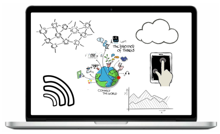
CSC 498R: Internet of Things

Lecture 02: IoT Hardware Platforms

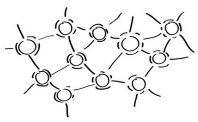
Instructor: Haidar M. Harmanani

Fall 2017

IoT Components

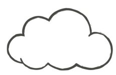


- Things we connect: **Hardware, sensors *and* actuators**

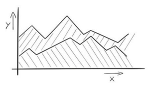


- Connectivity
  - Medium we use to connect things

- Platform
  - Processing and storing collected data
    - Receive and send data via standardized interfaces or API
    - Store the data
    - Process the data.



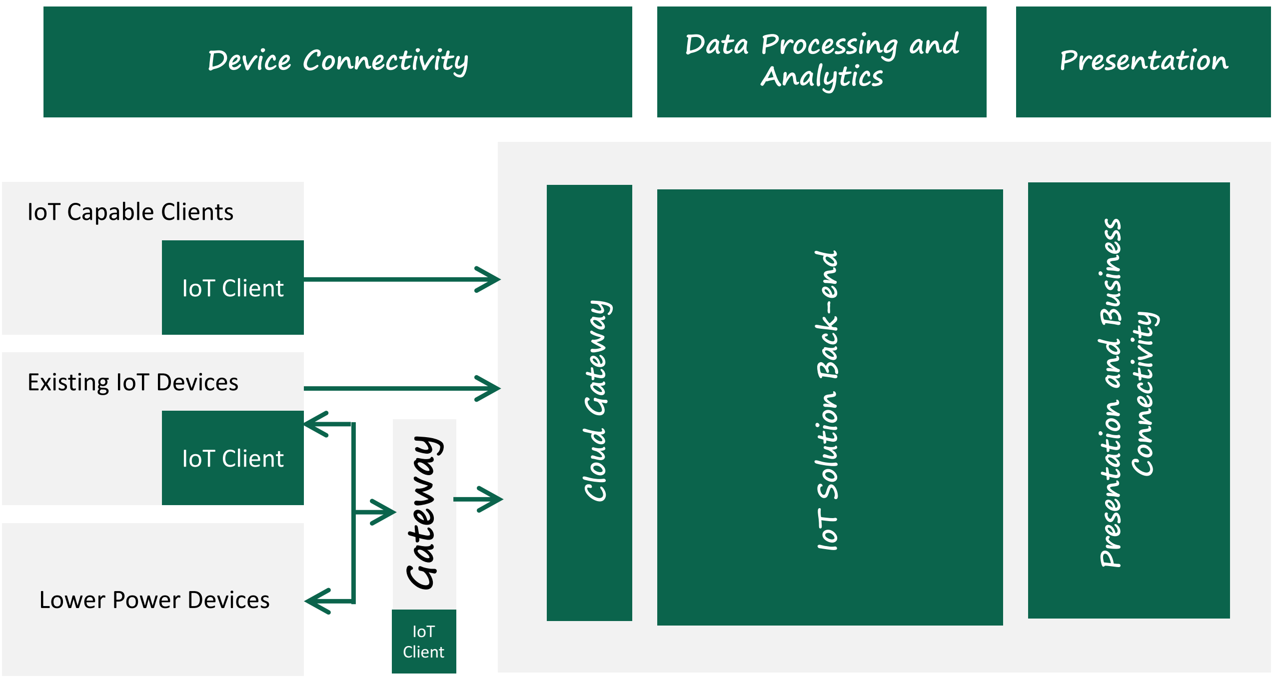
- Analytics
  - Get insights from gathered data



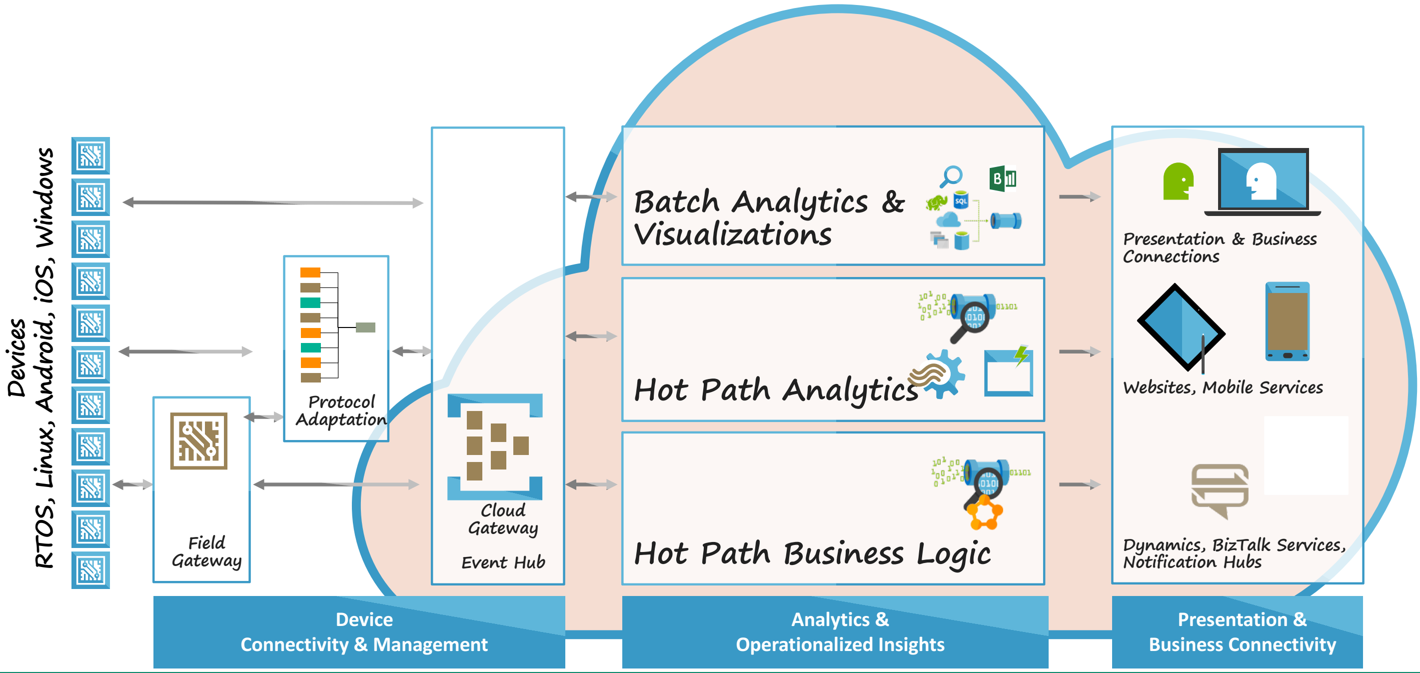
- User Interface

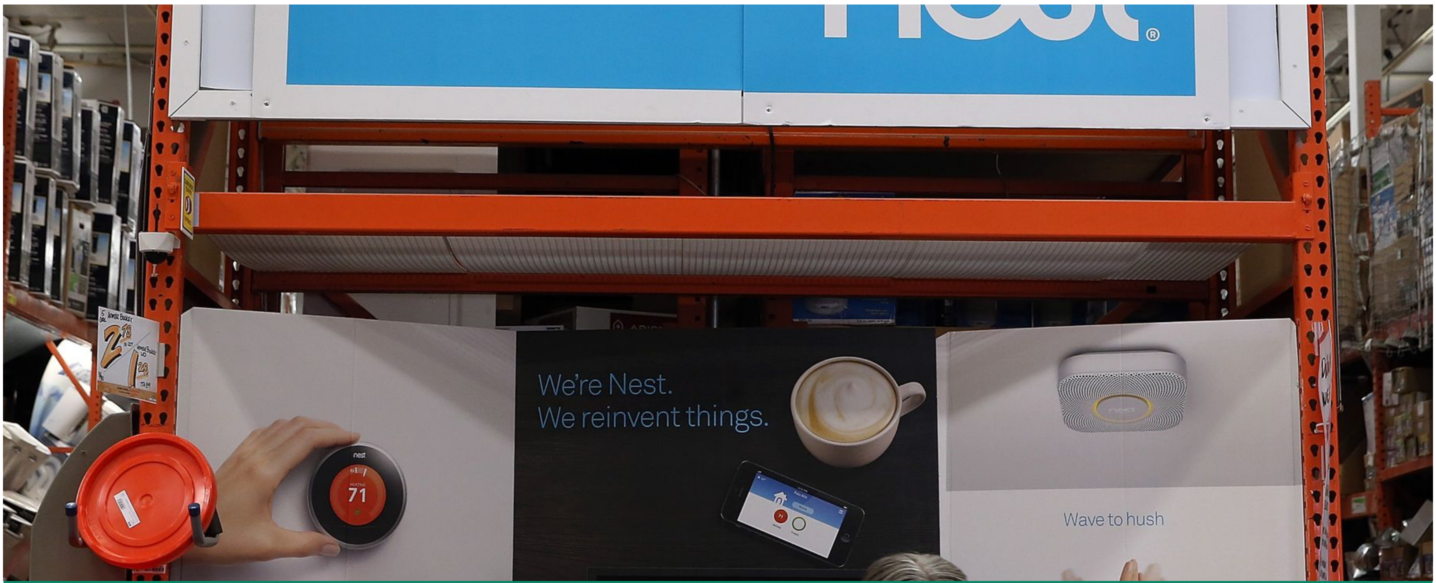
Introduction

- An IoT solution is made of hardware devices and an ingestion system
  - Ingest all events and data sent from devices or sensors
- Once data is acquired, the ingestion system feeds the data to a back end for analysis
  - A "hot" path for analyzing data as a stream in real time
  - A "cold" path for storing data and analyzing them in the future



IoT Device & Cloud Patterns





JANUARY 17, 2014

Earlier this week, Google bought Nest, a connected devices company, for $3.2 billion.

