Indoor Navigation for the Visually Impaired

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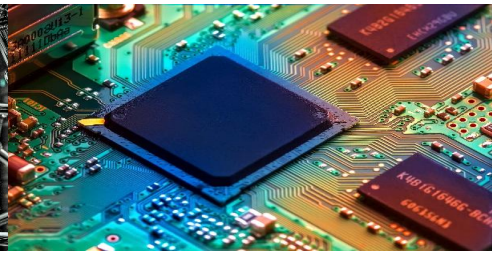
ECE 445: Team 73



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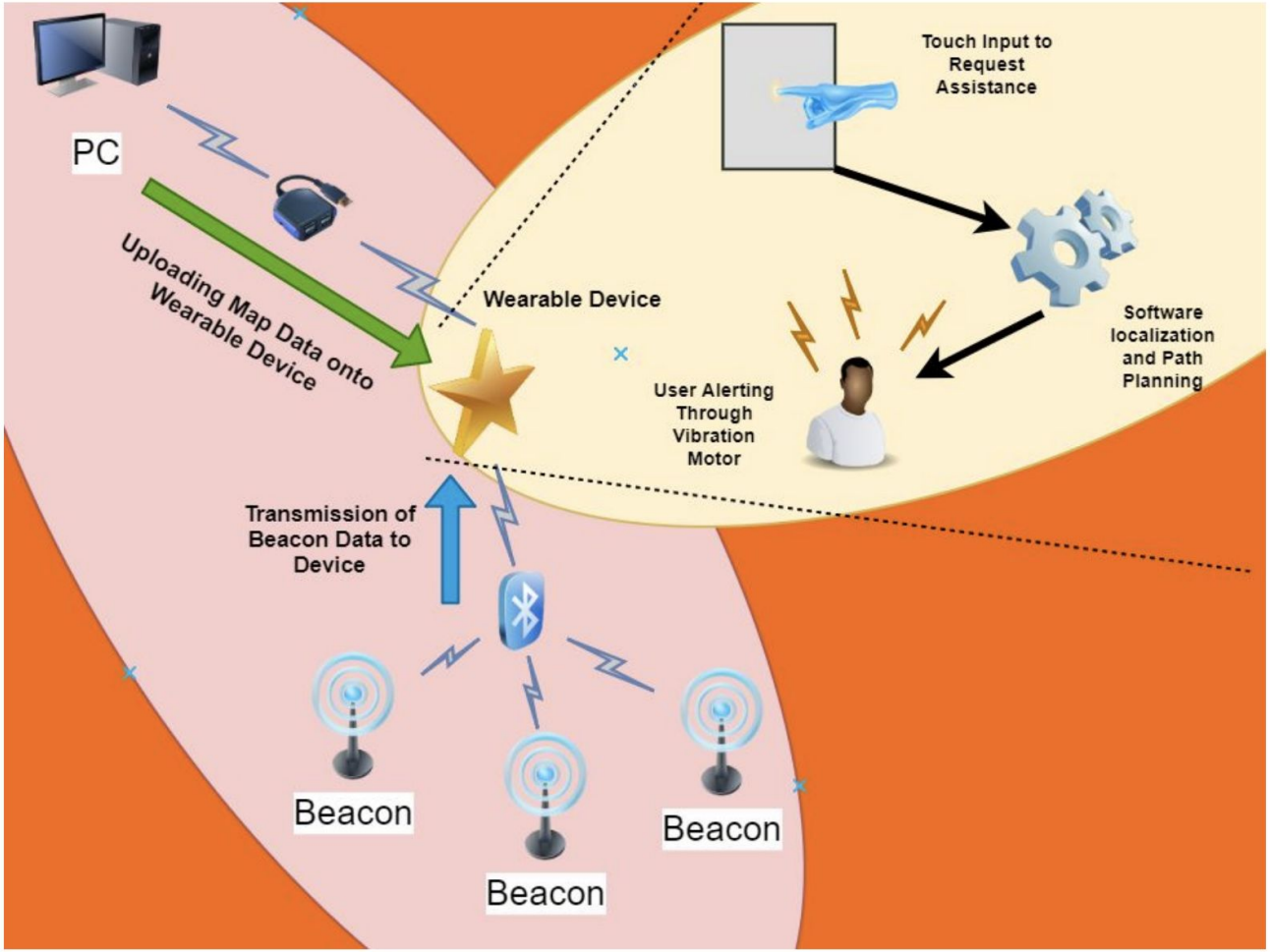
Problem

- Blind people face difficulties when navigating large unknown spaces
  - complex layouts
  - Existence of obstacles
  - new spaces

