Lecture #1: Introduction

Mario Bergés

Professor

12-778: Sensors, Circuits and Data Interpretation/Mgmt. for CEE

Civil & Environmental ENGINEERING

Carnegie Mellon

Who Google thinks I Am

About me

Born and raised in 

Became a Civil Engineer there 

Came to CARNEGIE MELLON UNIVERSITY, to merge my degree with 

Now doing research on smart infrastructure

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About the 7 of you

- CEE ……… 6
- Architecture …… 1

- __ Professionals?
- __ Students?

Student Introduction

- Good opportunity to get to know your classmates
- Your program and year (undergraduate or graduate)
- Interest for this class (why you are taking this course)
- Future plans (going to industry or continuing for Ph.D.)
- Other information that you like to share with others

Let’s read the syllabus

WHY ARE YOU HERE?

Objectives

- Understand:
  - Physical Principles of Sensors
  - Fundamentals of Data Acquisition
  - Basic Signal Processing
  - Measurement Uncertainty and Errors
  - Data Management

Objectives

- Acquire skills to develop:
  - Prototype sensing systems using Raspberry Pis and Python
  - Simple “Internet of Things” applications

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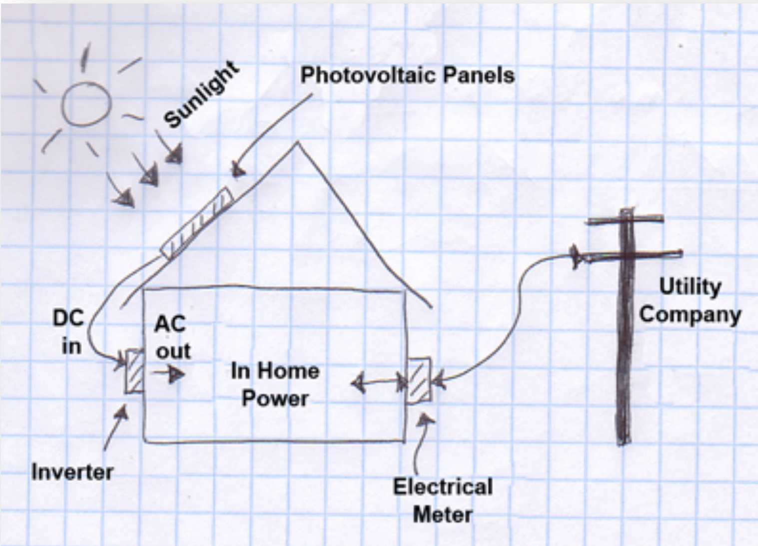
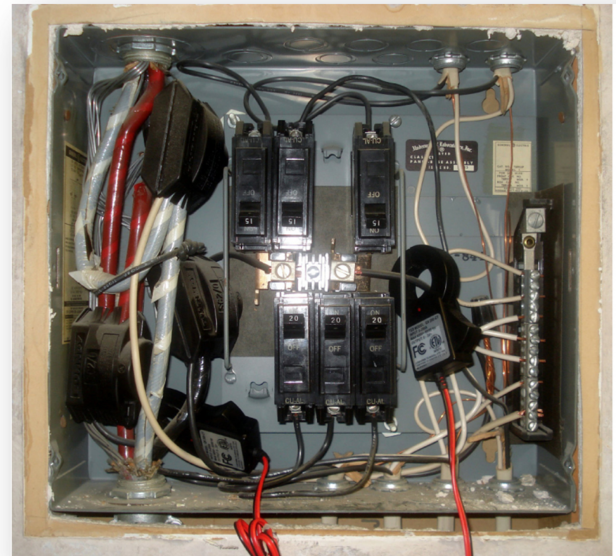
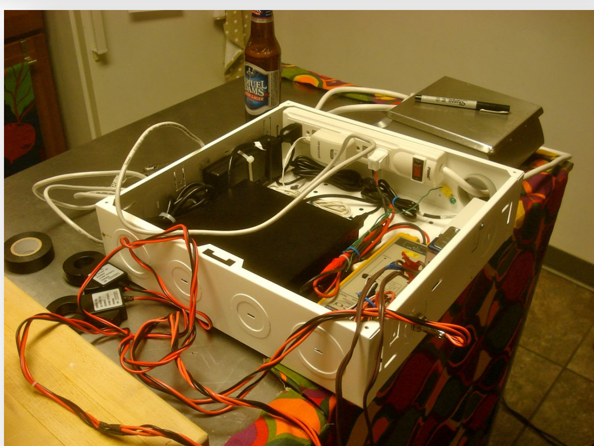
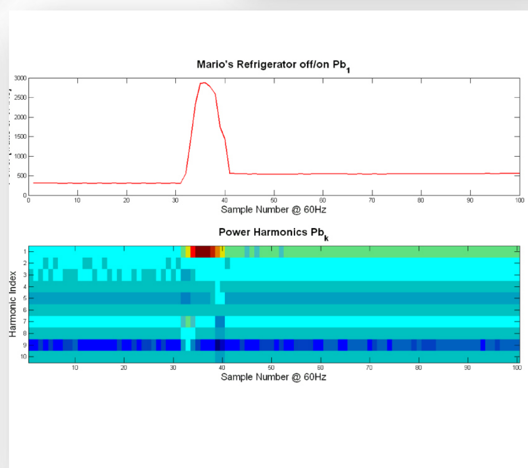
Objectives


Sunlight
Photovoltaic Panels
DC in
AC out
In Home Power
Utility Company
Inverter
Electrical Meter






Mario's Refrigerator off/on Pb1
Sample Number @ 60Hz
Power Harmonics Pbk
Harmonic Index
Sample Number @ 60Hz

Schedule of Classes

TUESDAY	THURSDAY
Aug 29th **1** **THEORY: Introduction**	Aug 31st **2** **THEORY: Principles of Sensors**
Sep 5th **3** **PRACTICE: Preparing Your Instrumentation Environments** **HW1: Out**	Sep 7th **4** **PRACTICE: Sensing with the Rapsberry Pi Pico**
Sep 12th **5** **THEORY: Electronic Devices and Circuit Theory**	Sep 14th **6** **THEORY: Fundamentals of Data Acquisition I**

Schedule of Classes

Sep 19th **7** **THEORY: Fundamentals of Data Acquisition II**	Sep 21st **8** **THEORY: Resistive Sensors** **HW1: Due** **HW2: Out**
Sep 26th **9** **THEORY: Resistive and Capacitive Sensors**	Sep 28th **10** **PRACTICE: Practical Signal Conditioning and Sampling**
Oct 3rd **11** **PRACTICE: Practical Measurements with an MCU**	Oct 5th **12** **THEORY: Fourier Analysis**

Schedule of Classes

Oct 10th **13** **THEORY: Fourier Analysis II**	Oct 12th **14** **THEORY: Linear Systems Theory** **HW2: Due**
Oct 17th **15** NO CLASS: Fall Break	Oct 19th **16** NO CLASS: Fall Break
Oct 24th **17** **THEORY: Measurement Noise and Errors** **HW3: Out**	Oct 26th **18** Project Proposal Presentations

Schedule of Classes

TUESDAY	THURSDAY
Oct 31st **19** **THEORY: RECORDED LECTURE Uncertainty Quantification and Propagation**	Nov 2nd **20** **THEORY: Networked Sensors: IoT and WSNs** **PRACTICE: Project Assistance**
Nov 7th **21** NO CLASS: Democracy Day	Nov 9th **22** **THEORY: Time-series Data: Representation, Processing** **HW3: Due** **HW4: Out**
Nov 14th **23** **THEORY: Set Theory and Entity Relationship Diagrams**	Nov 16th **24** **THEORY: Relational Databases**

Schedule of Classes

Nov 21st **25** **THEORY: SQL**	Nov 23rd **26** NO CLASS: Thanksgiving Break
Nov 28th **27** **THEORY: Database Design and Normalization** **HW4: Due**	Nov 30th **28** **THEORY: Lessons Learned from Computer Systems Research: Planning Monitoring Campaigns**
Dec 5th **29** **PRACTICE: No Lecture: Assistance for Project**	Dec 7th **30** **PRACTICE: No Lecture: Assistance for Project**

Schedule of Assignments

- 4 homework assignments
  - HW1: out on 9/5, due on 9/21
  - HW2: out on 9/21, due on 10/12
  - HW3: out on 10/24, due on 11/9
  - HW4: out on 11/9, due on 11/28