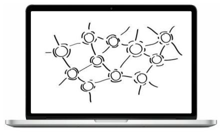
Today's Agenda

- This Week
  - Things we connect: Hardware, sensors and actuators
  - Prototyping boards
- Next Week
  - Integration of Sensors and Actuators with the Pi
  - Introduction to Raspberry Pi Programming using Python
  - Implementation of IoT with Raspberry Pi

IoT Hardware Platforms

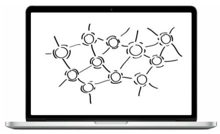
- Multiple microcontrollers could work as central logic controller for an IoT project
- Each device has its own pros and cons

IoT Devices



- Are smartphones and tablets IoT devices?
  - Smart phones and tablets have sensors, accelerometers, gyroscopes and so on
  - Are embedded devices with displays and keypad
  - Can be connected to the Internet
  - Have IP addresses
- Qualcomm CEO Paul Jacobs agrees although the issue is at debatable among various academicians and industrialists

IoT Devices



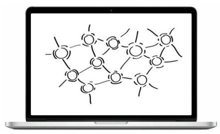
- Typically IoT devices should be Smart Devices
  - “An electronic device, generally connected to other devices or networks via various wireless protocols such as Bluetooth, NFC, WiFi, 3G and so on that can operate to some extent interactively and autonomously”
- Smart devices also refer to a *ubiquitous computing* devices
  - A device that exhibits some properties of ubiquitous computing

Ubiquitous Computing Properties

- *Devices need to be networked, distributed and transparently accessible.*
- *Human-computer interaction with devices is hidden to a degree from its users.*
- *Devices exhibit Context awareness of an environment to optimize their operation in that environment.*

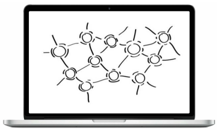
Definition

IoT Technologies: RFID



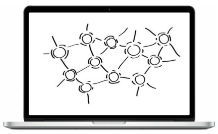
- A RFID chip holds information about the "thing"
- A RFID chip is attached and transfers data to the reader.
- The antenna on the RFID module is used to receive energy that is used to operate the RFID device and transmit information back to the reader.
- RFID enables efficient management, tracking and monitoring processes and logistics and supply chain applications.

IoT Technologies: WSN



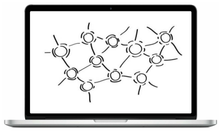
- Wireless Sensor Networks (WSN)
  - Efficient, low-cost, low-power devices for use in remote sensing applications.
  - Low-power integrated circuits and wireless communications.
  - A large number of intelligent sensors collect raw data, and create valuable services by processing, analyzing, and spreading data.
  - Challenges are related to limited processing capability and storage, and sensor data sharing for multiple device/system cooperation.

IoT Technologies

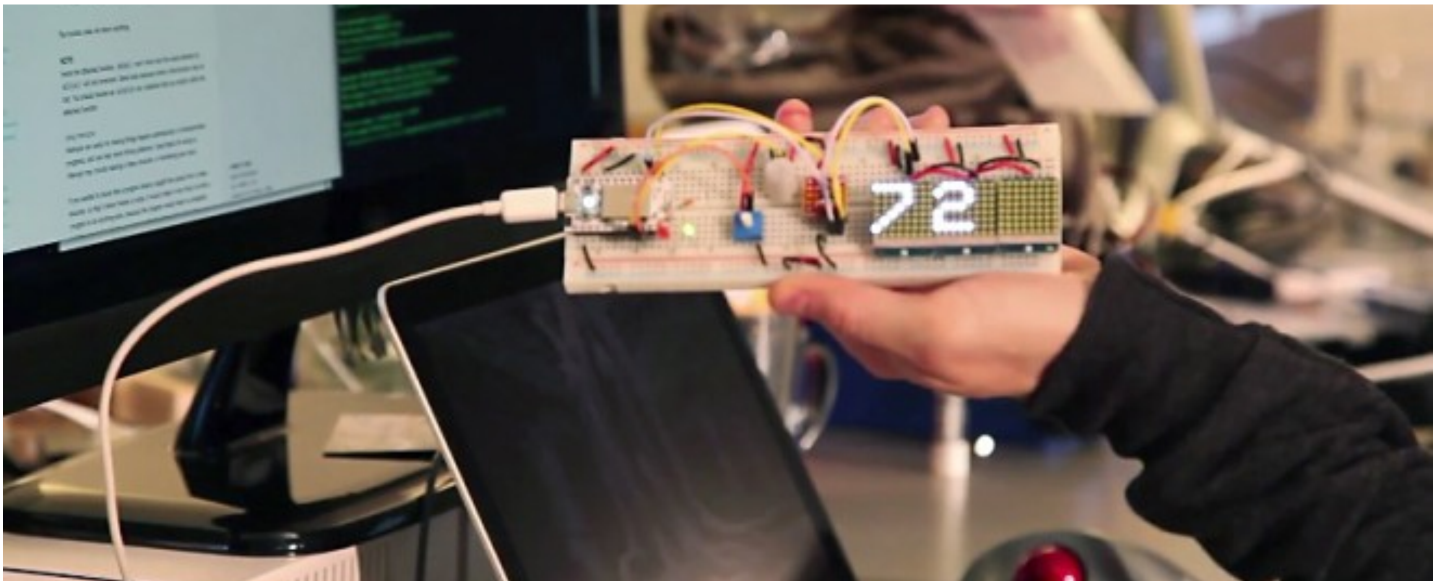


- IoT Cloud Computing Support
  - For Advanced IoT services, IoT networks may need to collect, analyze and process segments of raw data and turn it in into operational control information.
  - Advanced IoT services will need support of cloud computing.
  - Numerous IoT connections will be made to various devices and sensors.
  - Many IoT devices will not have PC or smartphone level of sufficient data processing capability or interoperability functionality.

IoT Technologies



- Cloud Computing
  - IoT applications will need support from a reliable, fast, and agile computing platform.
  - IoT devices can overcome a lack of software, firmware, memory storage, hardware and data processing capability using cloud computing.
  - The following are cloud service models:
  - Software as a Service (SaaS)
  - Platform as a Service (PaaS)
  - Infrastructure as a Service (IaaS)

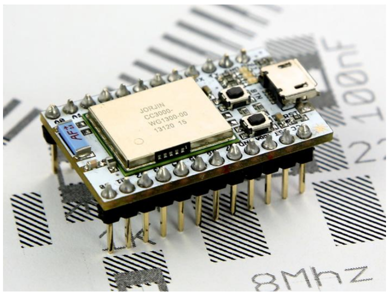


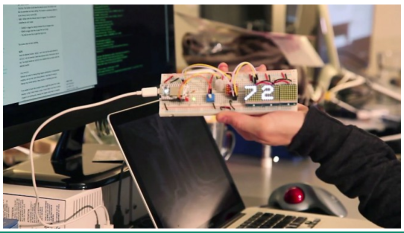
What is Out There?

Spark Core for Open Nest

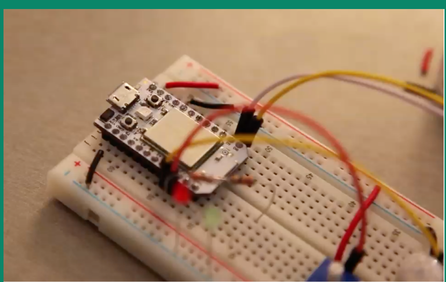
Spark Core

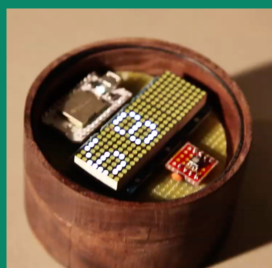
- Pros
  - Wireless built-in
  - Small form factor
  - HTTP Server
  - Cloud-based IDE
- Cons
  - Slow processor (72 Mhz)
  - Configuring Wifi can be difficult
  - Not Android compatible



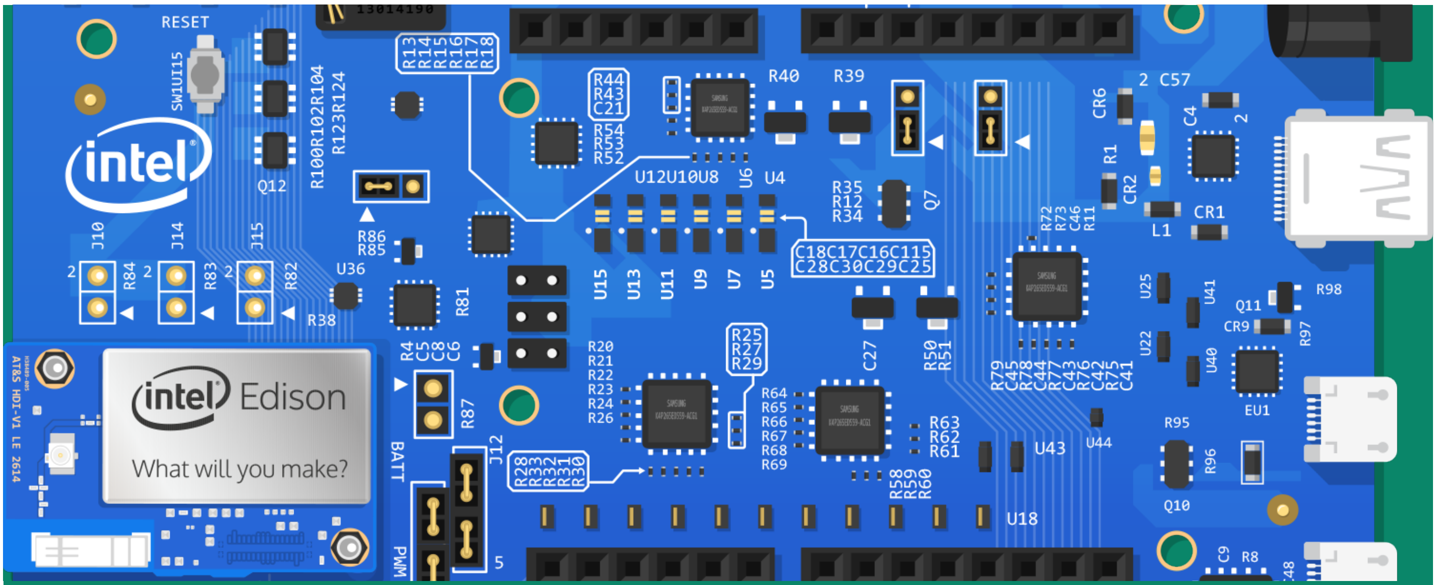


https://blog.particle.io/2014/01/17/open-source-thermostat/





Open Source Nest



What is Out There?

