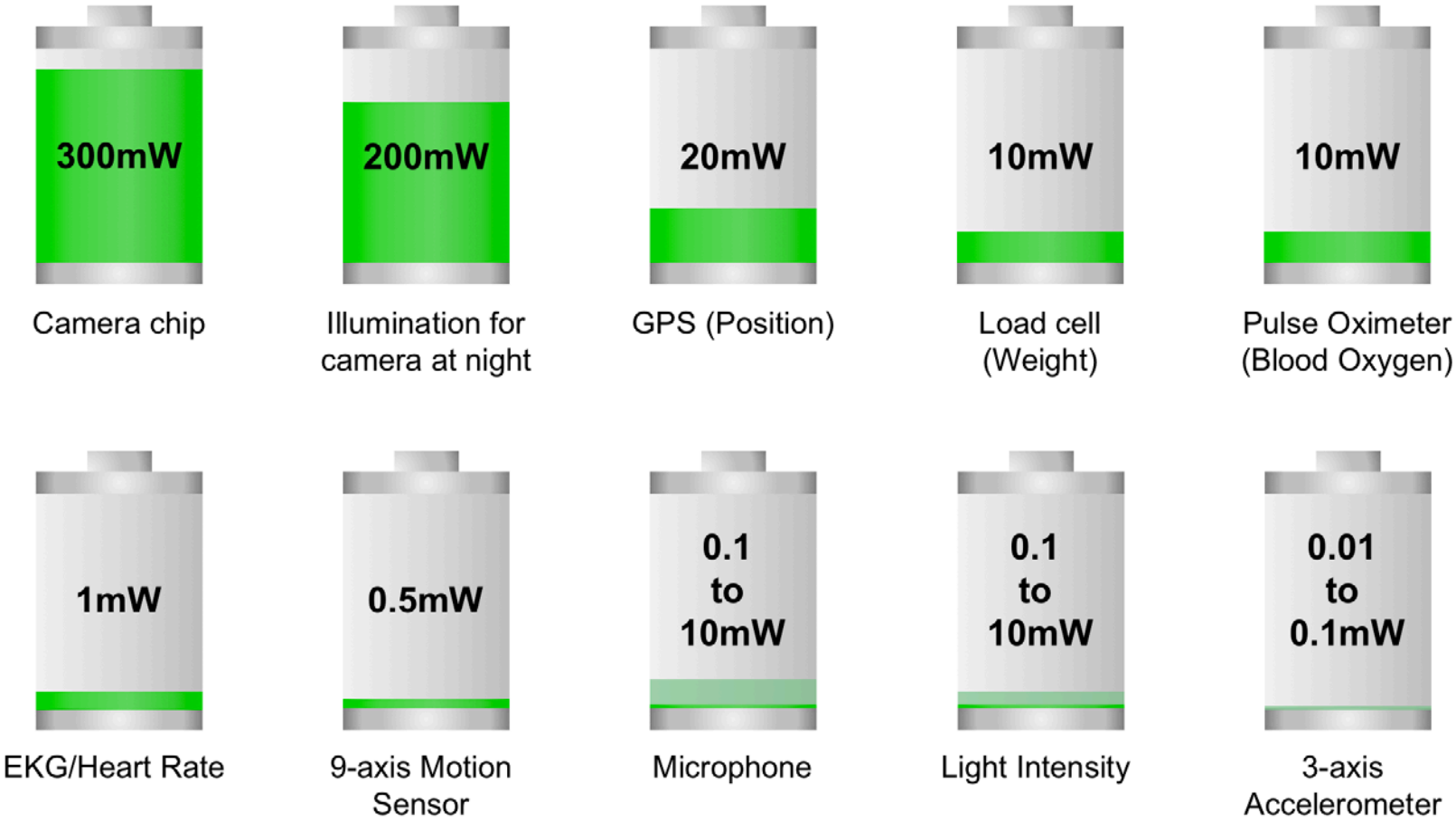
	10 bytes/sec	1 Kbytes/sec	1 Mbytes/sec
1 m	lowest power	data rate	
100 m	distance		
1 km			highest power

Power- How Much? How Far?

	10 bytes/sec	1 Kbytes/sec	1 Mbytes/sec
1 m	BLE/Zigbee 0.15 LoRa 0.5 Bluetooth 25 WiFi 50	BLE/Zigbee 7.5 LoRa 10 Bluetooth 50 WiFi 75	WiFi 300
100 m	LoRa 0.5 WiFi 100 3G Cellular 100 LTE Cellular 100	LoRa 10 WiFi 100 3G Cellular 120 LTE Cellular 120	WiFi 400 LTE Cellular 500
1 km	LoRa 1 3G Cellular 120 LTE Cellular 120	LoRa 30 3G Cellular 150 LTE Cellular 150	LTE Cellular 700

Power in milliWatts

How Much Power Do Sensors Use?



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

Walt Maclay, Voler Systems
Walt@volersystems.com

Quality Electronic Design & Software

Wearable Devices

Sensor Interfaces

Wireless

Motion Control

Medical Devices

Voler SYSTEMS