Prototyping the Internet of Things

Björn Hartmann
UC Berkeley

Secure Internet of Things Project Workshop
Stanford University
August 11, 2014

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- Assistant Professor, UC Berkeley
  - Ph.D. in CS from Stanford, 2009

SWARM LAB UC BERKELEY

CITRIS INVENTION LAB

- Research: Human-computer interaction at the intersection of hardware and software
  - User interface design & prototyping tools
  - User interface software architectures

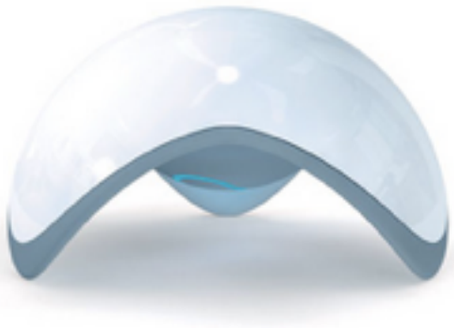
Nest

Philips HUE

Pebble

Oculus

Ninja Sphere: Give your home a mind of its own



Next generation control of your environment with accurate in-home location data and a gesture control interface.

CycleAT: Tire sensors

CycleAT is a Bluetooth tire sensor that allows motorcyclists & bicyclists to monitor/map tire pressure, temperature, and motion data.

Source: iotlist.co/category/Kickstarter

Emberlight: Turn any light into a smart light

1

Mold your lights around your life. Control any dimmable bulb with your existing WiFi and phone. Automate with proximity awareness.

Sense: Track your sleep behavior

0

Sense is a simple system that tracks your sleep behavior, monitors the environment of your bedroom and reinvents the alarm.

Source: iotlist.co/category/Kickstarter

Airfy: iBeacon for home automation

Airfy beacon allows you to make your home smart using one or more "beacons" - tiny receivers that connect to your phone through Bluetooth Low Energy (iBeacon).

Iota: GPS tracker and motion sensor

The Iota is the world's smallest real time GPS tracker and motion sensor running on a crowd sourced free nationwide network.

Source: iotlist.co/category/Kickstarter

oort: Internet of everything

oort is a system of intelligent connected devices that lets you control your whole living environment with a single app.

Edyn: Welcome to the connected garden

Edyn is a smart garden system that monitors and tracks environmental conditions, helping you help your plants thrive.

Source: iotlist.co/category/Kickstarter

Homey: Talk to your home

Homey is speech-controlled home automation. Talk to your home to control everything: from lights to music, from climate to TV.

Smash: The game changing tennis wearable

Smash is a lightweight wristband combined with an app that provides easy access to technique analysis and personalized recommendations.

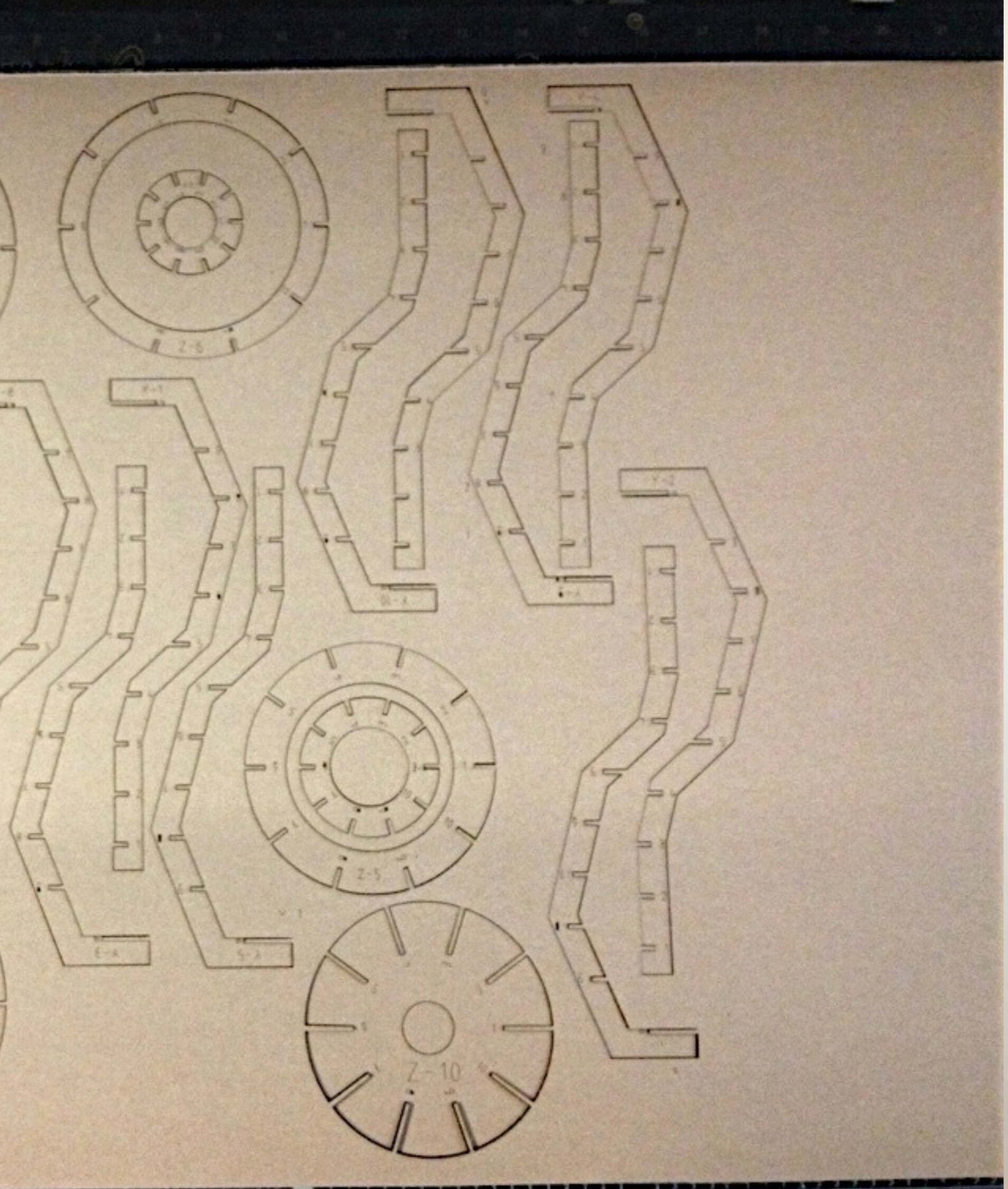
Source: iotlist.co/category/Kickstarter

“Indie” IoT Realities

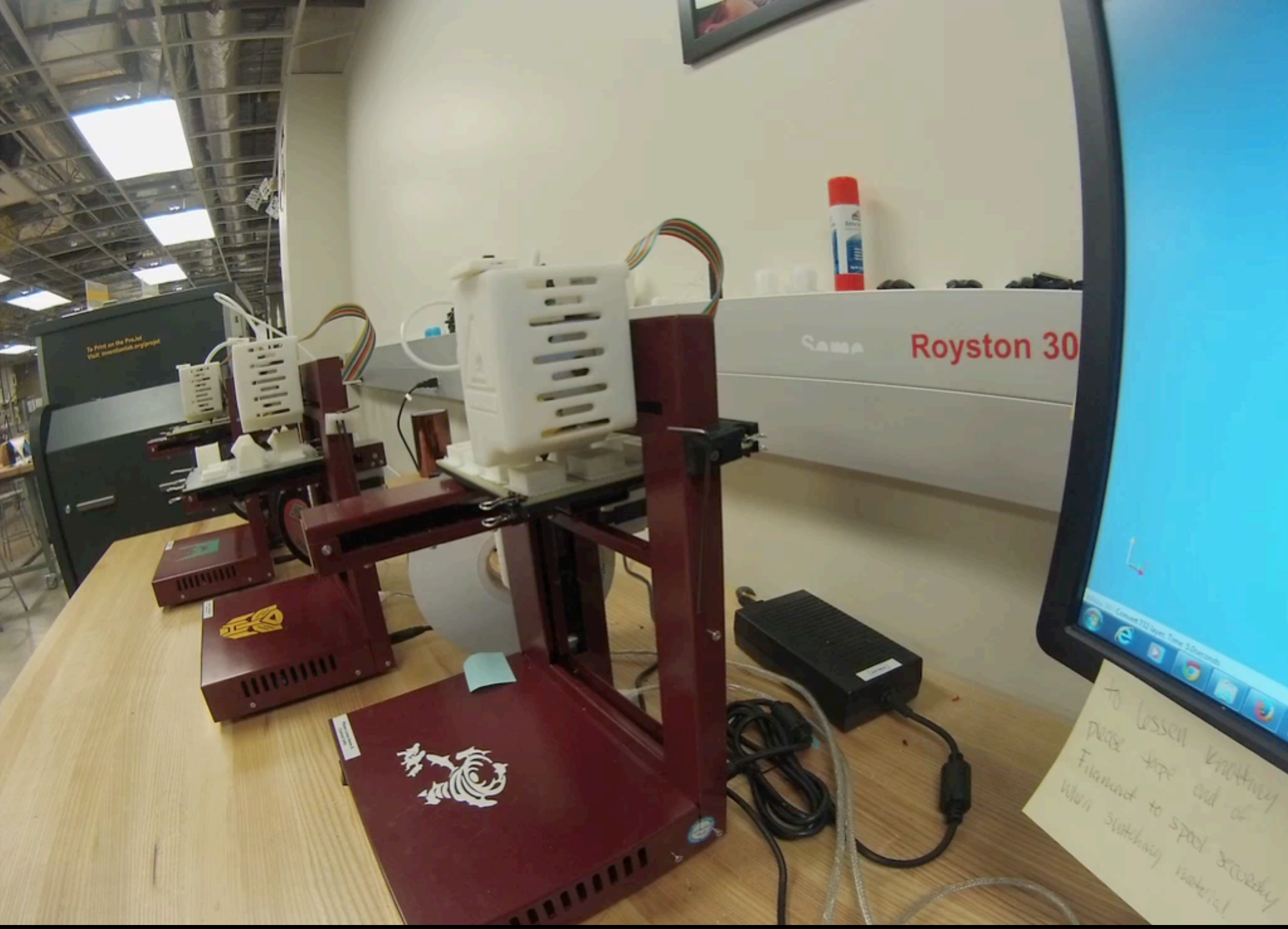
- Enabled by digital desktop fabrication + small scale, rapid contract manufacturing (Shenzhen)
- Anecdotally, successful crowdfunding now pre-requisite for VC funding of consumer hardware
- Encourages rush to “working prototype”, worry about DFM, robustness, security later
- HW becoming like SW, but not in a good way: Compare to Web development practices