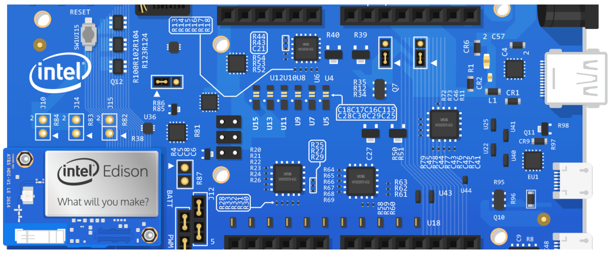
Intel Development Boards

Intel Galileo Generation 2

- Pros
  - Intel® Quark™ SoC X1000 application processor
  - PCI-e/microSD/USB
  - Wired Ethernet
  - Encryption capabilities
  - Arduino shield compatible
- Cons
  - 400 MHz x86 – not the fastest processor
  - Large form factor

Intel Edison

- 22 nm Intel® Atom™ SoC
- 1 GB RAM
- 4 GB flash storage
- Wi-Fi
- Bluetooth Low-Energy (LE)
- Integrated power management
- Less than 1 W of power when fully operating
- USB ports
- 40 multiplexed GPIO interfaces, perfect for connecting a sensors, a small LCD screen, and a variety of expansion boards



What is Out There?

Arduino Yun

Arduino Yun

- Pros
  - Wireless built-in
  - Ethernet/USB/microSD
  - Arduino IDE
  - Extensive shields
- Cons
  - 400 MHz MIPS – not the fastest controller
  - One Core

Sensor Devices

- Chromecast
- Kinect
- Android 2.2+ Phones
- Pebble Watch
- Roomba
- 3D Cameras
- Anything else you can integrate into a project

Digital and Analog Sensors

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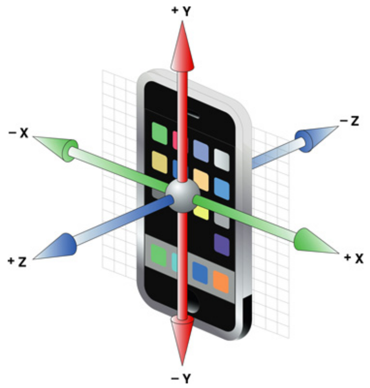
Sensors: Introduction

- A sensor is a converter that measures a physical quantity and transforms it into a signal
- Sensors are calibrated against a gold known standard
  - A temperature sensor against a thermostat
- Recent advanced sensors are based on MEMS
  - Micro Electron Mechanical Sensors
  - Ex. Accelerometers, Gyroscope, …

Some sensors included in your phone

- Proximity
- Touch
- Tilt
- Accelerometers
- Gyroscope
- Temperature
- GPS
- Camera
- Speech
- Altitude
- Pressure
- Light
- Magnetometer

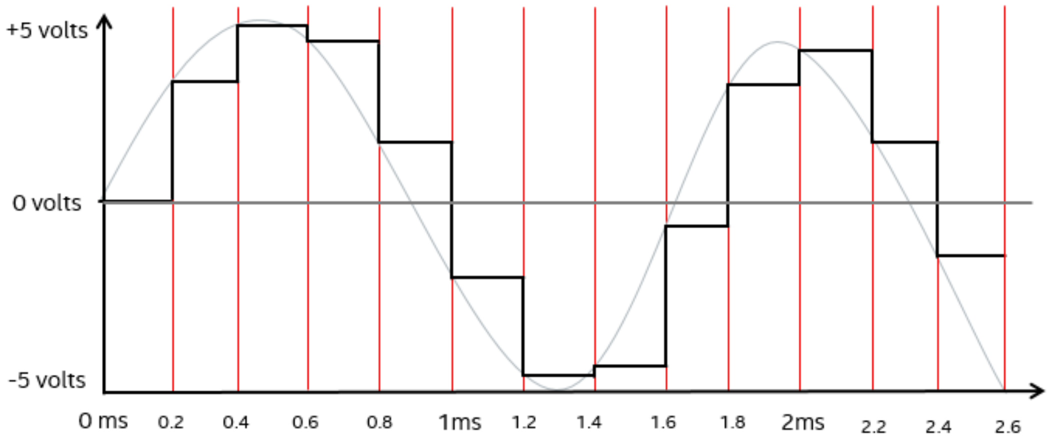


Sensor type	Examples
Acoustic, sound, vibration	Microphone
Automotive, transportation	Parking sensor, speedometer
Chemical	Breathalyser, smoke detector
Electric current, electric potential, magnetic, radio	Metal detector
Flow, fluid velocity	Water meter
Ionizing radiation, subatomic particles	Geiger counter
Navigation instruments	Depth gauge, gyroscope
Position, angle, displacement, distance, speed, acceleration	Impact sensor
Optical, light, imaging, photon	Light sensor
Pressure	Barometer
Force, density, level	Hydrometer
Thermal, heat, temperature	Thermometer
Proximity, presence	Touch switch

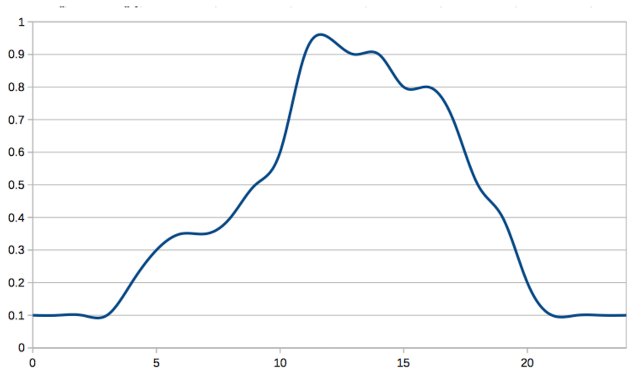
Analog Versus Digital

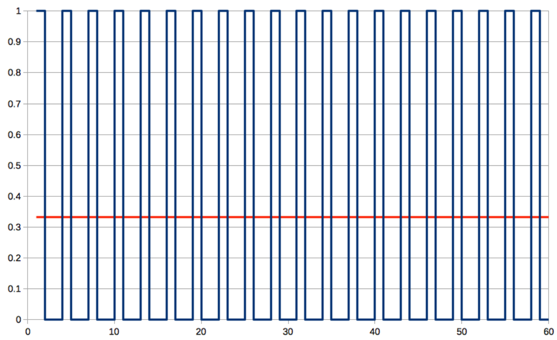
- Analog signals passes through infinite number of voltage levels between +5/-5 Volts
- Solution
  – Use an ADC
  – A sample at 5kHz takes a snapshot of the voltage level every 200 us

Analog Versus Digital



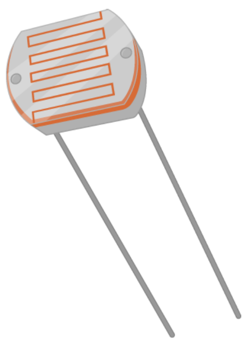
Analog Versus Digital



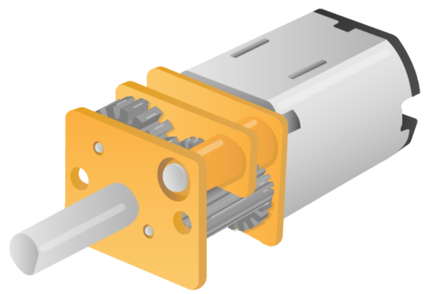


Analog Input and Output

Light Dependent Resistor (LDR)



A motor is an example of an analogue *output* component.



Pulse Width Modulation

- To use an analogue output component with the GPIO pins, you need to use *Pulse Width Modulation* (PWM)
  - Send very rapid pulses of 1s and 0s to the component, which when taken as an average can be received as values in-between 1 and 0.

Analogue to Digital Convertor

- To use an analogue input component with the GPIO pins, you need to use an *Analogue to Digital Converter* (ADC)
  - Turn analogue signals into digital signals
- You can buy small ADCs for use in your circuits
  - There are also several add-on boards you can buy for the Raspberry Pi with ADCs included, such as the Explorer HAT

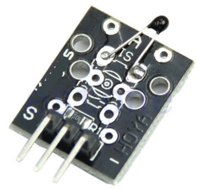
Interacting with sensors

- Many digital and Analog sensors are available
- Note
  - In this course we will use simple Raspberry Pi sensors
  - No fancy business

