IOWA STATE UNIVERSITY

IRP Meeting

Magic Door Sensor

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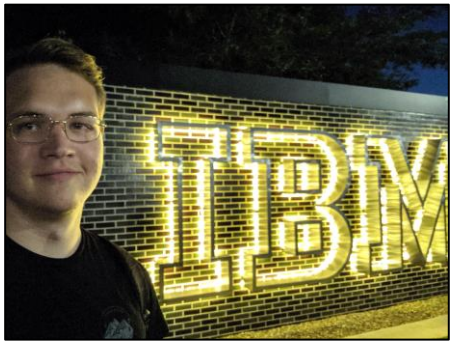
Meet the Team

Joseph Kueny



Collin Kauth-Fisher

Mitchell Bratina

Isaiah Exely-Schuman

Calvin Christensen

Problem Statement

The purpose of this project is to develop a wireless, low maintenance door sensor (no batteries or wired power).

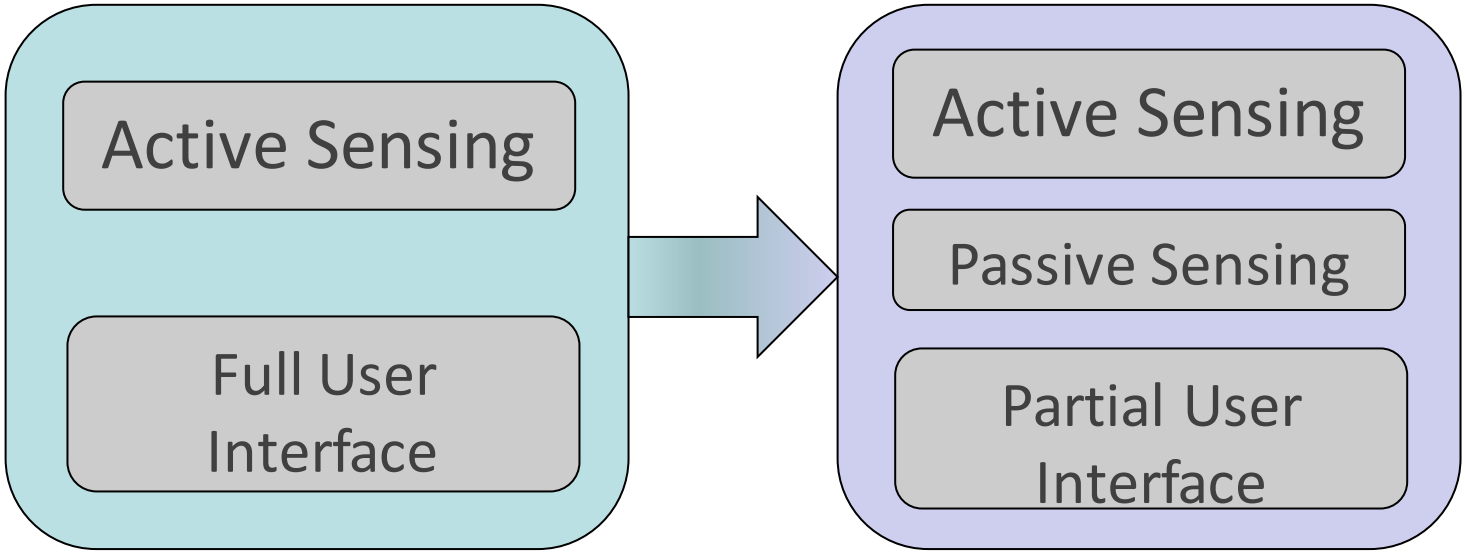
We intend to achieve this by utilizing machine learning to interpret Channel State Information (CSI) data passively while an active RF power-harvesting circuit sends out an event-triggered state update.

Outline

- **Project Focus Shift**
- Passive Sensing
  - Collection of CSI Frames
  - Metrics of the Models
  - Models We Tested
  - The Model We Chose
- Active Sensing
  - The ATTiny
  - Circuit Progression
  - Discoveries
- Bringing It Together

Project Focus Shift

To focus on safety of the team, we went entirely virtual starting April 2020.



Allowed for less physical interaction when less people are working on hardware.

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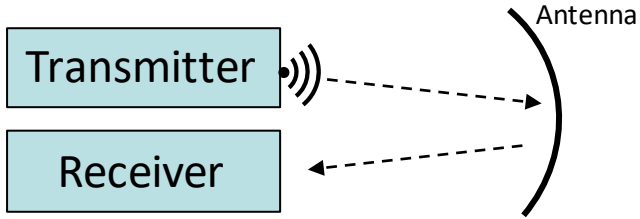
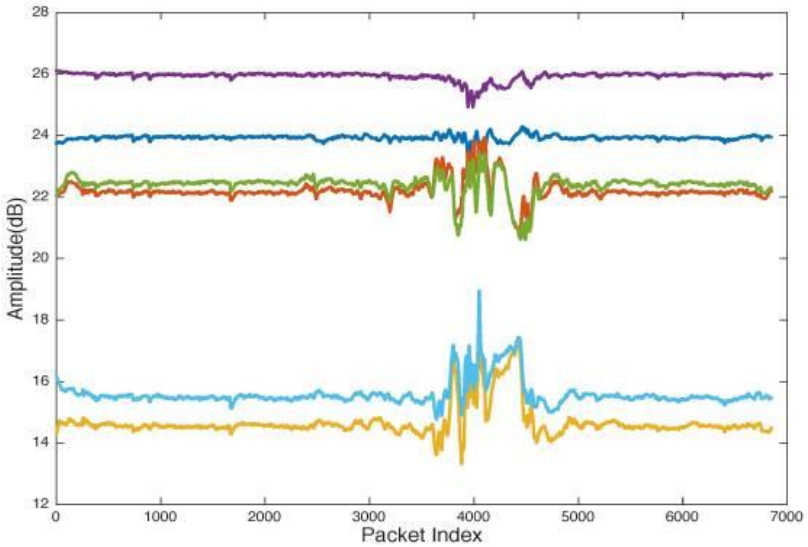
What is CSI?