CITRIS INVENTION LAB


UNIVERSAL
LASER SYSTEMS
PUREX

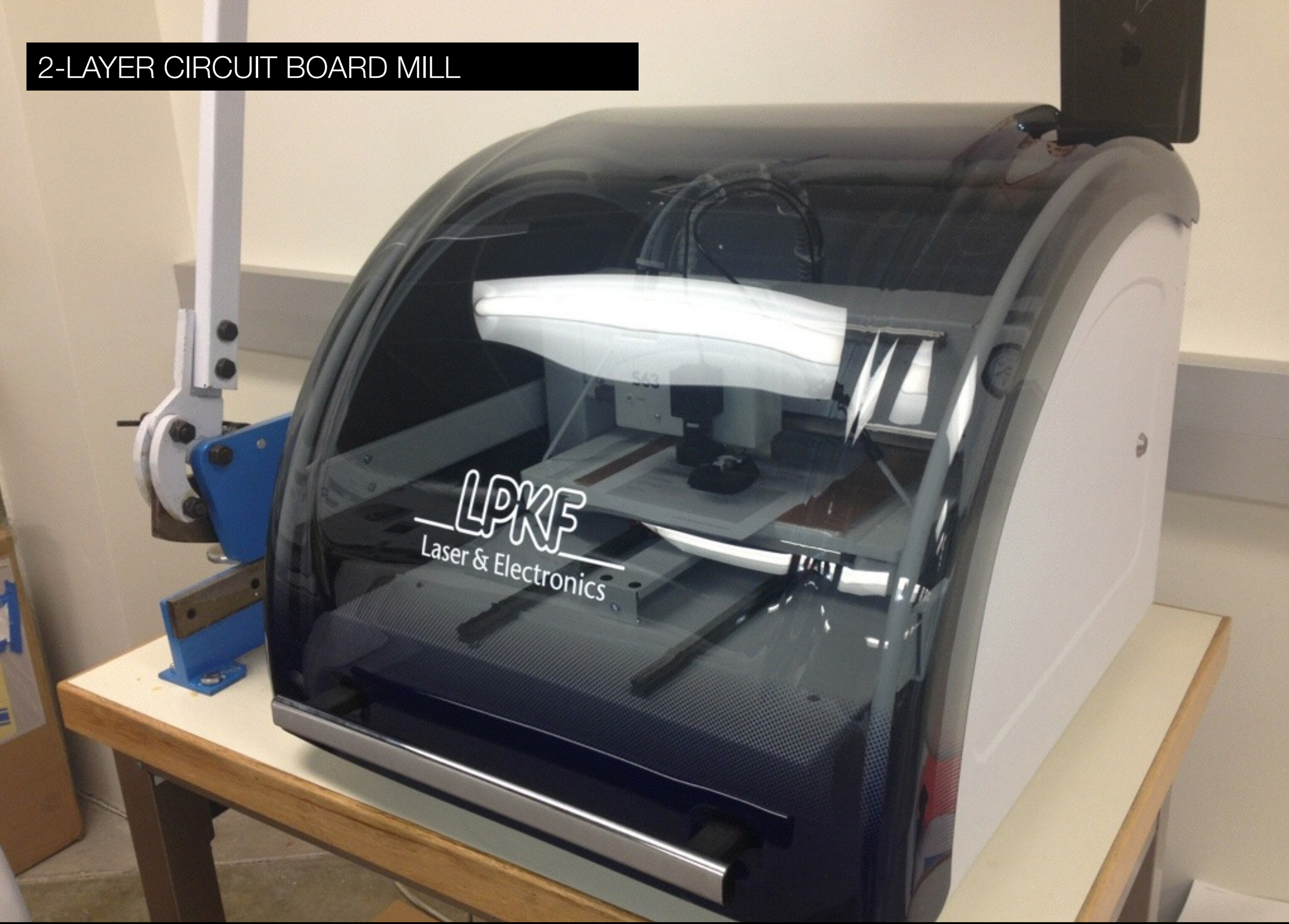

Z-6
Z-5
Z-10

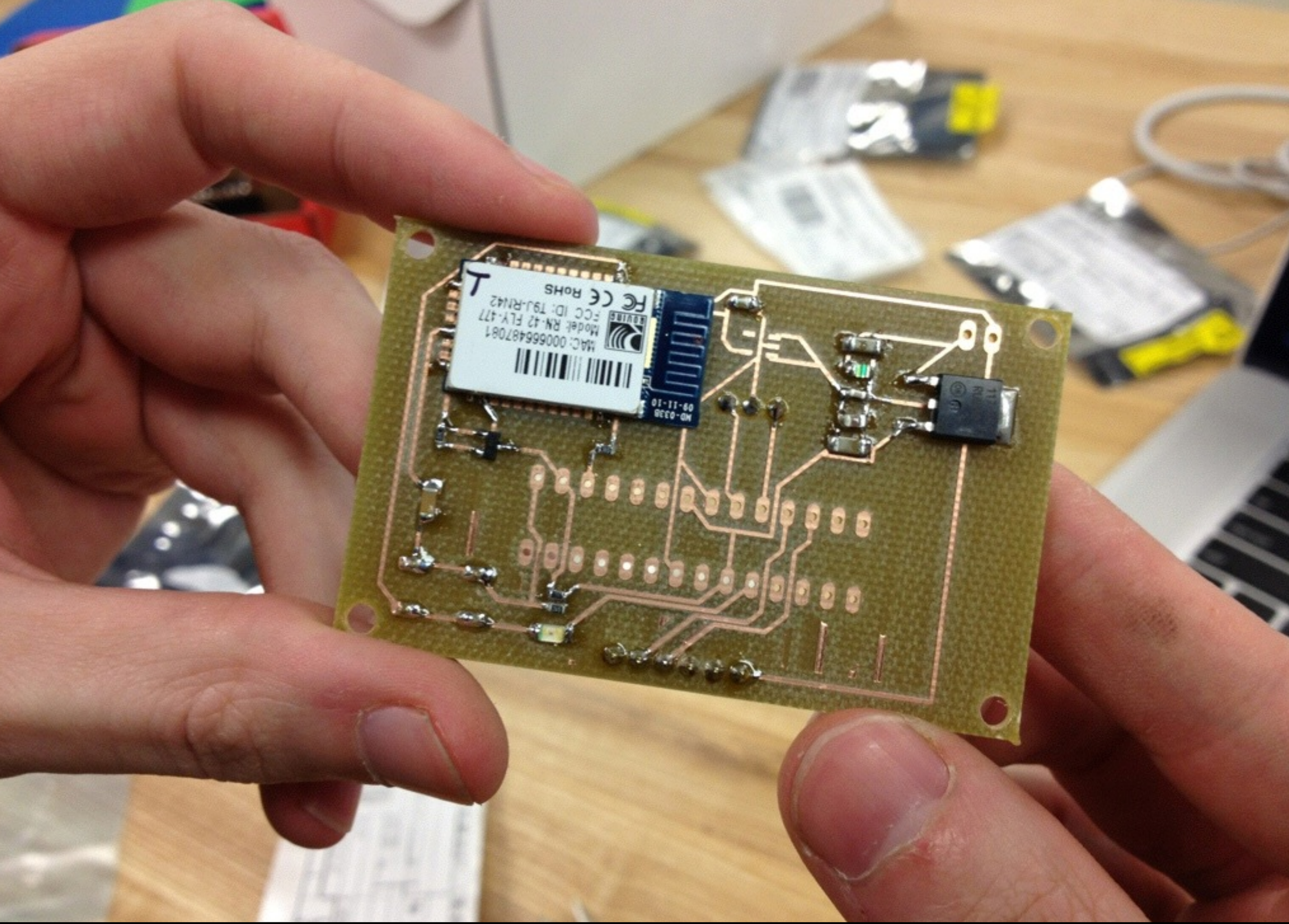
3D SCANNER


Royston 30

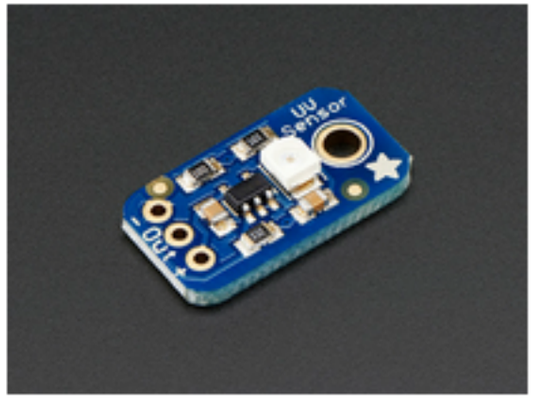

uPrint SE Plus

2-LAYER CIRCUIT BOARD MILL





OBJECT ORIENTED HARDWARE



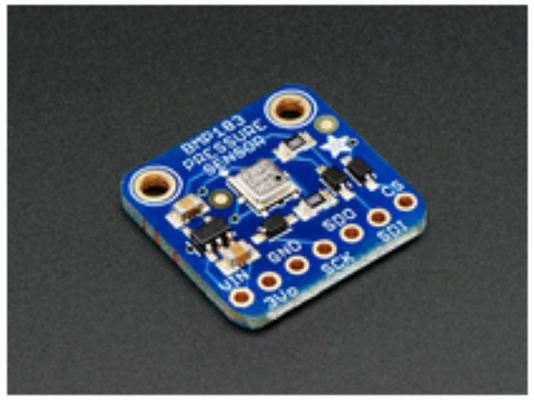
Analog UV Light Sensor Breakout - GUVA-S12SD

PRODUCT ID: 1918

Extend your light-sensing spectrum with this analog UV sensor module. It uses a UV photodiode, which can detect the 240-370nm range of light (which covers UVB and most of UVA spectrum). The signal level from the photodiode is very small, in the nano-ampere level, so we tossed on an opamp to amplify the signal to a more manageable volt-level. This sensor is much simpler than our Si1145 breakout, it only does one thing and gives an analog voltage...

ADD TO CART

$6.50
IN STOCK



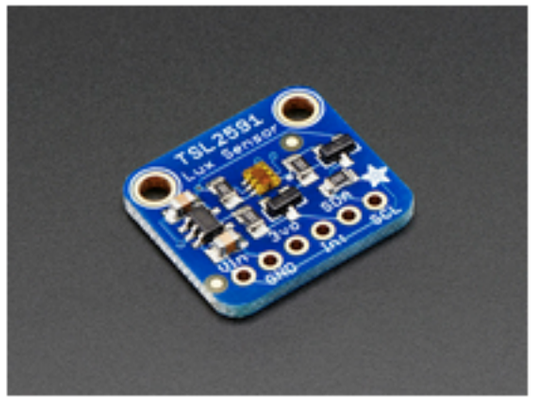
Adafruit BMP183 SPI Barometric Pressure & Altitude Sensor

PRODUCT ID: 1900

Fans of the BMP085/BMP180 will want to take a look at the new BMP183 - an SPI spin on the old familiar classic. This precision sensor from Bosch is the best low-cost sensing solution for measuring barometric pressure and temperature. Because pressure changes with altitude you can also use it as an altimeter! The BMP183 is the next-generation of sensors from Bosch, and is the fraternal twin of the BMP180 - with a low altitude noise of 0.25m and...

ADD TO CART

$9.95
IN STOCK



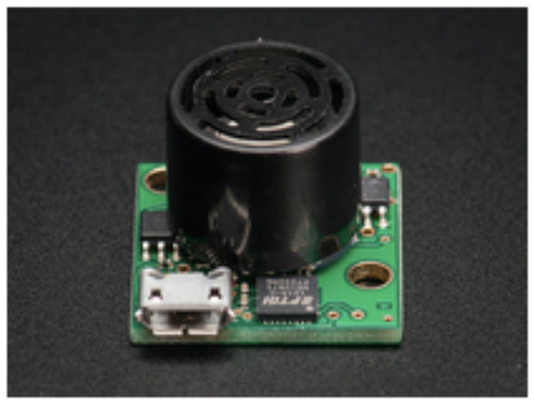
Adafruit TSL2591 High Dynamic Range Digital Light Sensor

PRODUCT ID: 1980

When the future is dazzlingly-bright, this ultra-high-range luminosity sensor will help you measure it. The TSL2591 luminosity sensor is an advanced digital light sensor, ideal for use in a wide range of light situations. Compared to low cost CdS cells, this sensor is more precise, allowing for exact lux calculations and can be configured for different gain/timing ranges to detect light ranges from 188 uLux up to 88,000 Lux on the fly. The best...

ADD TO CART

$6.95
IN STOCK



Maxbotix Ultrasonic Rangefinder - HR-USB-EZ1

PRODUCT ID: 1343

The HRLV-MaxSonar-EZ sensor line is the fastest way to get precision range-finding into your computer. No microcontroller or adapter required, simply connect any micro B USB cable (not included) into the sensor and install the FTDI drivers to get serial sonar distance data via serial on any computer operating system. The HR-USB-EZ sensor line provides high accuracy and high resolution ultrasonic proximity detection and ranging in air, in a...