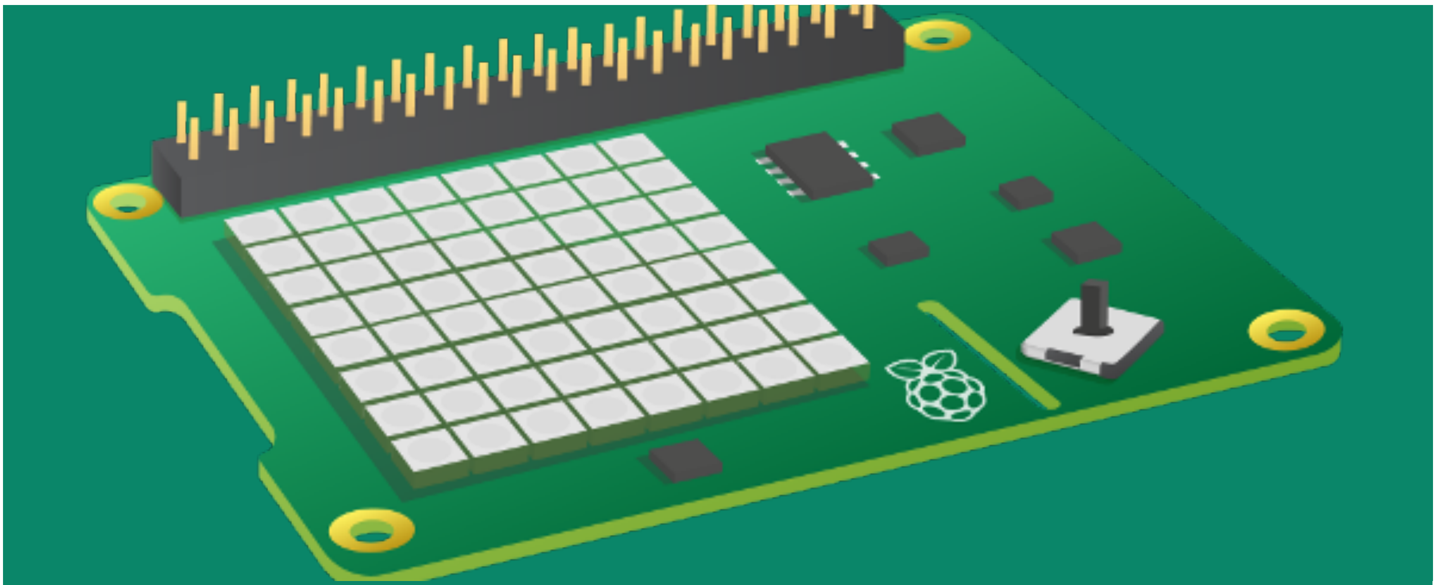
Digital sensors

- A digital sensor interacts with the physical environment and returns us a binary information.
- For example, a digital push button is pressed, or not.
  - It has two states, 0 or 1.
- Three wires can be connected :
  - A black one, for the ground.
  - A red one, for input voltage.
  - A green one, transmitting the information

Analog sensors



- An analog sensor interacts with the physical environment and sends us a physical value, which is almost always a voltage.
- For example, an analog linear temperature sensor is a circuit involving a resistor.
  - Its value changes linearly with the temperature.
  - According to Ohm's law, voltage also changes and this is the value we get and measure.
- As a digital sensor, common analog sensors have three pins:
  - As usual, black on ground and red on voltage input.
  - And a blue one, corresponding to the voltage returned by the sensor.



Sense HAT

Sense HAT

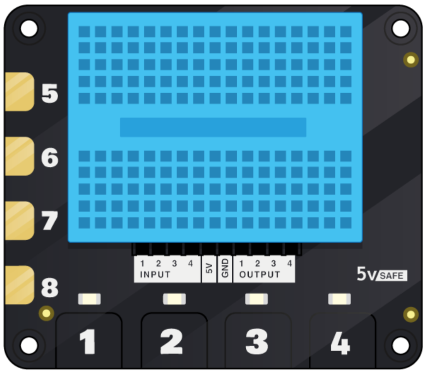
- Designed especially for the Raspberry Pi as part of the *Astro Pi education program*
- Has the ability to sense a wide variety of conditions and provide output via the built-in LED matrix
- There are two on board the *International Space Station* that can be programmed by competition winners from across ESA member states

Sense HAT Sensors

- A gyroscope
  - Measures the orientation of an object
- An accelerometer
  - Measures an object's acceleration
- A magnetometer
  - Measures the strength and direction of a magnetic field
- A temperature sensor
- A humidity sensor
- A pressure sensor or a barometer

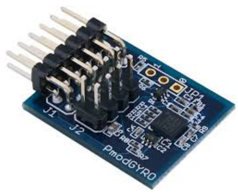
Other Interesting Add-ons: Explorer HAT

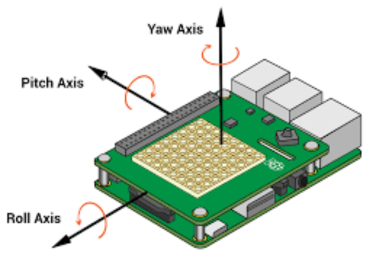
- Includes
  - Has eight capacitive touch pads
  - Many useful sensors



Gyroscope

- Measures the orientation of an object
- Has multiple degrees of movement:
  - Pitch (up and down like a plane taking off and landing
  - Yaw: left and right like steering a car
  - Roll: Imagine a corkscrew movement, like a fighter jet in a barrel roll)





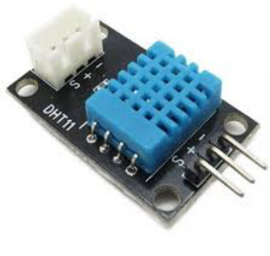
Magnetometer

- Measures the strength and direction of a magnetic field
- Used to measure the Earth’s magnetic field in order to find the direction of north
  - The compass in your phone or tablet uses a magnetometer to find north

Other Interesting Sensors

Temperature Sensor

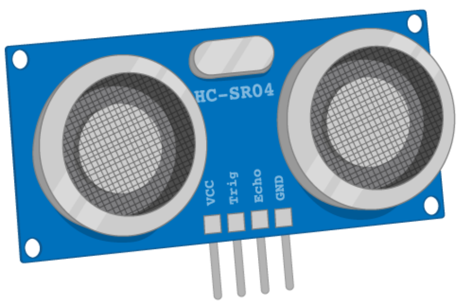
- Measure hot and cold, exactly like a thermometer

Submersible

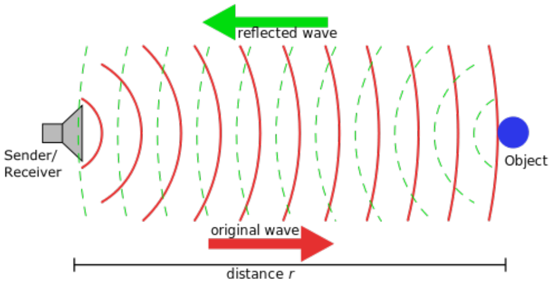
Ultrasonic Sensor

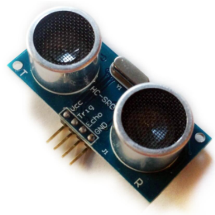
- An ultrasonic pulse is sent out from the sensor and when the echo is received the time taken can be used to calculate the distance



Ultrasonic RangeFinder

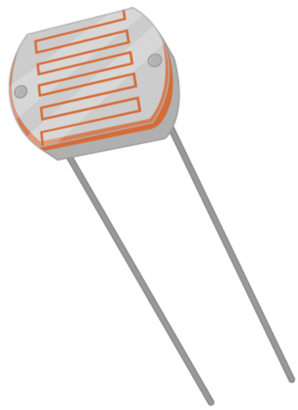
- The HC-SR04 ultrasonic sensor uses sonar signals to determine distance to an object





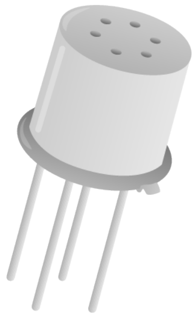
Light Dependent Resistor

- A component whose resistance will change depending on the intensity of light shining upon it
- Can be used to detect changes in light
- Commonly used in street lighting to turn on when it gets dark at night and turn off when it gets light in the morning.



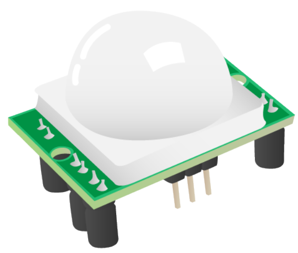
Air Quality Sensor

- Used to determine air quality by detecting polluting gases
- When air enters the sensor, it is energized by a small heater which allows its electrical resistance to be measured
  - Pass a low level of electricity across a small gap of energized air
  - The more contaminated the air is, the less resistance it has and the better it will conduct electricity (like a variable resistor)
- Output is an analog voltage that goes up and down according to how contaminated the air is
  - The more contaminants, the higher the voltage output.

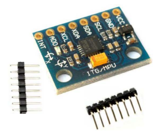


Passive Infra Red (PIR) Sensor

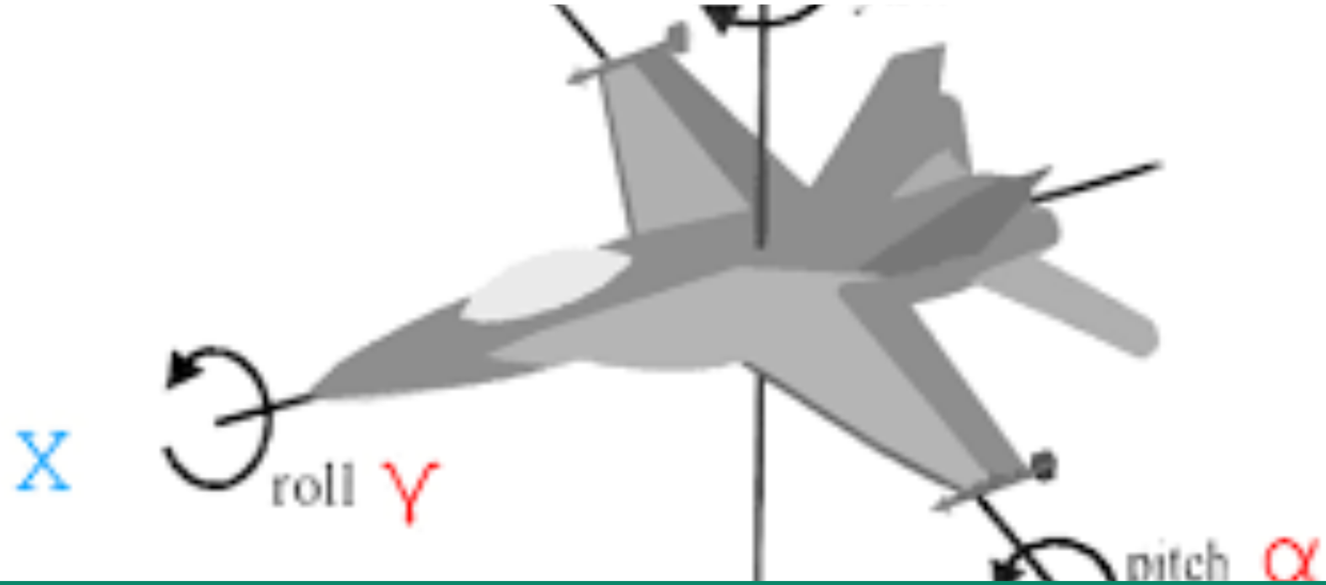
- Detects movement by detecting objects whose temperatures are above absolute zero since they emit infra red radiation
  - Can be used to activate cameras or for burglar alarm systems.
- Infra red wavelengths are not visible to the human eye, but they can be detected by the electronics inside one of these modules
- The sensor is regarded as passive because it doesn't send out any signal in order to detect movement
- It adjusts itself to the infra red signature of the room it's in and then watches for any changes
- Any object moving through the room will disturb the infra red signature, and will cause a change to be noticed by the PIR module