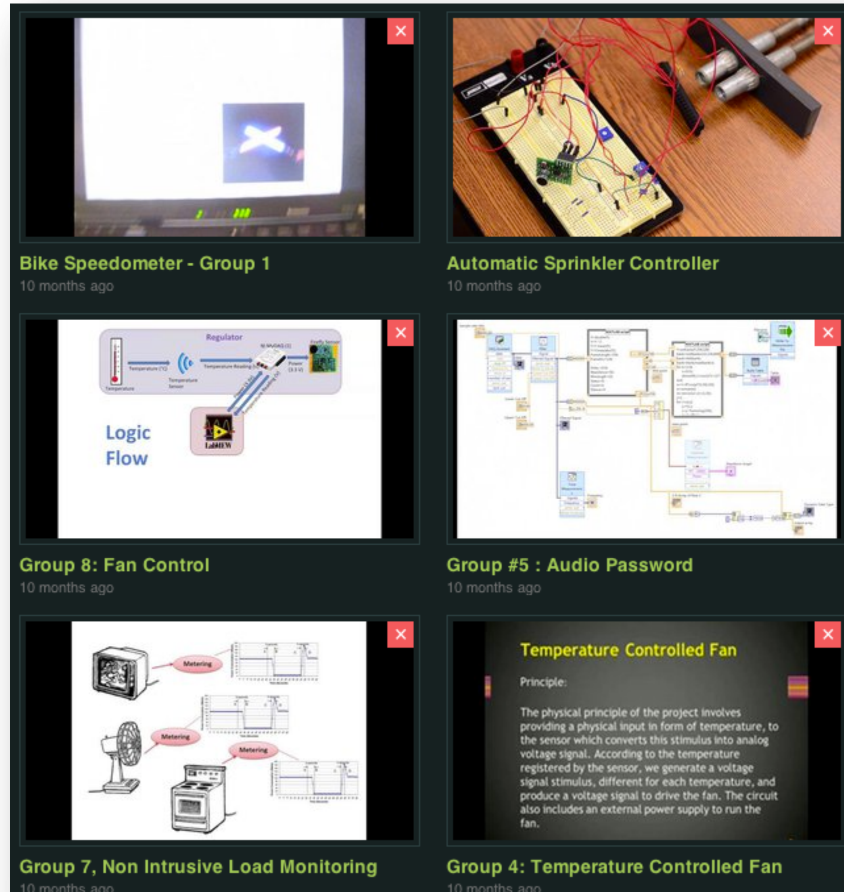
- 1 Project Proposal due 10/26

Projects

- Presentation (Video)
- Report (Github Pages)
- Themes:
  - M: Velocity of a Fan, S: Light Intensity Sensor
  - M: Audio Password, S: Microphone
  - M: Distance Traveled, S: Accelerometer
  - M: Temperature Vocoder, S: Temp. Sensor

Past Projects

- [Project Reports (2019)]()
- [Vimeo Group (2014)]()
- [Vimeo Group (2013)]()
- [Wiki Reports]()



Grading

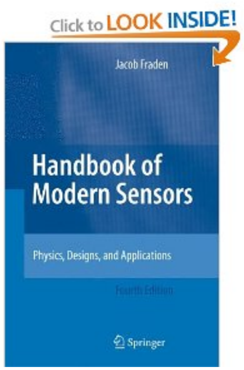
Grading:

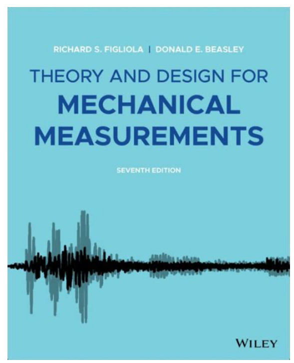
Assignments	40%
Final Project (Report)	20%
Final Project (Presentation)	20%
Final Exam	20%

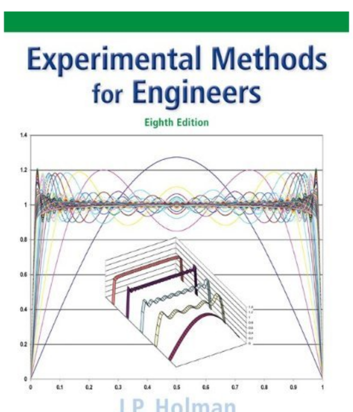
Class Policy

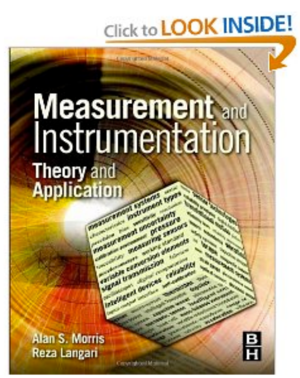
Readings

- Recommended books:









- Other references:
  - Will be listed on Canvas

Discussion

- What is a measurement?

Measurement Science

Measurement: the estimation of the magnitude of some attribute of an entity.

Usually involves a measuring instrument: ruler, scale, thermometer, etc.

Measurements are not perfect, thus they have three attributes to describe this imperfection:

- Estimate
- Error bound
- Confidence level

The history of measurement science is tightly linked to the history of science itself.

Measuring Instruments

Measuring instruments allow us to assess the relationship between:

- an attribute of an item under study (e.g. height of a tree)
- a referenced unit of measurement (e.g. a meter)

Traditional instruments:

- Hardware based
- Fixed, limited versatility
- Specific to a stimulus
- Example: oscilloscopes

Virtual Instruments:

- Hardware/software
- Versatile
- Less expensive

Sensors

- Broad definition: “devices that receive and respond to a signal or stimulus”
  - Human eye
  - A trigger in a pistol
- For our scope: “devices that receive a signal or stimulus and responds with an electrical signal”
  - Where electrical signal means: can be amplified, modified and channeled by electronic devices.
  - Examples:
    - Video camera
    - Microphone
    - Accelerometer on your iPhone

Actuators

- For our purpose:
  - They are the inverse of sensors
  - They convert an electrical signal into a physical stimulus
- Example:
  - Sound speakers
  - Electric Motors
  - Relay

