Building seCure, Heterogeneous, and Effective Networks

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My Journey

Acknowledgement

- Sigma Xi selection committee

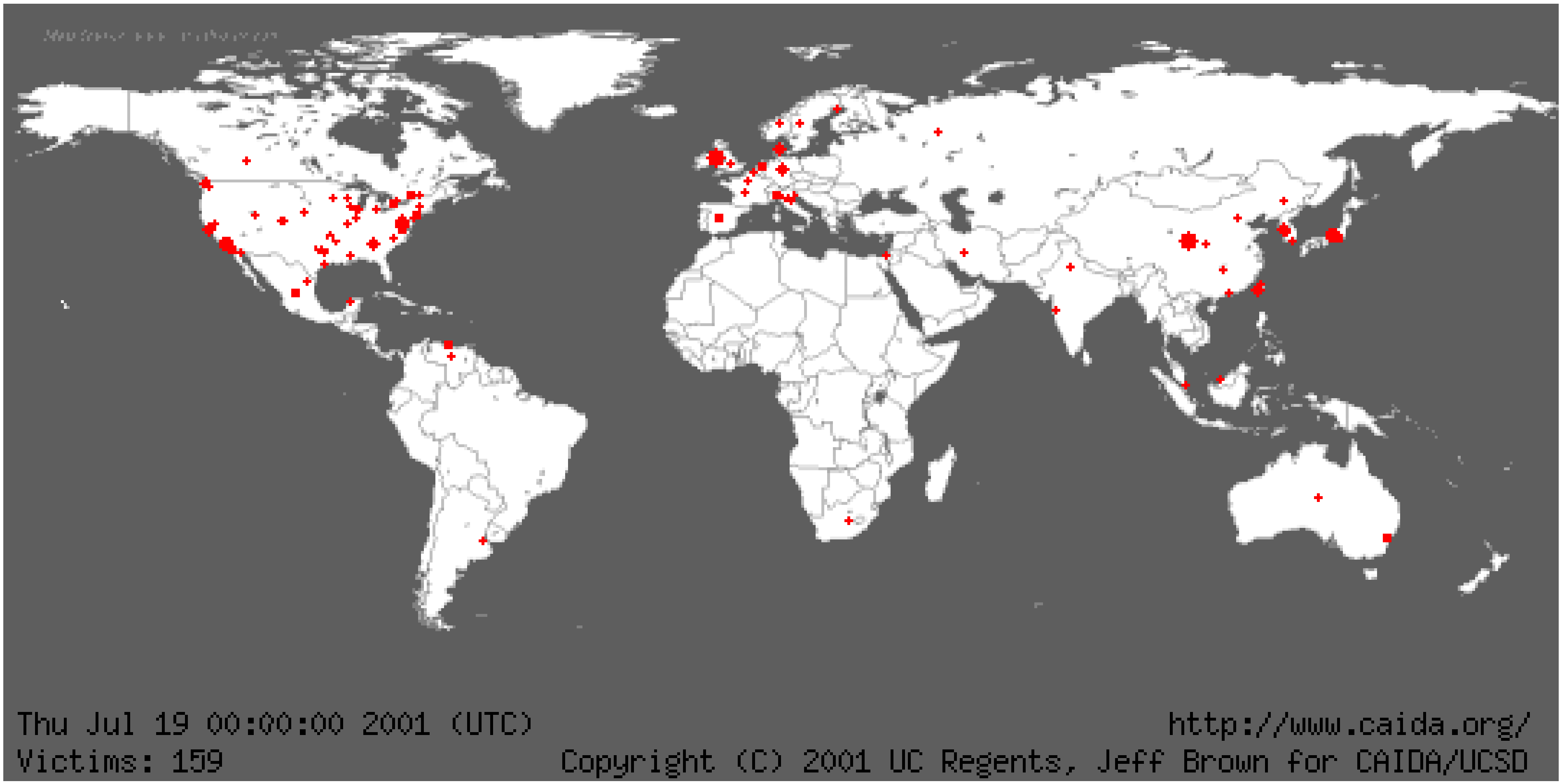



- CS students working with me
- Jesus Christ

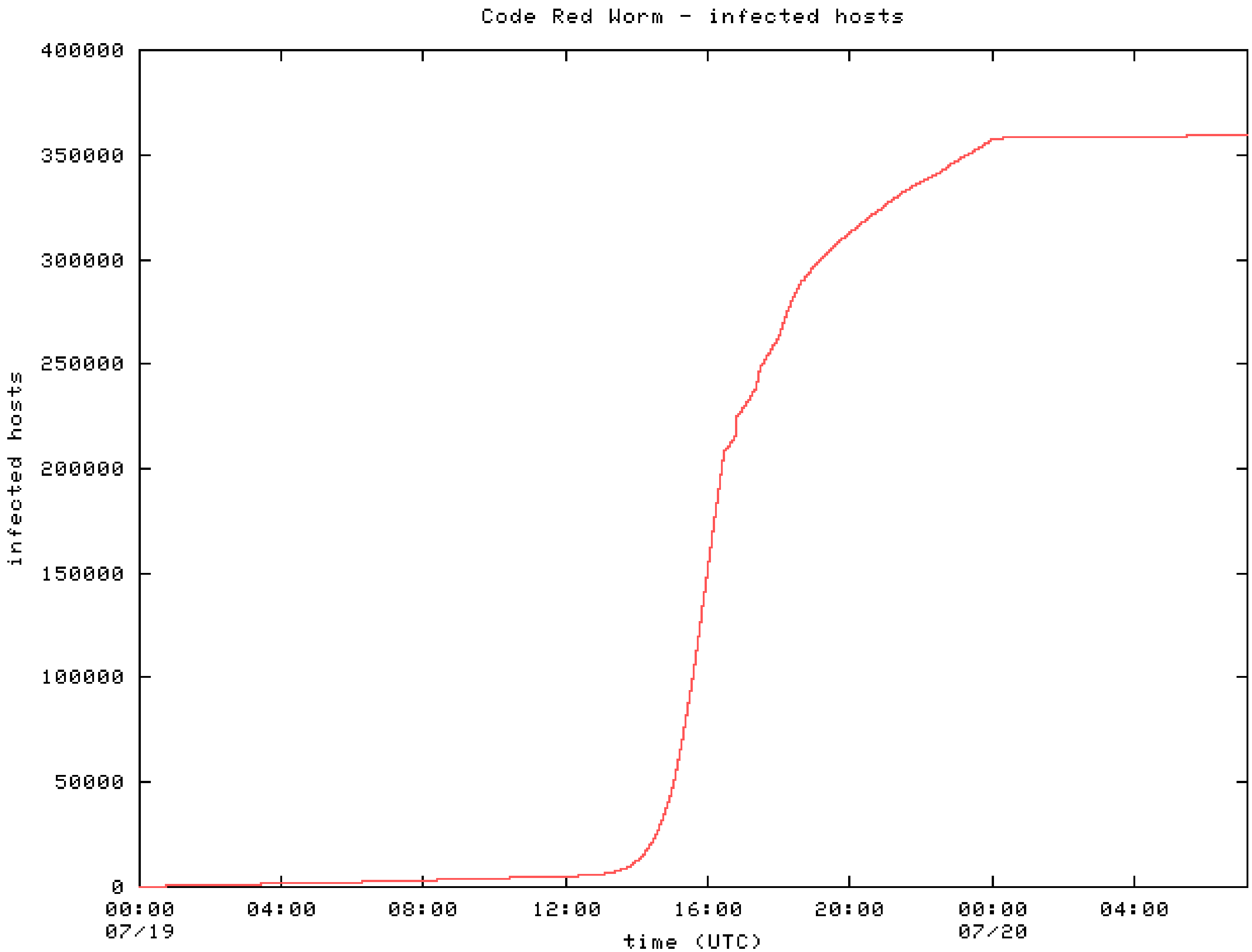
Outline

- Epidemic Thresholds and Spread in Complex Networks
- Internet of Things and Its Applications
- Impact of My Research

Illustration of the Spread of Code Red v2 (From CAIDA)



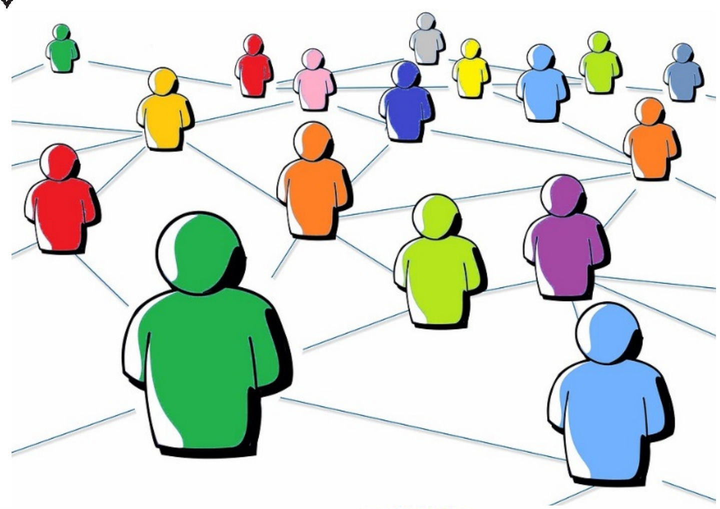
Spread of Code Red v2 (from David Moore's analysis)