Accelerometer



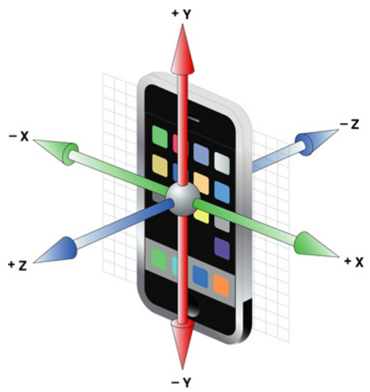
- Measures an object's increase in speed (acceleration)
  - At rest, it measures the direction and force of gravity, but in motion it measures the direction and force of the acceleration acting on it
- Often found in devices that need to know when they are pointing downwards, such as a mobile phone or tablet
  - When you turn the screen sideways the accelerometer inside detects that the direction of gravity has changed, and therefore changes the orientation of the screen.

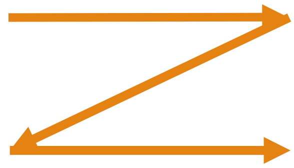


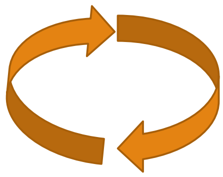
Understanding Accelerometer

Accelerometer

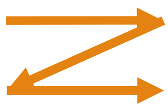
- Distinguish two gestures

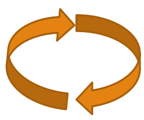




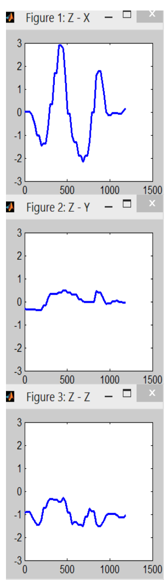


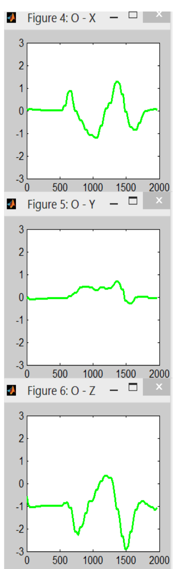
http://tech.pro/tutorial/968/iphone-tutorial-reading-the-accelerometer

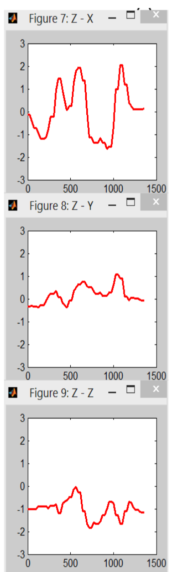




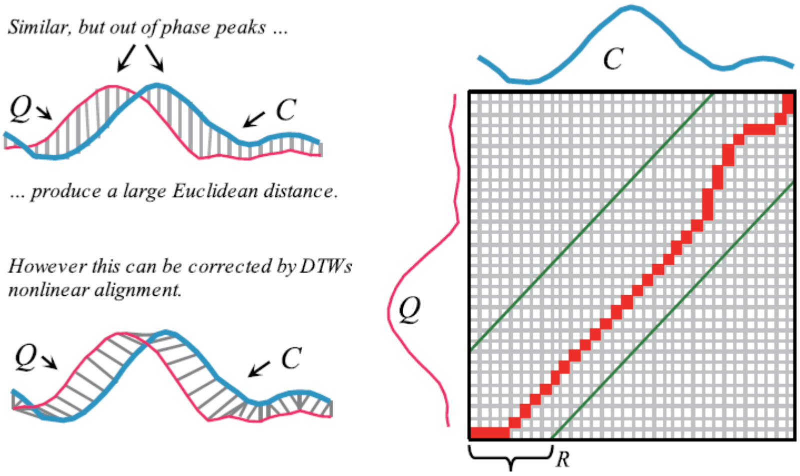
Which gesture?





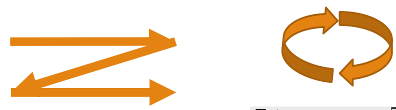


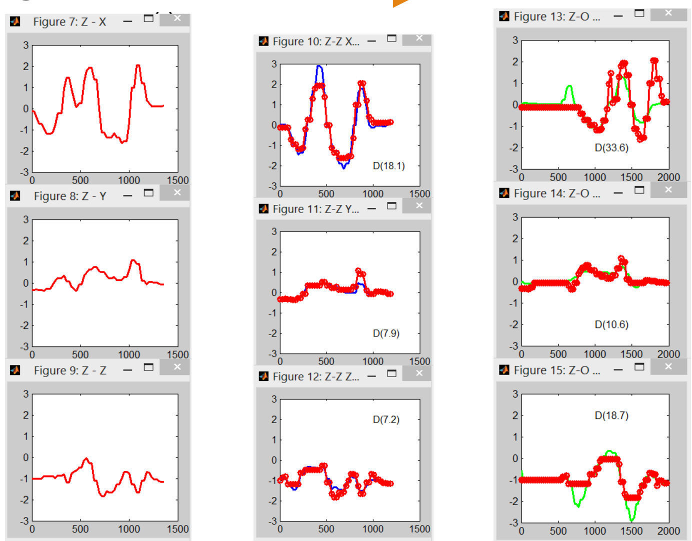
Dynamic Time Warping



T. Rakthanmanon, et al. ACM Transactions on Knowledge Discovery from Data, 7(3), September 2013

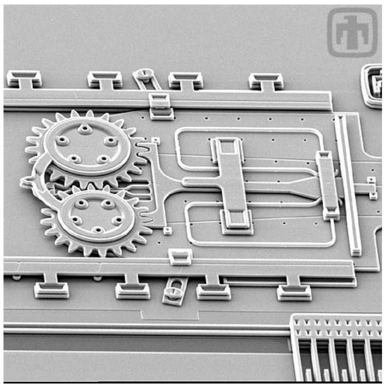
Which gesture?





Focus: MEMS in Mobile Devices

Len Sheynblat, Qualcomm, Sensors System Integration Problems, MIG M2M Workshop, Spring 2012

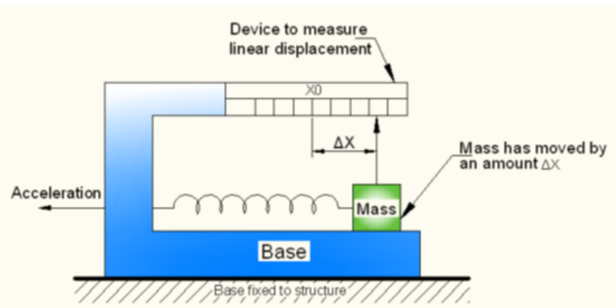


Incredible MEMS Clutch mechanism. This is actually a complex device that required a working clutch mechanism. Gears are 50 microns across.

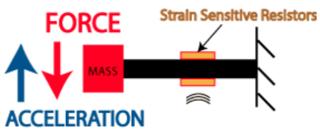
MEMS Accelerometer: Principle

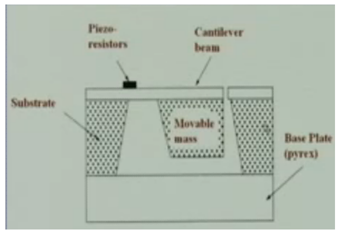
Force $F = ma = k\Delta x$. From measured Δx, we can compute acceleration:

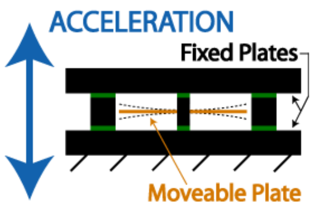
$$a = \frac{k}{m}\Delta x$$

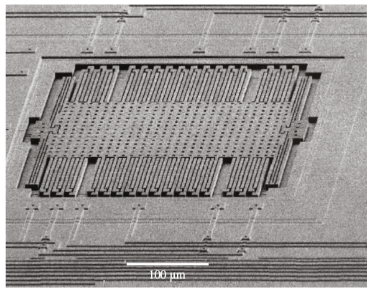


Hooke's law:
$F = k\Delta x$









ANALOG DEVICES

Small, Low Power, 3-Axis ±3 *g* Accelerometer

ADXL335

FUNCTIONAL BLOCK DIAGRAM

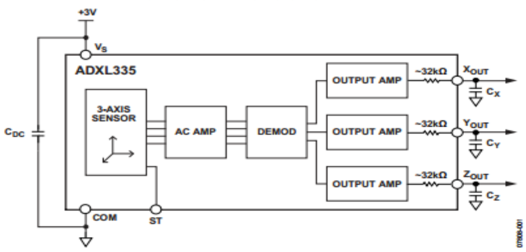
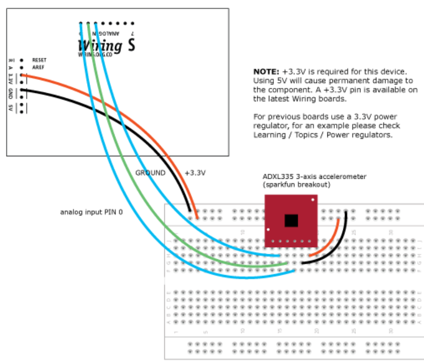
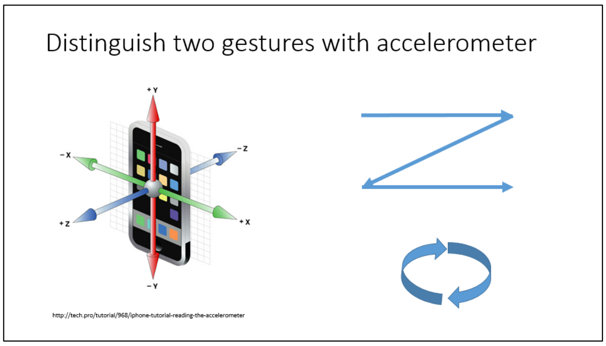
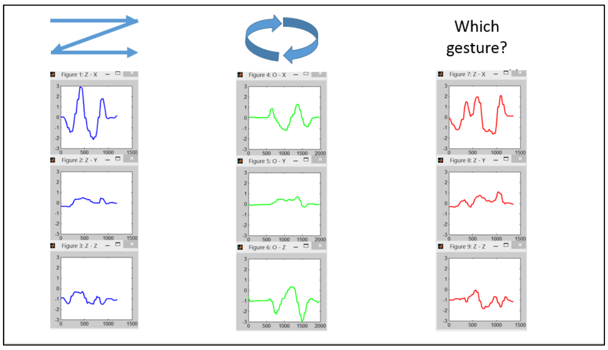