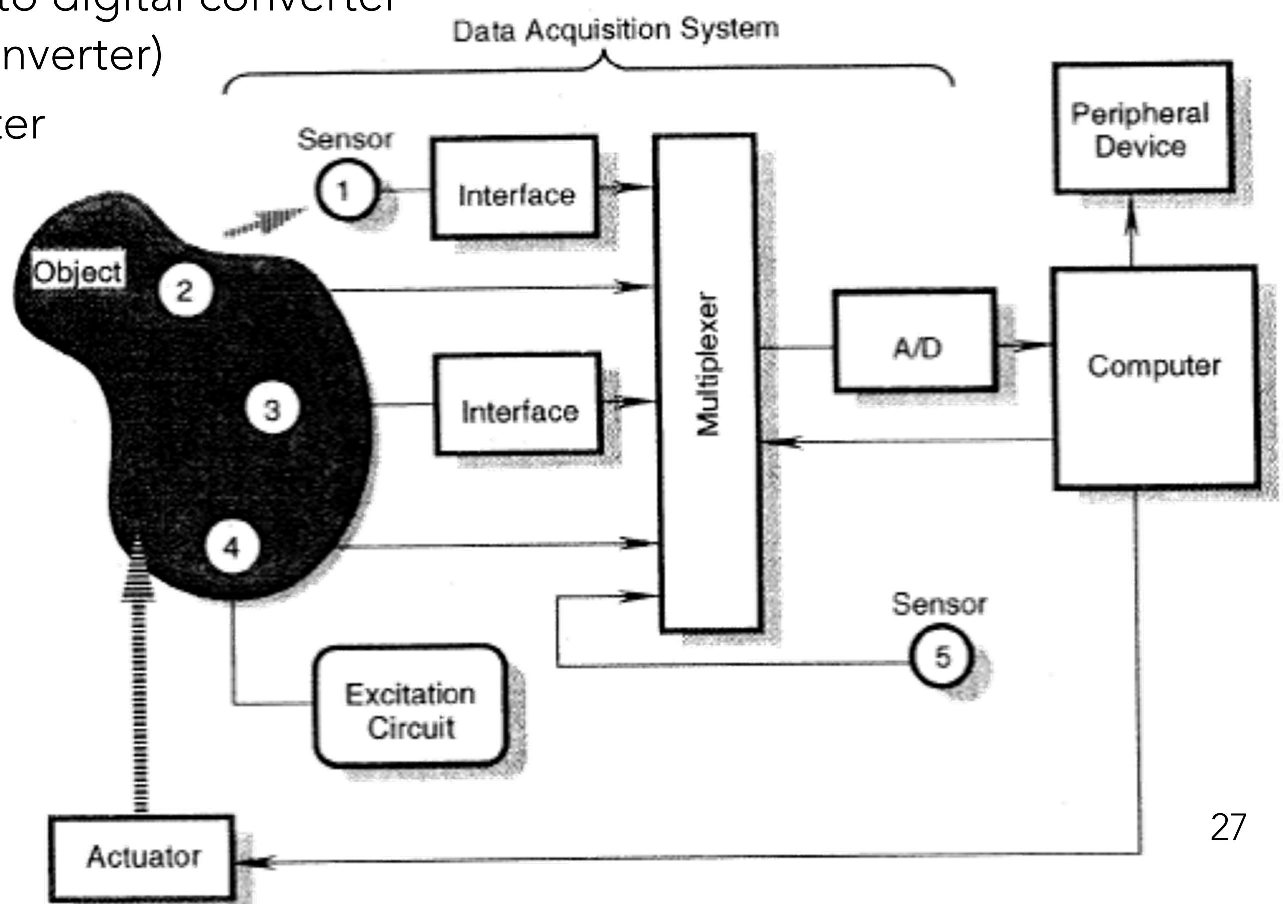
Transducers

- In broad terms:
  - A converter of one type of energy into another.
- For our purposes:
  - A term that encompasses both sensors and actuators.

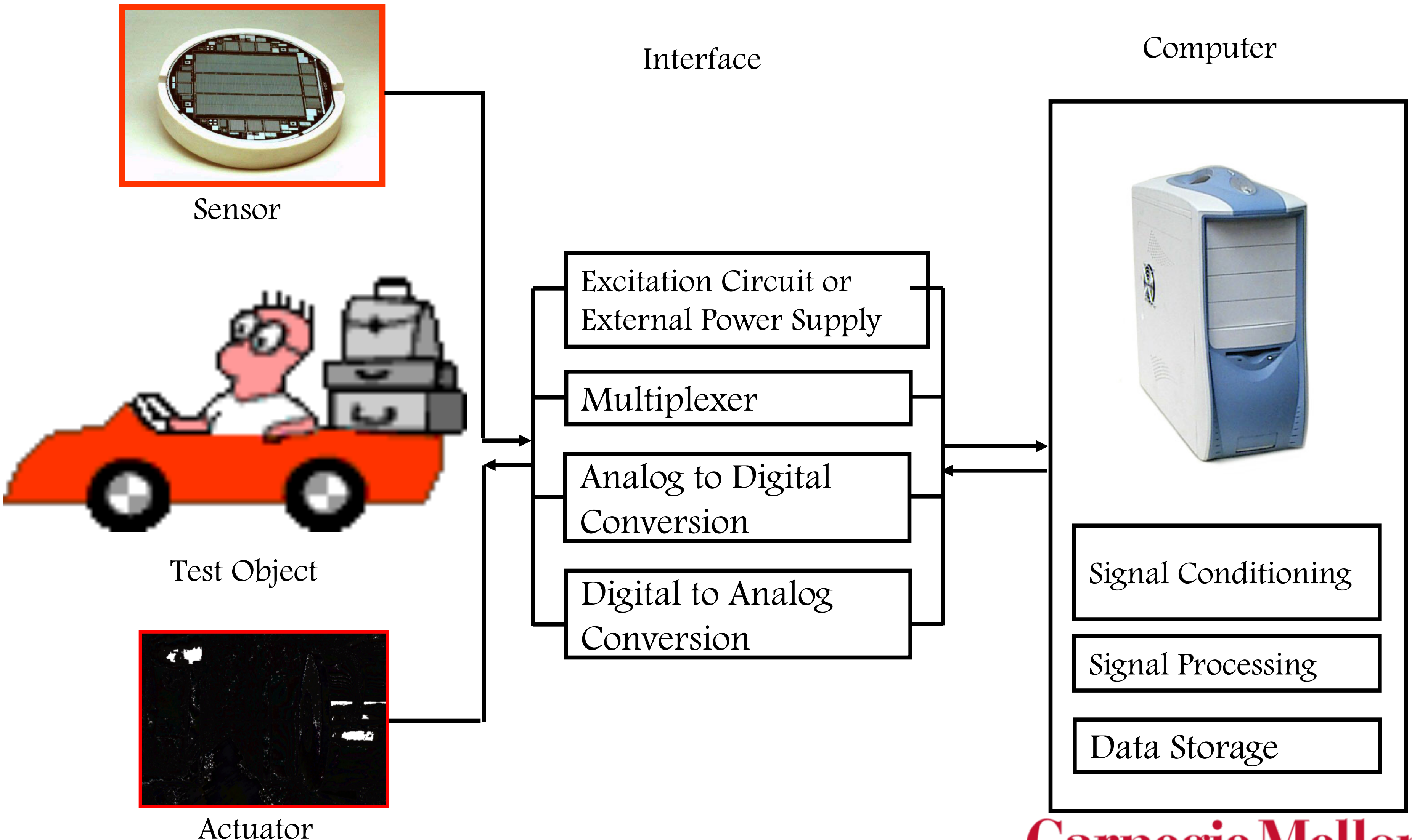
- Examples:
  - The sound speaker is a transducer and can be used both as an actuator (a speaker) or a sensor (a microphone).

Data Acquisition Systems

- Components:
  - Sensors
  - Actuators
  - Multiplexer (MUX)
  - Analog to digital converter (A/D Converter)
  - Computer



