Leveraging the Raspberry Pi for CS Education

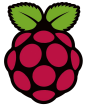
Joel Adams, Calvin College
(Moderator)

Richard Brown, St. Olaf College

Jalal Kawash, University of Calgary

Suzanne Matthews, West Point

Elizabeth Shoop, Macalester College



75-Minute Session Overview

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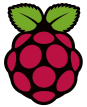
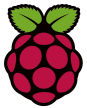


An Inexpensive, Quick Laptop Setup for the Raspberry Pi

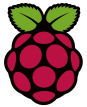
Richard A. Brown

St Olaf College

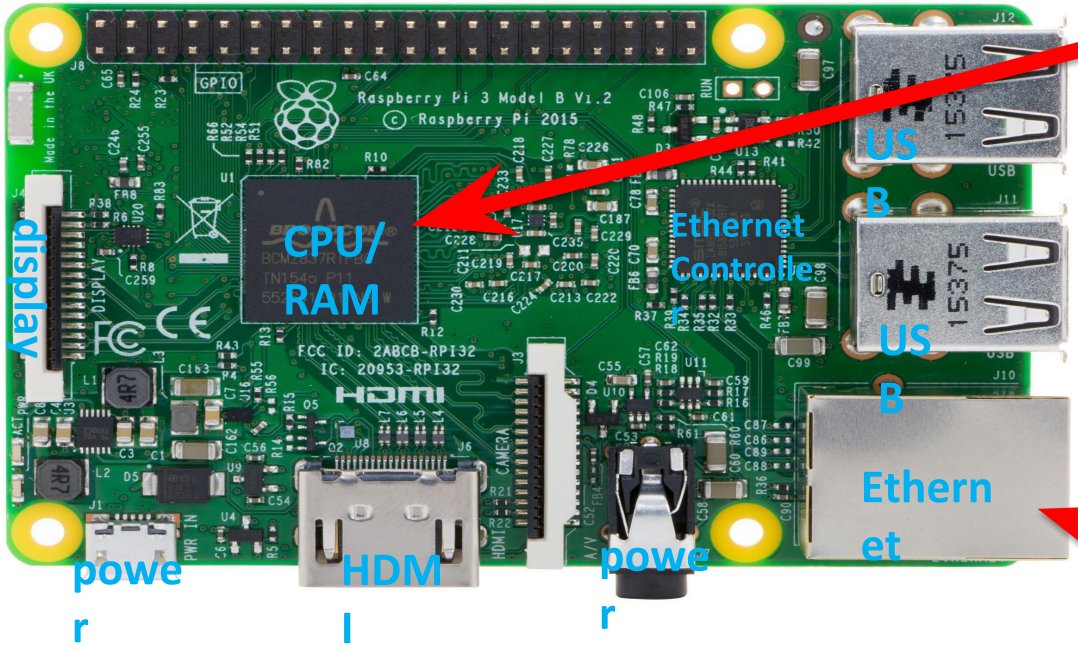


The Raspberry Pi and PDC

- ***Parallel and Distributed Computing (PDC)*** is now expected for CS majors (CS2013)
  - Virtually all machines are multicore – even phones
  - Role of web services, cloud computing, etc.
- *The Raspberry Pi provides an inexpensive, hands-on platform for teaching PDC concepts*