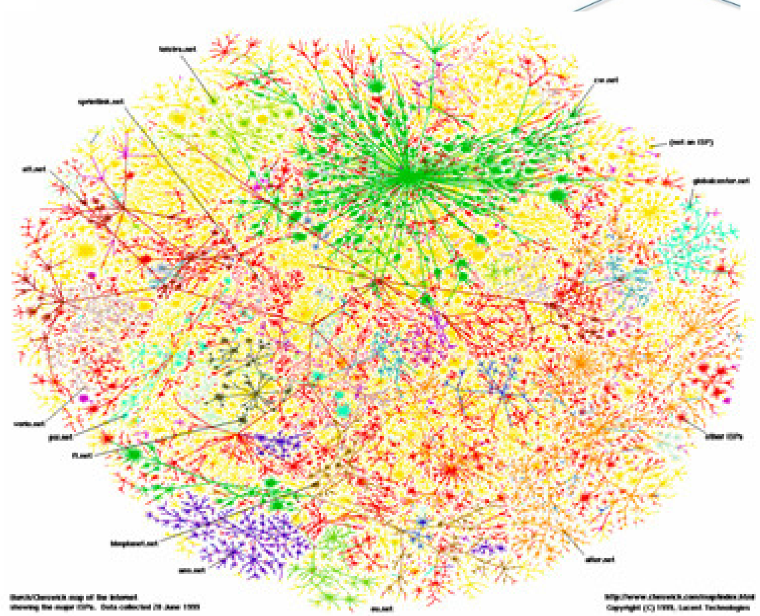


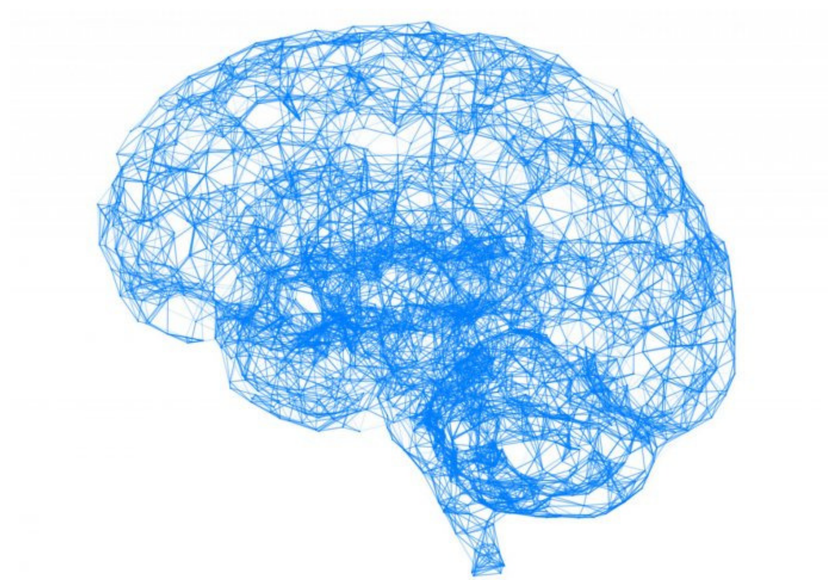
Ph.D. Study

- Provide theoretical foundation for worm propagation
  - Mathematical framework and models
    - Analytical active worm propagation (AAWP) model
  - Optimal and suboptimal worm scanning methods
    - Importance scanning and self-learning worms
  - Information-theoretical view of worm propagation
    - Non-uniformity factor
  - Game theory between attackers and defenders
- Give practical implications for worm defense

Epidemic Spread in Complex Networks

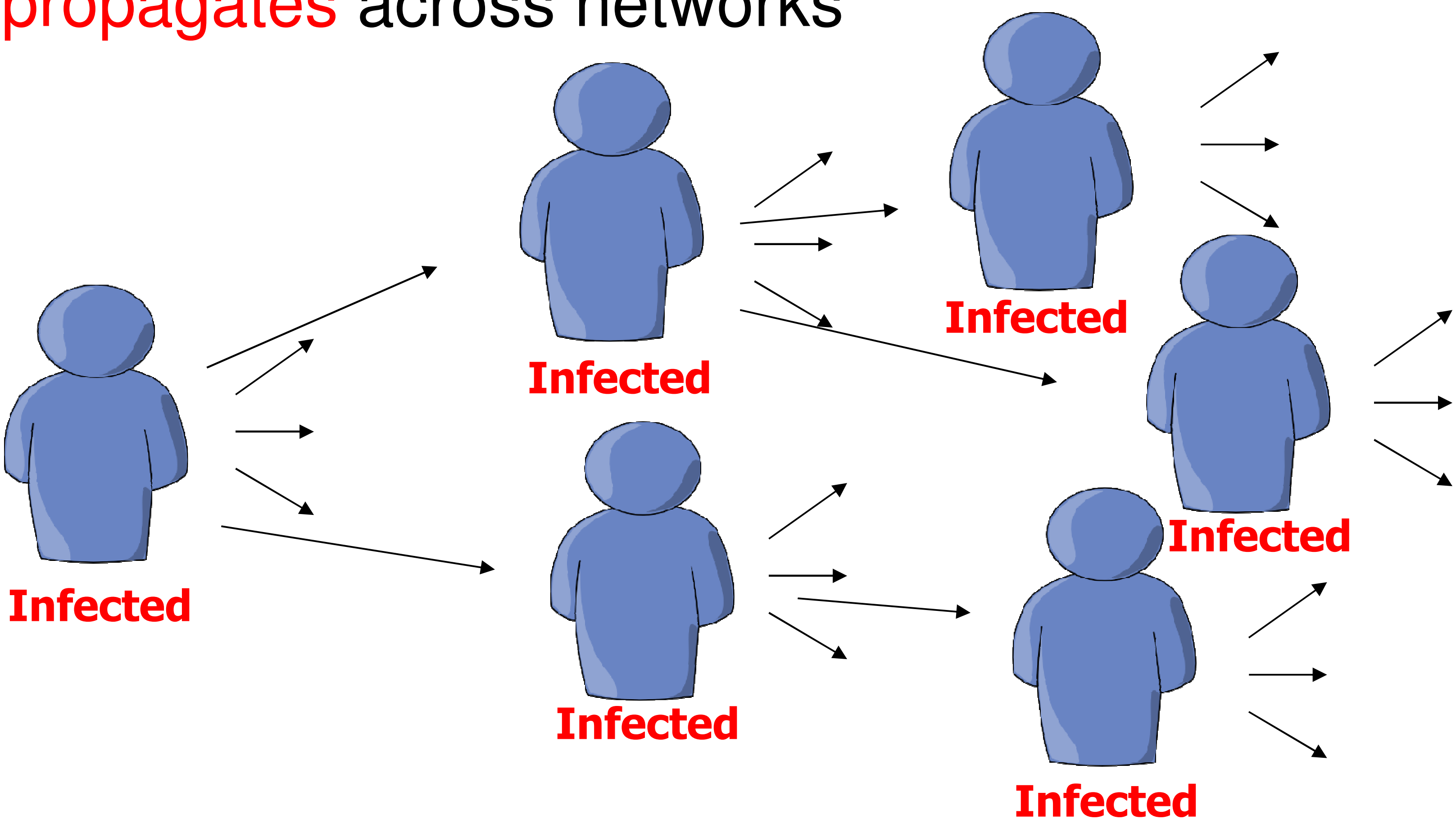




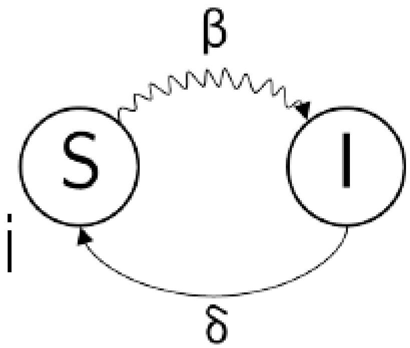


Epidemic Process

- Epidemic process is a process that information self-propagates across networks



Epidemic Thresholds



- Fundamental metric used to evaluate epi spread
- Condition on which an information will either die out or become epidemic
- In Susceptible-Infected-Susceptible (SIS) model
  - Birth rate
  - Death rate
  - Ratio between birth rate and death rate
    - β / δ > epidemic threshold, become epidemic
    - β / δ <= epidemic threshold, die out

State of the Art

$$\tau = \frac{\mathbf{1}}{\lambda_{\boldsymbol{max}}(\boldsymbol{A})}$$

- $\lambda_{max}(A)$ is the largest eigenvalue of the adjacency matrix A of the network

Assume that the states of nodes in the network are independent of each other!