- Channel State Information.
- A type of data that accompanies Wi-Fi packets.
- Used to make observations about the wave's path of travel.

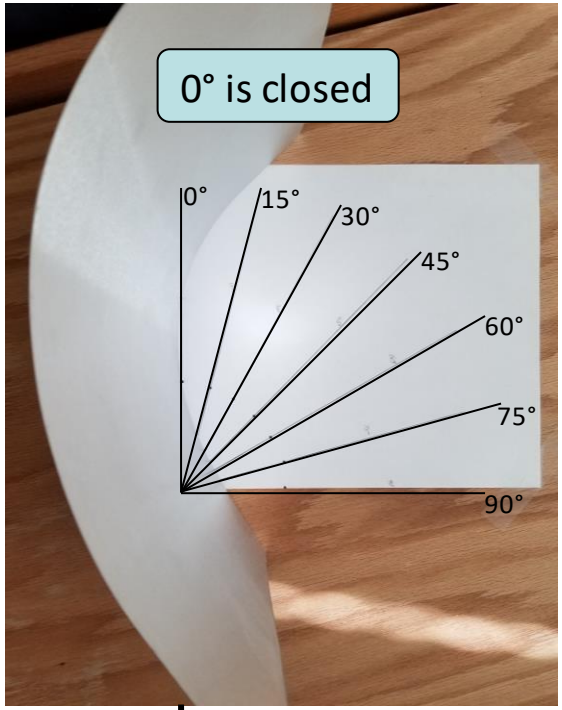


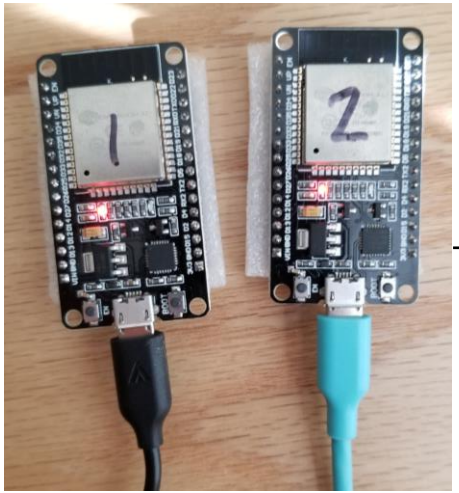


Collection of CSI Frames

- Raspberry Pi begins the collection through ESP32s.
  - Creates small caches of CSI frames.
- Each cache is dumped to the ML model.
  - Within the model the CSI frames are analyzed and classified.
  - The output is sent to the server for user distribution.

Collection of CSI Frames





Raspberry Pi

Metrics of the Models

Door Closed = 0	Predicted 0	Predicted 1
Actual 0	TN	FP
Actual 1	FN	TP

Metrics

- Accuracy
  - (TP + TN) / Total Predictions
- Precision
  - TP / (TP + False Positive)
- Recall
  - TP / (TP + False Negative)

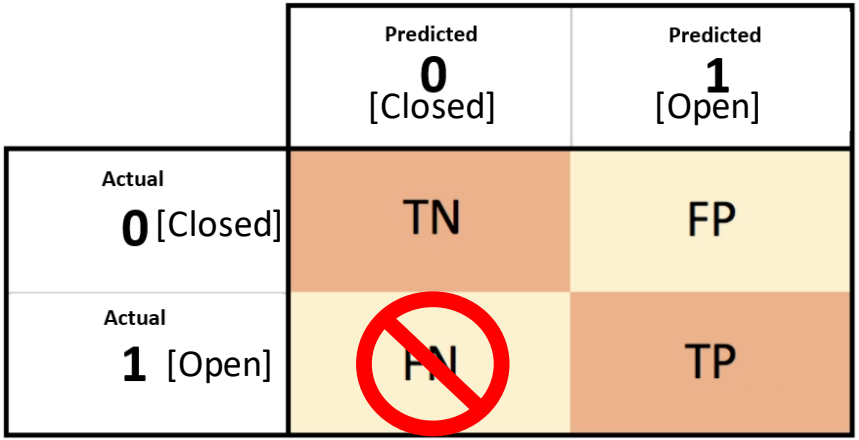
Our Use

- Accuracy
  - Measure of overall accuracy.
- Precision
  - How valid are the open-door state predictions?
- Recall
  - How often did we correctly predict an open-door state?

Metrics of the Models

Our Focus

- Keep accuracy high.
- Focus on minimizing False Negatives.
- Need to maximize the Recall score.
  - Minimizing False Negatives.
- It would be worse for a door to be open and un-reported.