The Raspberry Pi and PDC



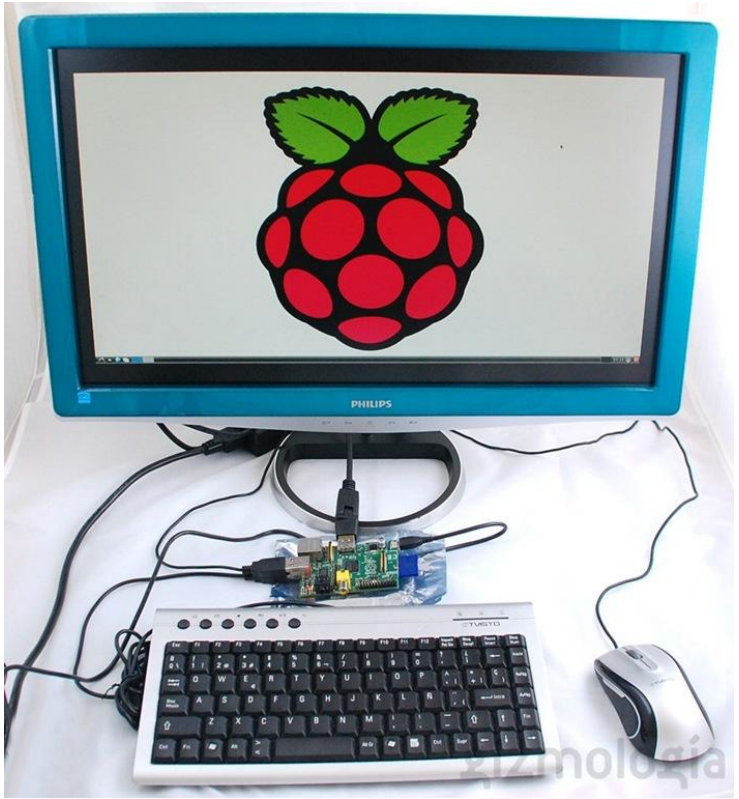
Quad-core processor

- 1GB RAM
- 1GHz speed

Fast Ethernet

Monitor/Keyboard/Mouse to Pi

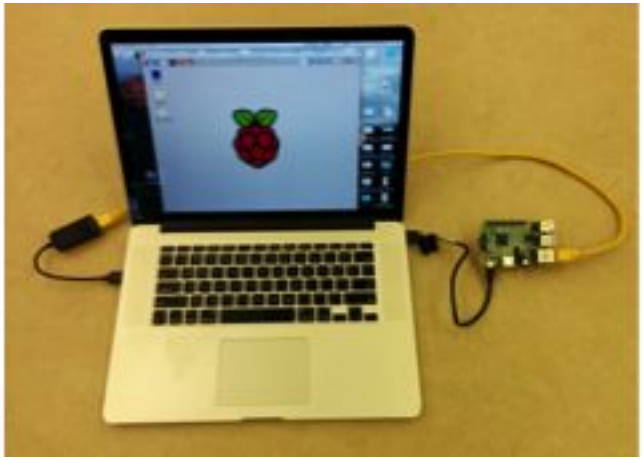
- Traditional setup for using Pi's
- Requires equipment (monitor, etc.)
- In-class setup time
  - unless preset in lab



A laptop-based R-Pi setup

- Inexpensive, versatile, *quickly deployed* Raspberry Pi setup, using a laptop

Kit
~$50, pi
included



Video project

PDC course project by two juniors, Fall ’16

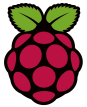
- Create teaching videos
  - Download/install/test a Pi system image
  - Laptop setup
  - Support multiple OS’s
- Teach with videos in two classes