Our Discovery

$$\tau_{c,ind} = \frac{1}{\lambda_{max}(A)}$$

↓

$$\tau_{c,mar} = \frac{1}{\lambda_{max}(A)(1-\rho)}$$

Mathematical Framework

- $X_i(t)$: status of node *i* at time *t*

$$X_i(t) = \begin{cases} 0, & if\ susceptible \\ 1, & if\ infected \end{cases}$$

$$\delta = P(X_i(t+1) = 0 \mid X_i(t) = 1)$$

$$I_i(t) = P(X_i(t+1) = 1 \mid X_i(t) = 0)$$

$$P(X_i(t+1) = 1) = P(X_i(t) = 1)(1 - \delta) + P(\,X_i(t) = 0)\,I_i(t)$$

Spatial Approximation

- Complex equation

$$P\left(X_{N_i}(t) = x_{N_i}(t) \,\middle|\, X_i(t) = 0\right)$$

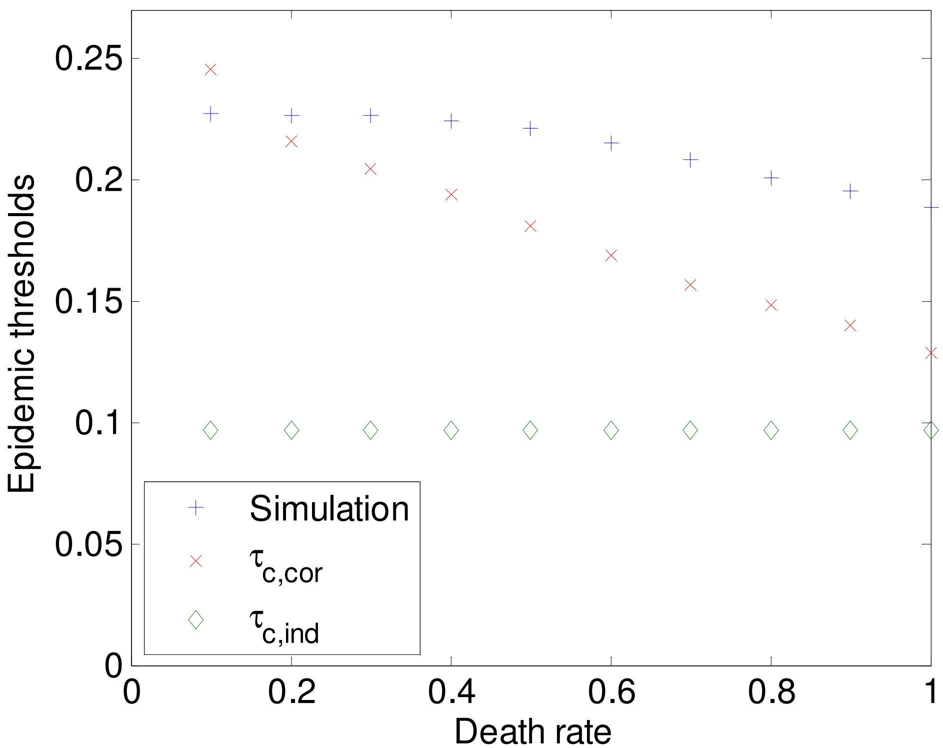
- Independent model
  - Spatial independence

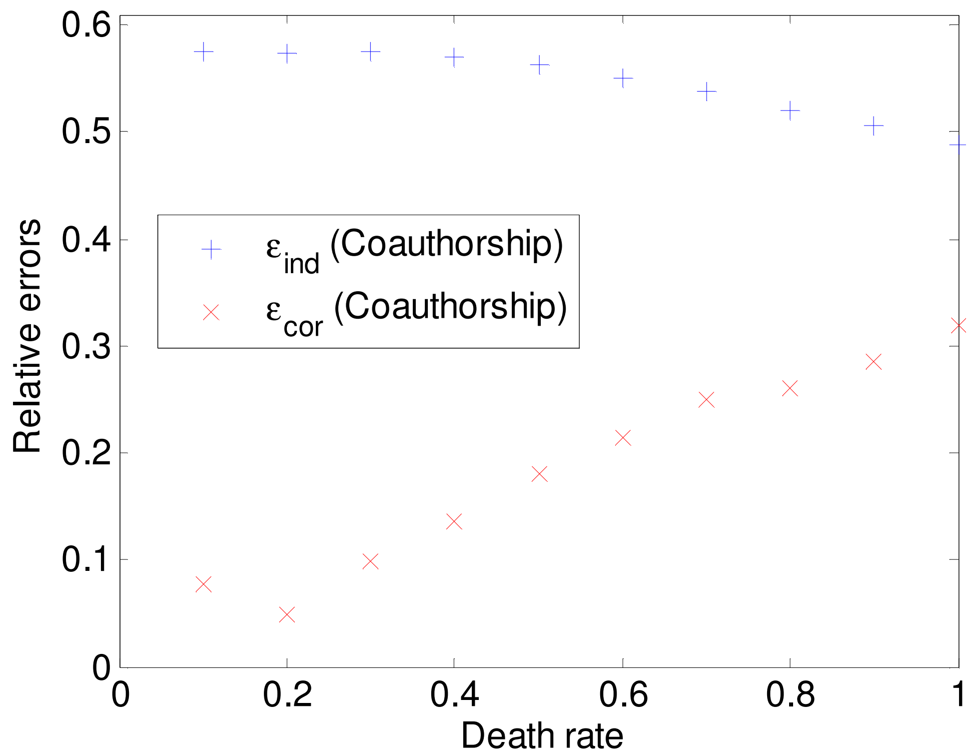
$$P\left(X_{N_i}(t) = x_{N_i}(t) \,\middle|\, X_i(t) = 0\right) = \prod_{j \in N_i} P(X_j(t) = x_j(t))$$

- Markov model
  - Conditional independence
  - Certain spatial dependence

$$P\left(X_{N_i}(t) = x_{N_i}(t) \,\middle|\, X_i(t) = 0\right) = \prod_{j \in N_i} P\left(X_j(t) = x_j(t) \,\middle|\, X_i(t) = 0\right)$$

Performance Evaluation (Coauthorship Network)





Birth Rates and Death Rates

- The actual birth/infection rates and death/recovery rates are heterogeneous

$$\beta \rightarrow \beta_{ij}$$

$$\delta \rightarrow \delta_i$$

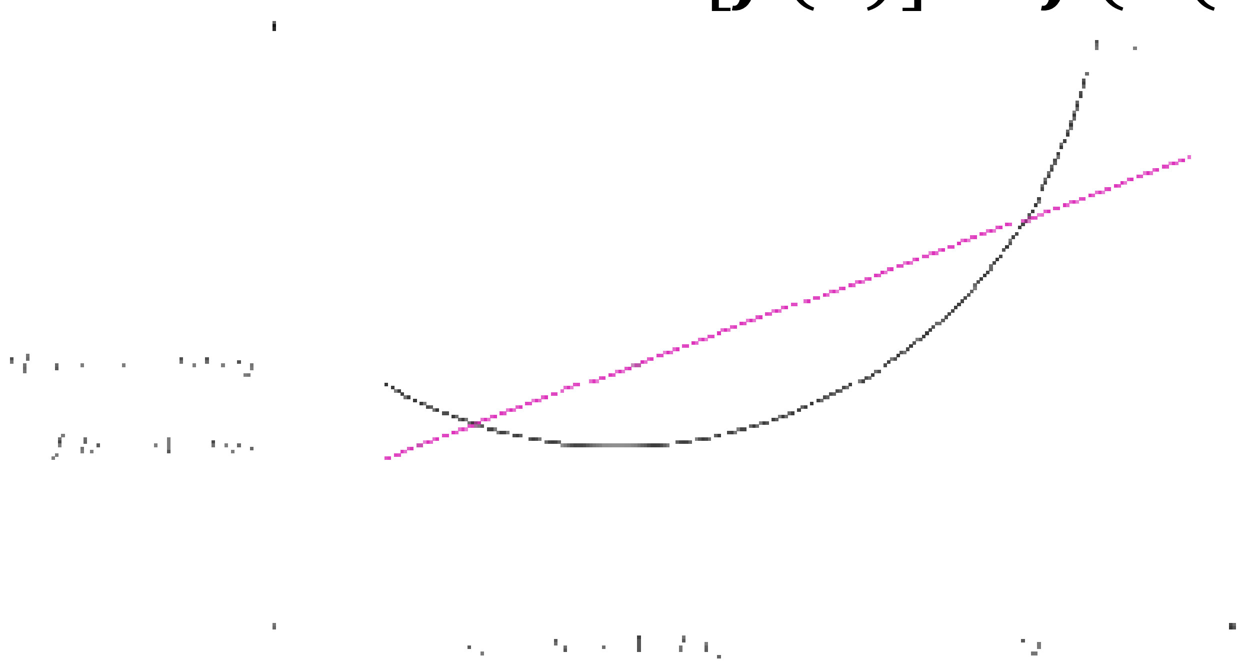
- Compared with the homogeneous case, how do heterogeneous infection rates and recovery rates affect epidemic thresholds?