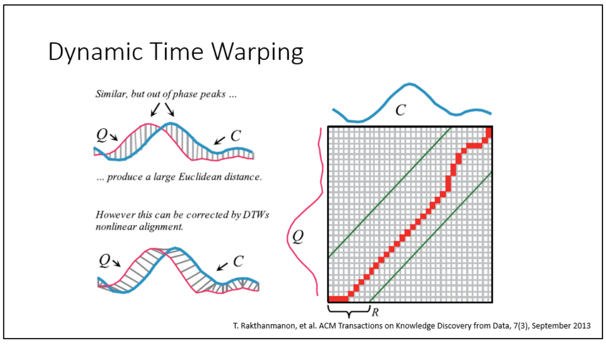
Figure 1.

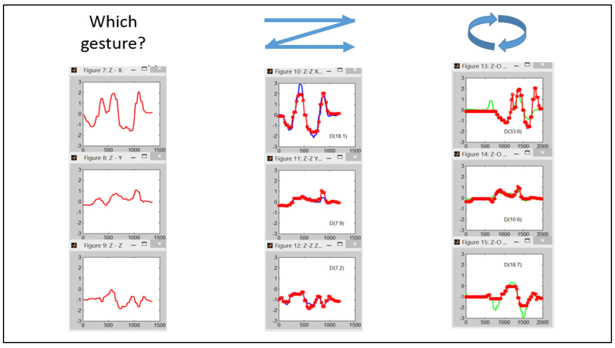


```
int x, y, z;

void setup()
{
  Serial.begin(9600);       // sets the serial port to 9600
}

void loop()
{
  x = analogRead(0);        // read analog input pin 0
  y = analogRead(1);        // read analog input pin 1
  z = analogRead(2);        // read analog input pin 1
  Serial.print("accelerations are x, y, z: ");
  Serial.print(x, DEC);     // print the acceleration in the X axis
  Serial.print(" ");        // prints a space between the numbers
  Serial.print(y, DEC);     // print the acceleration in the Y axis
  Serial.print(" ");        // prints a space between the numbers
  Serial.println(z, DEC);   // print the acceleration in the Z axis
  delay(100);               // wait 100ms for next reading
}
```



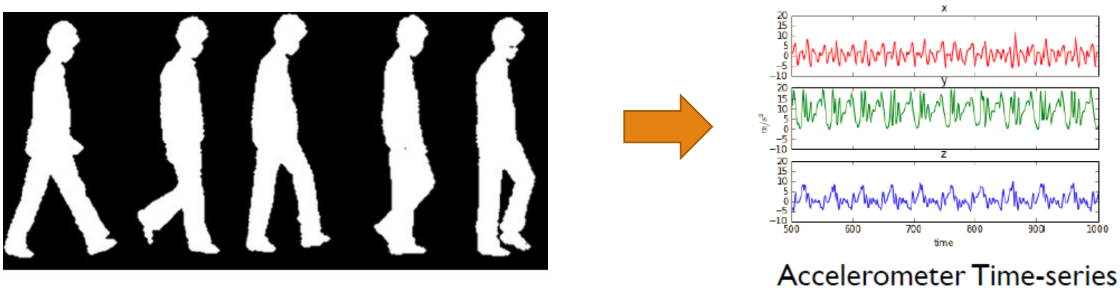




Gait Recognition Using Encodings With Flexible Similarity Measures

Michael B. Crouse   Kevin Chen   H. T. Kung
School of Engineering and Applied Sciences
Harvard University

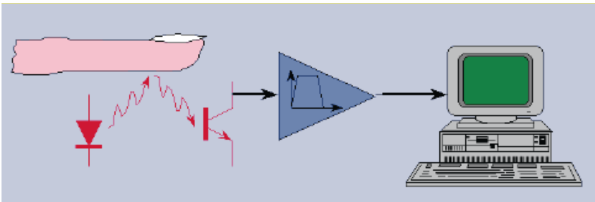
11th International Conference on Autonomic Computing (ICAC '14), June 2014

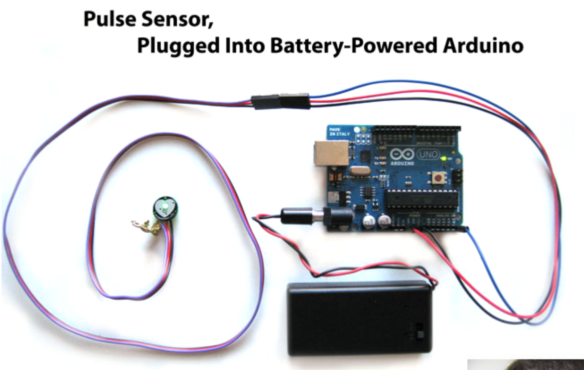


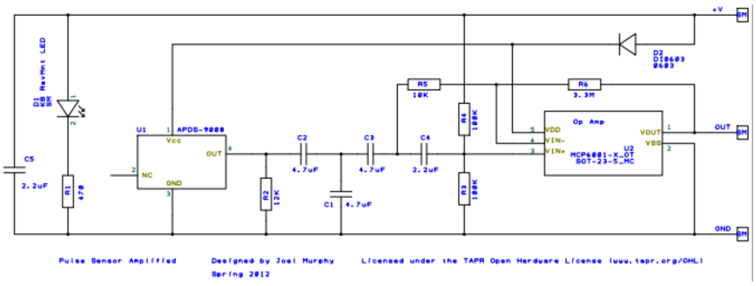
Accelerometer Time-series

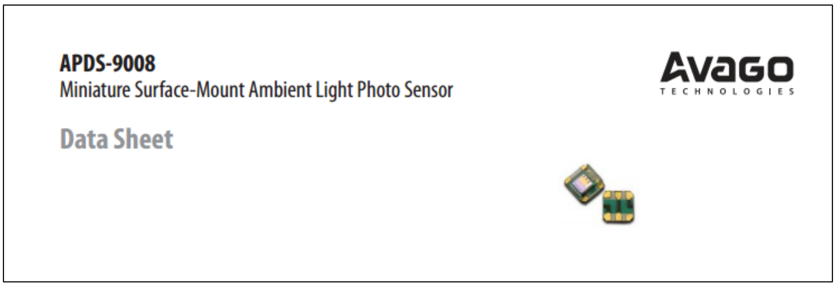
Finger Photoplethysmography

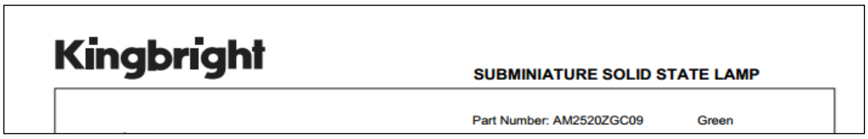
- IR transmission is partially blocked by blood
- Changes in blood volume in the finger cause changes in reflected IR levels
- Changes in reflected IR are converted to changes in voltage, filtered and digitized

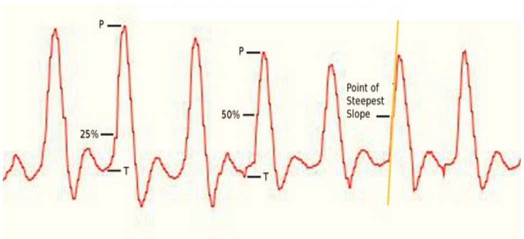


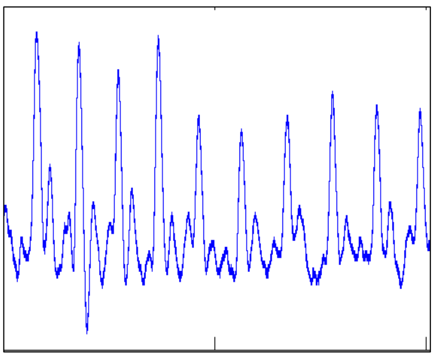




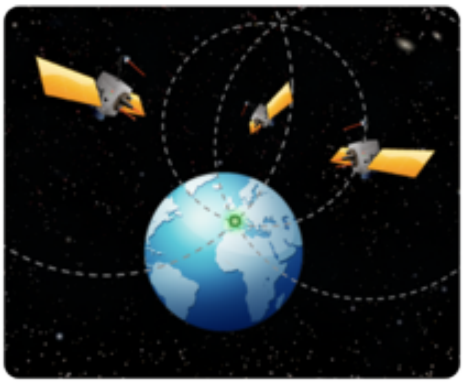

APDS-9008
Miniature Surface-Mount Ambient Light Photo Sensor
Data Sheet
AVAGO TECHNOLOGIES