Margaret Zimmermann

Jesus Caballero

Video project - teaching

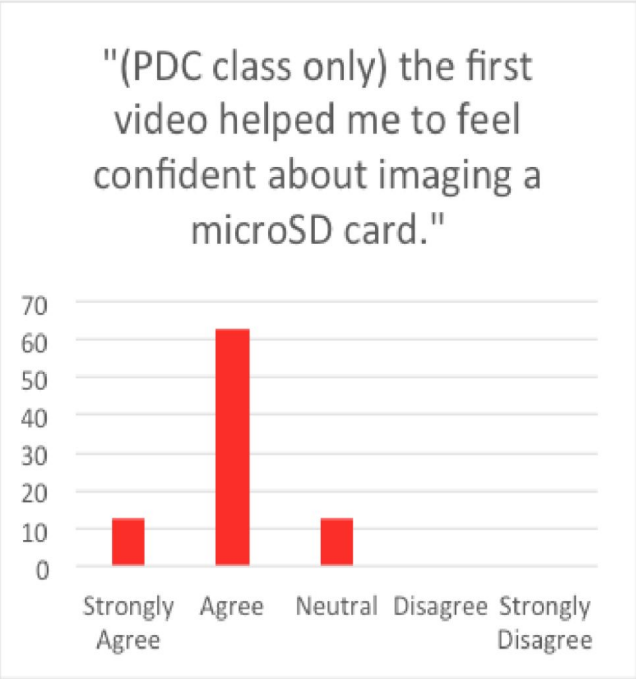
- Margaret and Jesus led teaching activities with their videos in two courses in Fall ‘16
- PDC course (CS 300):
  - “Flipped” exercise/lab to install a Pi system image
  - Followup PDC exercises in class on Pi’s/their image
- Hardware Design course (CS 241, cf. Cpt. Org.):
  - In-class exercise to watch video, perform laptop setup, carry out a multicore computation on Pi

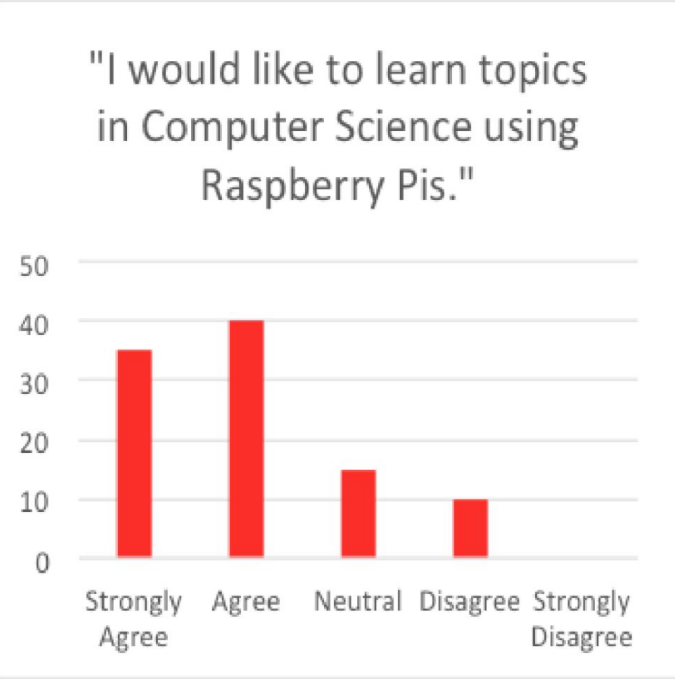


Video project - teaching

Well-received by students

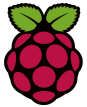
HD: **Only 25 min** for video + laptop + exercise!





Next steps

- Self-configuring clusters
  - Single system image
  - Run script to start head node, but not worker node
  - Auto-recognize cluster changes/update config
- Container-based deployment on SBCs
  - Update system software without reimaging!
  - Platform not limited to Raspberry Pi



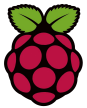
Programming for Embedded Systems Using the Raspberry Pi

Jalal Kawash

University of Calgary

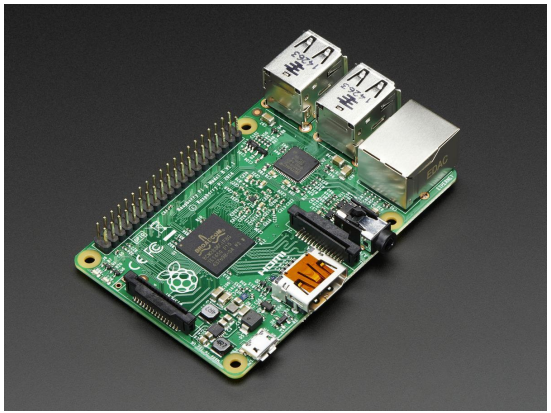
The Course

- Computing Machinery II
- Second in a series of low-level courses
- Focus on the hardware/Software interface
  - Digital logic
  - Microarchitecture
  - Interrupts
  - Device drivers
  - Frame buffers