Intuition

$$E[f(x)] \neq f(E(x))$$

- Jensen's inequality
  - If *f(x)* is a convex function

$$E[f(x)] \geq f(E(x))$$

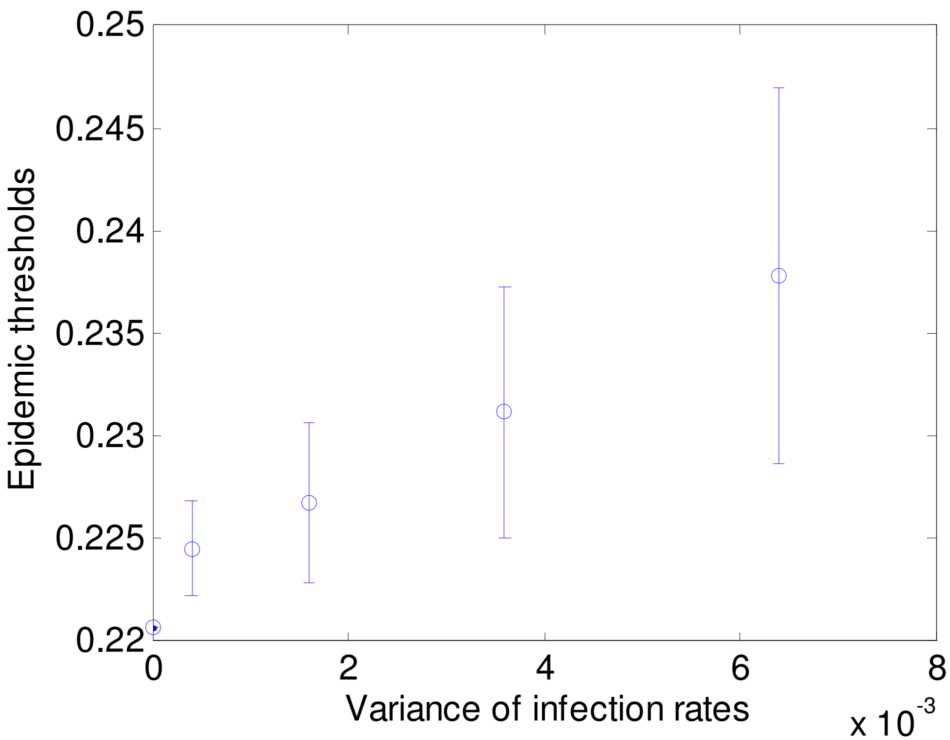


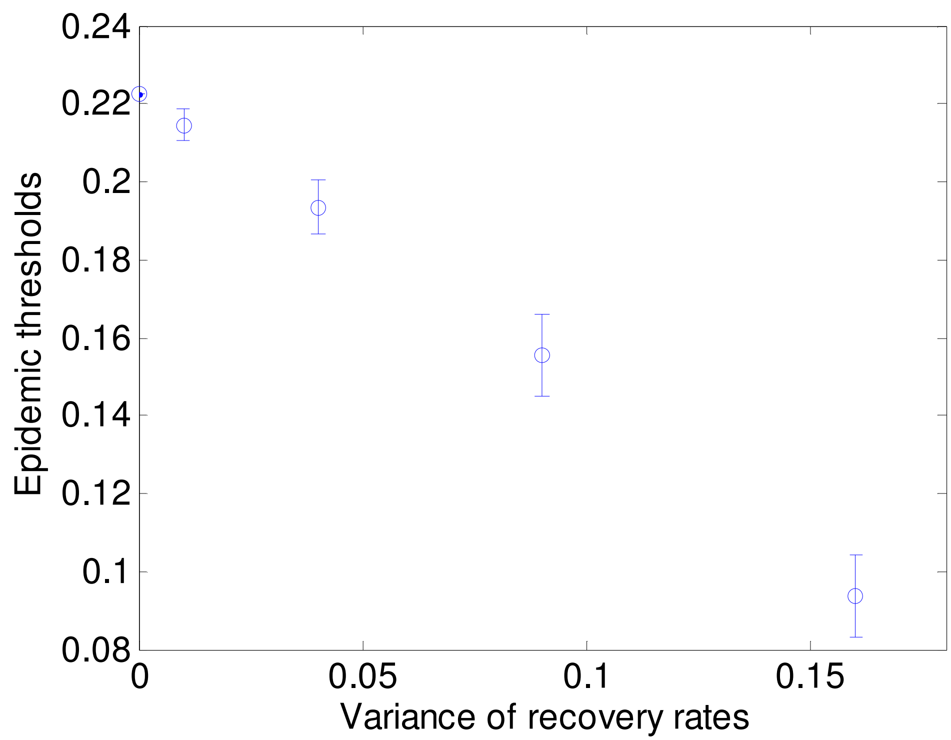
From: Wikipedia page of Jensen's inequality

Our Discovery

- The heterogeneity in infection rates leads to a larger epidemic threshold than in the homogeneous case
  - Moreover, as the degree of the heterogeneity of infection rates gets higher, the epidemic threshold increases
- The heterogeneity in recovery rates generates a smaller epidemic threshold than in the homogeneous case
  - The epidemic threshold decreases as the degree of the heterogeneity of recovery rates gets higher

Performance Evaluation (Coauthorship Network)





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- Internet of Things and Its Applications
- Impact of My Research

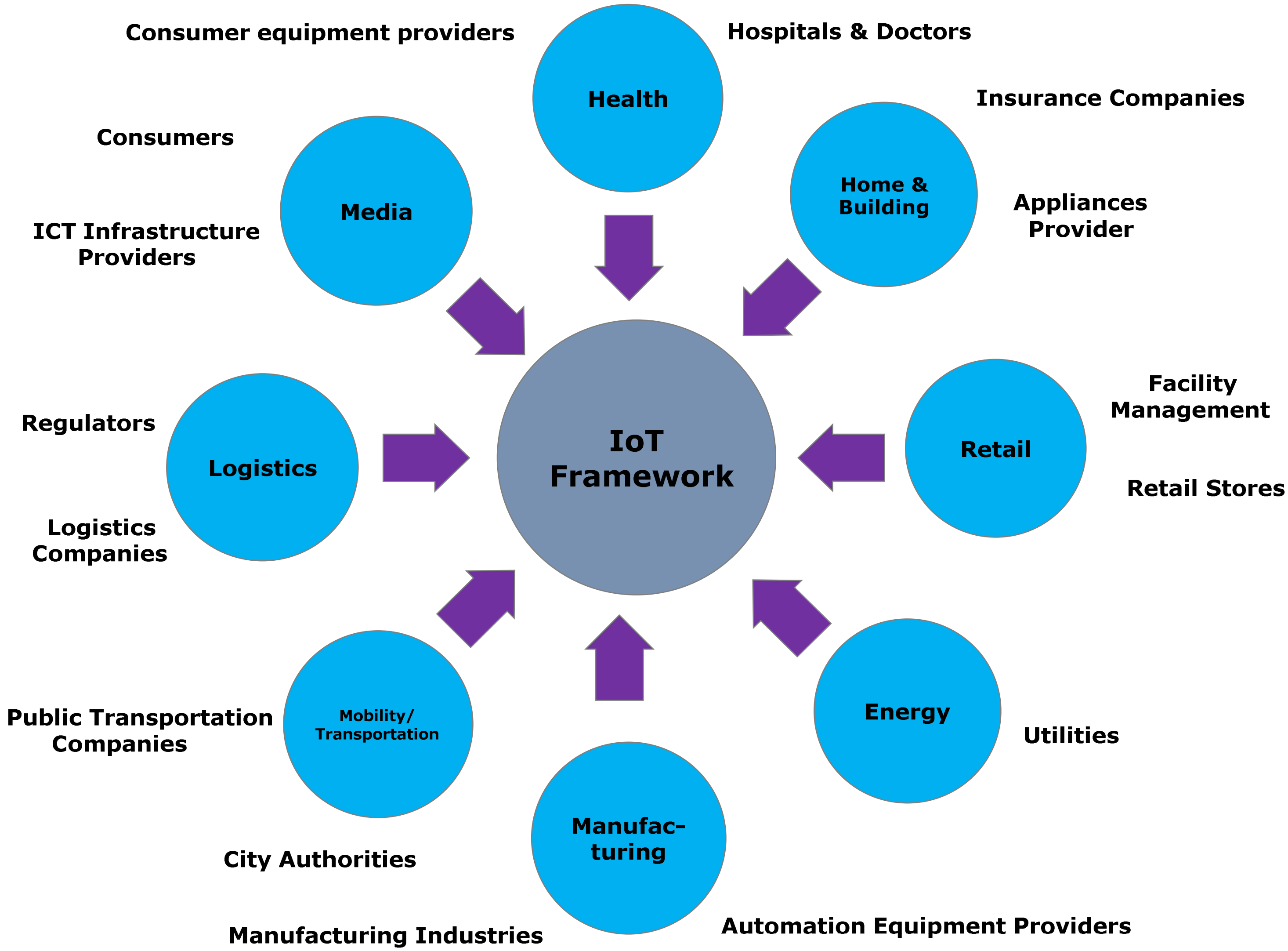
Internet of Things (IoT)

- IoT is not a second Internet.
- "A network of items – each embedded with sensors – which are connected to the Internet."

  – *IEEE Institute*

- By 2020, there will be around 30 billion devices connected to the Internet.
- The IoT's true value lies in the data that interconnected items share.