Overview of Data Acquisition Course



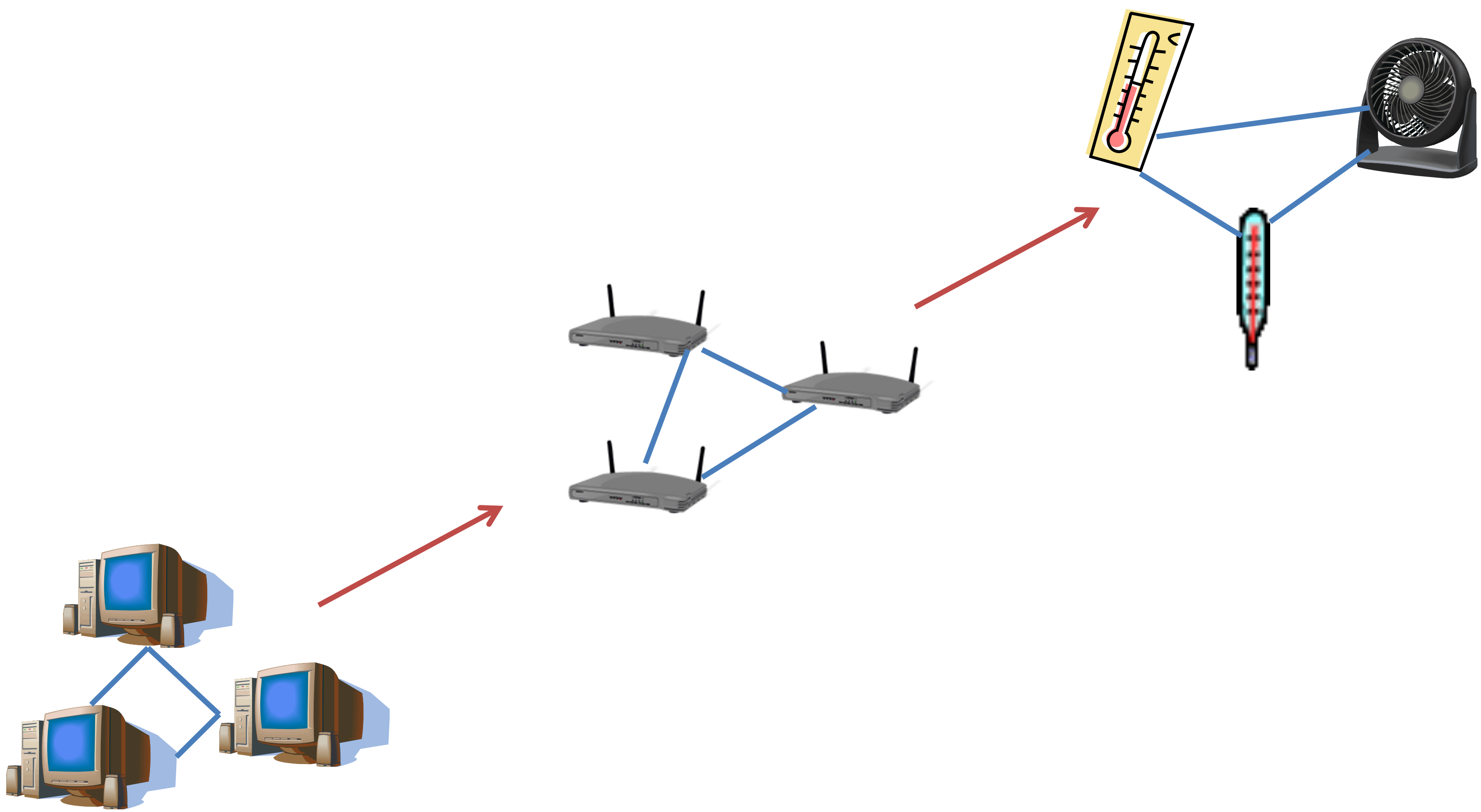
Data Acquisition System

- Illustration Example:
  - Imagine a a car door monitoring arrangement.
    - Every door has a sensor detecting open or closed position.
    - Signals from all doors are in a digital format (ones or zeros).
    - A microprocessor identifies which door is open, and sends an indicating signal to the peripheral devices (dashboard display, sound alarm).
    - The driver (actuator) gets the message and acts on the object (closes the door).

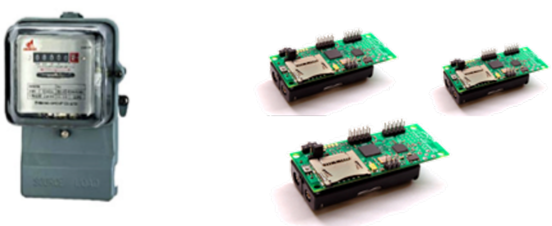
Sensor Andrew

A Living Laboratory for Infrastructure Sensing Technologies

Origins



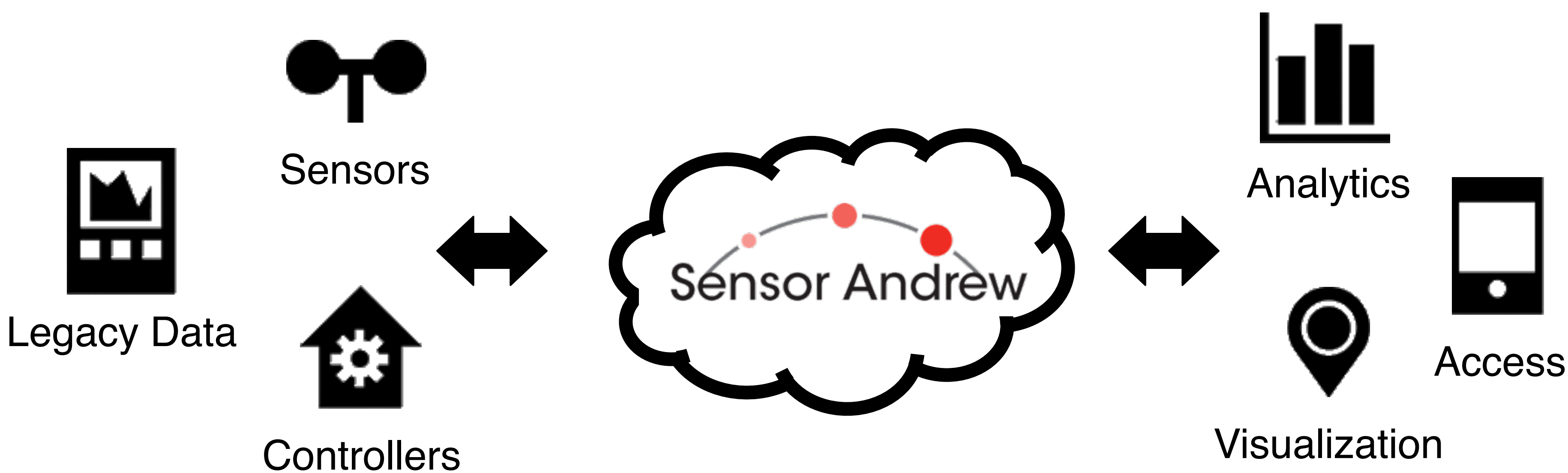
More and more *Physical* data is becoming available…



How do we make high-quantity data *high-quality* data?

Sensor Andrew

- Infrastructure to help connect the *virtual* and *physical world*
- Access, store, control, describe and search sensor data while maintaining security and privacy
- Internet-scale performance and Extensibility



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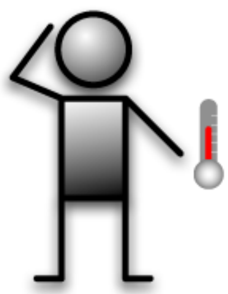
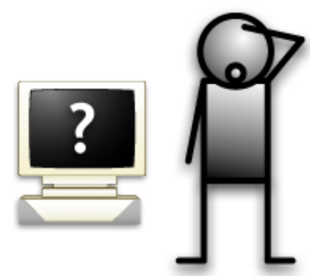
What is Sensor Andrew?





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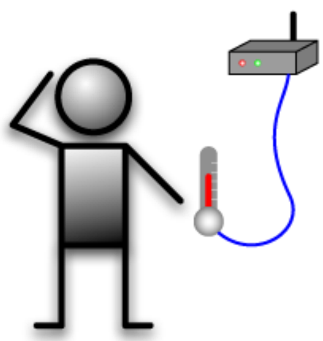

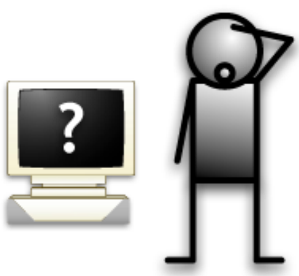

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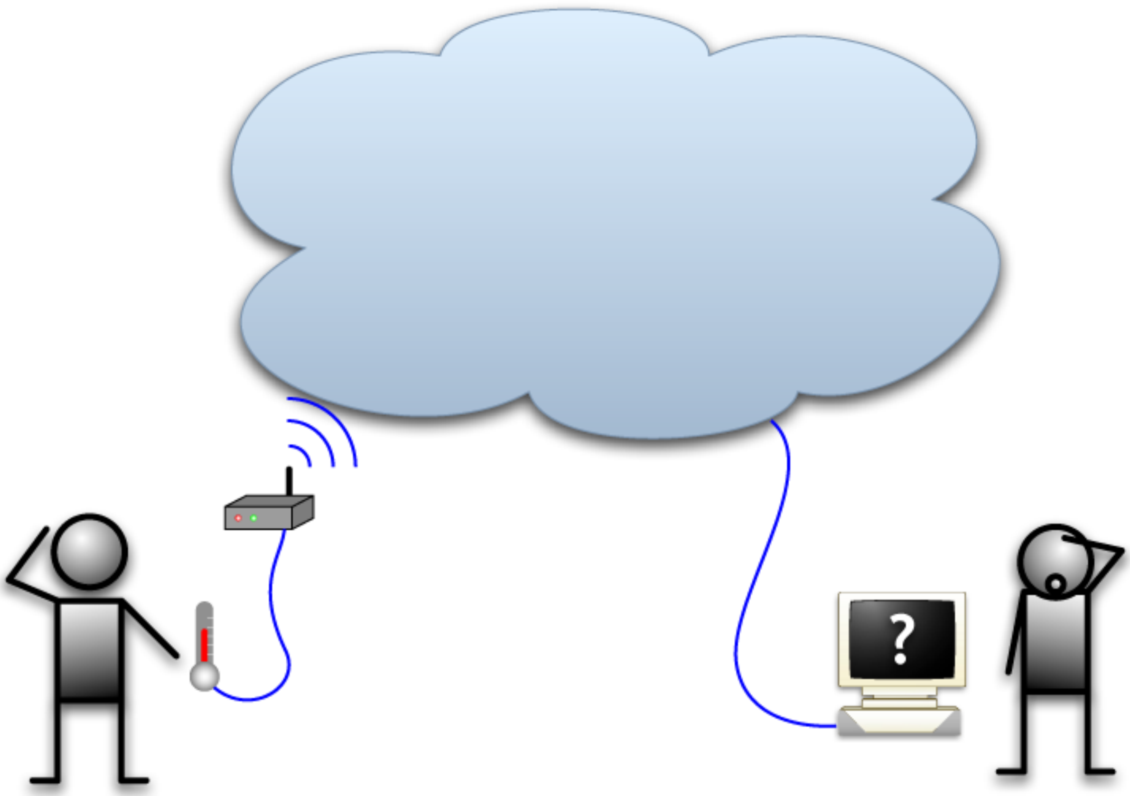