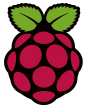
Module Objectives

- Advanced ARM Assembly Programming
- General-Purpose Input/Output
- Universal Asynchronous Receiver/Transmitter Protocol
- Video Programming
- Interrupts and Exceptions

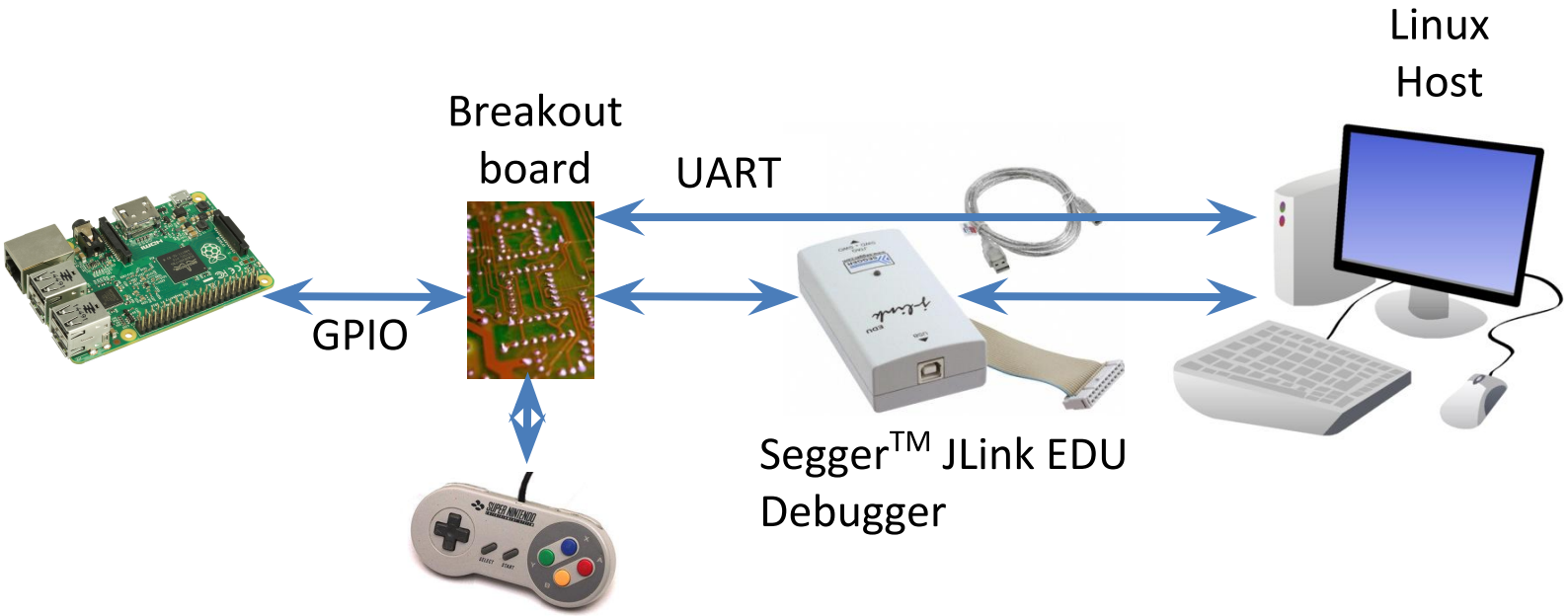


The Pi as an Embedded Device

- No operating system
  - Direct access to hardware
- Main deliverable: Retro video game
  - Written almost entirely in ARM AL
  - Specialized device driver for input (SNES)
  - Interrupt handling
  - Video programming