Models We Tested

Methods Tested

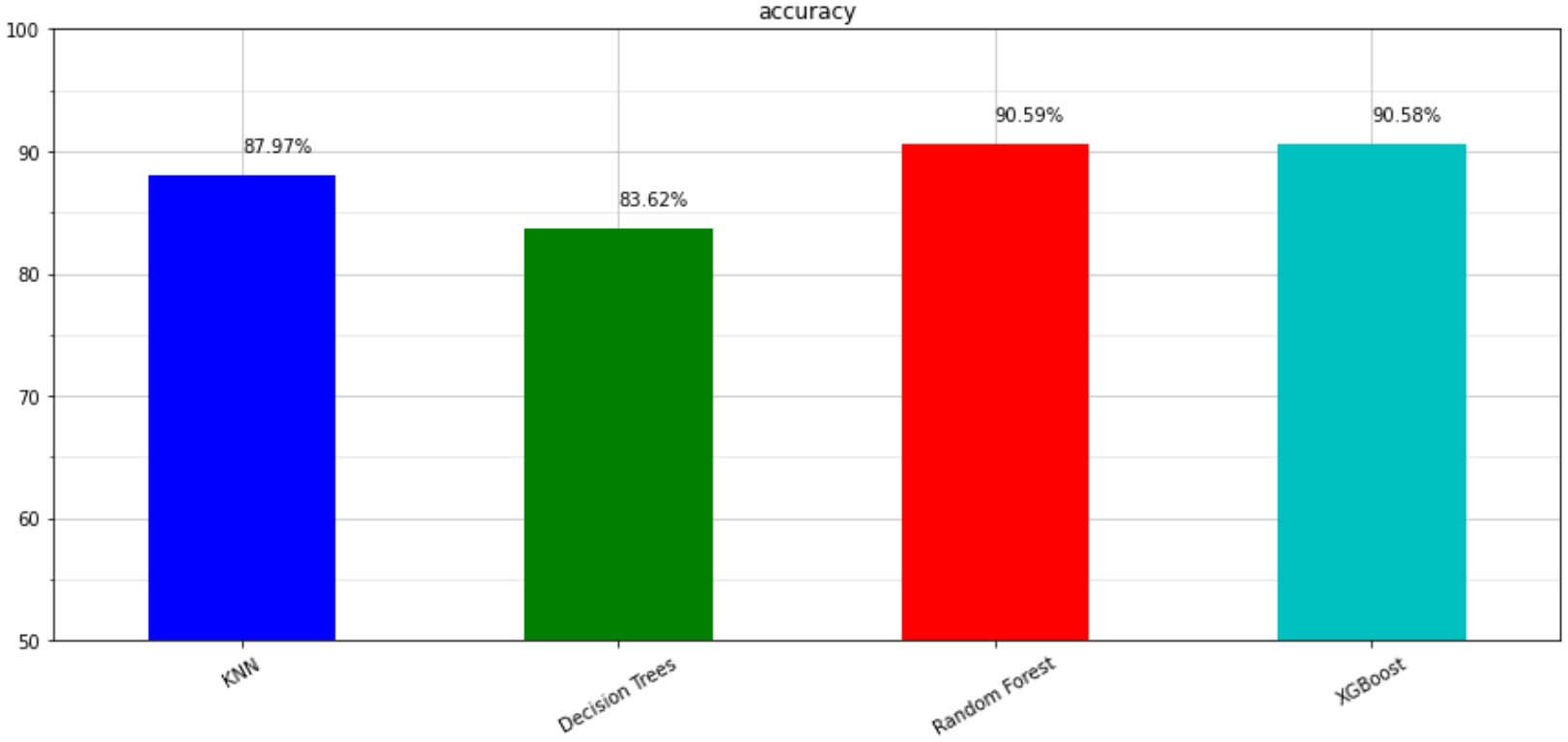
- KNN (Uniform & Weighted)
- SVC
- Decision Trees
- Random Forest
- XGBoost
- Neural Network