ADD TO CART

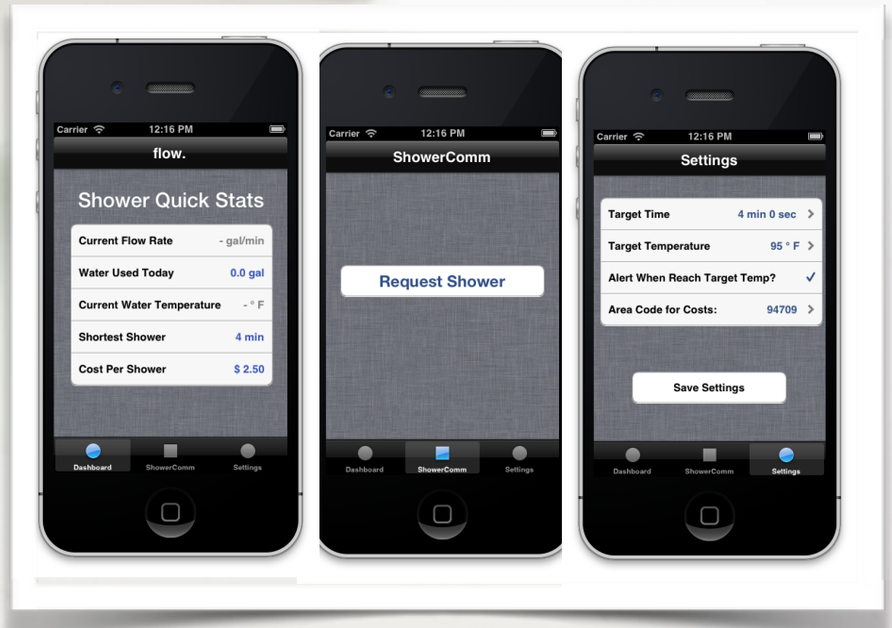
$49.95
9 IN STOCK

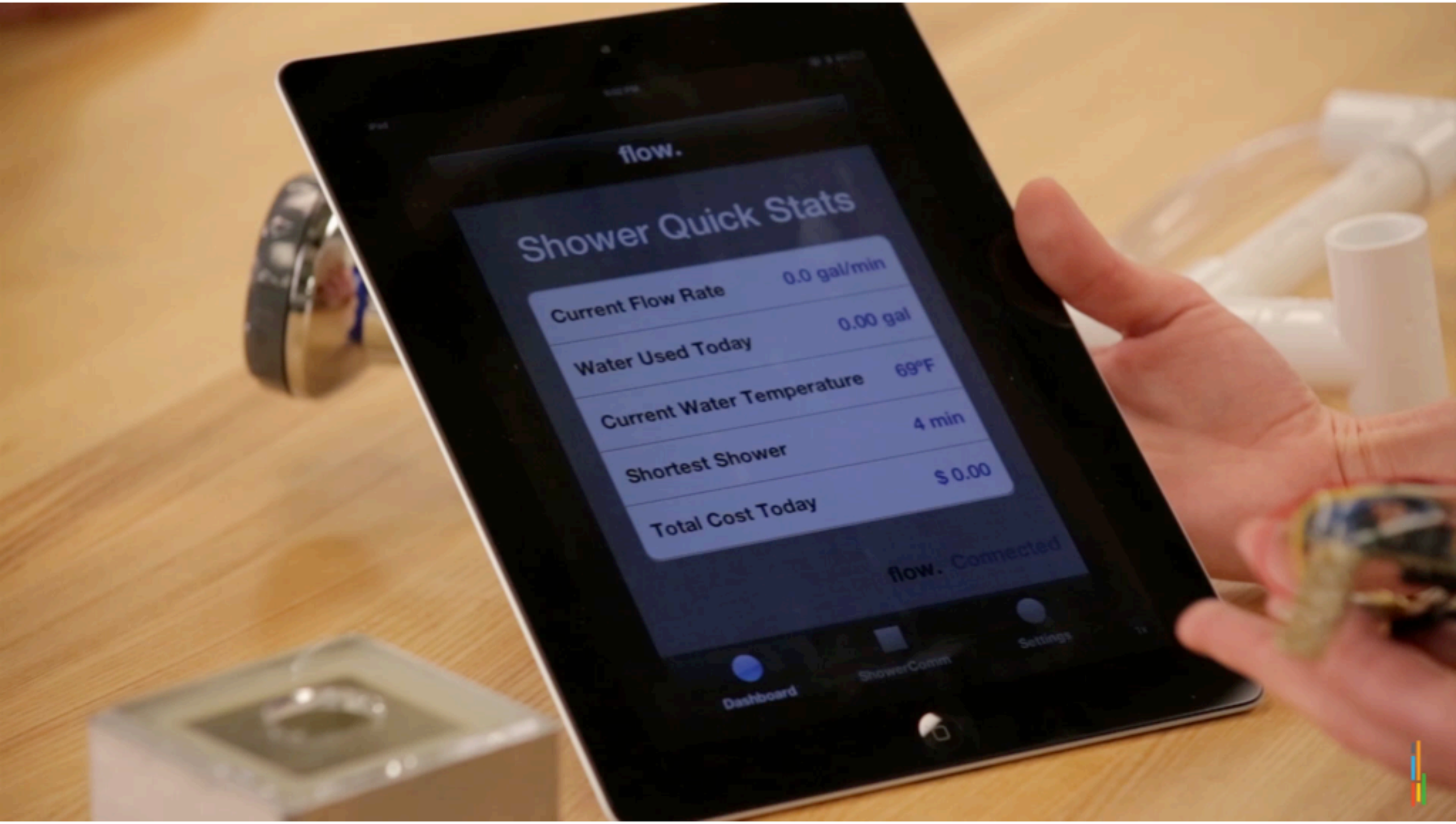
Source: adafruit.com

BESPOKE INTERACTIVE DEVICE DESIGN

flow

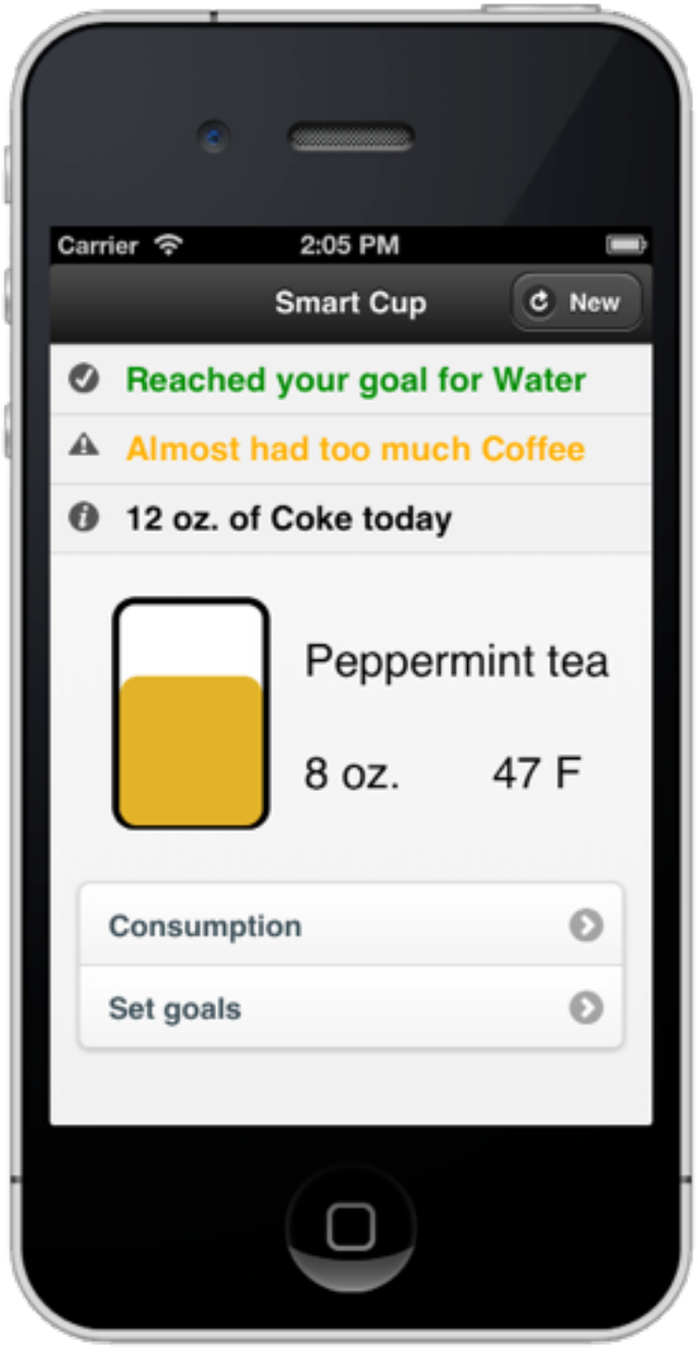
Zach Wasson
Jackie Leverett
Tim Lee

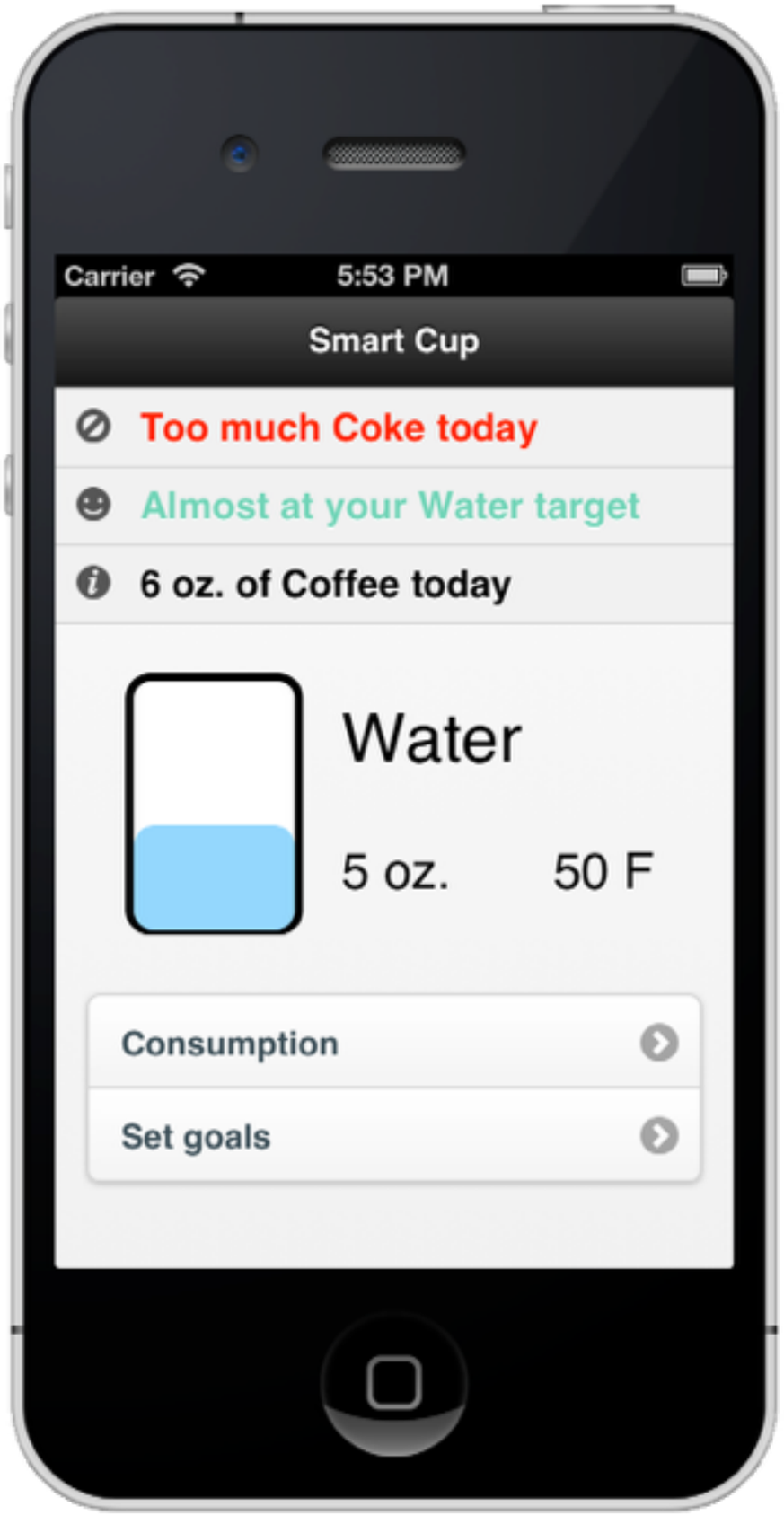


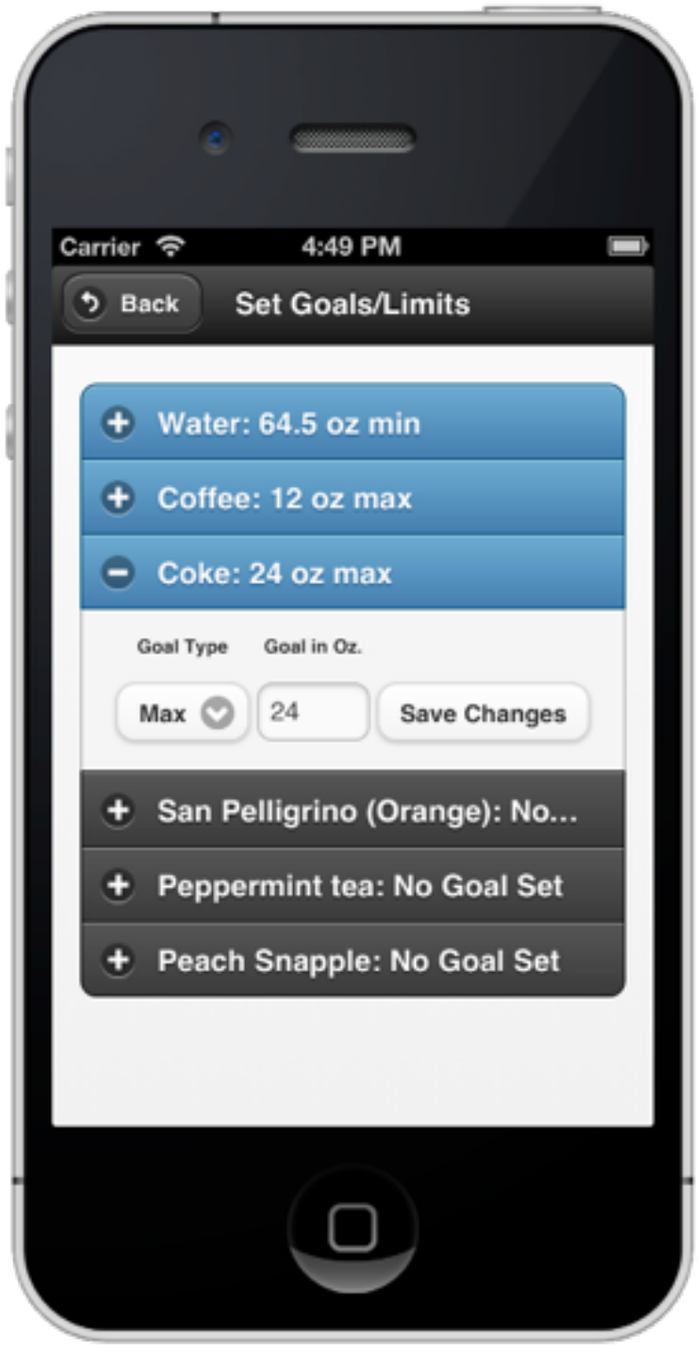

flow.
Shower Quick Stats
Current Flow Rate
0.0 gal/min
Water Used Today
0.00 gal
Current Water Temperature
69°F
4 min
Shortest Shower
$ 0.00
Total Cost Today
flow. Connected
Dashboard
ShowerComm
Settings

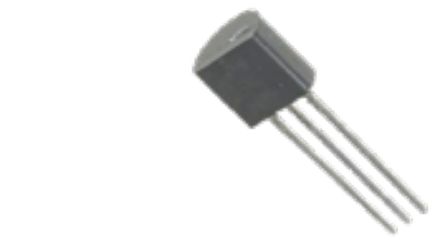
DRINKE SMART CUP

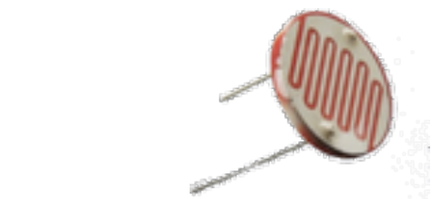
Amy Pavel
Steve Rubin
Elliot Nahman
Sean Chen

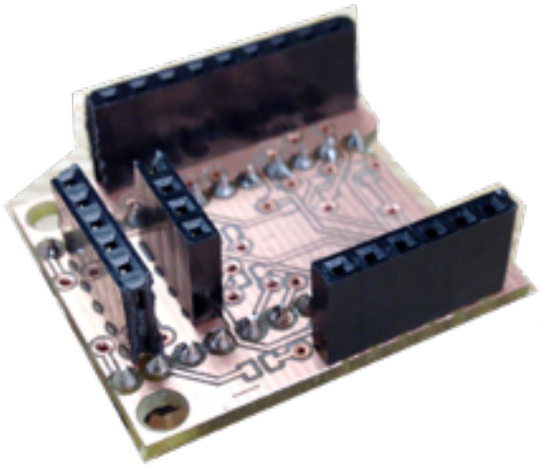

Carrier
2:05 PM
Smart Cup
New
Reached your goal for Water
Almost had too much Coffee
12 oz. of Coke today
12 oz. of Coke today
Peppermint tea
8 oz.
47 F
Consumption
Set goals


