Magic Door Sensor

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Project Statement & Requirements

Requirements

- A prototype of the RF circuit will be created
  - Supercapcitor charged by an RF harvesting antenna
  - Door state transmitted to RasPi
- CSI frame collection will be autonomous
- A prototype of the CSI modeling use will be created
  - Classification model will predict within one second
  - Classification model accuracy will not drop below 90% while maximizing recall score
- The system must accurately report door status 95% of the time

Problem Statement

Design a door monitoring security system that requires no wiring to or batteries on the door.

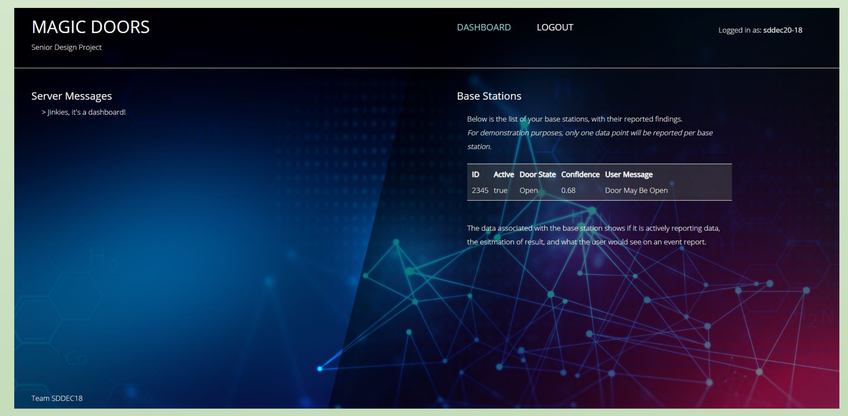
System Overview

Intended Use

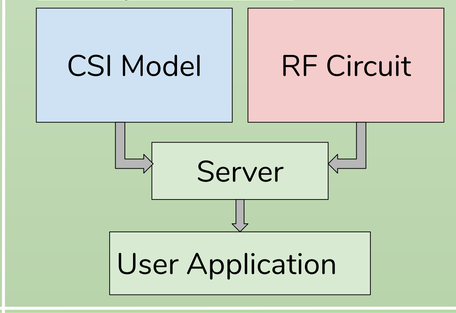
- Determining the state of a door in an average home environment

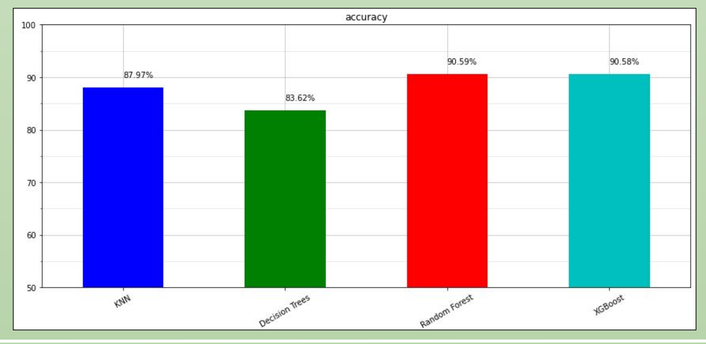
Project Resources

- 1.5F Supercapacitor
- ATTiny microcontrollers
- ECE Server Space
- Personal Computers
  - Used for model training



Conceptual Sketch





CSI Data Collection

Gathering CSI Frames

- Two ESP32 microcontrollers
  - One access point & one client
  - Send and receive CSI frames
- Frames go to Raspberry Pi
  - Frames are placed into JSONs
- The JSON files of CSI data are sent to the server for processing

Manipulating CSI Frames

- Not all of the information we collected was needed
- The CSI frame includes:
  - Channel
  - Packet information
  - Sub-carrier Index
  - Total bytes
- We only cared about the Sub-carrier Index
  - This is where the data is
- CSI data gets turned into amplitude & phase angle
- Used for ML

What is CSI?

- Channel State Information
- A type of data that accompanies WiFi packets
- Thought of as a 'preamble'
- This data describes how the signal wave propagates through the air
- We use it to make observations about the wave's path of travel

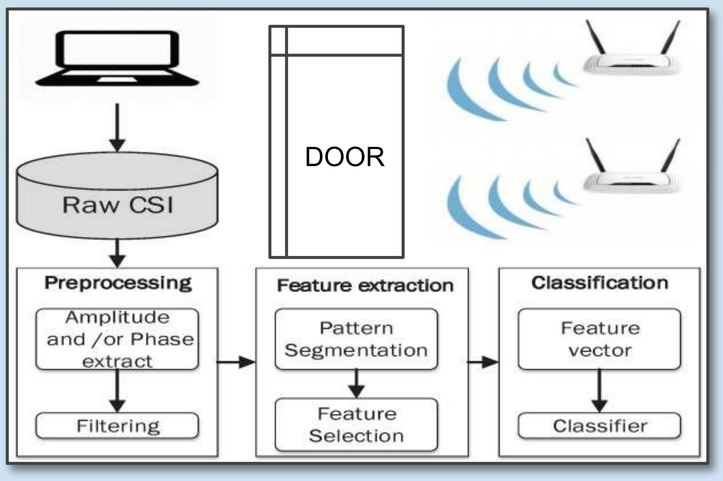


Figure 1: CSI Propagation & Use

CSI Machine Learning

	Predicted 0	Predicted 1
Actual 0	TN	FP
Actual 1	FN	TP

Figure 2: Circuit Schematic

Methods Tested

- sklearn package
- KNN (Uniform & Weighted)
- Decision Trees
- Random Forest
- XGBoost

Future Changes

- Better training with smaller data sets
- Balance number of degree readings for training sets
- Work on improving recall metric