Models We Tested

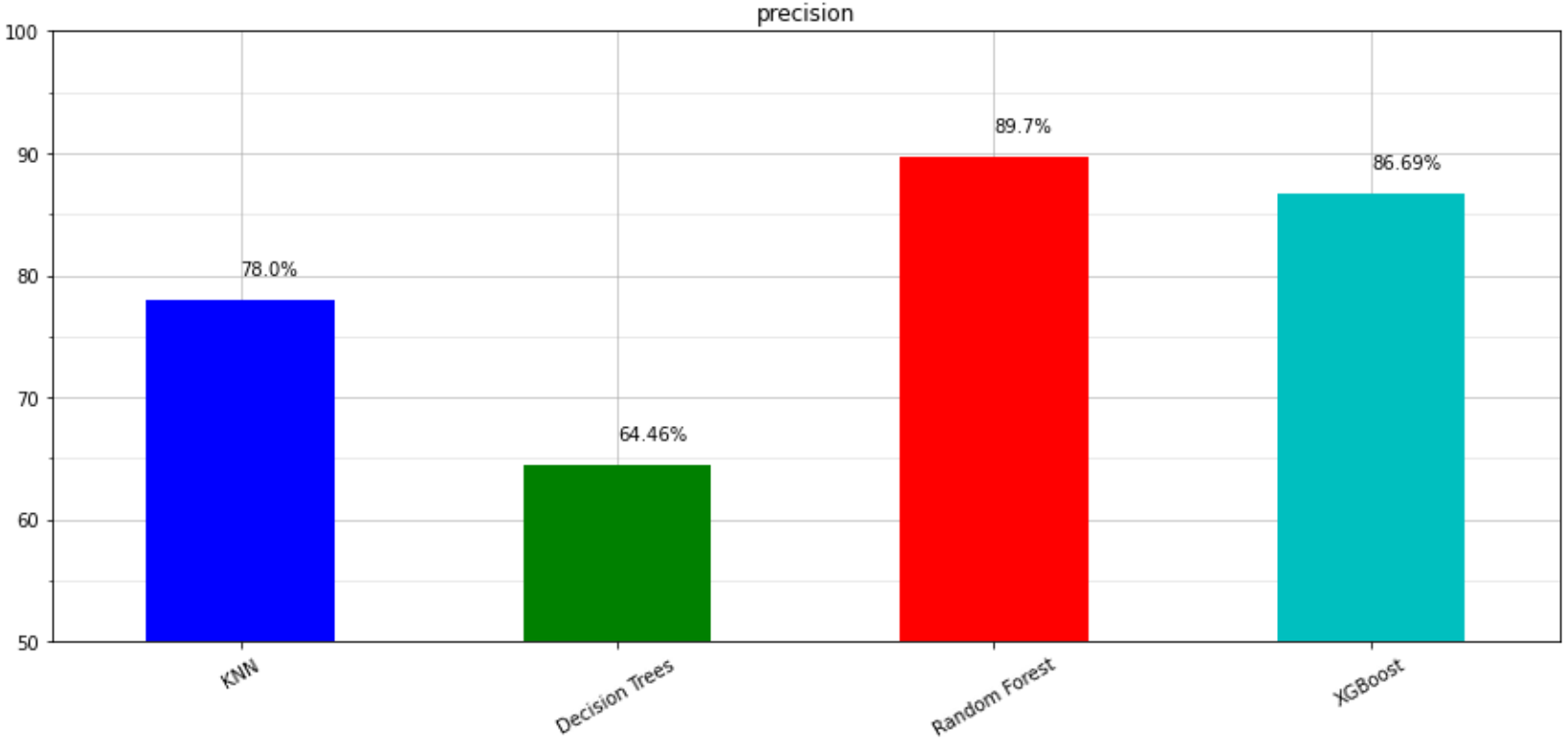
KNN (Uniform) Stats

- Deciding between:
  - 0° and 90° >99% Accuracy Score
  - 0° and 90° (15° incr.) ~40% Accuracy Score
  - 0° and not 0° >80% Accuracy Score