Carrier
5:53 PM
Smart Cup
Too much Coke today
Almost at your Water target
6 oz. of Coffee today
Water
5 oz.
50 F
Consumption
Set goals

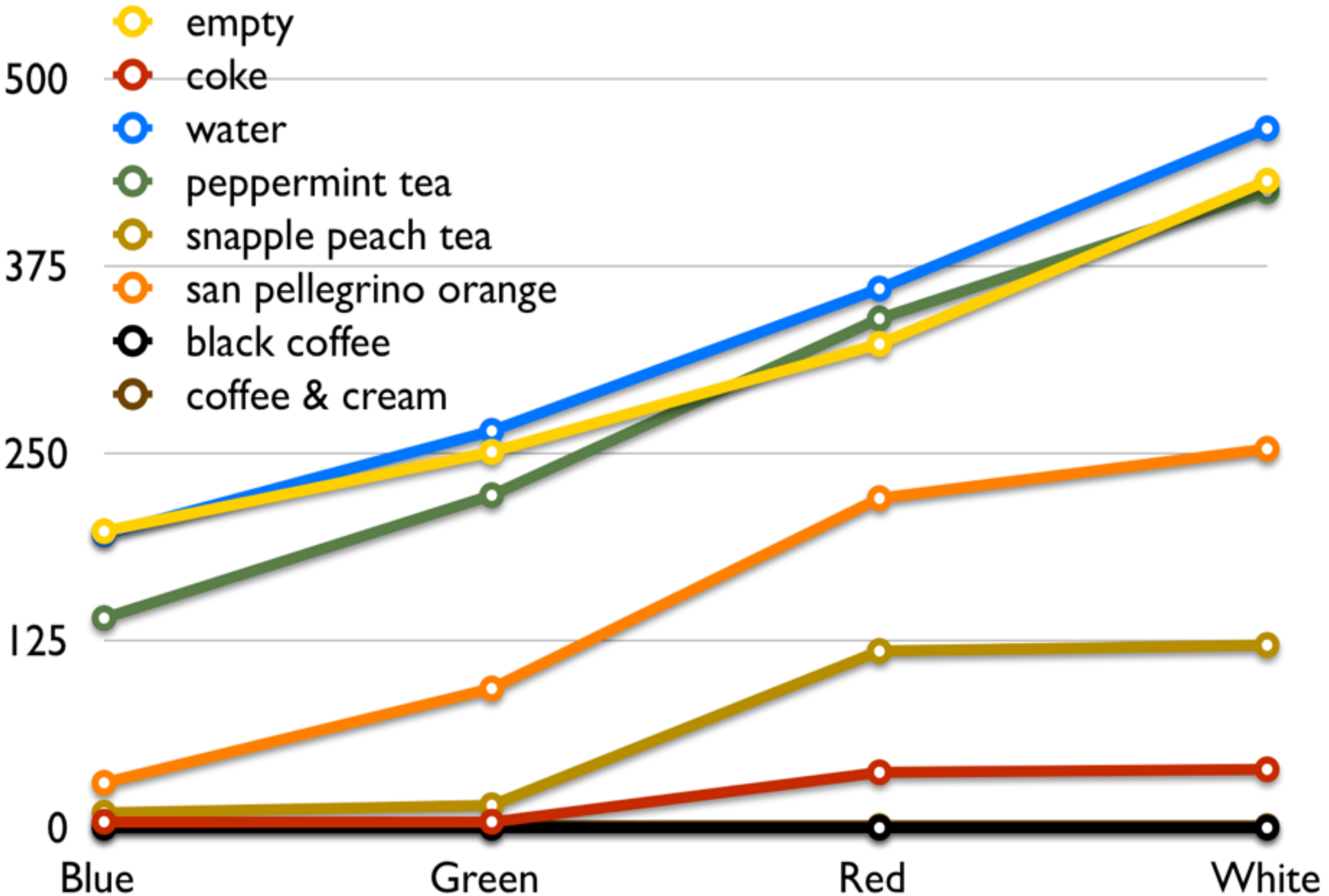

Carrier
4:49 PM
Back
Set Goals/Limits
Water: 64.5 oz min
Coffee: 12 oz max
Coke: 24 oz max
Goal Type
Goal in Oz.
Max
24
Save Changes
San Pelligrino (Orange): No...
Peppermint tea: No Goal Set
Peach Snapple: No Goal Set








XBee
PRO

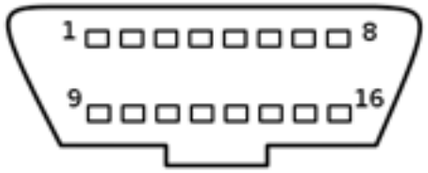

empty
coke
water
peppermint tea
snapple peach tea
san pellegrino orange
black coffee
coffee & cream
500
375
250
125
0
Blue
Green
Red
White

CAR, PhD

Daniel Haas
Daniel Bruckner
Chris Thompson

Car

OBD II



CarPhD

Bluetooth

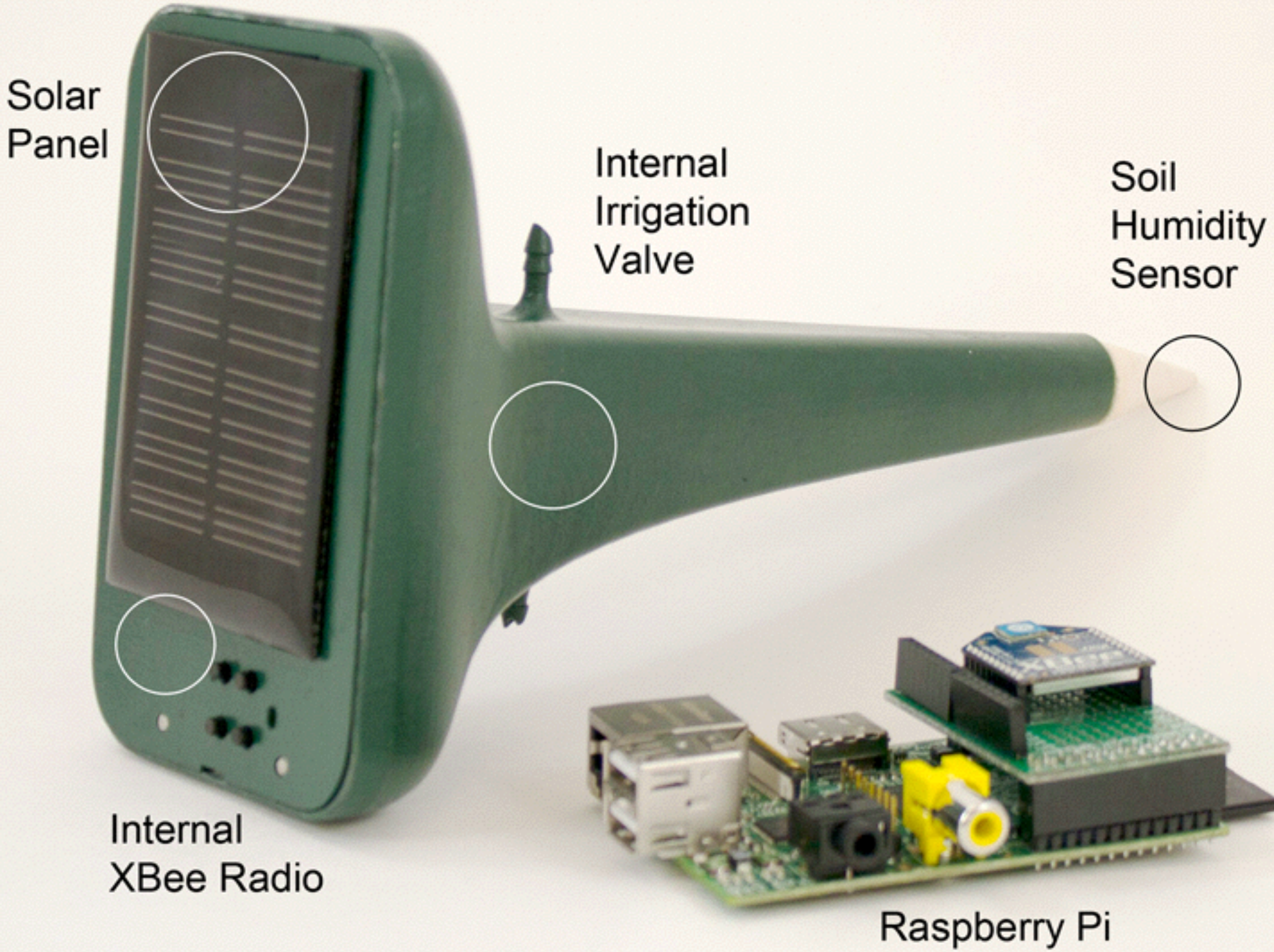
Phone

WiFi

4G

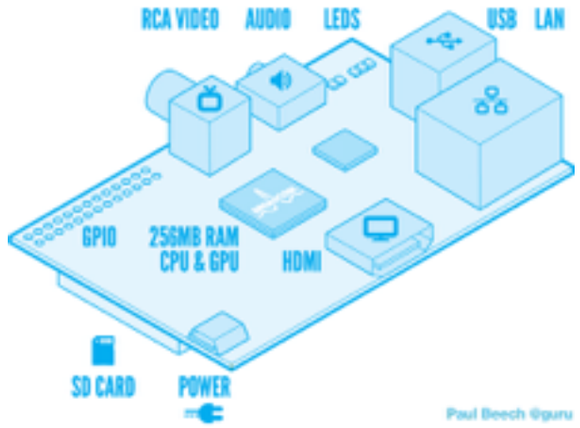
H2O IQ
Drip Irrigation Controller

Valkyrie Savage
Shiry Ginosar
Mark Fuge

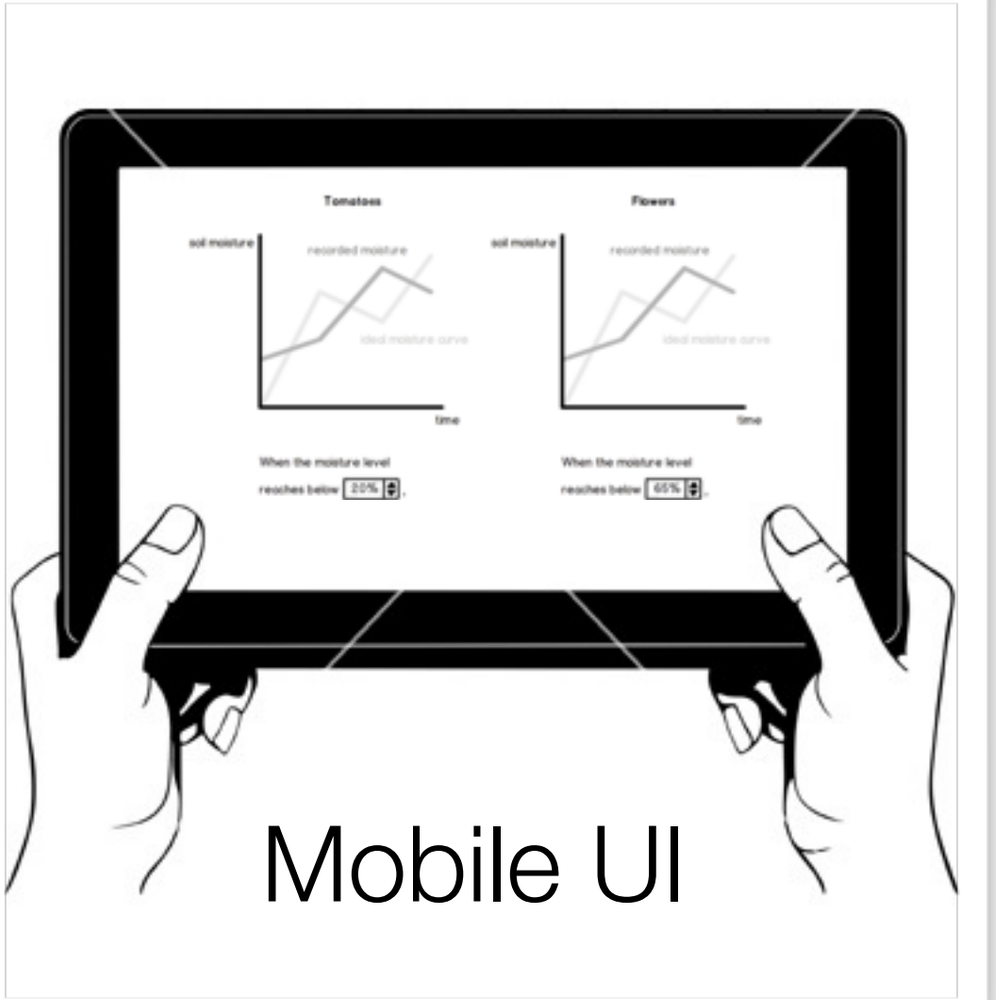

Solar
Panel
Internal
Irrigation
Valve
Soil
Humidity
Sensor
Internal
XBee Radio
Raspberry Pi

Garden Hub

(Raspberry Pi Web Server)