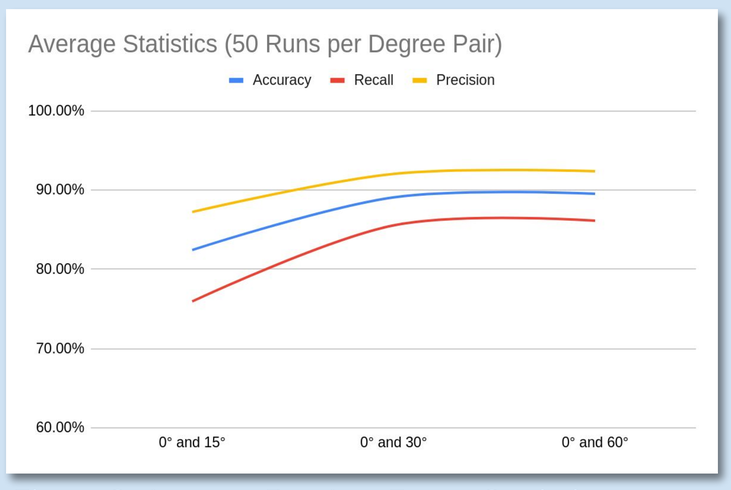


Figure 3: Average Random Forest Statistics

Testing

- 15° angle changes
  - From 15° to 90°.
- Compared every open angle to 0°.
- This allowed us to examine the performance as the door shut.

Results

- Random Forest was optimal.
- Highest accuracy along with recall.
- Above 60° there were no distinguishable differences.

RF Circuit

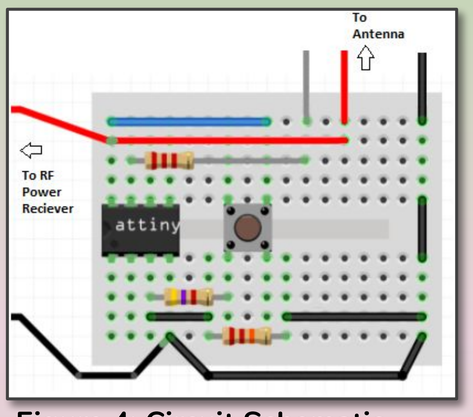


Figure 4: Circuit Schematic

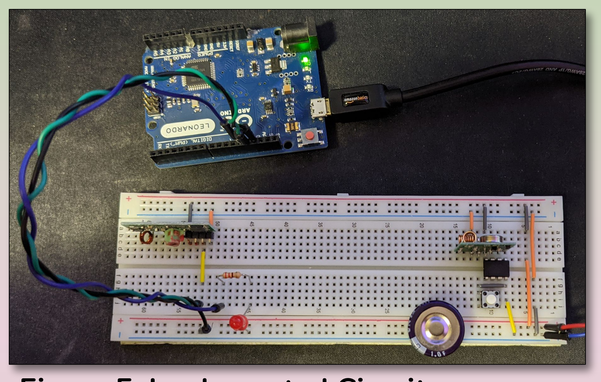


Figure 5: Implemented Circuit

Microcontroller

- ATTiny
- Chosen for small profile and low power consumption
- Easily programmed in Arduino API
- High clock speed allows a variety of transmission band options

Technical Details

- No battery or external power
- RF to DC converter supplies powerand charges the capacitor while the system is in low power mode (when not transmitting)
- Super capacitor supplies current during peak load (when transmitting)
- Button triggers transmission when its state changes

Operation

- The device collects RF power and charges the capacitor
- Once charged enough, the ATTiny will boot and enter low power mode
- Once the button changes state, an interrupt will wake the ATTiny and send a status signal to the base station that the door has opened/closed
- The device returns to low power mode

Testing

- Functional testing to verify operation
  - LED used for quick and easy diagnostics
- Parameter testing
  - Current draw (low power mode)
  - Current draw (while transmitting)
  - Rate of capacitor discharge

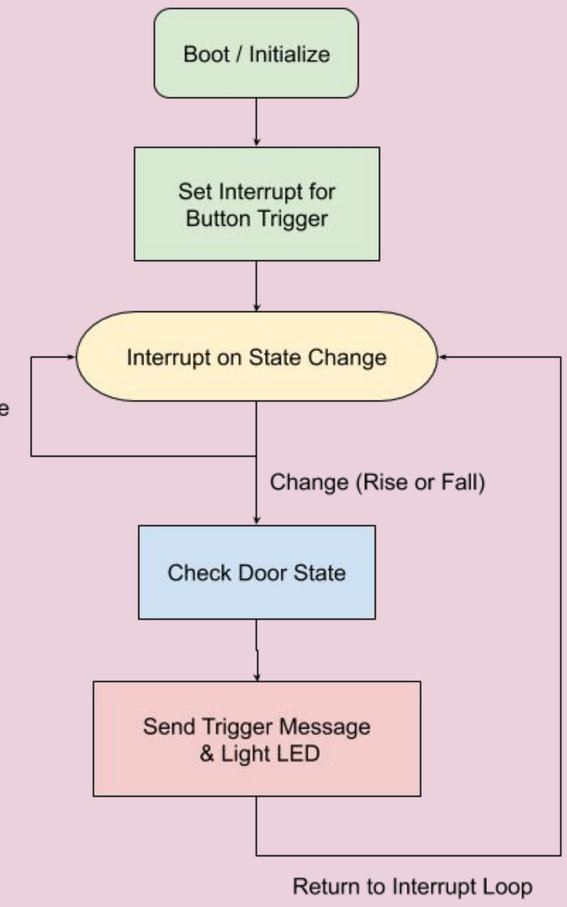


Figure 6: Logic Flow