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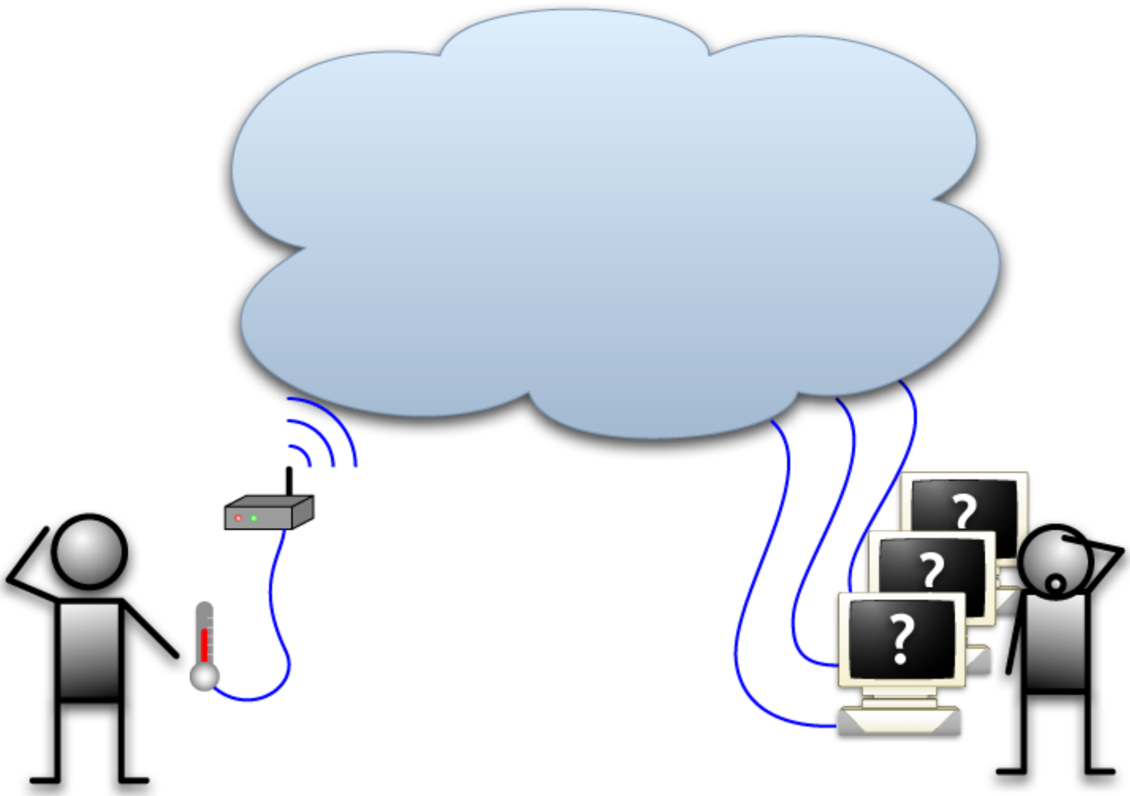

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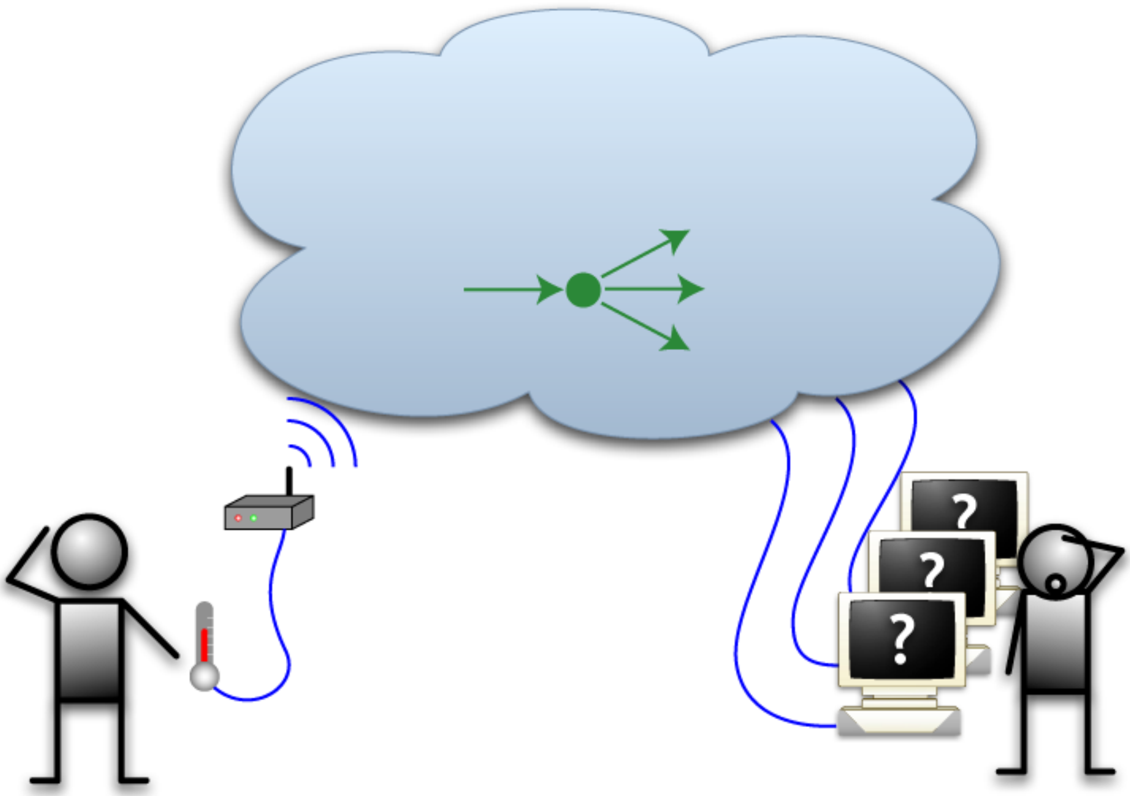

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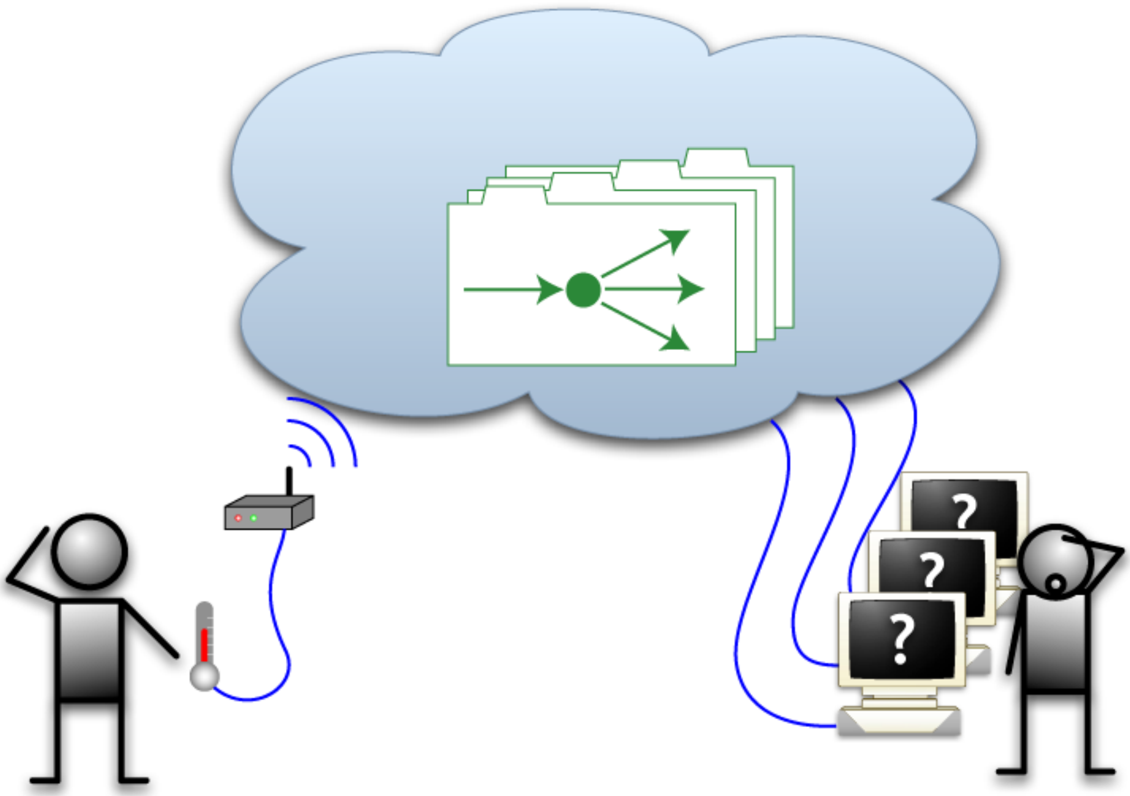
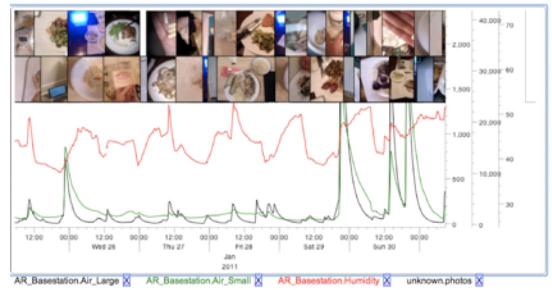
What is Sensor Andrew?