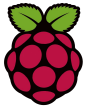


Lab Setup


Linux
Host
Breakout
board
UART
GPIO
Segger™ JLink EDU
Debugger

Observations

- Improved grades
- Improved student experience
  - Relevant to real-life
- Amazing projects
- Glitchy and not user friendly
- Technical issues with Pi2 & Pi3
  - Jtag compatibility
- Unable to work from home



Sample Projects

Sample Projects

Undergraduate Research Experiences with the Raspberry Pi

Suzanne J. Matthews

West Point

Overview

- XE401/XE402: Year-long capstone experiences that explored Raspberry Pis for energy-efficient parallel computing and data summarization (student teams).
- CS489 – Independent Studies (one on one).
- CS485 – Parallel Computing Elective

Timeline

ACM 2013

CS Prog. Meeting

CSinParallel DV'14

SIGCSE'15 BB Session

SIGCSE'16 MC Session

SIGCSE'17 Pi workshop

TODA

2013 2014 2015 2016 2017 2018

CS489 *CS485* Password Cracking SmartGrid capstone SmartGrid/RPASS capstones

National Pi Workshops CS489

KEY:

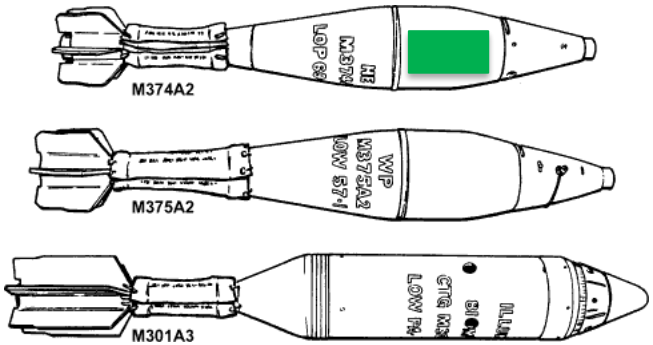
Event

Education

Research

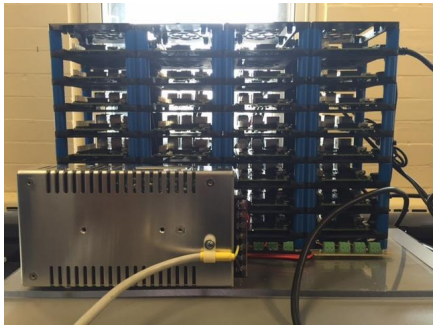
Project 1: Smart Mortar System

- Goal: Simulate the firing of a “smart” mortar system with 20 rounds in the magazine and a wireless “magazine server” sending firing commands using a cluster of Raspberry Pi B+s.
  - 20 Pis simulated mortars, one Pi simulated the magazine server.
  - 2015 Journal Paper (Ramirez2015) with two faculty and one student co-author

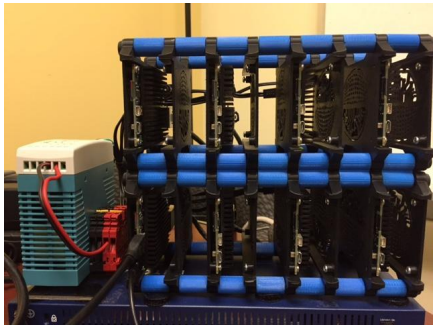


Project 2: Password Cracking

- Goal: Determine if SBC clusters can outperform a high-end laptop at password cracking at similar cost
  - Started out as student project in CS485, but…
  - Compared performance of password cracking on each cluster using JtR+MPI hybrid
  - Three faculty co-authors on CyconUS paper (Matthews2016)