HTTP



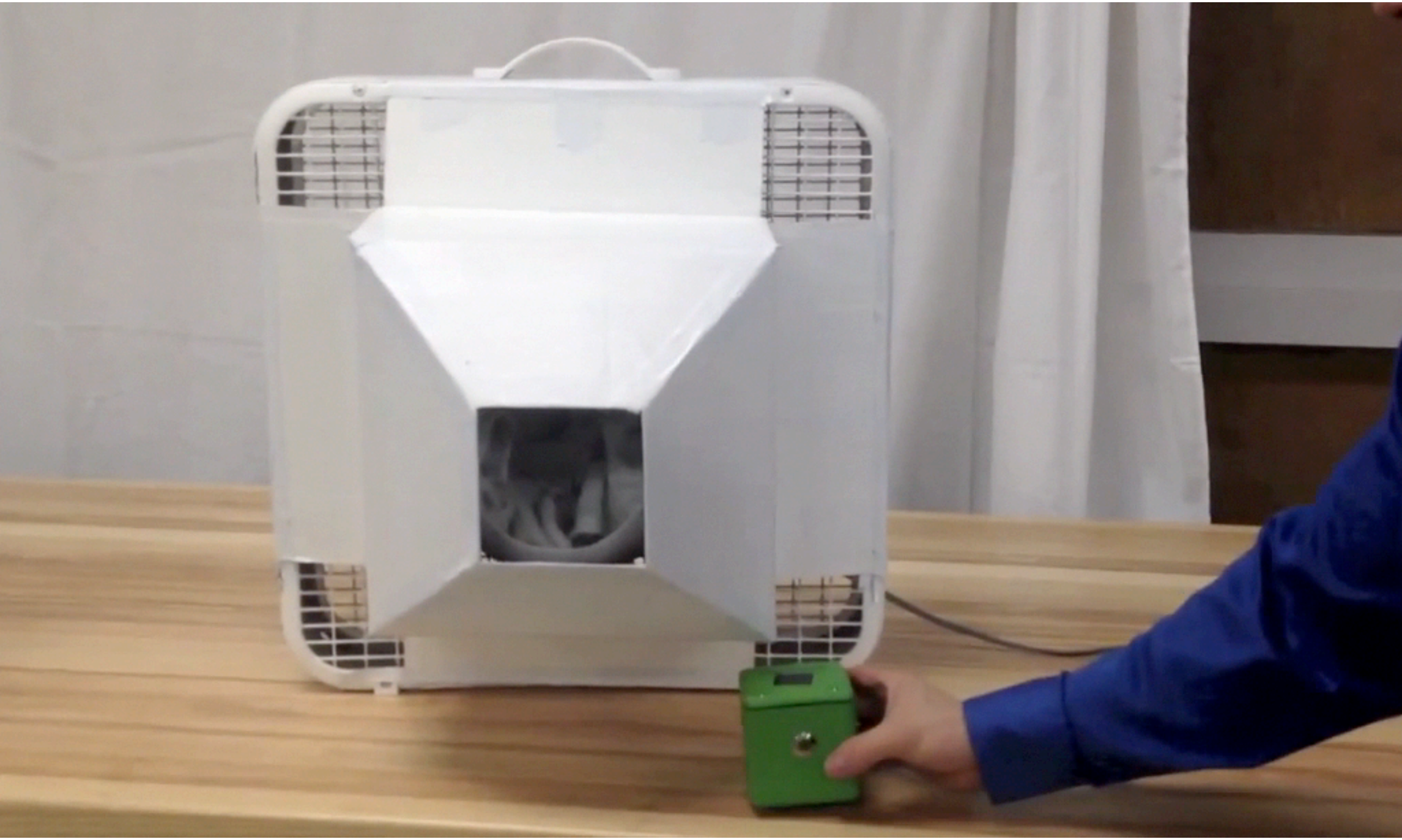
Mobile UI

XBee
802.15.4

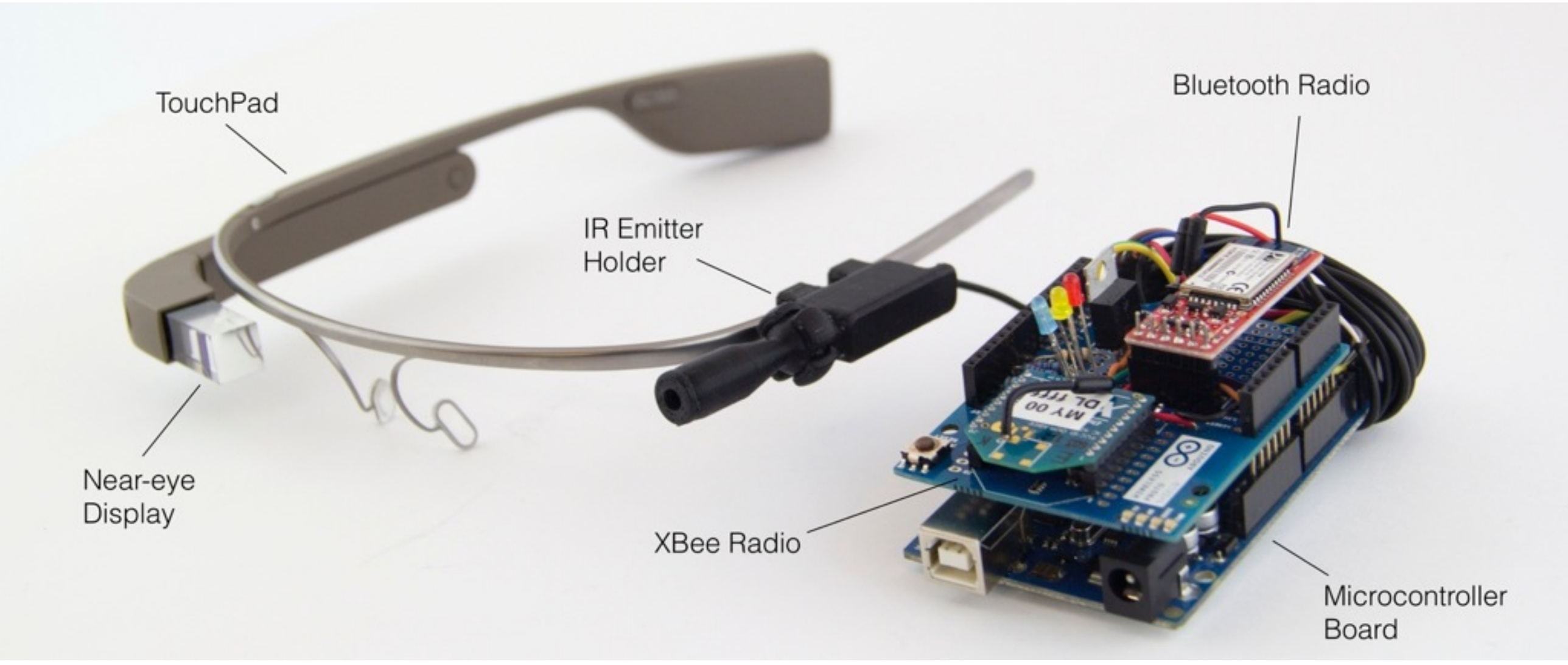
PV-powered soil sensors

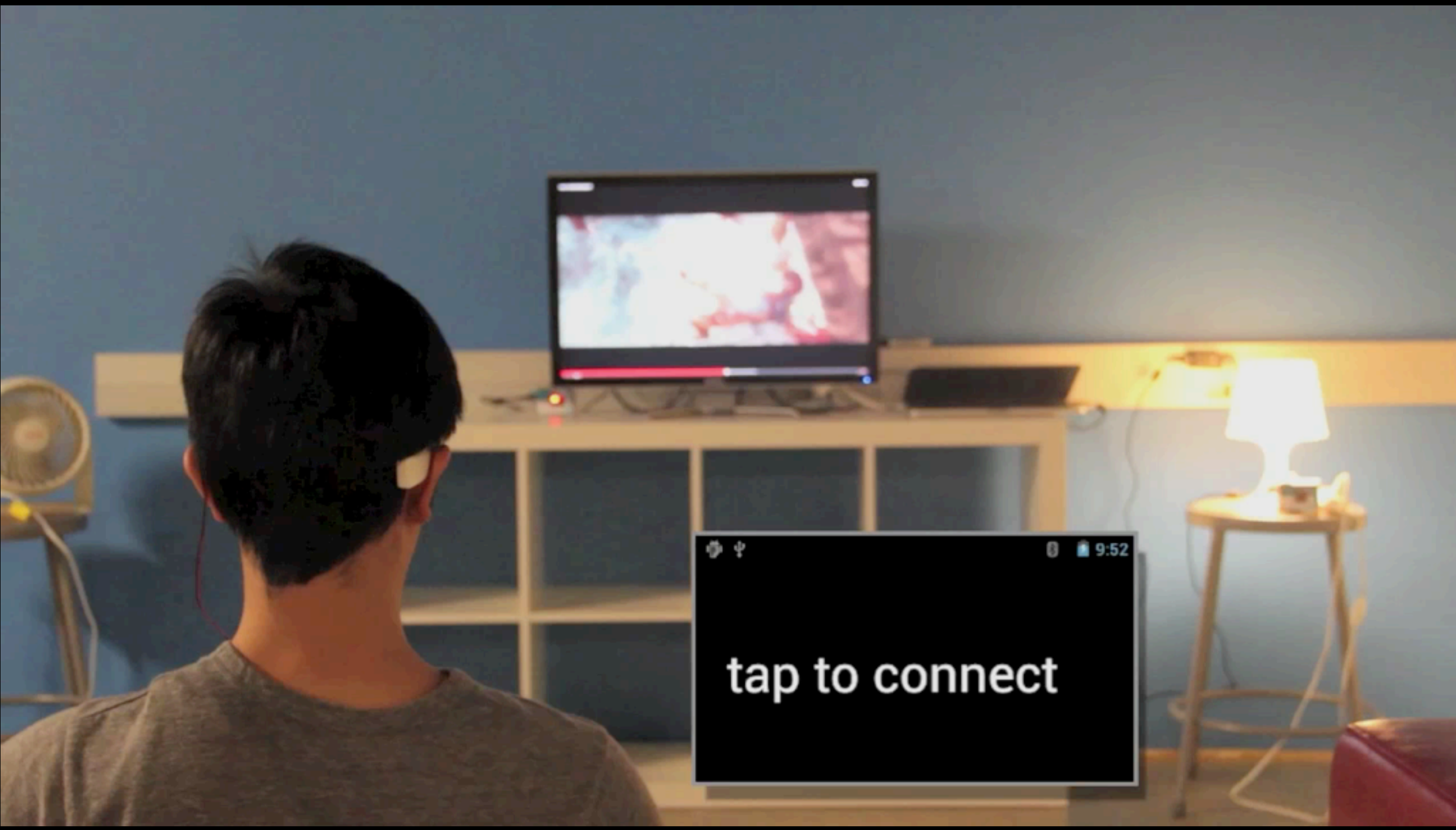
LaundryQb

Ross Yeager
Hassan Elahi
JJ Liu
Ryan Rho

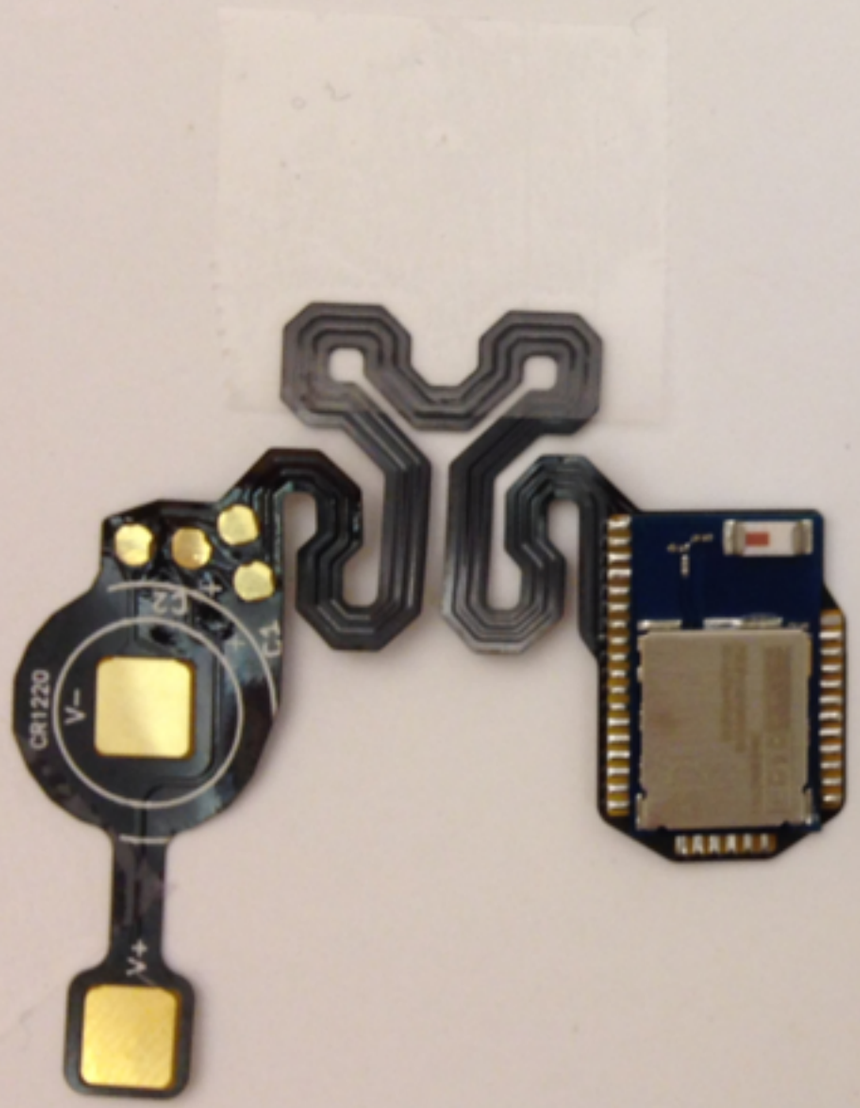


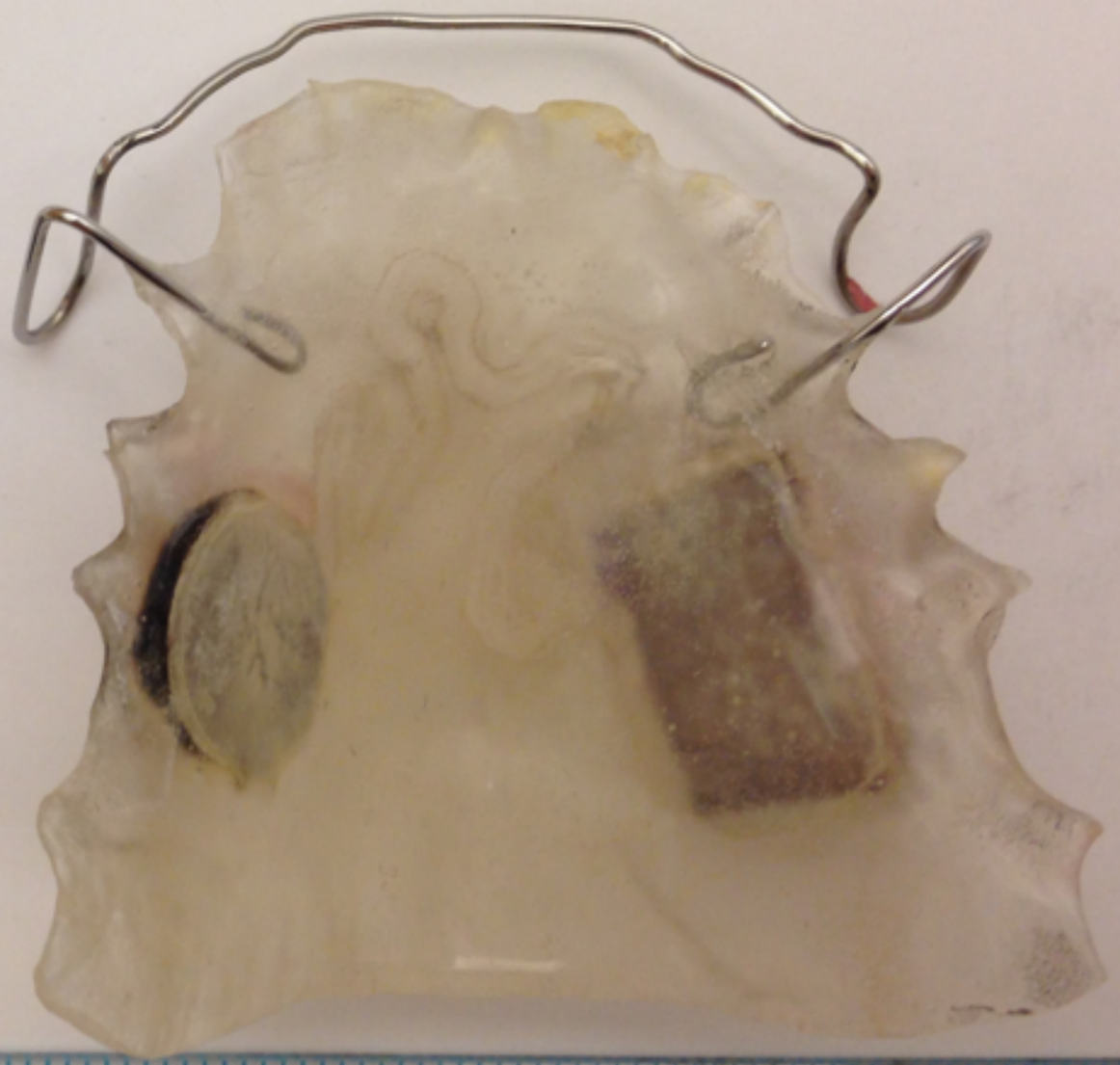
Secure Internet of Things


TouchPad
Bluetooth Radio
IR Emitter
Holder
Near-eye
Display
XBee Radio
Microcontroller
Board

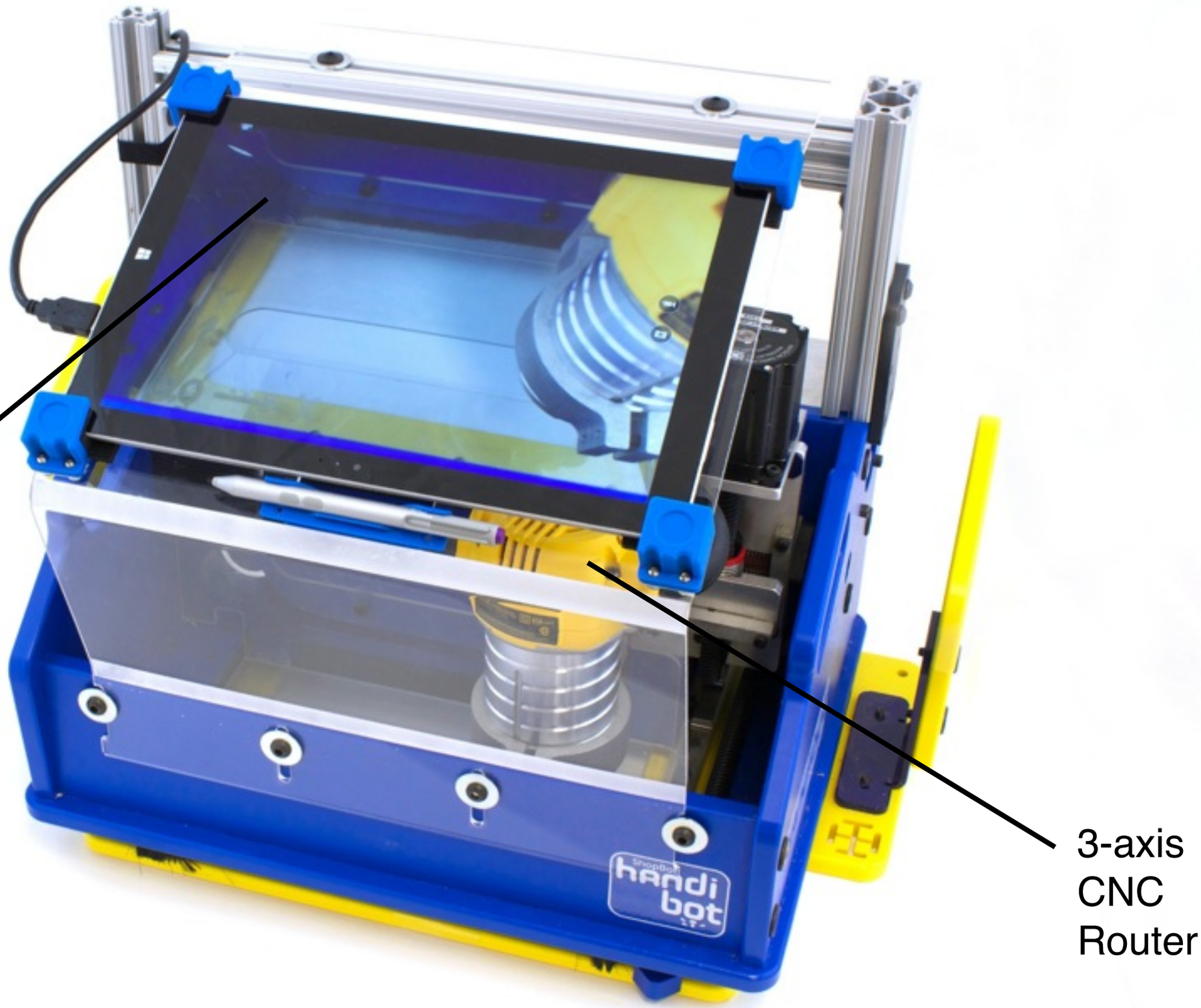

9:52
tap to connect

Biodesign Lab (Prof. Roy)
Department of Bioengineering & Therapeutic Sciences
UCSF School of Pharmacy





Consider Actuation



Tablet User Interface

3-axis CNC Router

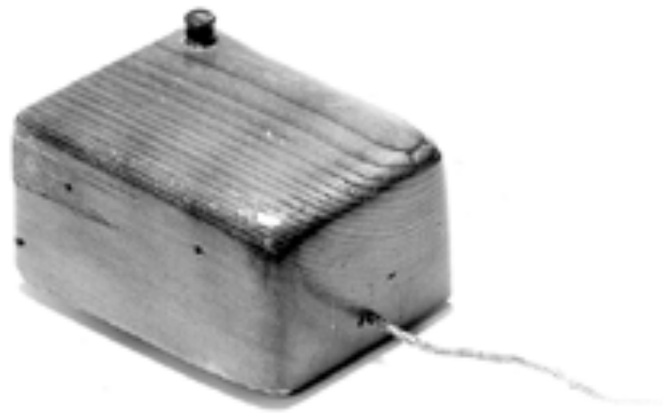
Lessons learned

- MGC Architecture is dominant (embedded, gateway, cloud):
  - 3 different platforms,