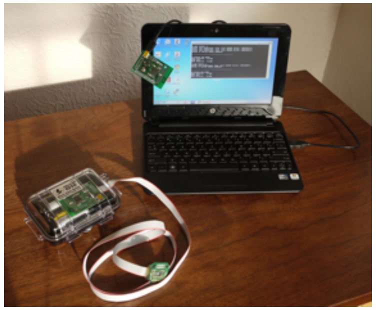
Motivation

Sensor Andrew Projects

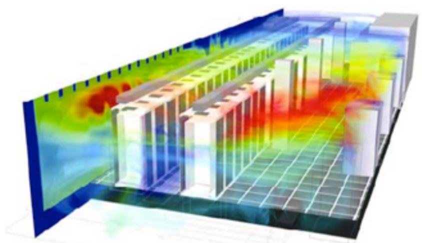
Smart Home



Body Track

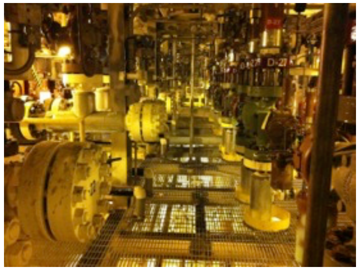


Water Quality Monitoring



Data Center Energy

Wireless Protocols



People Tracking

Building Automation Systems

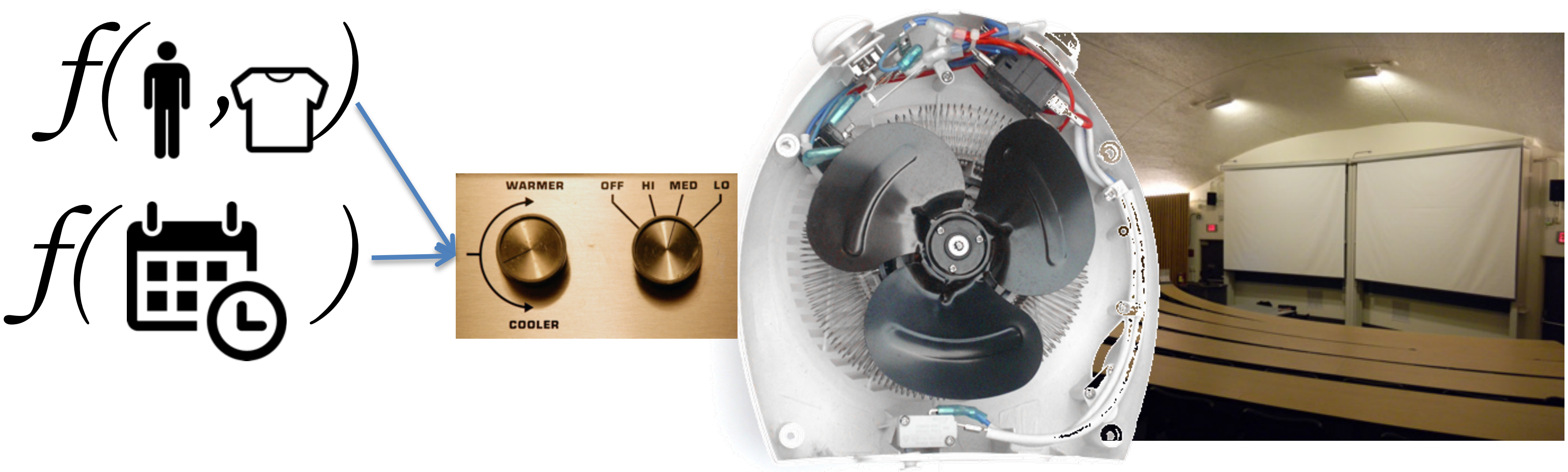
Campus Facilities

Air Quality Tracking

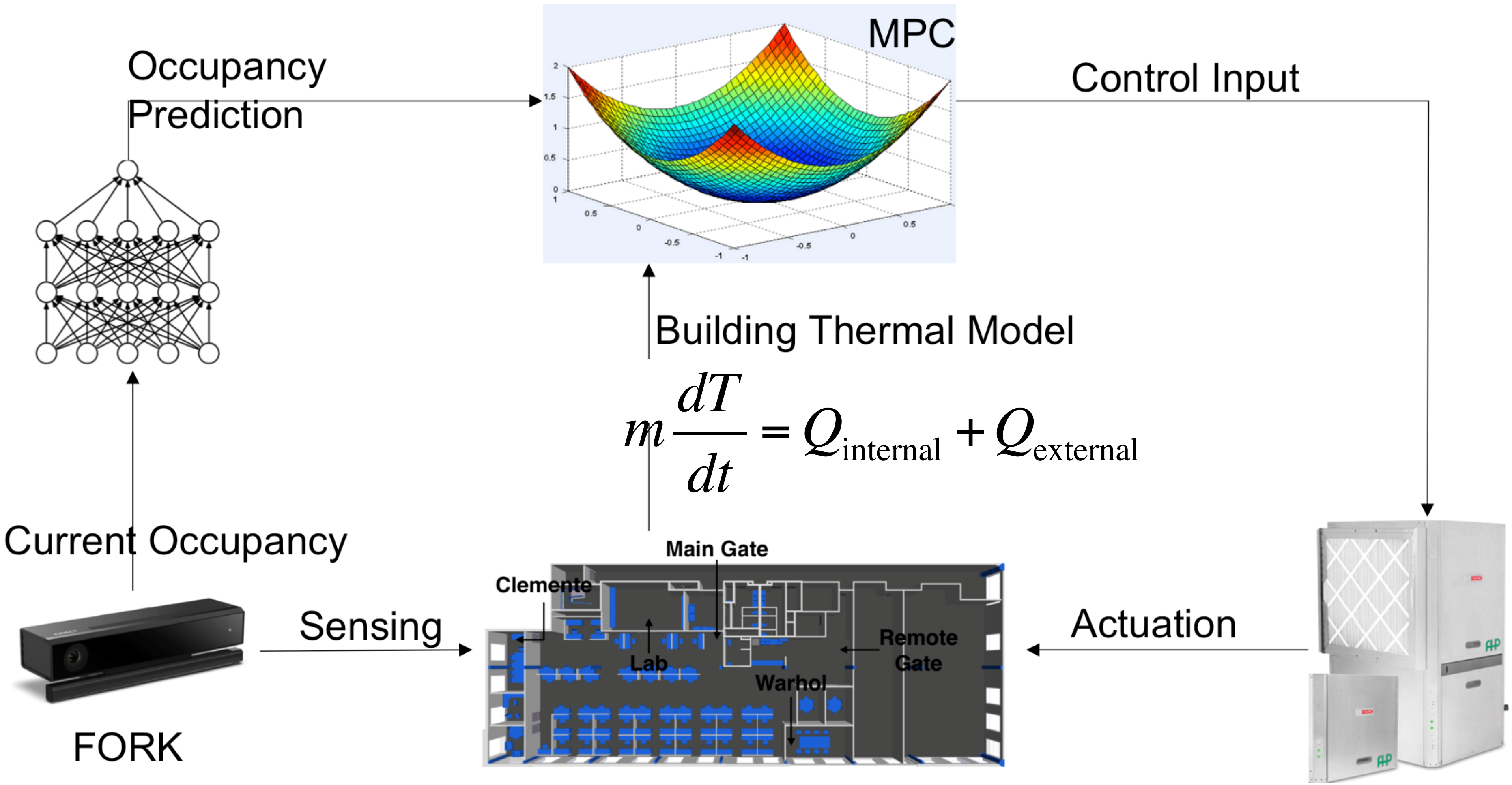
Human-in-the-loop Sensing and Control for Commercial Building Energy Efficiency and Occupant Comfort

What if we could incorporate room-level occupancy counts and thermal comfort preferences into our building controls?