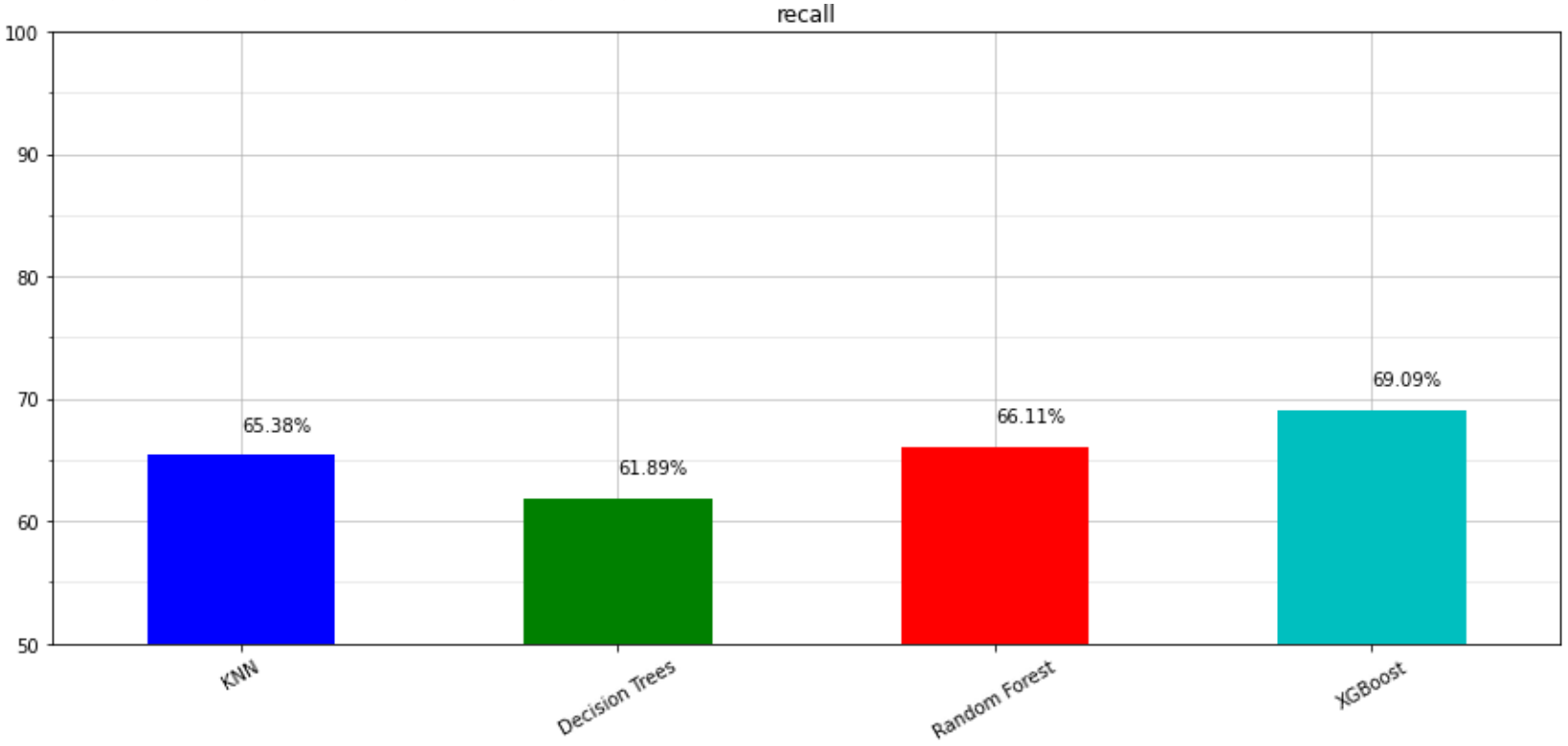
Models We Tested



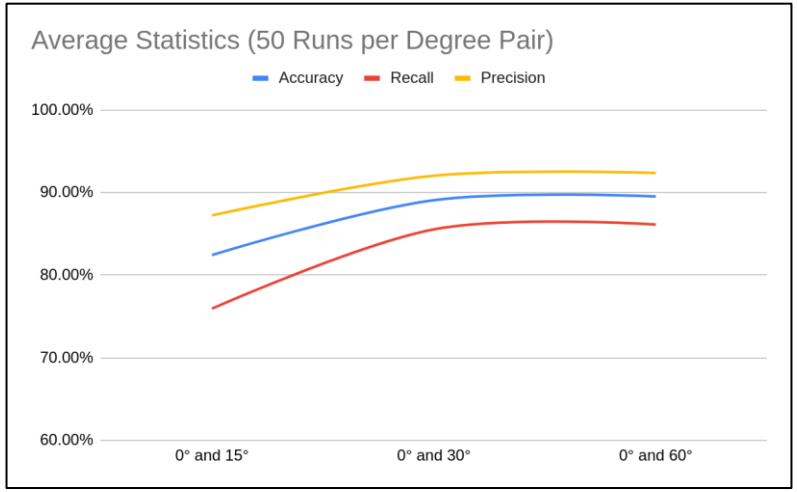
Models We Tested



Models We Tested



The Model We Chose



Random Forest Testing

- Same data used as KNN [0° and not 0°]
- Testing data for 50 runs:
  - Mean Accuracy: 89.79%
  - Variance: < 0.000852%
  - Maximum Accuracy: 90.36%
  - Minimum Accuracy: 89.19%
- Training and testing data points were randomized for each run.

- Big jump in accuracy from KNN
  - From ~80% to ~90%

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  - Discoveries
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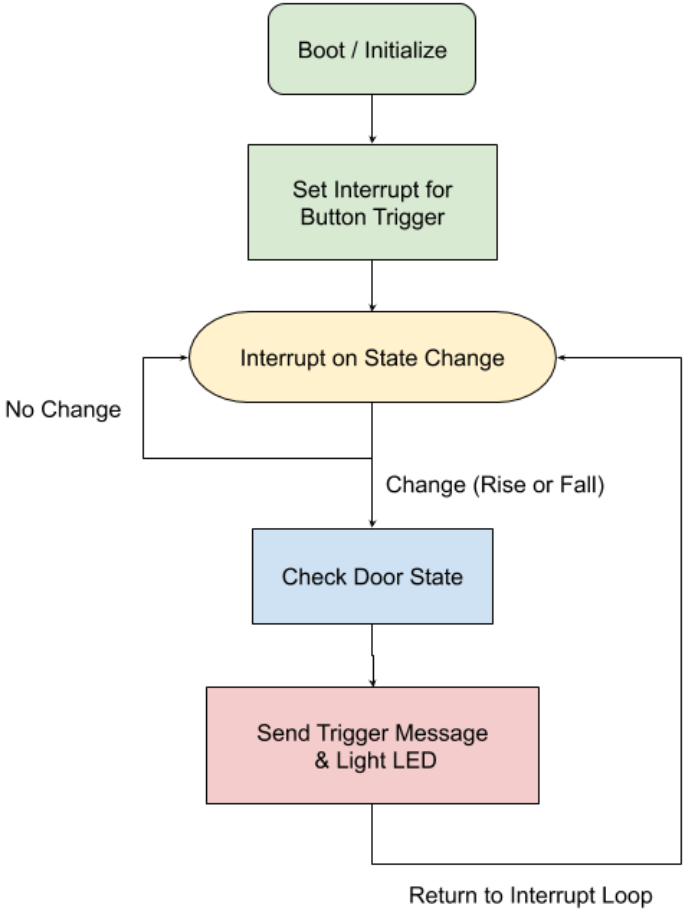
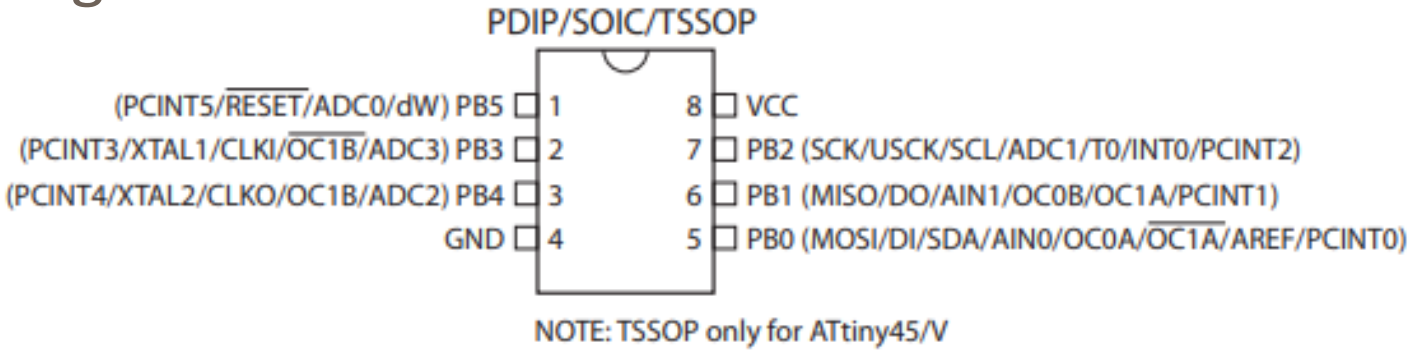
The ATTiny

- Code
  - Necessary libraries identified.
  - ATTiny programmed.
  - Tested and working as intended.