  - 5+ different languages (C, Obj-C, Ruby, JavaScript, HTML)
- Just getting this ecosystem to run is challenging
- Devices are “prototyped into existence”: Choice of tools driven by accessibility, productivity
- Driven by user/application considerations, not technology per se
- Security not only an afterthought, but often actively resisted & circumvented

Implications for Platforms

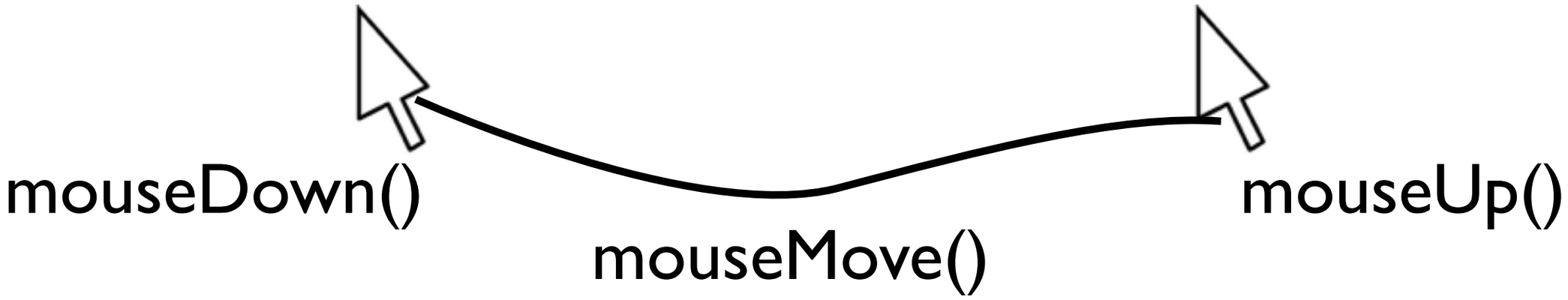
- Embrace iterative, prototype-driven development
- Enable application (not technology) experts to be productive quickly
- Provide desired (security/robustness/…) guarantees by embodying them in the API
- **Key question: what are appropriate abstractions that enable these desiderata?**

Analogy:
Gesture Recognition

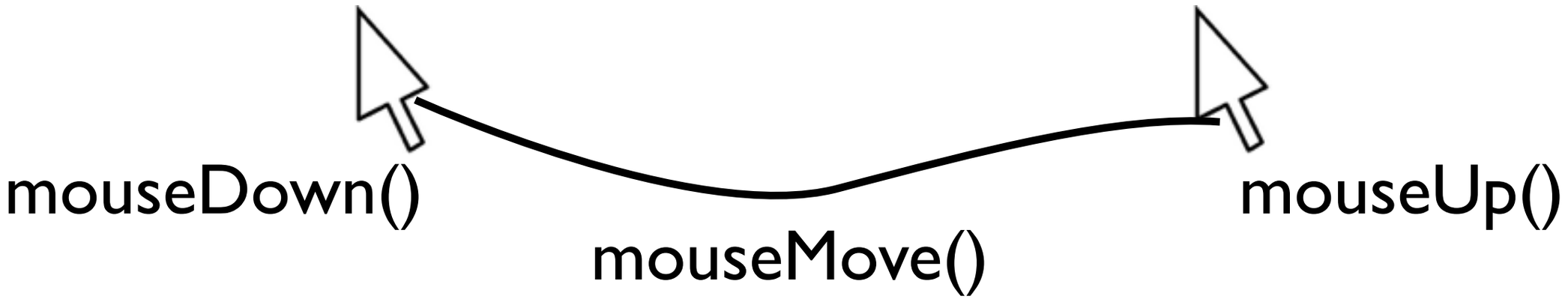


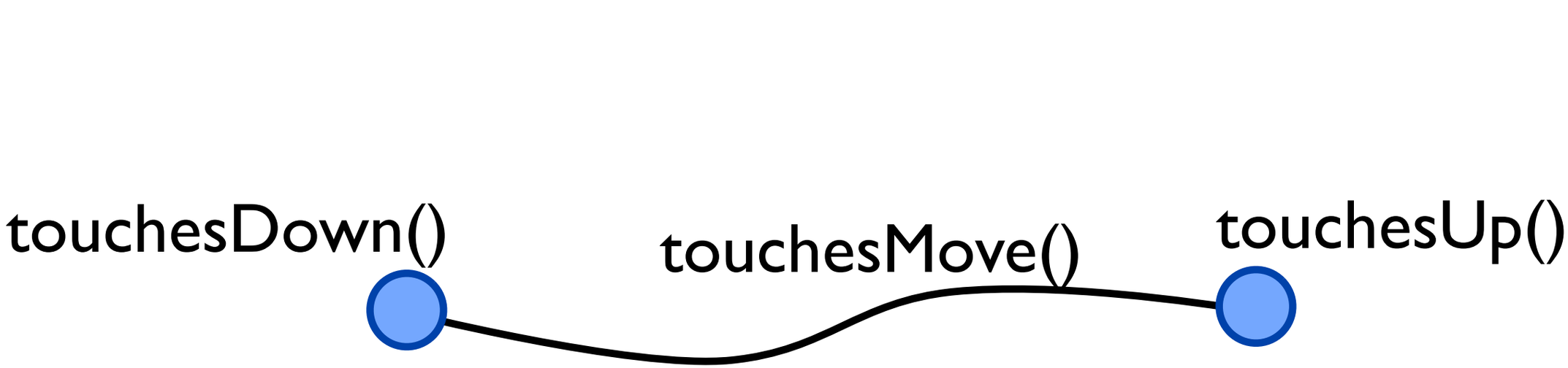
[Engelbart & English ’63]