Kingbright
SUBMINIATURE SOLID STATE LAMP
Part Number: AM2520ZGC09 Green



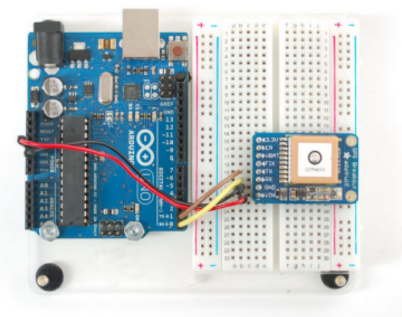


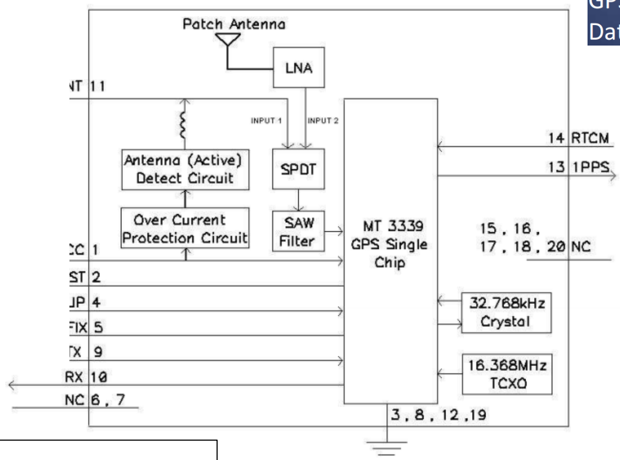
```
ISR(TIMER2_COMPA_vect){
  Signal = analogRead(pulsePin);
  sampleCounter += 2;
  int N = sampleCounter - lastBeatTime;


if ( (Signal > thresh) && (Pulse == false) && (N > ((IBI/5)*3) ){
    Pulse = true;
    digitalWrite(pulsePin,HIGH);


if (Signal < thresh && Pulse == true){
   digitalWrite(13,LOW);
   Pulse = false;
```



GlobalTop Technology Inc.

FGPMMOPA6H
GPS Standalone Module
Data Sheet





TX (Pin9)

This is the UART transmitter of the module. It outputs the GPS information for application.

RX (Pin10)

This is the UART receiver of the module. It is used to receive software commands and firmware update.

(National Marine Electronics Association)

Sample NMEA data file
(output GGA, GSA, GSV and RMC messages)

```
aa - WordPad
檔案(F) 編輯(E) 檢視(V) 插入(I) 格式(O) 說明(H)

$GPRMC,104426.591,A,5920.7019,N,01803.2893,E,0.117980,320.93,141204,,*0F
$GPGGA,104427.591,5920.7009,N,01803.2938,E,1,05,3.3,78.2,M,23.2,M,0.0,0000*4A
$GPGSA,A,3,05,24,17,30,02,,,,,,,,5.6,3.3,4.5*34
$GPGSV,3,1,12,30,72,254,30,05,70,125,39,24,37,083,43,02,36,113,45*7B
$GPGSV,3,2,12,04,32,059,34,01,27,307,00,14,26,256,00,06,24,219,00*7F
$GPGSV,3,3,12,17,22,135,40,25,20,311,31,09,19,159,25,20,08,346,34*7C
$GPRMC,104427.591,A,5920.7009,N,01803.2938,E,0.146345,320.93,141204,,*08
$GPGGA,104428.591,5920.7008,N,01803.2943,E,1,05,3.3,78.9,M,23.2,M,0.0,0000*43
$GPGSA,A,3,05,24,17,30,02,,,,,,,,5.6,3.3,4.5*34
$GPGSV,3,1,12,30,72,254,31,05,70,125,41,24,37,083,44,02,36,113,46*71
$GPGSV,3,2,12,04,32,059,34,01,27,307,00,14,26,256,00,06,24,219,00*7F
$GPGSV,3,3,12,17,22,135,40,25,20,311,30,09,19,159,25,20,08,346,35*7C
$GPRMC,104428.591,A,5920.7008,N,01803.2943,E,0.164145,320.93,141204,,*08
$GPGGA,104429.591,5920.7012,N,01803.2931,E,1,05,3.3,77.1,M,23.2,M,0.0,0000*4B
$GPGSA,A,3,05,24,17,30,02,,,,,,,,5.6,3.3,4.5*34
$GPGSV,3,1,12,30,72,254,31,05,70,125,40,24,37,083,43,02,36,113,46*77
$GPGSV,3,2,12,04,32,059,34,01,27,307,00,14,26,256,00,06,24,219,00*7F
```

First epoch

Second epoch

GGA Message Format

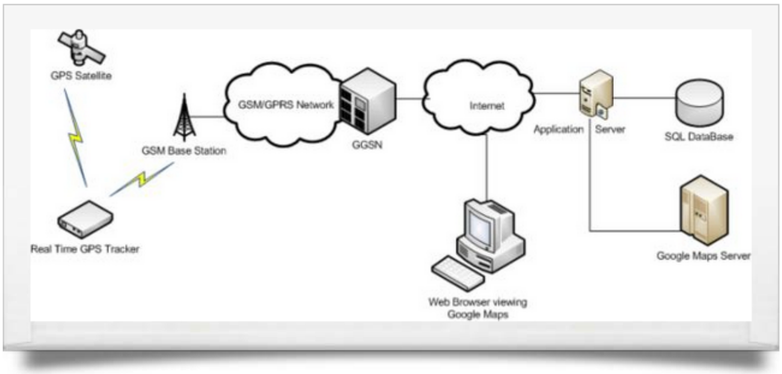
$GPGGA,092204.999,4250.5589,S,14718.5084,E,1,04,24.4,19.7,M,,,,0000*1F

Field	Example	Comments
Message ID	$GPGGA	
UTC Time	092204.999	hhmmss.sss
Latitude	4250.5589	ddmm.mmmm
N/S Indicator	S	N = North, S = South
Longitude	14718.5084	dddmm.mmmm
E/W Indicator	E	E = East, W = West
Position Fix	1	0 = Invalid, 1 = Valid SPS, 2 = Valid DGPS, 3 = Valid PPS
Satellites Used	04	Satellites being used
HDOP	24.4	Horizontal dilution of precision
Altitude	19.7	Altitude (WGS-84 ellipsoid)
Altitude Units	M	M= Meters
Geoid Separation		Geoid separation
Separation Units		M= Meters
Time since DGPS		in seconds
DGPS Station ID		
Checksum	*1F	always begin with *

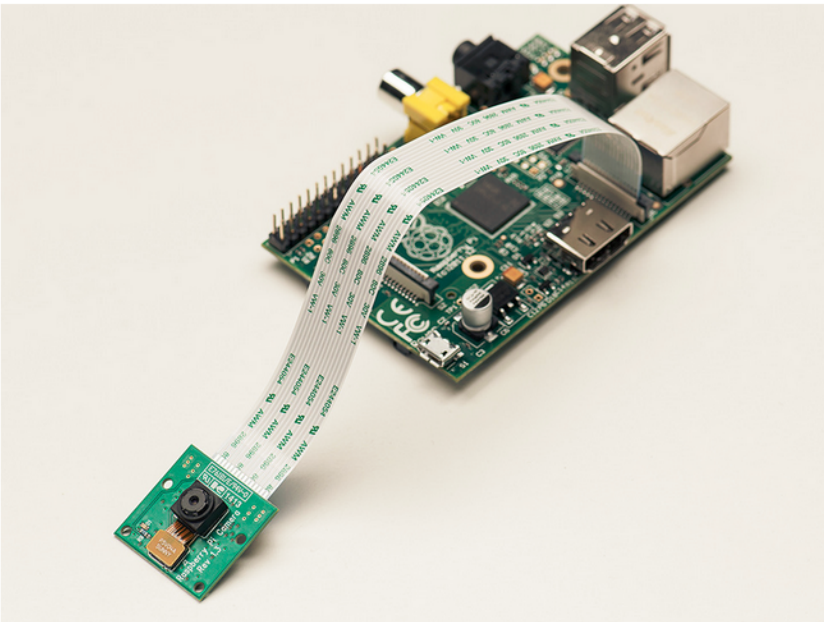
```
int32_t timer = millis();
void loop() // run over and over again
{
    // read data from the GPS in the 'main loop'
    char c = GPS.read();
    // if you want to debug, this is a good time to do it!
    if (GPSECHO)  if (c) Serial.print(c);

    // if a sentence is received, we can check the checksum, parse it...
    if (GPS.newNMEAreceived()) {
        // a tricky thing here is if we print the NMEA sentence, or data
        // we end up not listening and catching other sentences!
        // so be very wary if using OUTPUT_ALLDATA and trytng to print out data
        Serial.println(GPS.lastNMEA()); // this also sets the newNMEAreceived() flag to false
        if (!GPS.parse(GPS.lastNMEA())) // this also sets the newNMEAreceived() flag to false
            return; // we can fail to parse a sentence in which case we should just wait for another
    }
    // if millis() or timer wraps around, we'll just reset it
    if (timer > millis()) timer = millis();

    // approximately every 2 seconds or so, print out the current stats
    if (millis() - timer > 2000) {
        timer = millis(); // reset the timer
        …
```


Real Time GPS Tracker with Integrated Google Maps by jayes

Download | 7 Steps



This project describes how you can build a mobile real time GPS tracker with integrated Google Maps. I began this project mainly to see if I can integrate all the different pieces of hardware and software to make a workable solution, and it took some time, but finally when everything was said and done, it looked pretty cool. I tore down everything and rebuilt it from scratch, making detailed notes and documenting the process.