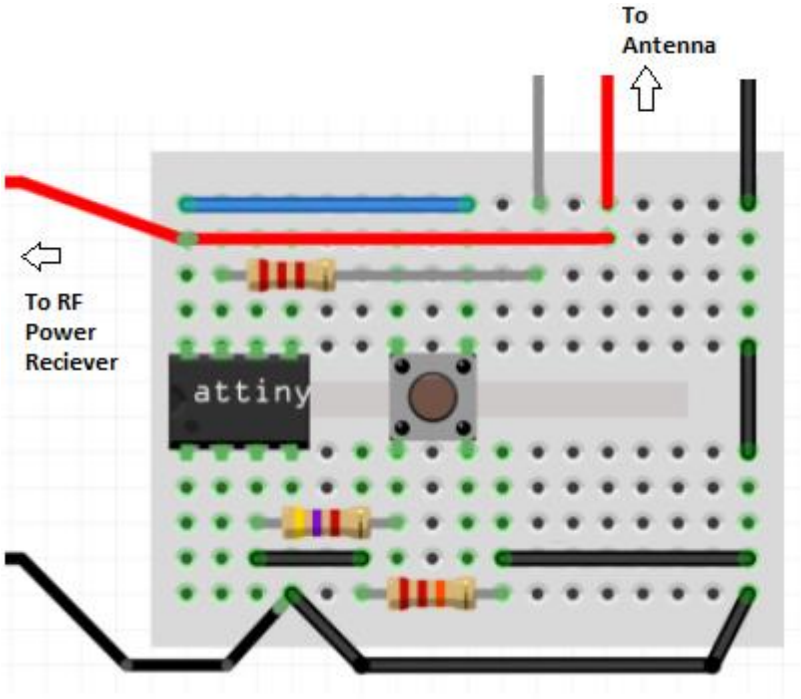
The ATTiny

- Low power consumption.
- Small profile.
- Supports most wireless transmitters.
- Easily programmed.