User Events

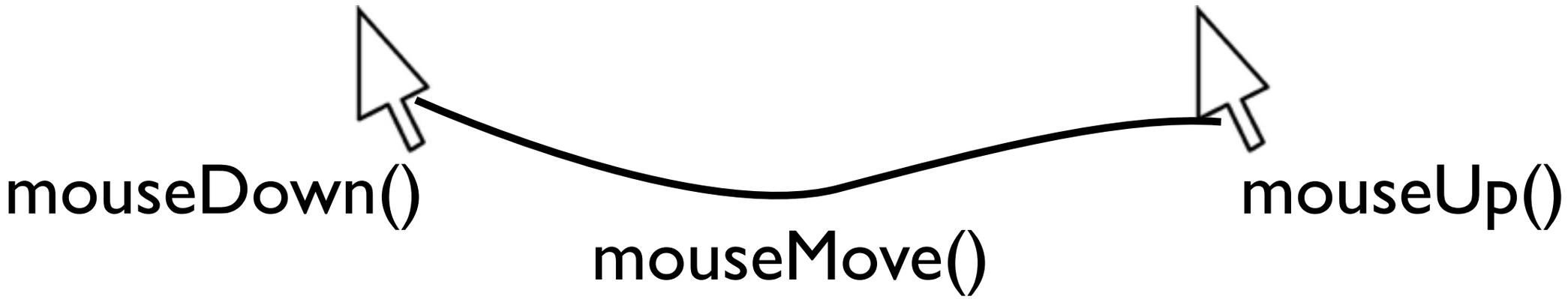


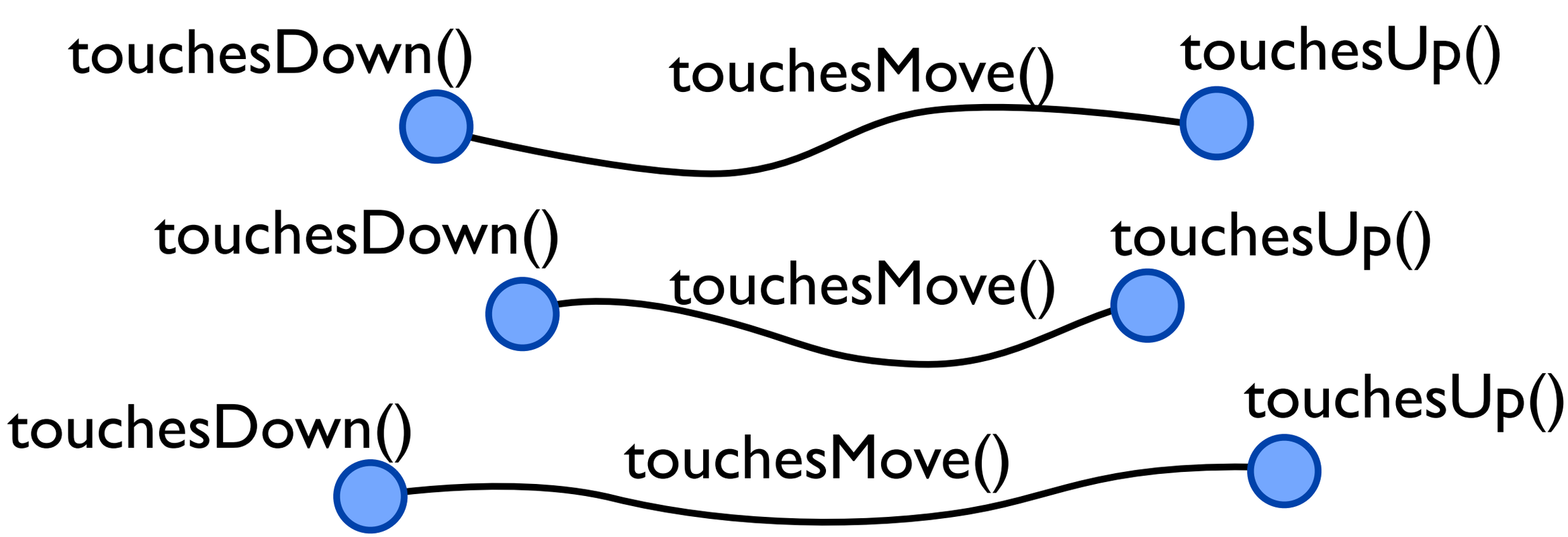
User Events


mouseDown()
mouseMove()
mouseUp()


touchesDown()
touchesMove()
touchesUp()

User Events

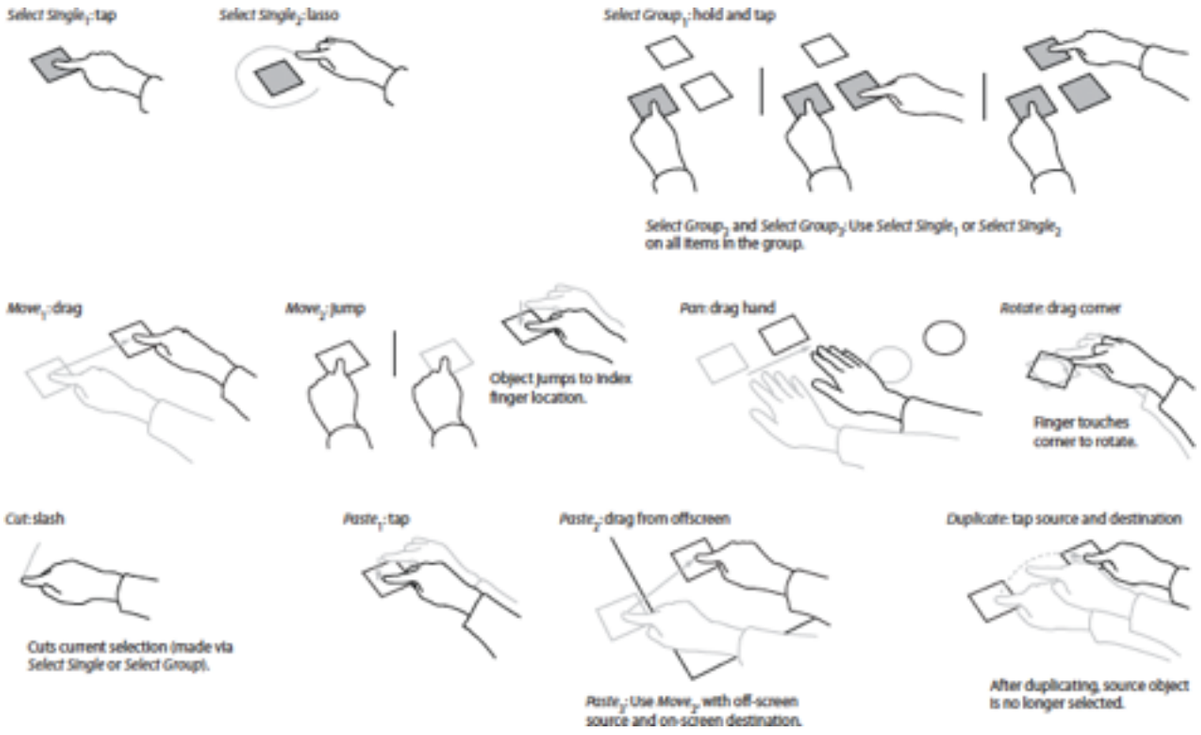

mouseDown()
mouseMove()
mouseUp()

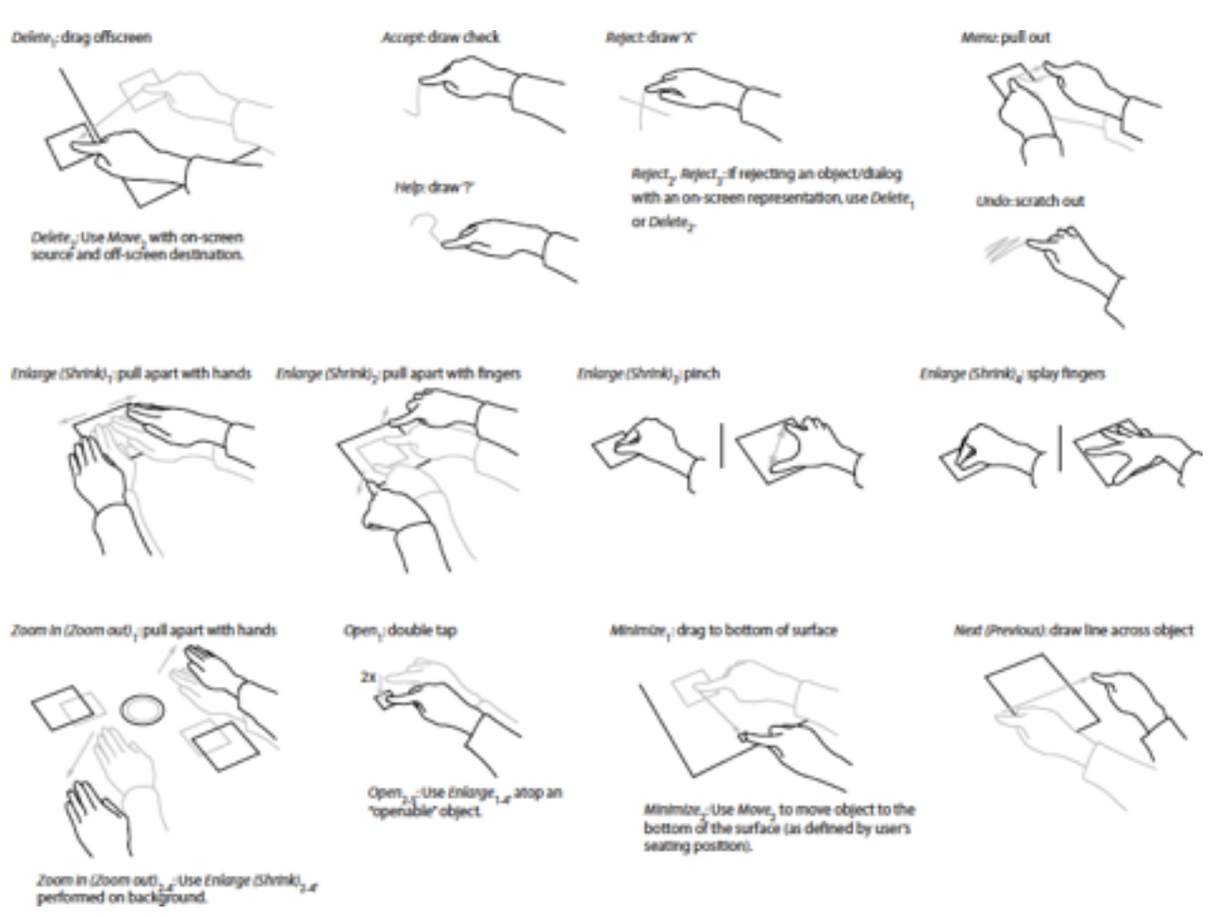

touchesDown()
touchesMove()
touchesUp()
touchesDown()
touchesMove()
touchesUp()
touchesDown()
touchesMove()
touchesUp()

Gesture Implementation

```
_state = GesturePossible;

touchesDown(Array *touches, Event *event)
  if(event->allTouches()->count() == 1)
    if(touches[0]->target() != 'n')
      _state = GestureFailed;
  else if(event->allTouches()->count() == 2)
    if(touches[0]->target() != 'm')
      _state = GestureFailed;
  else
      _state = GestureFailed;

touchesMove(Array *touches, Event *event)
  for(i = 0; i < touches->count(); i++)
    if(touches[i]->touchId() == 0 && touches[i]->target() != 'n')
      _state = GestureFailed;
    else if(touches[i]->touchId() == 1 && touches[i]->target() != 'm')
      _state = GestureFailed;

touchesUp(Array *touches, Event *event)
  if(touches[0]->touchId() == 0)
    if(event->allTouches()->count() == 1 && touches[0]->target() == 'n')
      connectNodes();
      _state = GestureRecognized;
    else
      _state = GestureFailed;
  else
    if(event->allTouches()->count() == 1 || touches[0]->target() != 'm')
      _state = GestureFailed;
```