Raspberry Pi Camera Board

PRODUCT ID: 1367

$29.95

56 IN STOCK

1 ADD TO CART

QTY DISCOUNT

1 $29.95

ADD TO WISHLIST

DESCRIPTION

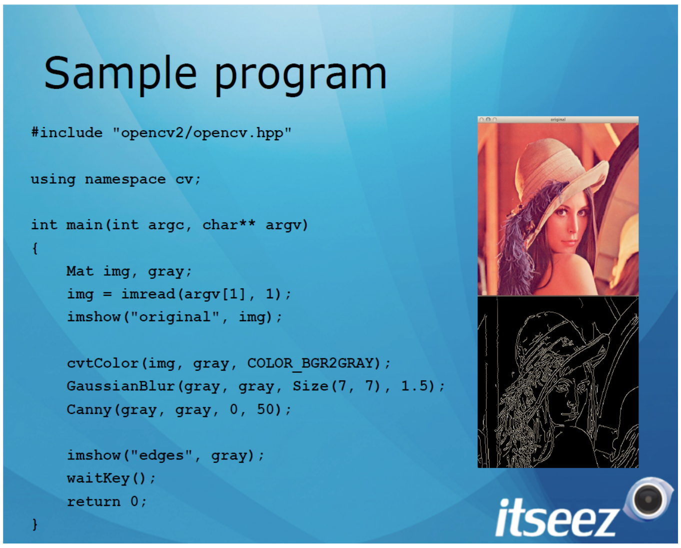
TECHNICAL DETAILS

LEARN

Google Trusted Store

Open-Source Computer Vision Library

- 2500+ algorithms and functions
- Cross platform, portable API
- Real-time performance
- Liberal BSD license
- Professionally developed
- Windows, Linux, Android, Mac, and iOS compatible



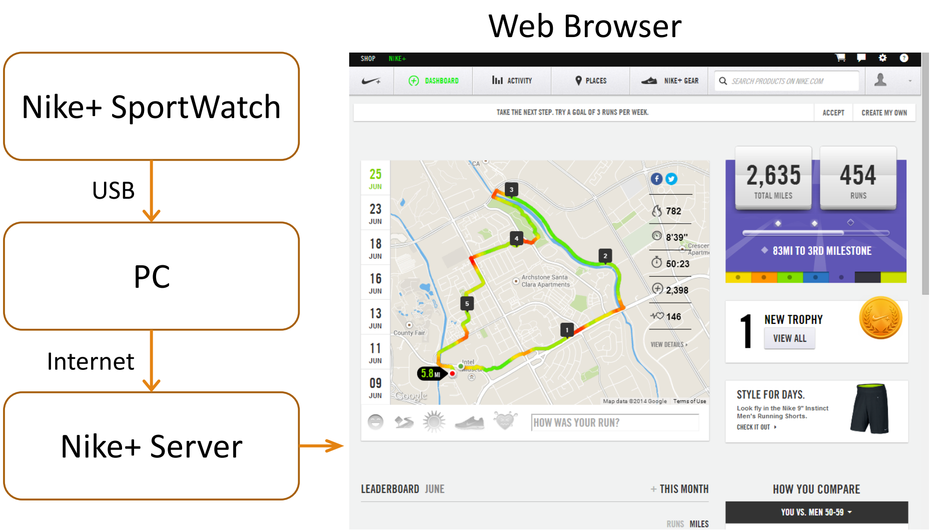
Data Collection Devices

- Nike+ GPS SportWatch
- Polar Wearlink Transmitter
- Garmin Swim

Nike+ GPS SportWatch

- Collects GPS coordinate data every second
- Collects shoe sensor data (2.4GHz)
- Collects heart rate data (5KHz)
- Uploads data to nikeplus.com via USB
- Doesn’t have data export feature!

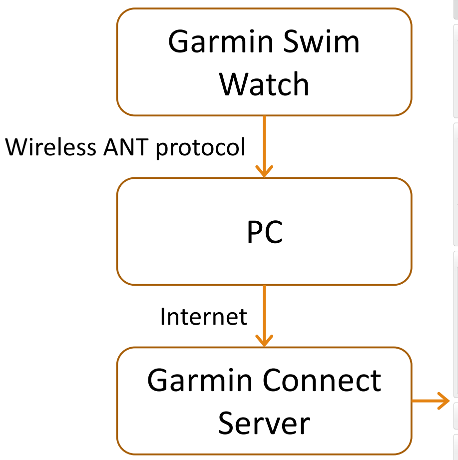
Nike SportWatch Normal Use

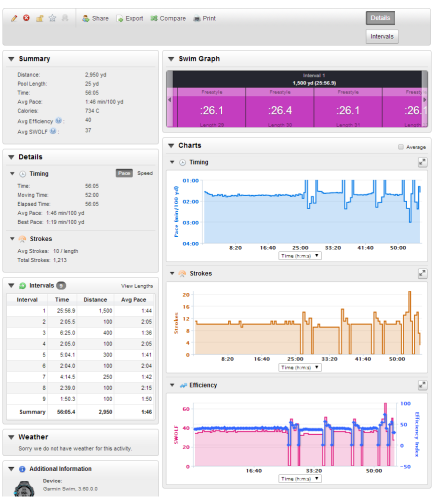


Garmin Swim Watch

- Dedicated for lap swimming!
- Data from accelerometer sensors
- On-watch processing of accelerometer data!
- Count laps:
  - surge in acceleration when kicking off from wall
- Detect swim style and stroke count:
  - Acceleration wave form analysis? (I'm guessing)
- Uploads data, wirelessly and automatically, using the ANT protocol (2.4GHz) when within reach of PC

Garmin Swim Watch





Takeaways

- Massive amounts of fitness sensor data available today!
- Making sense of data (visualization) is fun and challenging
- Common APIs for fitness data are coming (Google Fit, Apple iOS Healthkit)
- Good use case for how IoT, Client, and Server technologies can be combined for something helpful

FingerPrint Controller/Manager (FPCM)

Requirements/Specification

- Controller
  - Use fingerprints to control on/off state of relays
  - Different fingerprints control different relays
  - Actuate relays from web-browser remotely
- Manager
  - Registering/deregistering of valid fingerprints
  - Mapping of fingerprints to relay(s)
  - Manage 'valid' times for individual fingerprints
  - Keep/display log of activity
  - Send SMS/e-mails when unit is used

Possible Use Cases

- Locks (doors, garage openers, safe, cars)
  - Kids forget their keys
  - Temporary access for cleaning/repair/delivery people
  - Monitoring
  - A user can use different prints for different actions
- Turning 'dangerous things' on/off
  - Tablesaws, flamethrowers, car crushers, etc.
- Anything that has an on/off state:
  - Use your imagination!

GT-511C3 / GT-511C31

Fingerprint / Biometric Scanner

Click here Inquire Now

GT-511C3

GT-511C31

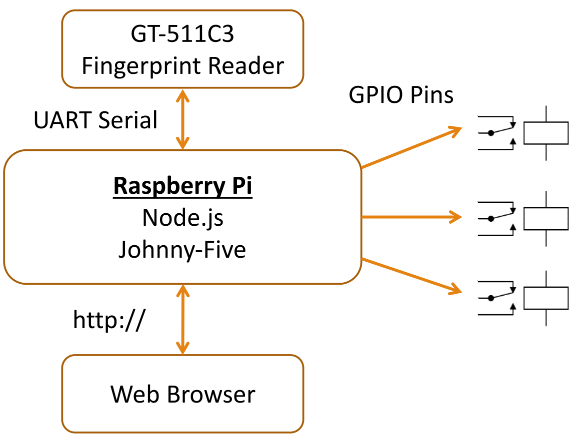
GT-511C3

Specification

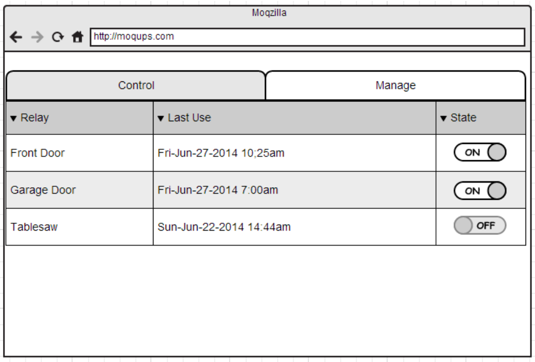
Item	Value
CPU	ARM Cortex M3 Core (Holtek HT32F2755)
Sensor	optical Sensor
Effective area of the Sensor	14 x 12.5(mm)
Image Size	202 x 258 Pixels
Resolution	450 dpi
The maximum number of fingerprints	200 fingerprints
Matching Mode	1:1, 1:N
The size of template	496 Bytes (template) + 2 Bytes (checksum)
Communication interface	UART, default baud rate = 9600bps after power on,USB Ver1.1, Full speed
False Acceptance Rate (FAR)	< 0.001%
False Rejection Rate(FRR)	< 0.1%
Enrollment time	< 3 sec (3 fingerprints)
Identification time	< 1.0 sec (200 fingerprints)
Operating voltage	DC 3.3~6V
Operating current	< 130mA
Operating environment	Temperature -20℃ ~ +60℃; Humidity 20% ~ 80%
Storage environment	Temperature -20℃ ~ +60℃; Humidity 10% ~ 80%

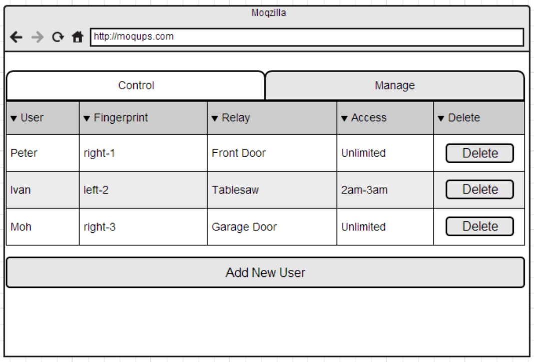
- Serial connection (UART)
- Recognition done on unit
- Communicates using command/response protocol
- Price: $50
- Raw image data from print can be retrieved
- Arduino C source available
- Good documentation of communication protocol

Architecture



GUI Mockups


Moqzilla
http://moqups.com
Control
Manage
Relay
Last Use
State
Front Door
Fri-Jun-27-2014 10:25am
ON
Garage Door
Fri-Jun-27-2014 7:00am
ON
Tablesaw
Sun-Jun-22-2014 14:44am
OFF


Moqzilla
http://moqups.com
Control
Manage
User
Fingerprint
Relay
Access
Delete
Peter
right-1
Front Door
Unlimited
Delete
Ivan
left-2
Tablesaw
2am-3am
Delete
Moh
right-3
Garage Door
Unlimited
Delete
Add New User