128-core Raspberry Pi 2 Cluster

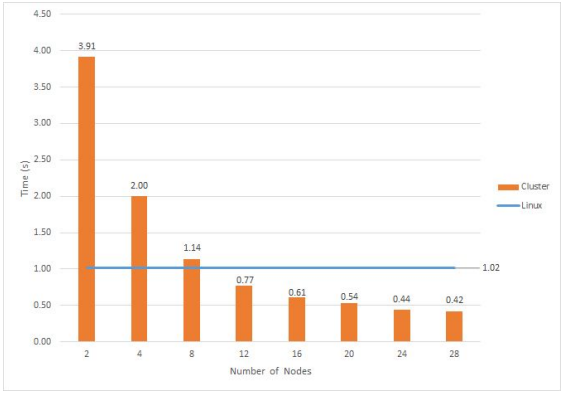


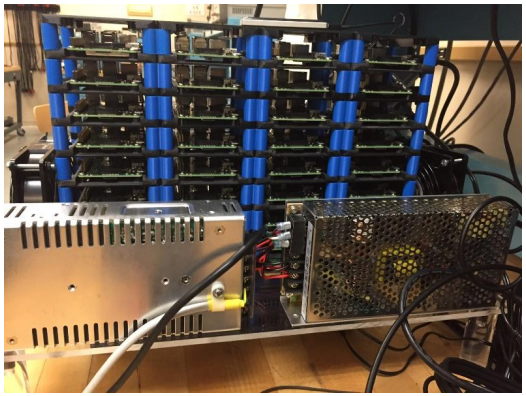
128-core Parallella Cluster

Intel Quad-Core Macbook Pro

Project 3: Anomaly Detection

- Goal: Assess feasibility of using a R-Pi 2 cluster for anomaly detection in the smart grid.
  - Pthreads + MPI hybrid.
  - 2017 URTC Paper (Candelario2017) that won Best Paper.
- Follow-up: 2017 UEMCON paper exploring use of one R-Pi 3 (instead of a cluster!)
  - This year's capstone team will be integrating Raspberry Pi 3 into smart grid testbed.





Reflection

- Products: 4 papers with 4 distinct faculty co-authors and 3 distinct student co-authors. One student paper won best paper.
- Great system to drive home networking principles along with parallel programming.
  - Students had to deal with NFS issues, networking issues, power issues, etc.
  - This can be a double-edged sword!
- Students and faculty really enjoy the “hands-on” aspect.
  - Pis have a definite “cool” factor that seems to attract students.
  - Great way to help students who aren’t academic “superstars” realize their potential.

A First-year Course:
"Introduction to computing by tasting Raspberry Pi"