IoT Applications (From *IEEE Institute*)



My Approach and Focus

Smart Home

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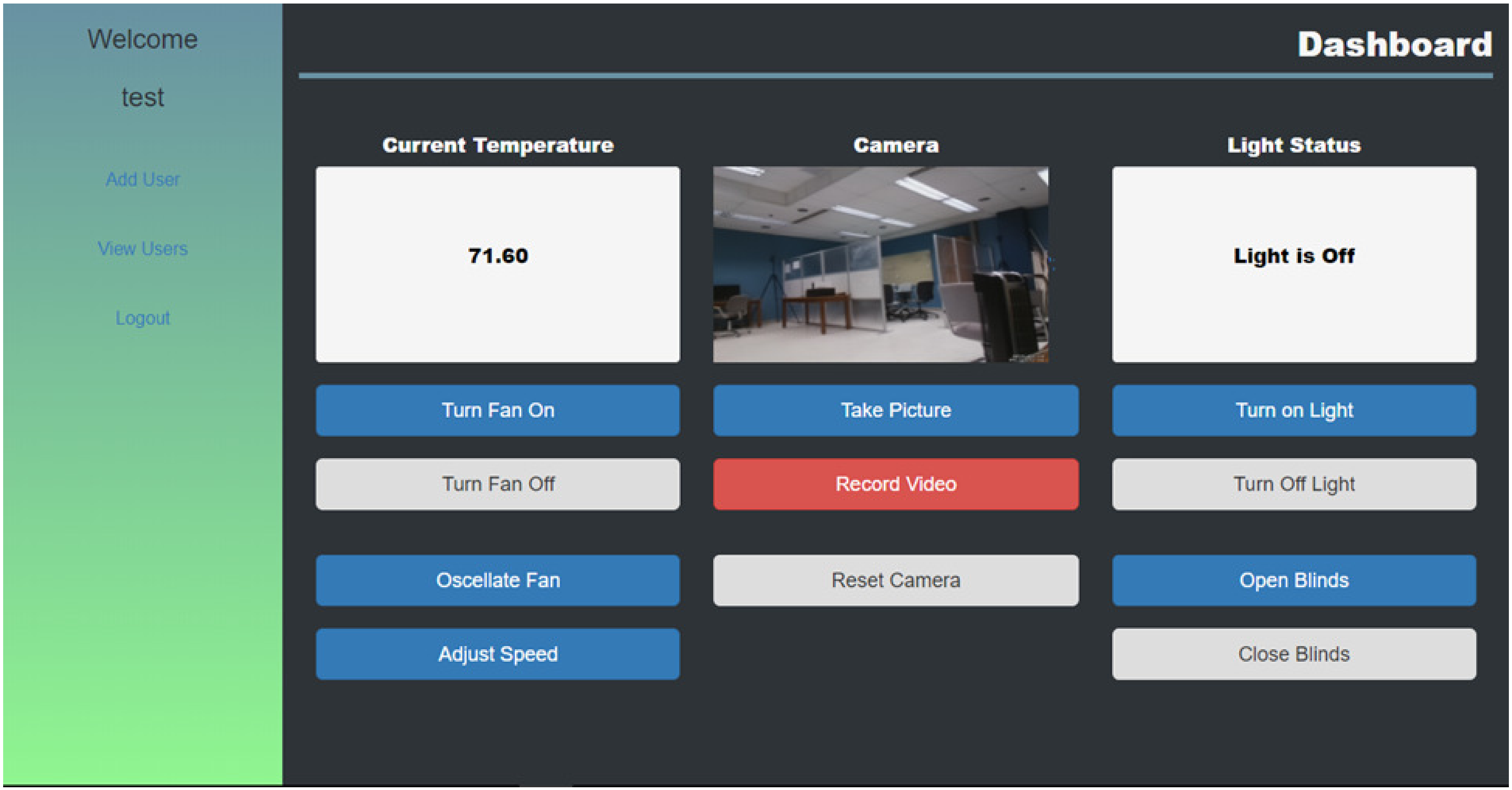
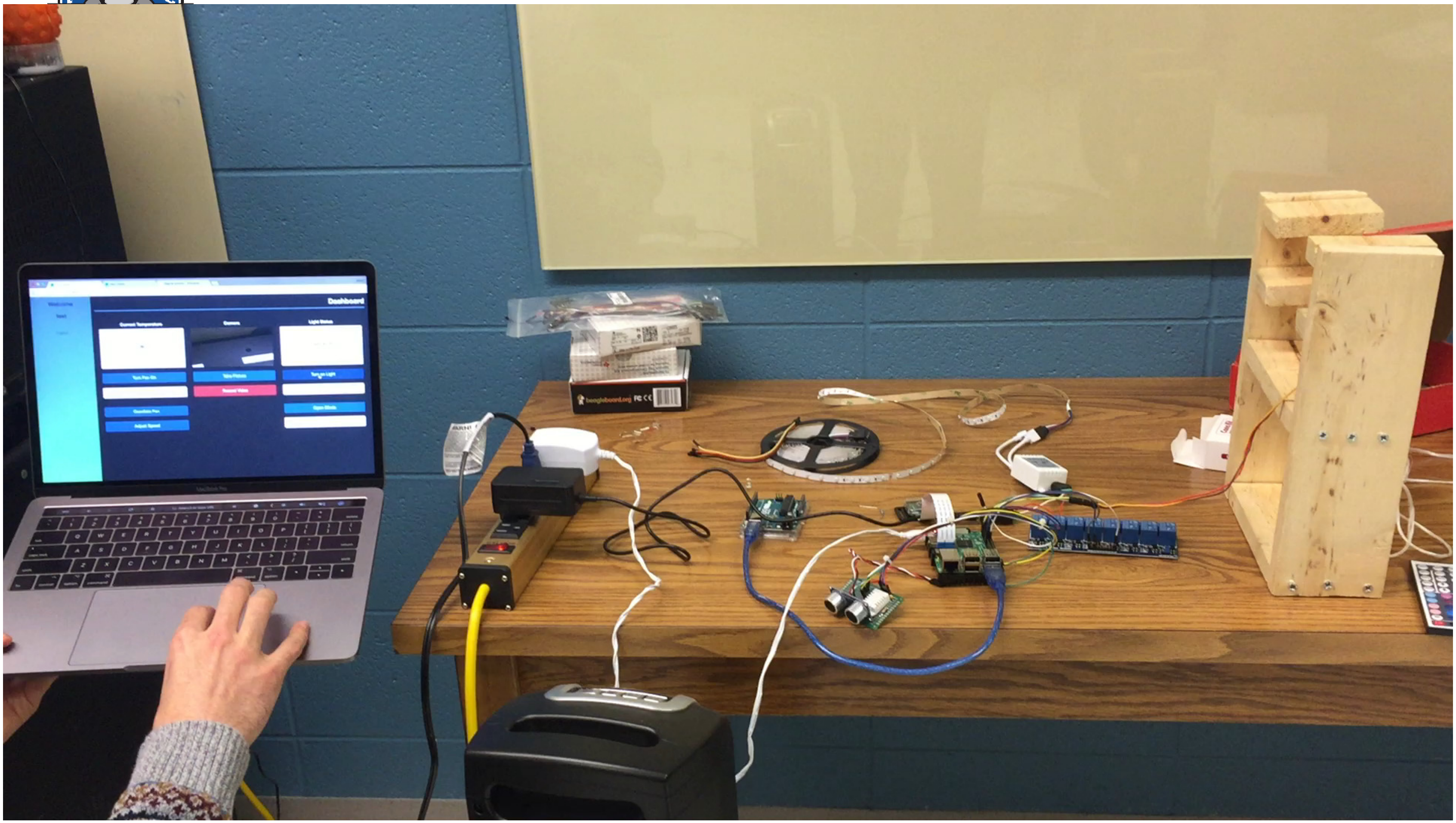
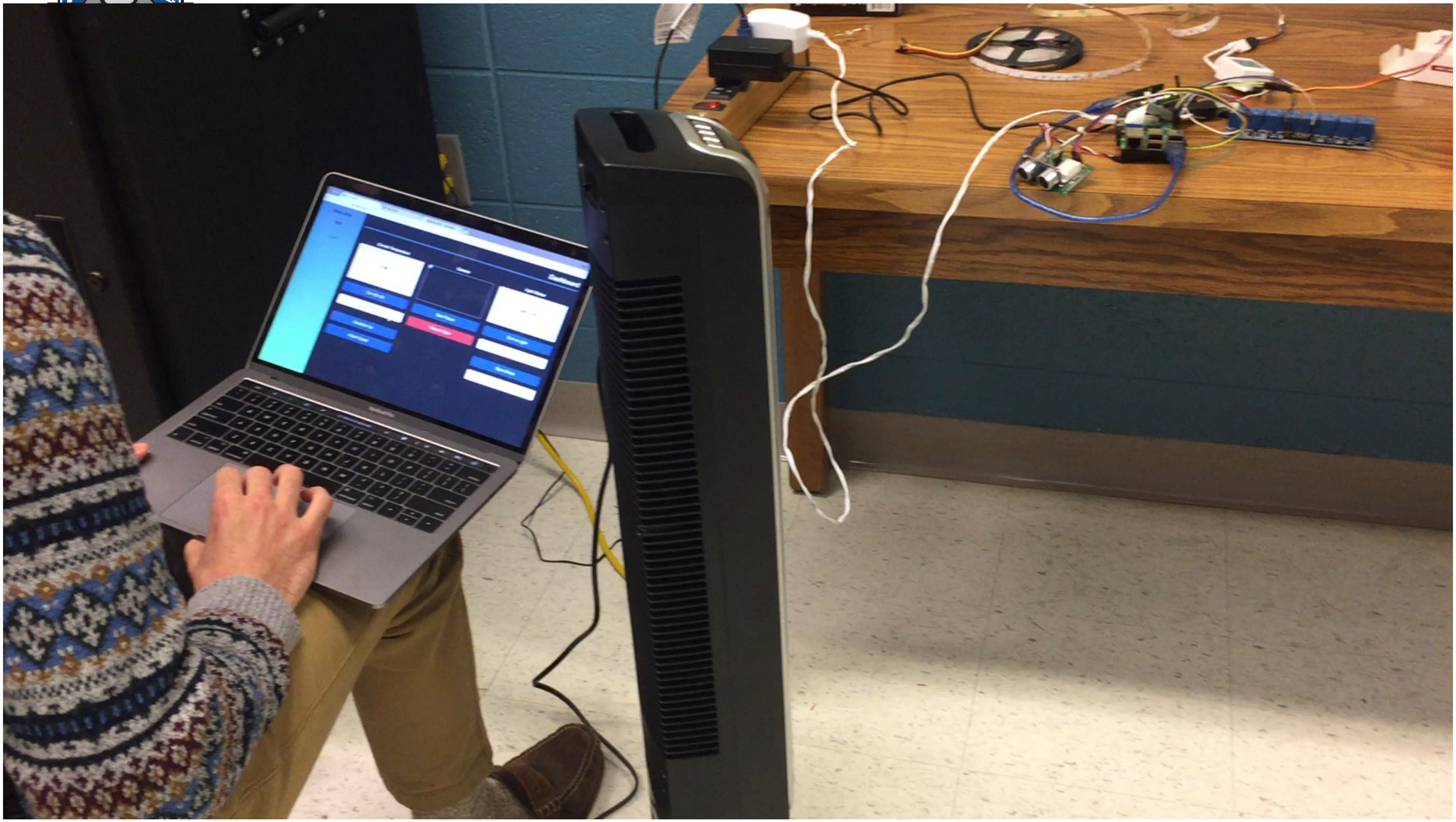
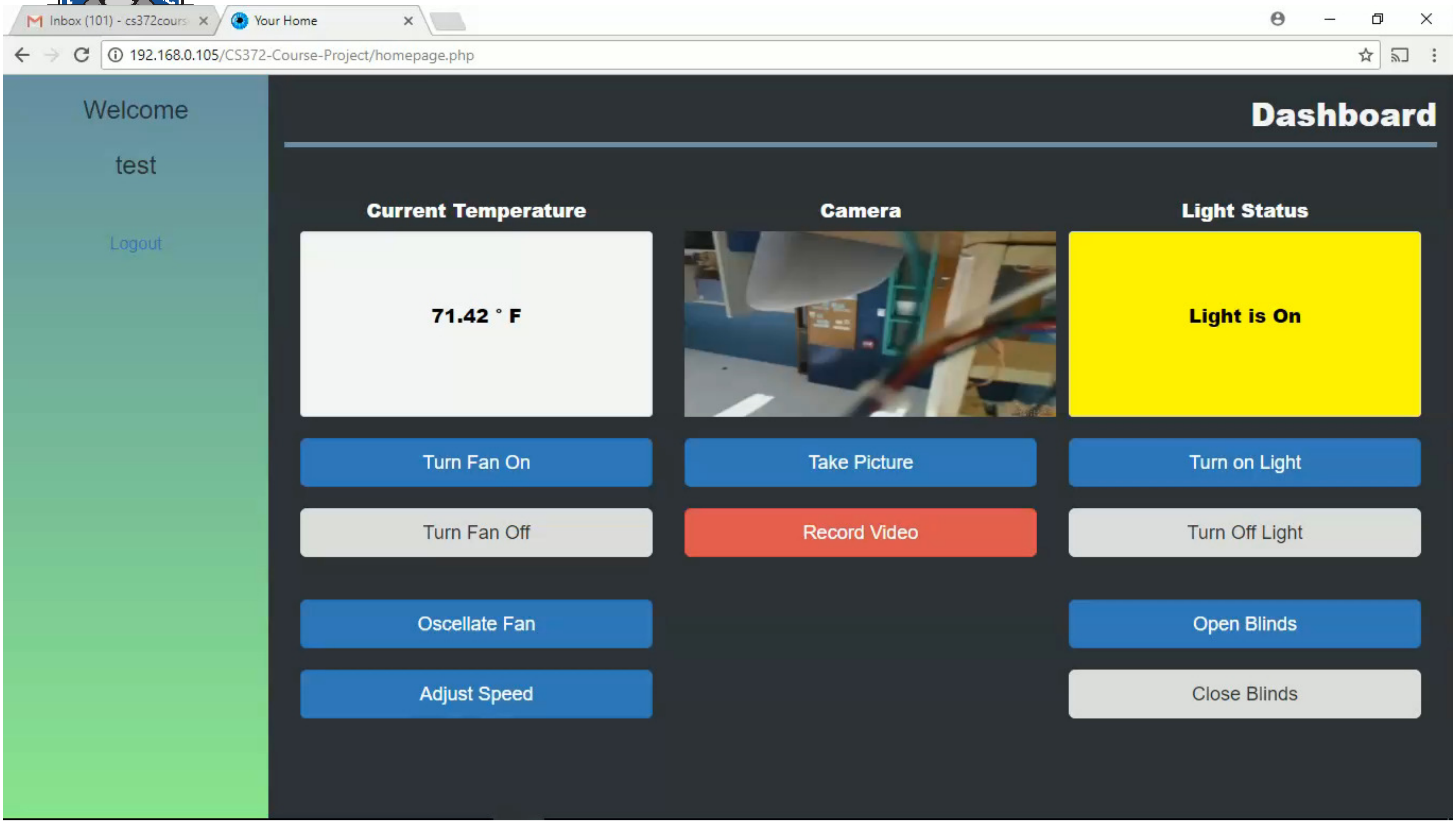