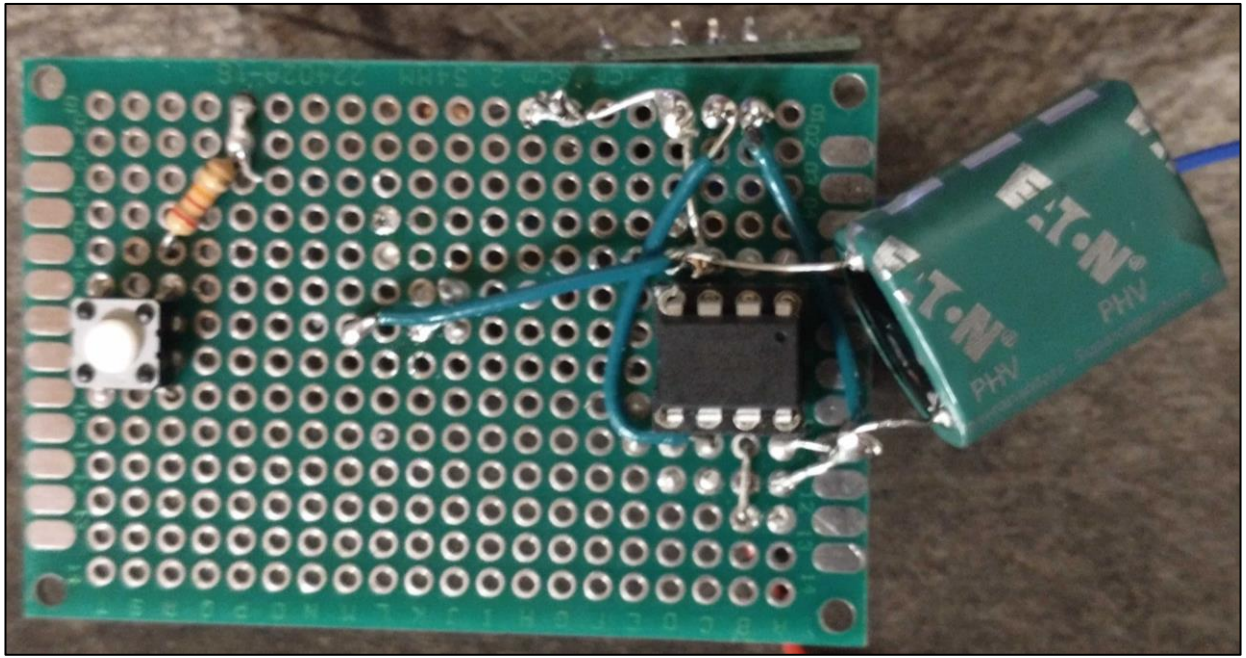
Circuit Progression

Rough Schematic



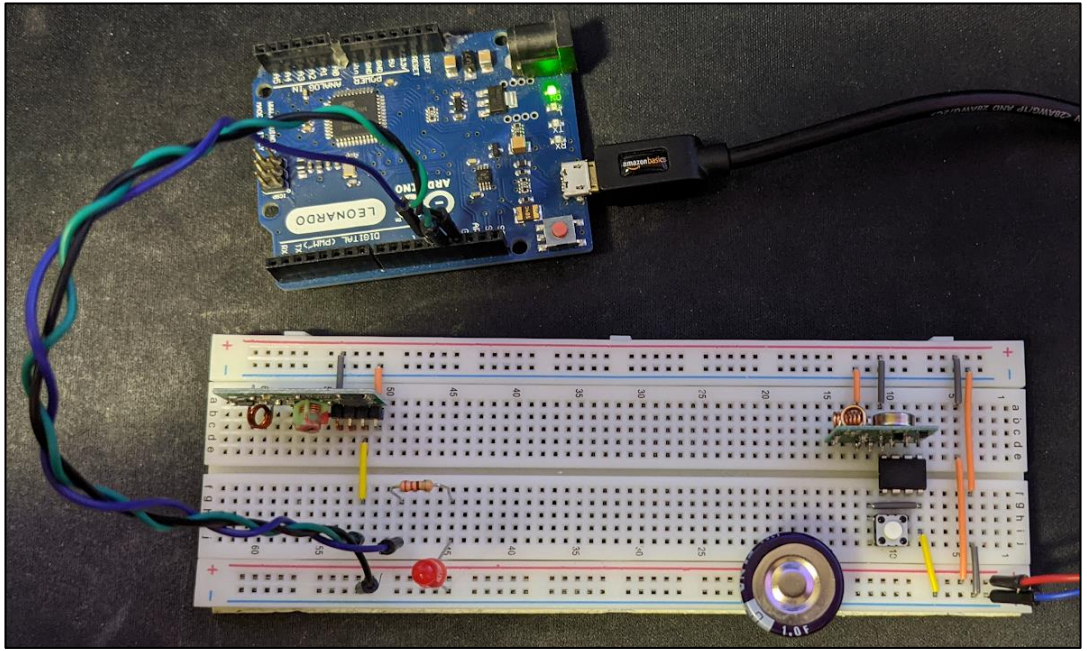
Circuit Progression

Perfboard Iteration



Circuit Progression

Current Implementation



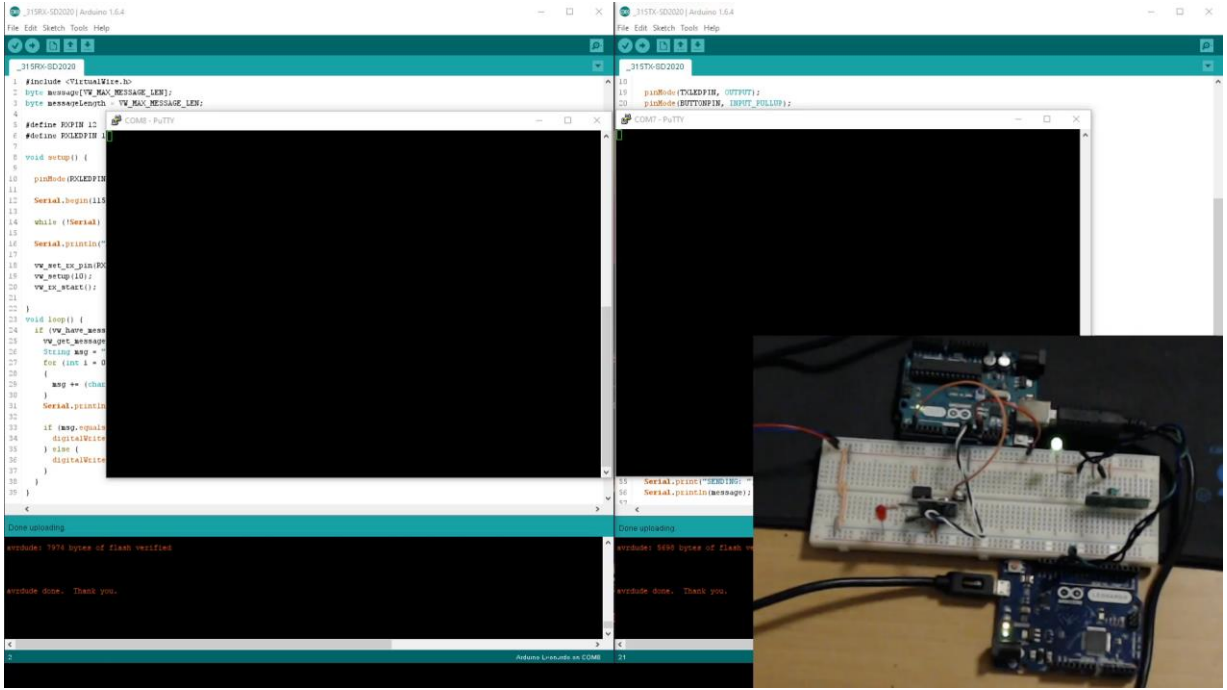
Discoveries

- Tested holdup time.
  - Half-Life ~3.4 minutes with 100 Ω load
  - In ATTiny range for ~3.8 minutes

Iout max powercast			
50mA			
Power consumption while idle		Power consumption when transmitting	
~1mA		150mA	
		^This is why cap is needed, for power surges	
net			
49mA			
time to min charge to operate:		time to min charge to send first signal:	
73 sec +10%		76 sec +10%	7 min to 99% charge
Cap holdup halftime		in ATTiny range	
3.4 min		3.8 min	