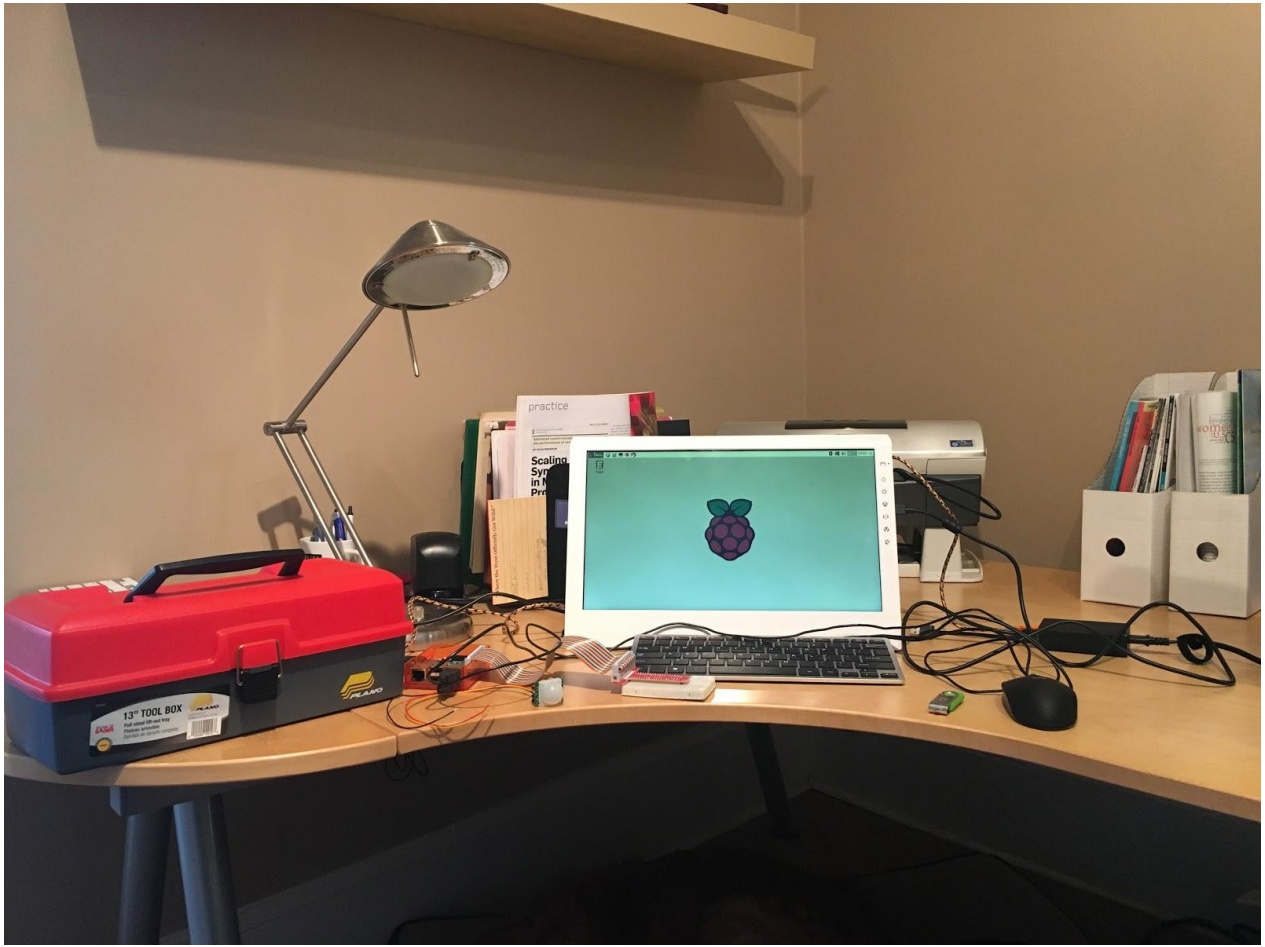
Elizabeth Shoop
Macalester College

Context: small liberal arts college

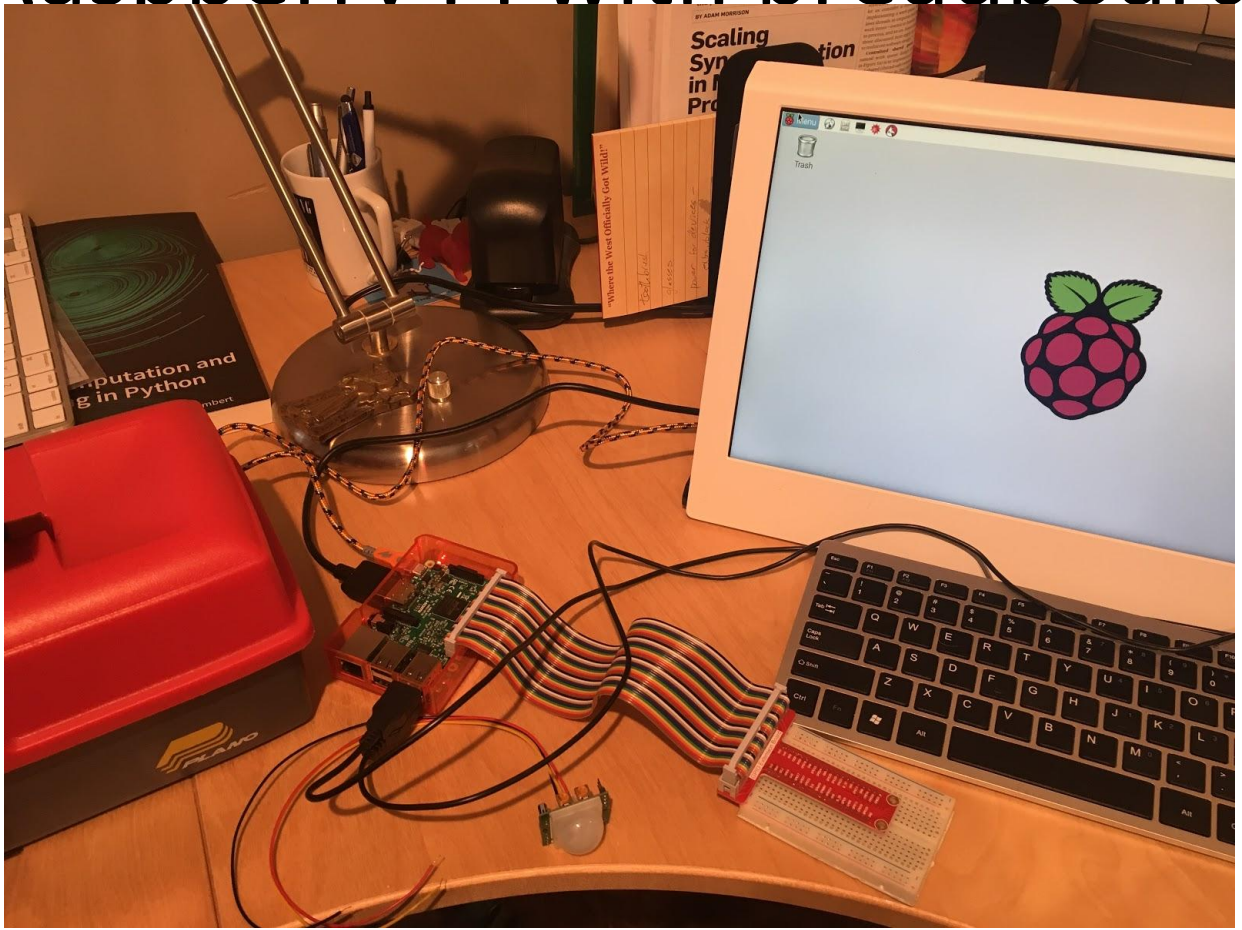
- First semester course of 16 first-year students
- They live near each other in the dorms
- I am their academic advisor
- Met 2 days/week for 1.5 hours

CONSENT IS MAG

Each Student Received:



Raspberry Pi with breadboard



Active Classroom Activities

jupyter/iPython Notebook

- Daily directed exercises where they spend their time coding
  - First just Python
    - Using same activities as our traditional CS1 course
  - Then added use of connected devices
    - LED light
    - Button and touch switch
    - Joystick
    - LCD screen
    - Others

Class Projects: teams of 3 (except 2 singles)

- GoPiGo robot controlled with a joystick
- Home automation simulation
- Motion sensing
- Weather conditions from weather underground displayed on small LCD screen
- ‘Beatbox’ - buttons control music snippets
- Blackjack game
- Role-playing game

The Good

- FUN!
- Collaborative work
  - In class
  - Outside class at the dorms
    - Assigned special undergrad TAs who held office hours

The Not So Good

- Setup time every class period
  - Was a hassle outside class for some:
    - Preferred their own computer, didn't like carrying toolbox and monitor
- Giving notebooks to them and turning in their work was challenging
  - OS doesn't support Google Drive or Dropbox
  - Used box.com, which had webdav support (problematic)
- Students would have liked to use Linux more

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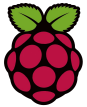

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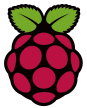

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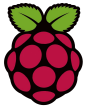
Thank you!