Dashboard




Inbox (101) - cs372cours
Your Home
192.168.0.105/CS372-Course-Project/homepage.php
Welcome
test
Logout
Dashboard
Current Temperature
71.42 ° F
Camera
Light Status
Light is On
Turn Fan On
Take Picture
Turn on Light
Turn Fan Off
Record Video
Turn Off Light
Oscellate Fan
Open Blinds
Adjust Speed
Close Blinds

Building an Affordable Smart Home Based on the Internet of Things

INDIANA UNIVERSITY
PURDUE UNIVERSITY
FORT WAYNE

Urvi Joshi, Aaron Dills, Eric Biazo, Cameron Cook
Department of Computer Science

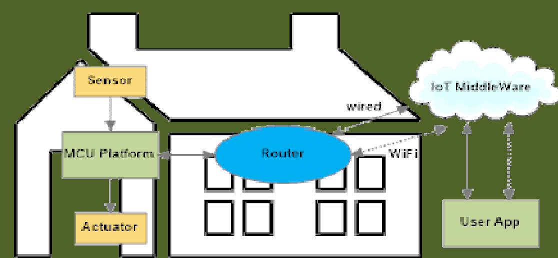
Introduction

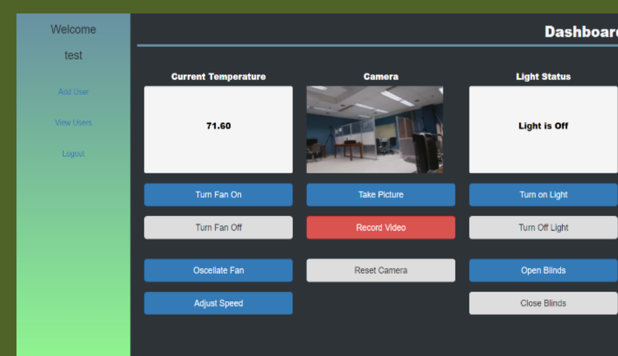
The Internet of Things (IoT) is made up of multiple Internet-connected devices with sensors. A smart home is one where you can control household devices remotely.

There are currently several smart home systems on the market. Some of the more popular ones include Google Home and Amazon Echo. However, both these systems are very expensive and only control devices that are compatible with them. For someone wanting to keep costs low and control devices they already have, Google Home and Amazon Echo are not practical options.

Our team has created a low cost smart home system which interfaces with devices people already have. Our system can turn on and off lights and fans, open and close blinds, and take pictures and videos from a security camera. A user can interact with our system using a web application that we developed.

Design





Contribution

The main contribution of this research is to build a basic, affordable smart home system that, with a few modifications, can be used with most lights, blinds, and fans already in many homes, based on the technologies of the IoT. It also serves as a starting point for a more advanced system that controls more devices and provides more security alerts.