Discoveries

Demonstration



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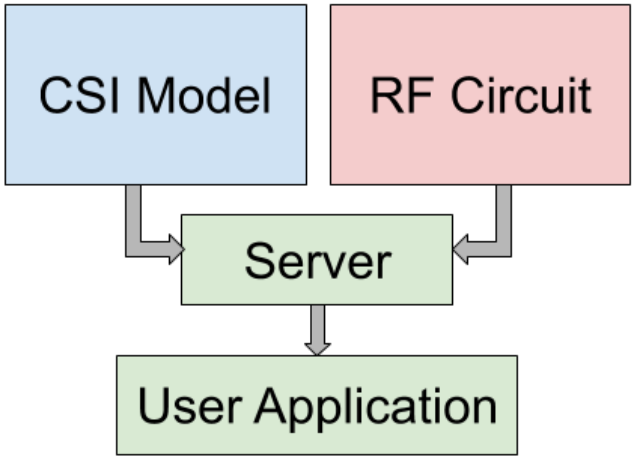
- **Bringing It Together**

Bringing It Together

Bringing It Together

- Door states from both interfaces are sent to the server.
  - Checks for user set triggers.
- Server delegates out notifications.
  - Dependent on the confidence of the ML prediction and comparison to the active sensing state.



Bringing It Together

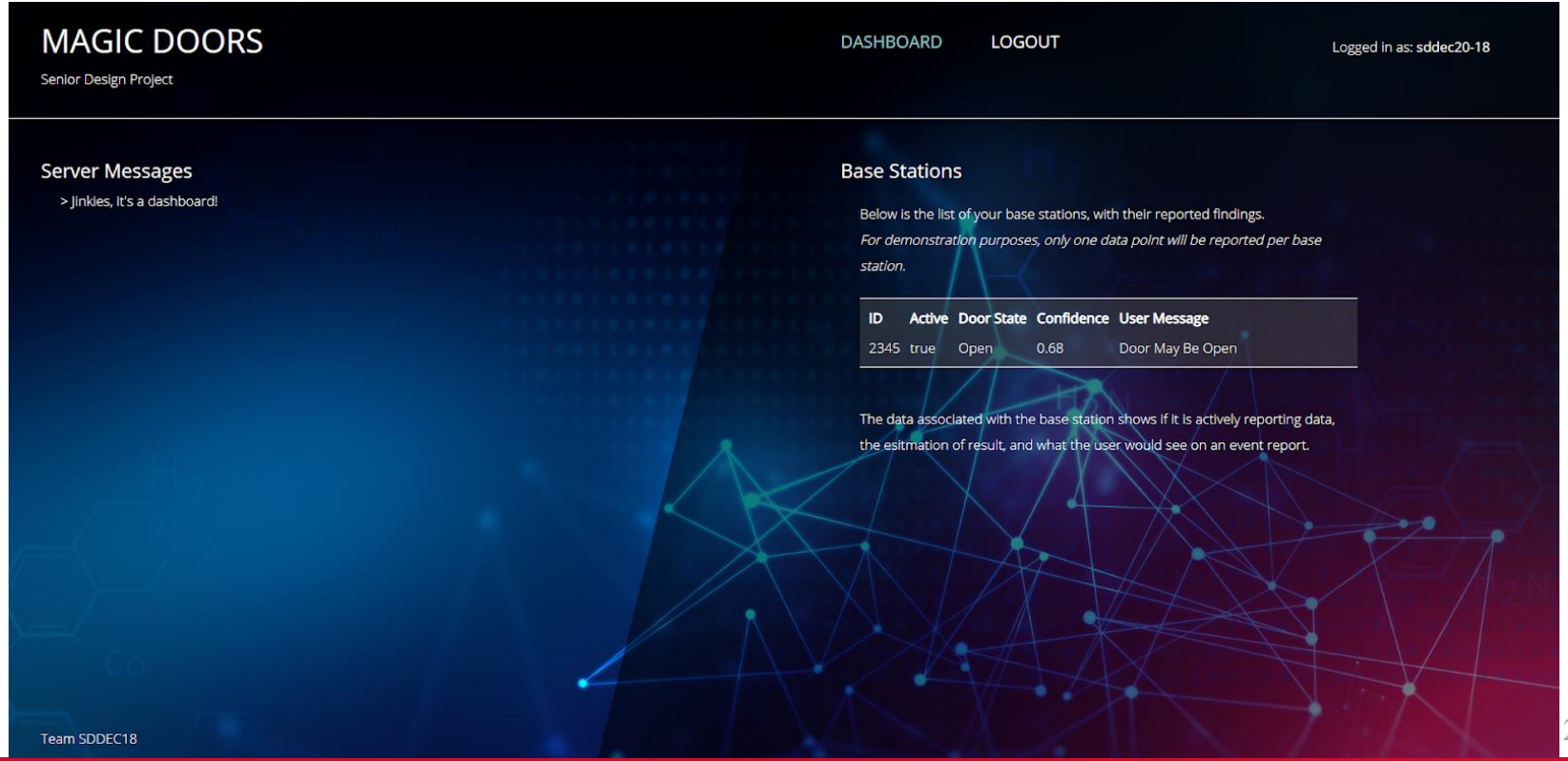
Live Data Processing

1. Collection of data.
2. Model processing.
   - Cached data fed through Python script.
   - Output is list of predictions and the confidence of those predictions.
3. Server decides how to notify user.

User Interface

- Account based login.
- Base stations are associated with accounts.
  - Base station linked sensors are displayed in a table.

Bringing It Together



QUESTIONS