What if we could do it at a low cost and with high accuracy?



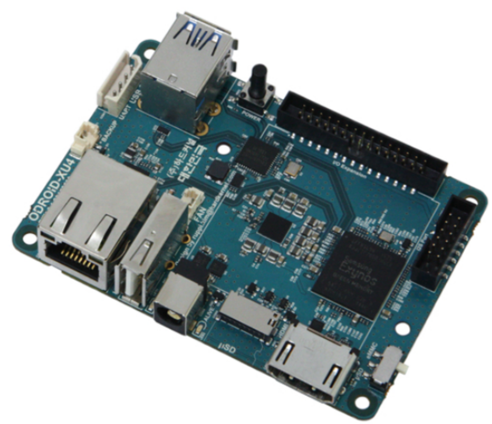
Human-in-the-loop Sensing and Control for Commercial Building Energy Efficiency and Occupant Comfort



Original Platform

(a)

(b)



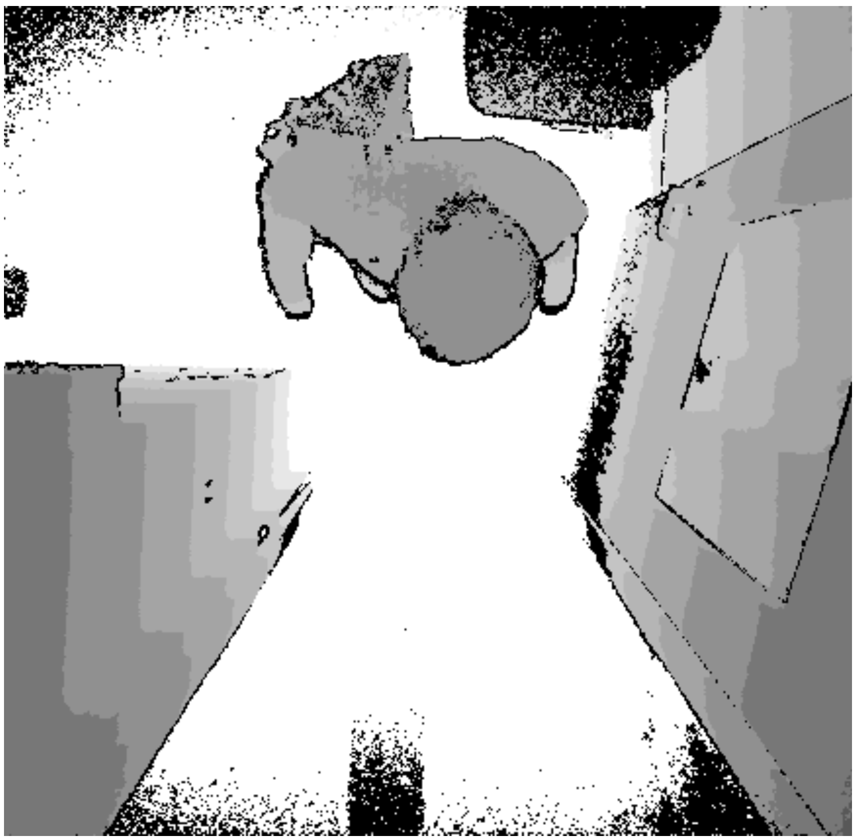
(c)

(a) Placement of a Kinect sensor on ceiling tile.

(b) Kinect sensor

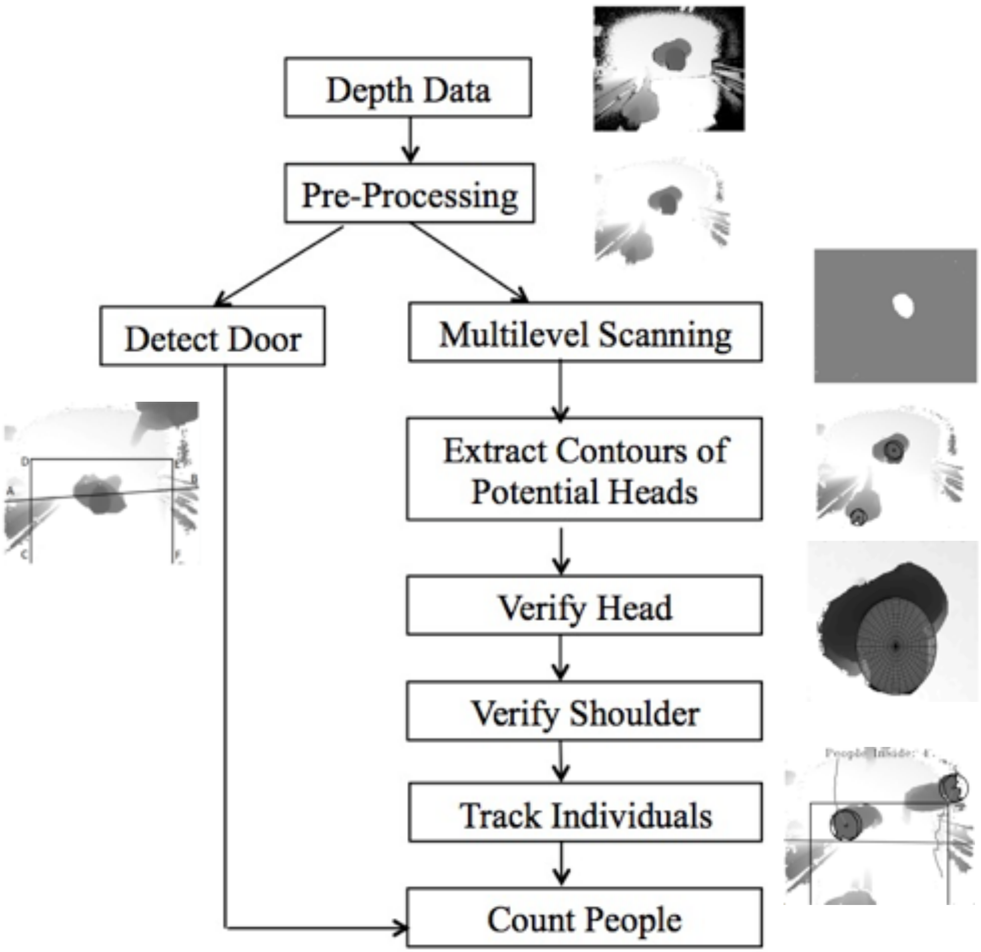
(c) Embedded computer: Odroid-XU4

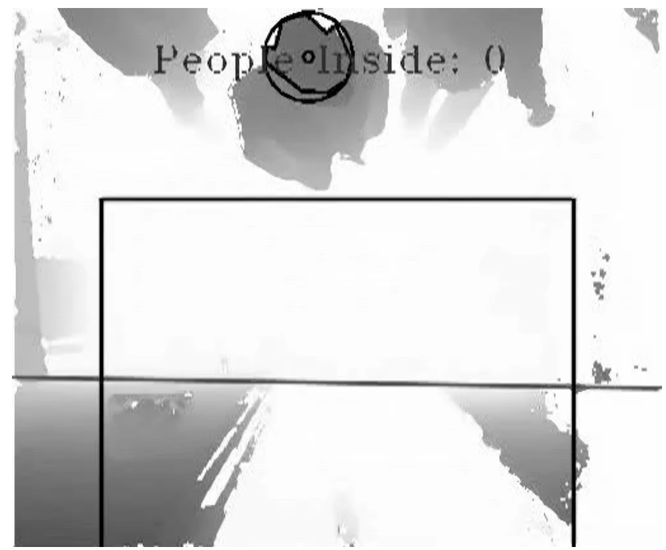
Depth Map



RGB Data

Algorithm (v1) Overview





Algorithm (v2)