Design Components

The MCU platform used is a Raspberry Pi 3 Model B, which hosts a website and interfaces with sensors and actuators. The sensors include a temperature sensor and a security camera. The actuators are lights, blinds, and a fan. To obtain the high quality live camera feed, we use another dedicated Raspberry Pi to collect camera data. An Arduino interfaces with the fan The user application is a web browser in the user's smart phone, tablet, or computer. A user can view the data from sensors and control the actuators through the web browser. For example, when a user clicks a button (e.g., "Turn on Light") in the web page, the request is sent to the MCU (i.e., Raspberry Pi), and the MCU interfaces with an actuator (e.g., light) to carry out the user's request.

Acknowledgements

Project Advisor: Dr. Zesheng Chen
Project Sponsor: Dr. Guoping Wang

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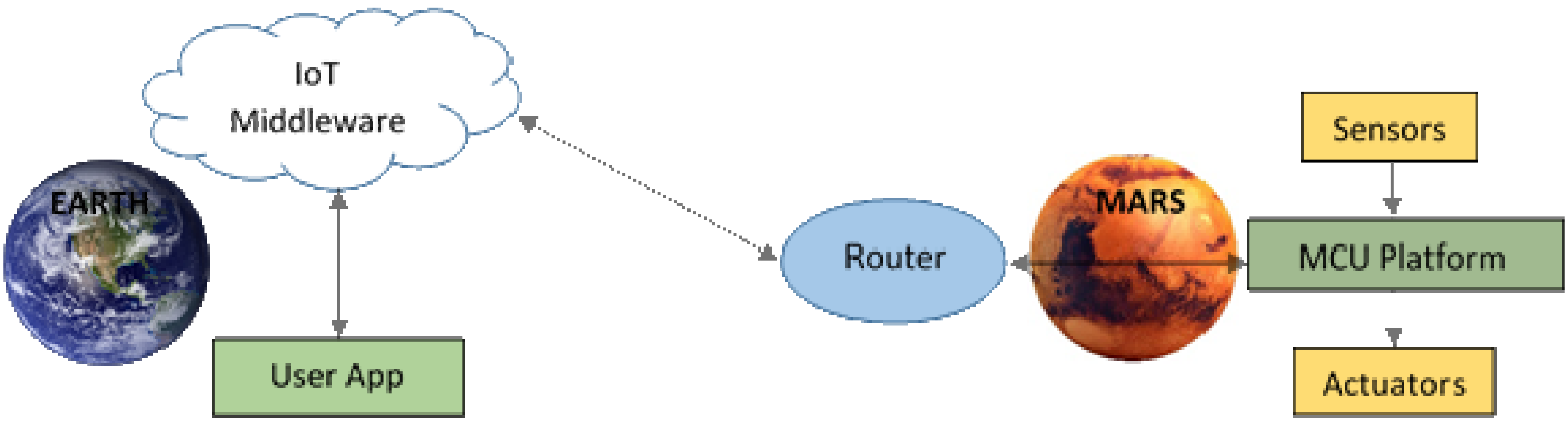
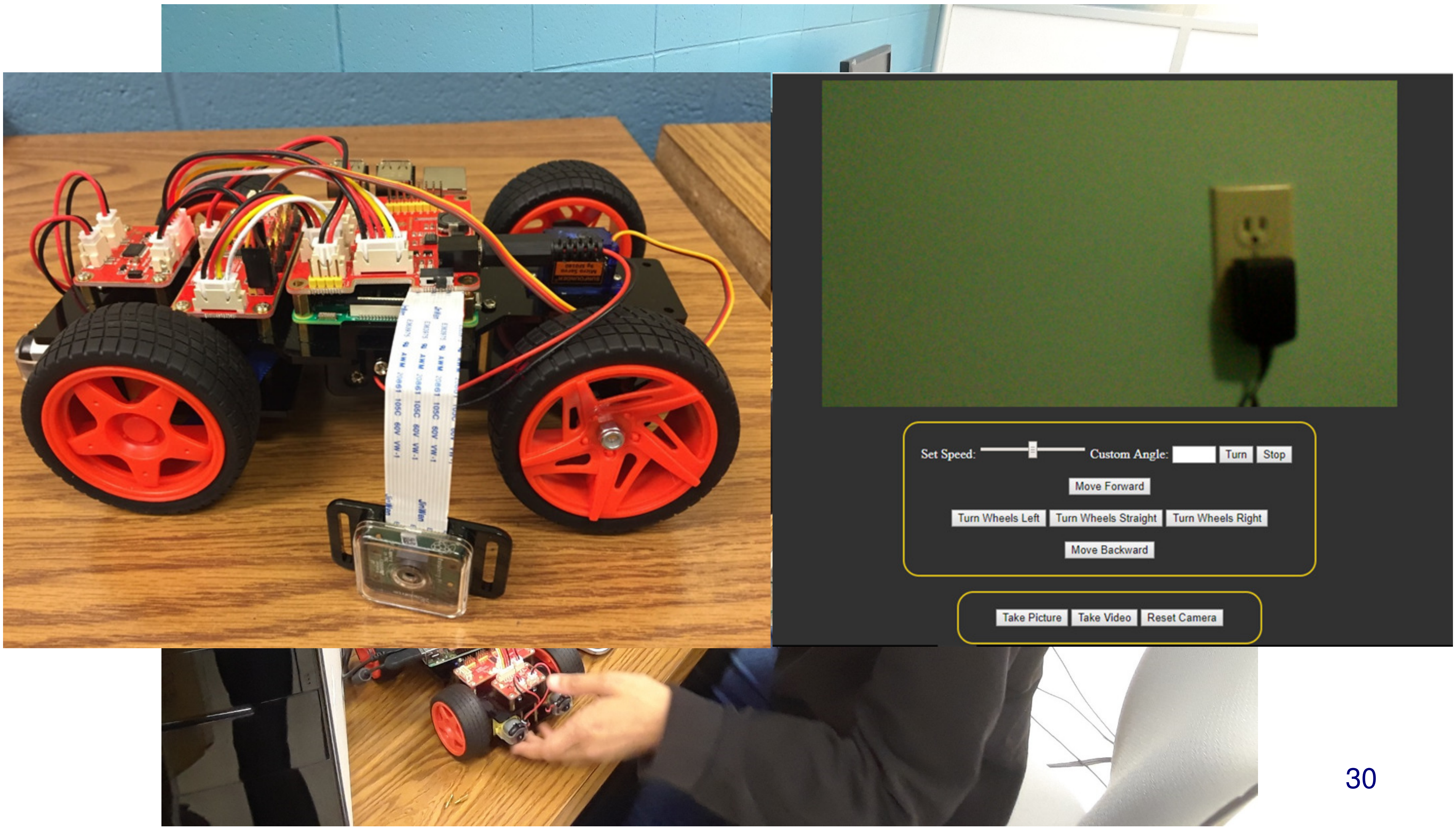
IoT in Space

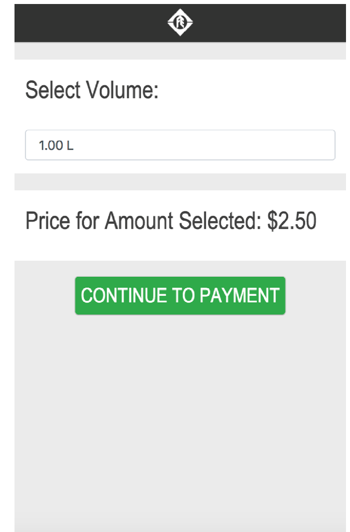


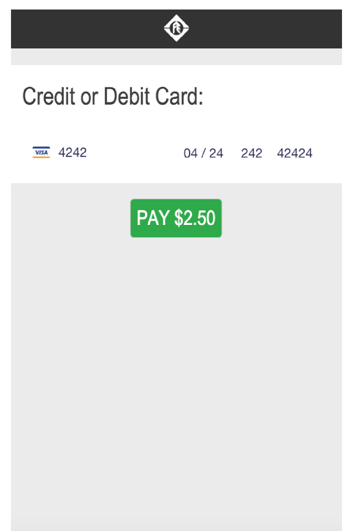
IoT
Middleware
EARTH
User App
Router
MARS
Sensors
MCU Platform
Actuators

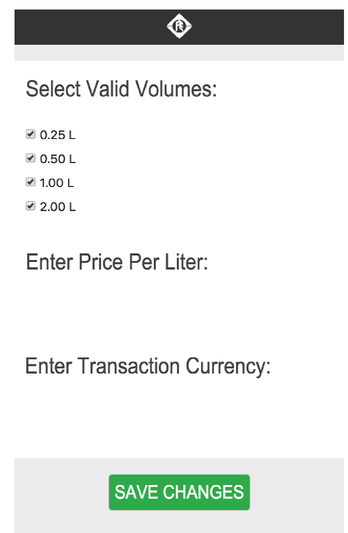
Testbed


Set Speed:
Custom Angle:
Turn
Stop
Move Forward
Turn Wheels Left
Turn Wheels Straight
Turn Wheels Right
Move Backward
Take Picture
Take Video
Reset Camera