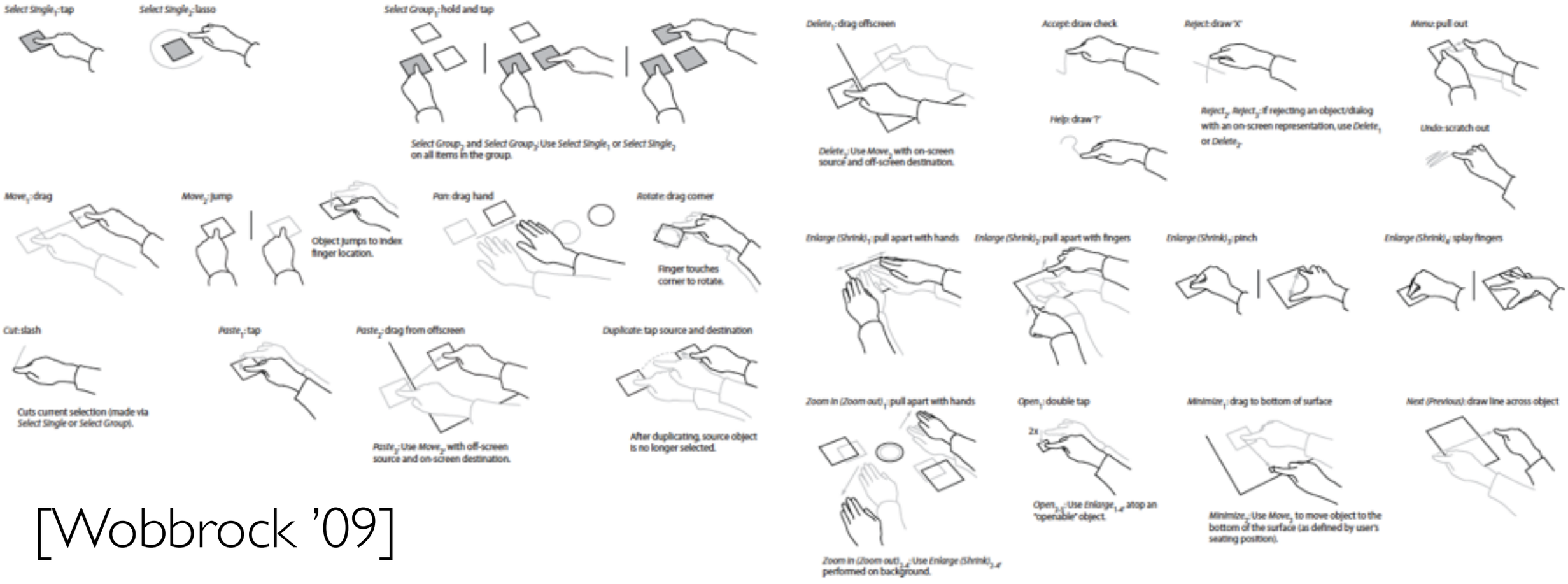
Managing Large Gesture Sets





[Wobbrock '09]

Managing Large Gesture Sets



[Wobbrock '09]

Conflict Detection and Resolution

```
gesture = D1n M1n * D2m (M1n | M2m) * U2m M1n * U1n
gesture.finalTrigger(connectNodes());
gestureMatcher.add(gesture);
```

```
gesture = D1n M1n * D2m (M1n | M2m) * U2m M1n * U1n
gesture.finalTrigger(connectNodes());
gestureMatcher.add(gesture);
```

Declarative Specification

```
gesture = D1n M1n * D2m (M1n | M2m) * U2m M1n * U1n
gesture.finalTrigger(connectNodes());
gestureMatcher.add(gesture);
```

Declarative Specification

Recognition Code Generation

```
gesture = D1n M1n * D2m (M1n | M2m) * U2m M1n * U1n
gesture.finalTrigger(connectNodes());
gestureMatcher.add(gesture);
```

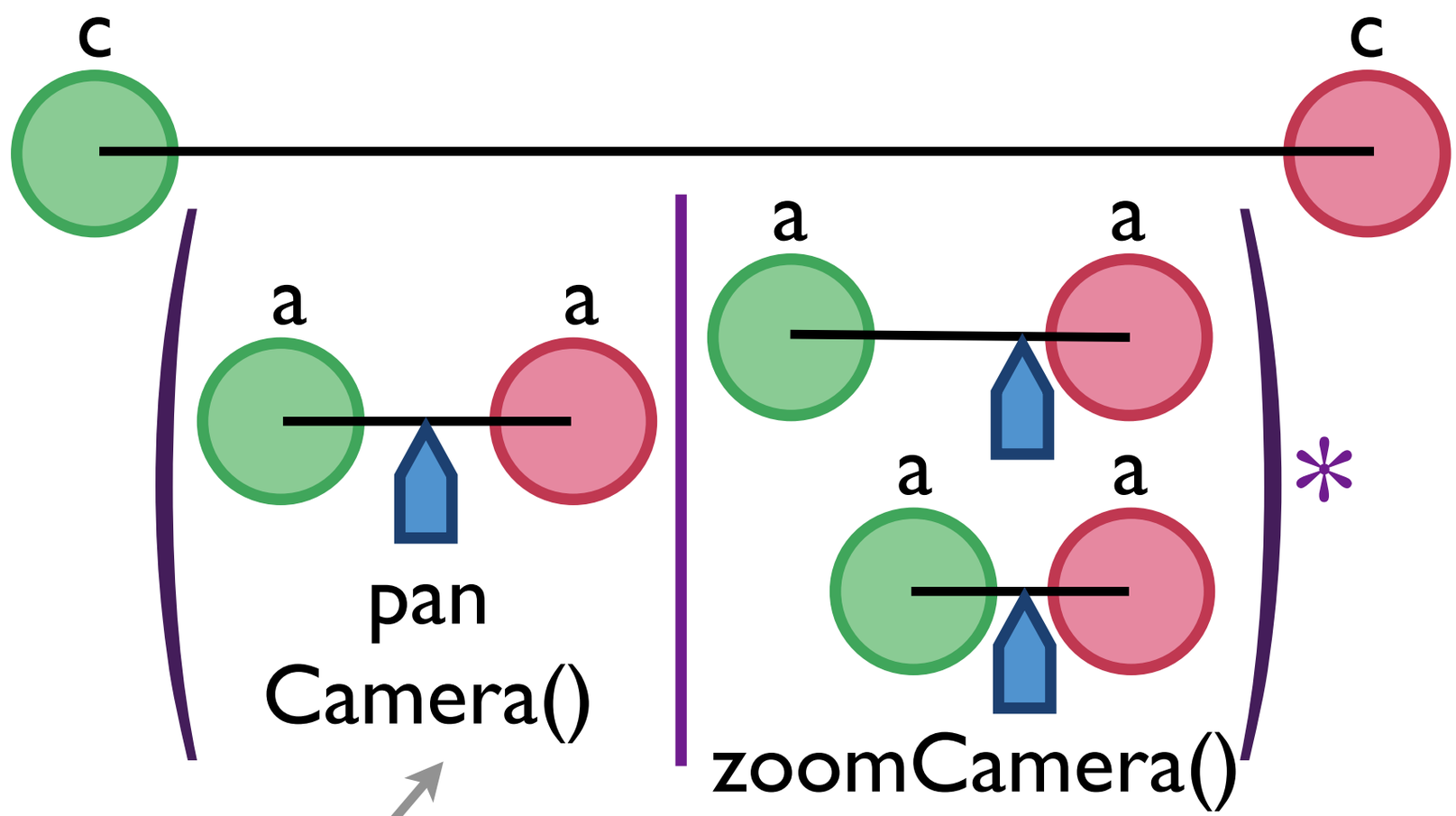
Declarative Specification

Recognition Code Generation

Conflict Detection

First Finger Down

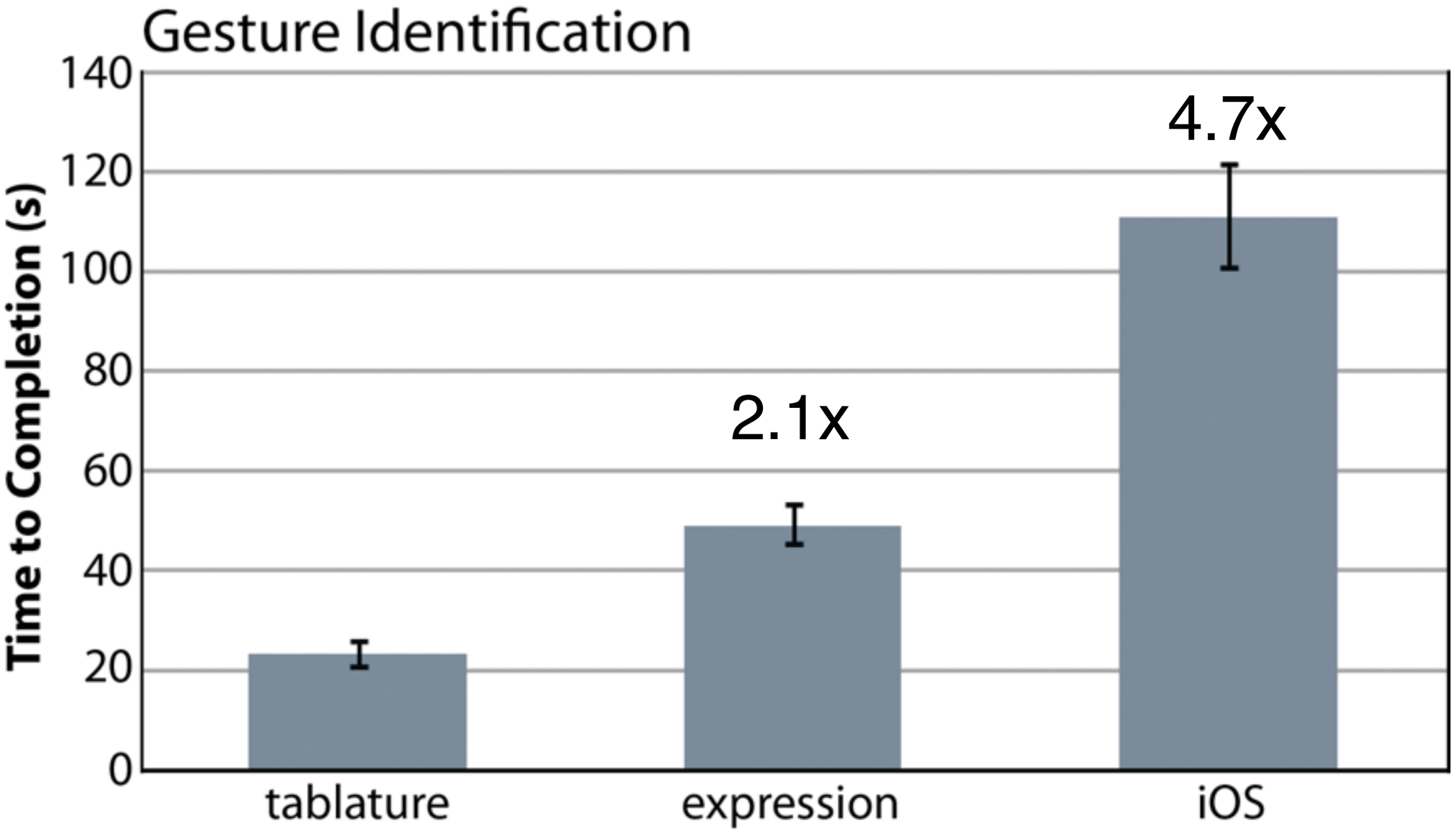
First Finger Up



One extra finger to pan

Two extra fingers to zoom

Abstractions matter.



MGC

Bluetooth

WiFi/
4G

eMbedded
Hardware

Gateway

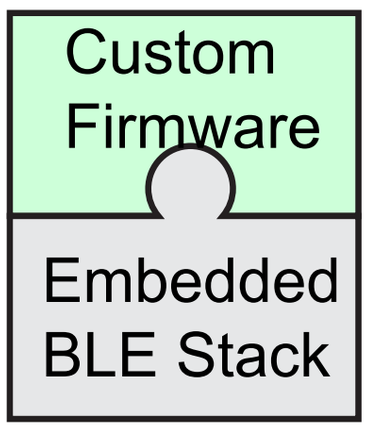
Cloud

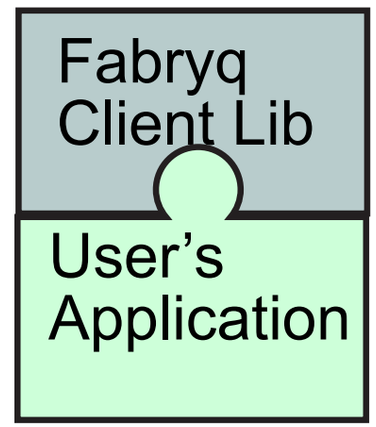
	Embedded		Phone		Server	
	Sensing	Display	UI	Relay to cloud	Aggregation/ Reporting	Web UI
Consumer Devices						
FitBit	✔	✔	✔	✔	✔	✔
Medical Devices						
Retainer	✔	—	—	✔	✔	—
Smart Water Bottle	✔	—	✔	✔	✔	✔
Student Projects						
Barrel Gauge	✔	—	—	—	✔	✔
Driving Suggestions	✔	—	✔	✔	✔	✔

Fabryq

Embedded Device

Web Client





Application developer's code

Fabryq framework

Existing network stacks

W. McGrath
M. Etemadi

	Embedded		Phone		Server	
	Sensing	Display	UI	Relay to cloud	Aggregation/ Reporting	Web UI
Consumer Devices						
FitBit	✔	✔	✔	✔	✔	✔
Medical Devices						
Retainer	✔	—	—	✔	✔	—
Smart Water Bottle	✔	—	✔	✔	✔	✔
Student Projects						
Barrel Gauge	✔	—	—	—	✔	✔
Driving Suggestions	✔	—	✔	✔	✔	✔

Summary

- IoT adoption will be driven by a large variety of different, domain-specific applications
- Designers of these devices will look more like web developers than hardware engineers and systems programmers
- Security and robustness are not part of prototyping practice - so tools and platforms must provide them

Prototyping the Internet of Things

Björn Hartmann
UC Berkeley

Secure Internet of Things Project Workshop
Stanford University
August 11, 2014