Approach: Faster RCNN (Region Based Convolutional Networks)

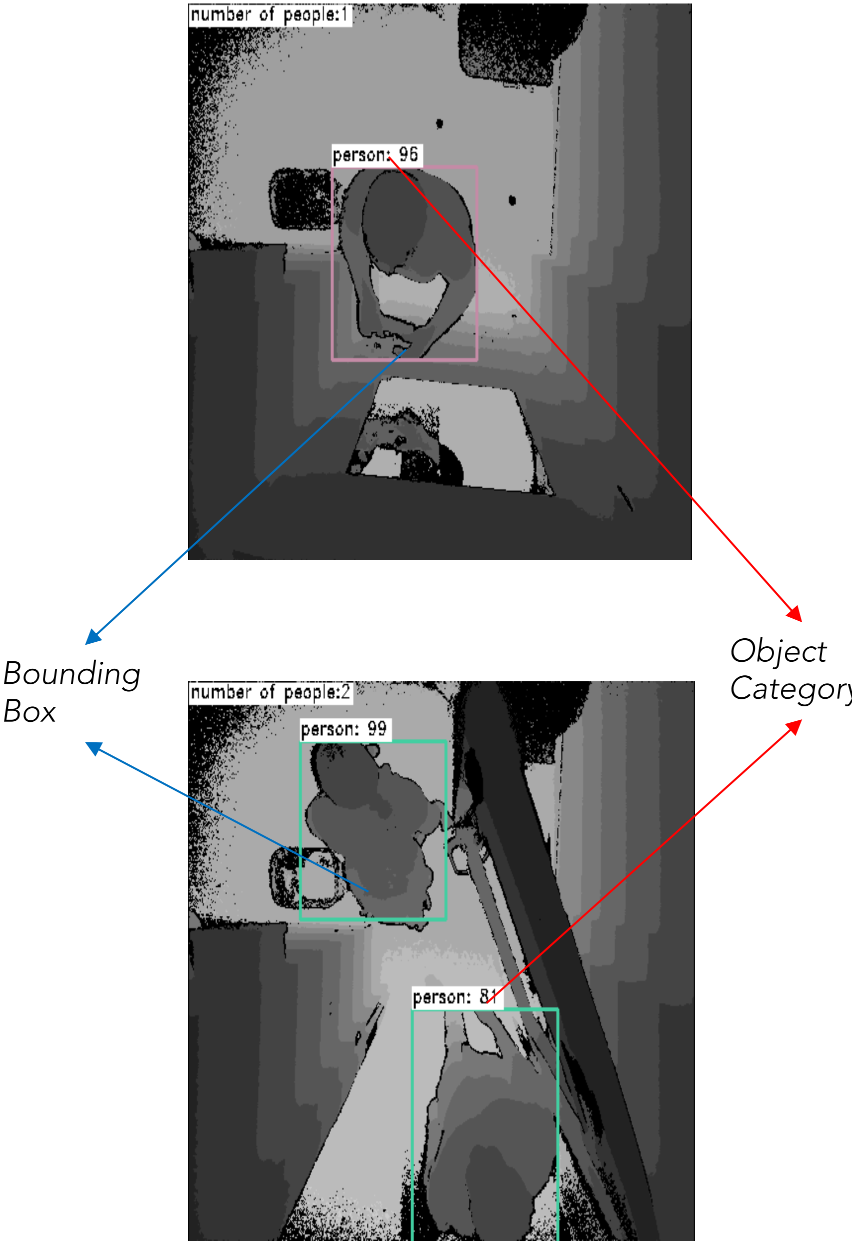
- Training stage
  - Inputs: Depth Image data
  - Targets: Bounding boxes and object category
    (Person - Background)

- Testing stage
  - Input: Depth Image data (unseen)
  - Output: Bounding box and object category
  - Number of people in frame

- Features are automatically learned.

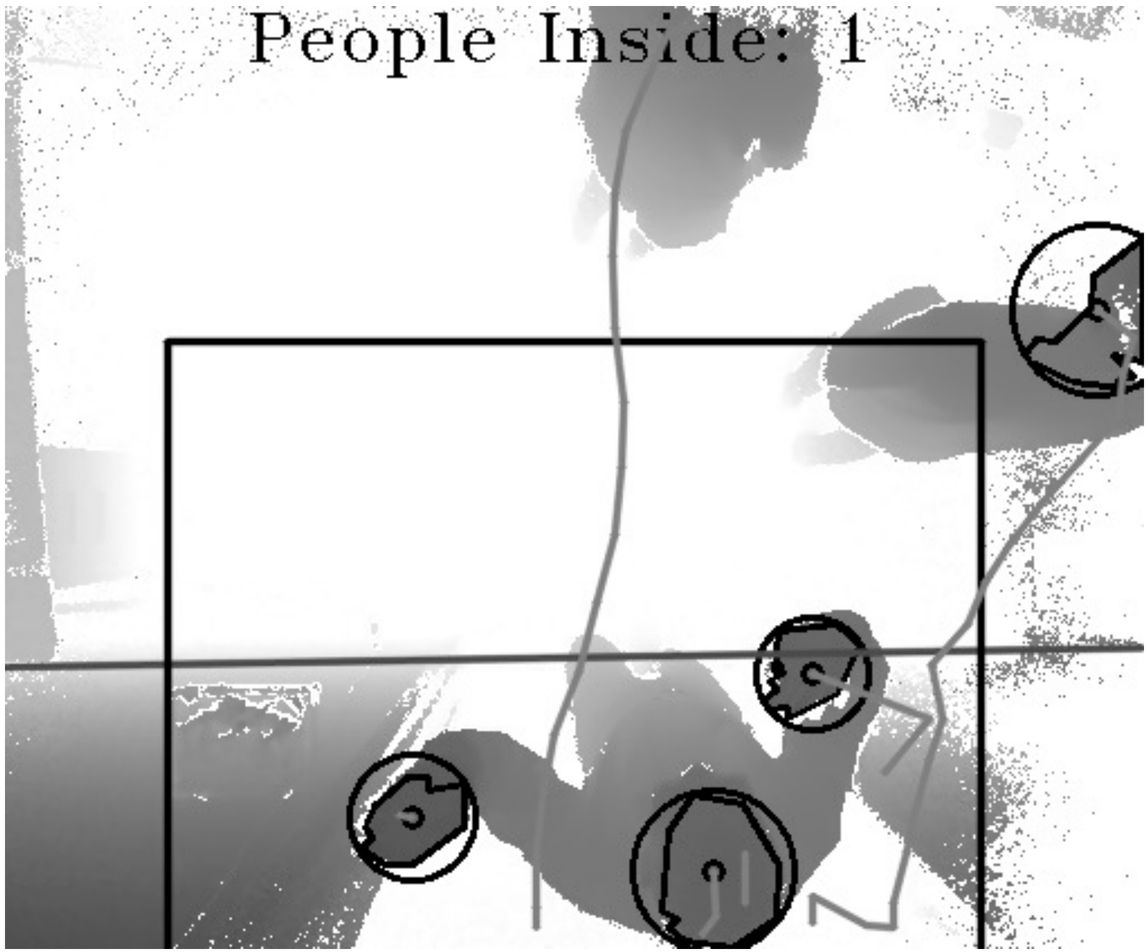
- People are first detected and then classified.

- Network can be trained to detect additional objects like backpacks, computers, etc.



FORK v1.0	FORK v2.0
Microsoft Kinect for XBOX One 	Intel D435 Depth Sensor 
Odroid XU4 	Intel Compute Stick 

Hands detected as heads



INFERLab

Intelligent Infrastructure Research Laboratory

Rethinking and redesigning our built environment to:

- improve its operational efficiency
- increase its resilience, adaptiveness and autonomy.

http://inferlab.org/

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The End

QUESTIONS?

@bergesmario

marioberges.com

INFERLab

Intelligent Infrastructure
Research Laboratory

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