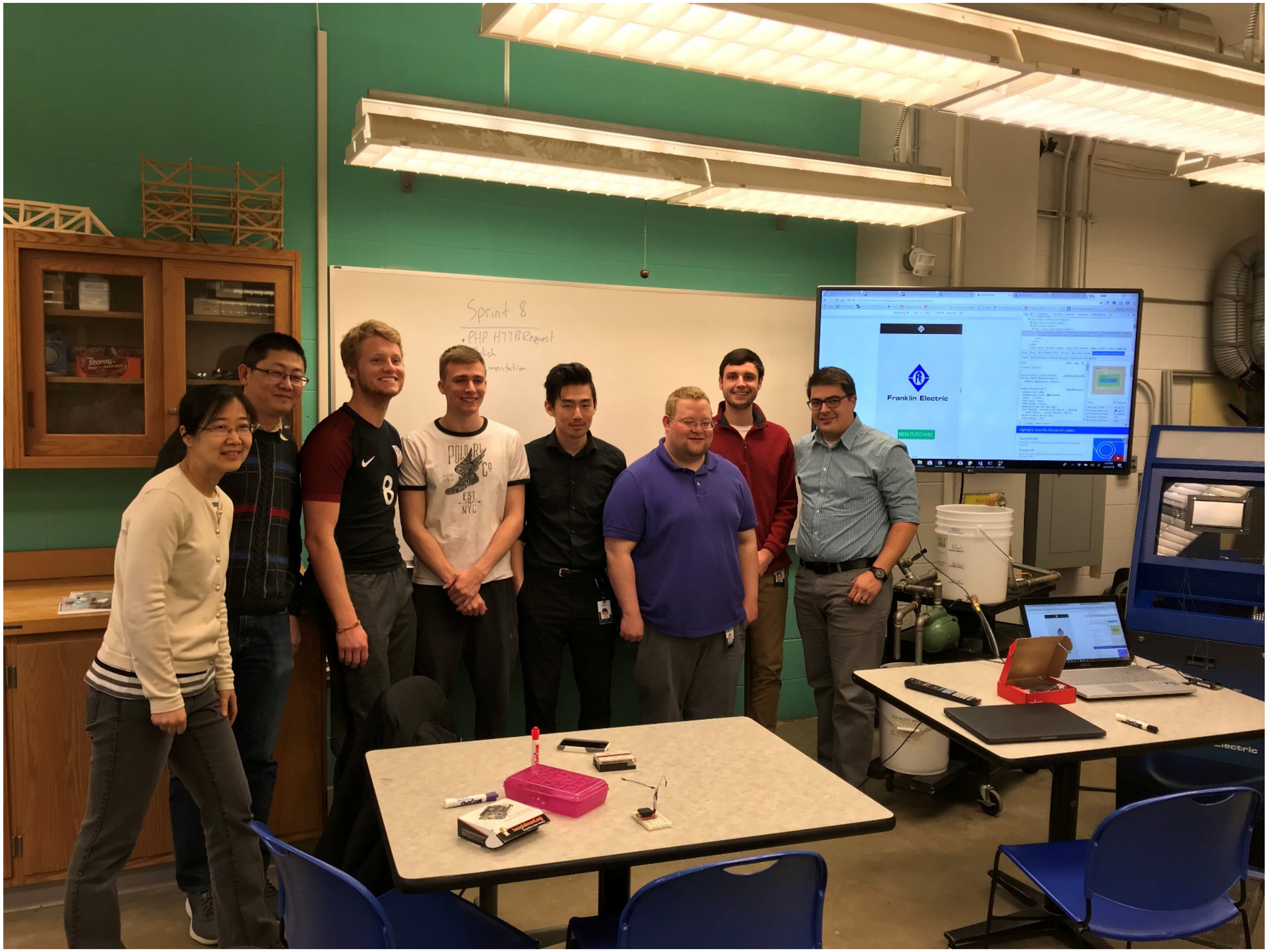
Senior Design Projects



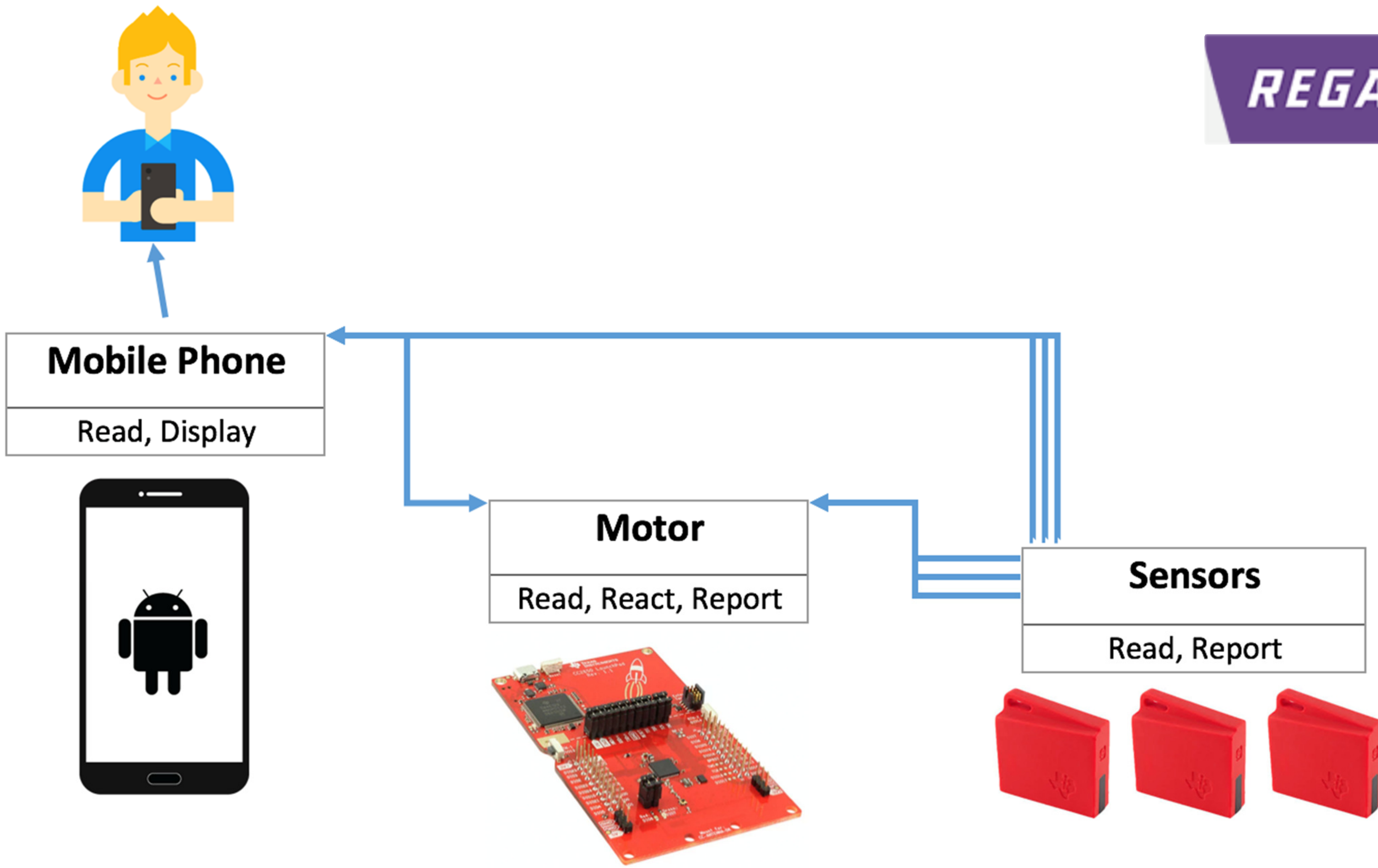




Senior Design Projects (Cont.)



Senior Design Projects (Cont.)



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Funding Agencies

Indiana Space Grant Consortium — INSGC — Inspire ★ Engage ★ Educate ★ Employ

N-MaC — Indiana Next Generation Manufacturing Competitiveness Center

IEEE — Advancing Technology for Humanity

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Computer Networks   Performance Evaluation

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TITLE	CITED BY	YEAR
Modeling the spread of active worms Z Chen, L Gao, K Kwiat INFOCOM 2003. Twenty-Second Annual Joint Conference of the IEEE Computer and …	675	2003
Spatial-temporal modeling of malware propagation in networks Z Chen, C Ji IEEE Transactions on Neural Networks 16 (5), 1291-1303	118	2005
Modeling primary user emulation attacks and defenses in cognitive radio networks Z Chen, T Cooklev, C Chen, C Pomalaza-Ráez Performance Computing and Communications Conference (IPCCC), 2009 IEEE	101	2009

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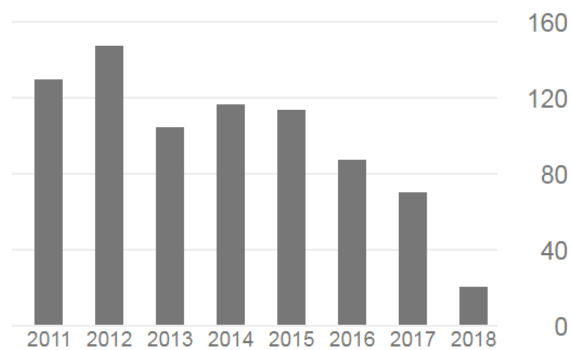

Thanks For Your Attention