- Current solutions are insufficient
  - Targeted towards the general population
  - Not an end-to-end solution

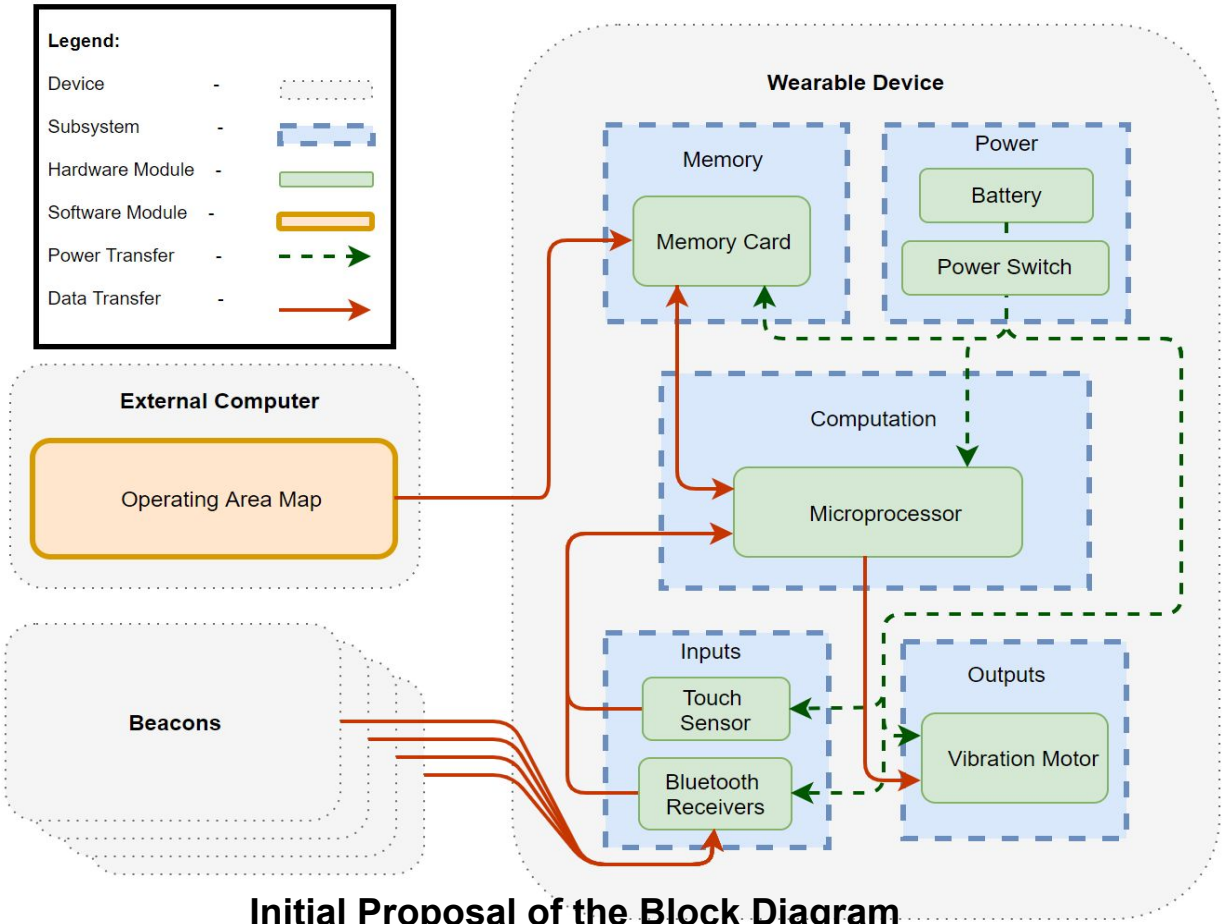
Proposed Solution

- An **Integrated** product that needs to accomplish:
  - A Localization and Navigation solution to find the user and a ‘way’ to their destination
  - Conversion of the ‘way’ to simplified and actionable instructions


PC
Uploading Map Data onto Wearable Device
Wearable Device
Touch Input to Request Assistance
Software localization and Path Planning
User Alerting Through Vibration Motor
Transmission of Beacon Data to Device
Beacon
Beacon
Beacon

High Level Requirements:

- **Localization** Requirement:
  - System should have a Circular Error (CE) 85 of 5m
    - CE85: less than 5m accuracy 85% accuracy of the time
- **Navigation** Requirement:
  - System should find a ***safe*** path to destination
- **User** Interaction and I/O:
  - System should navigate user via vibration motor
  - System should be able to change maps based on beacons

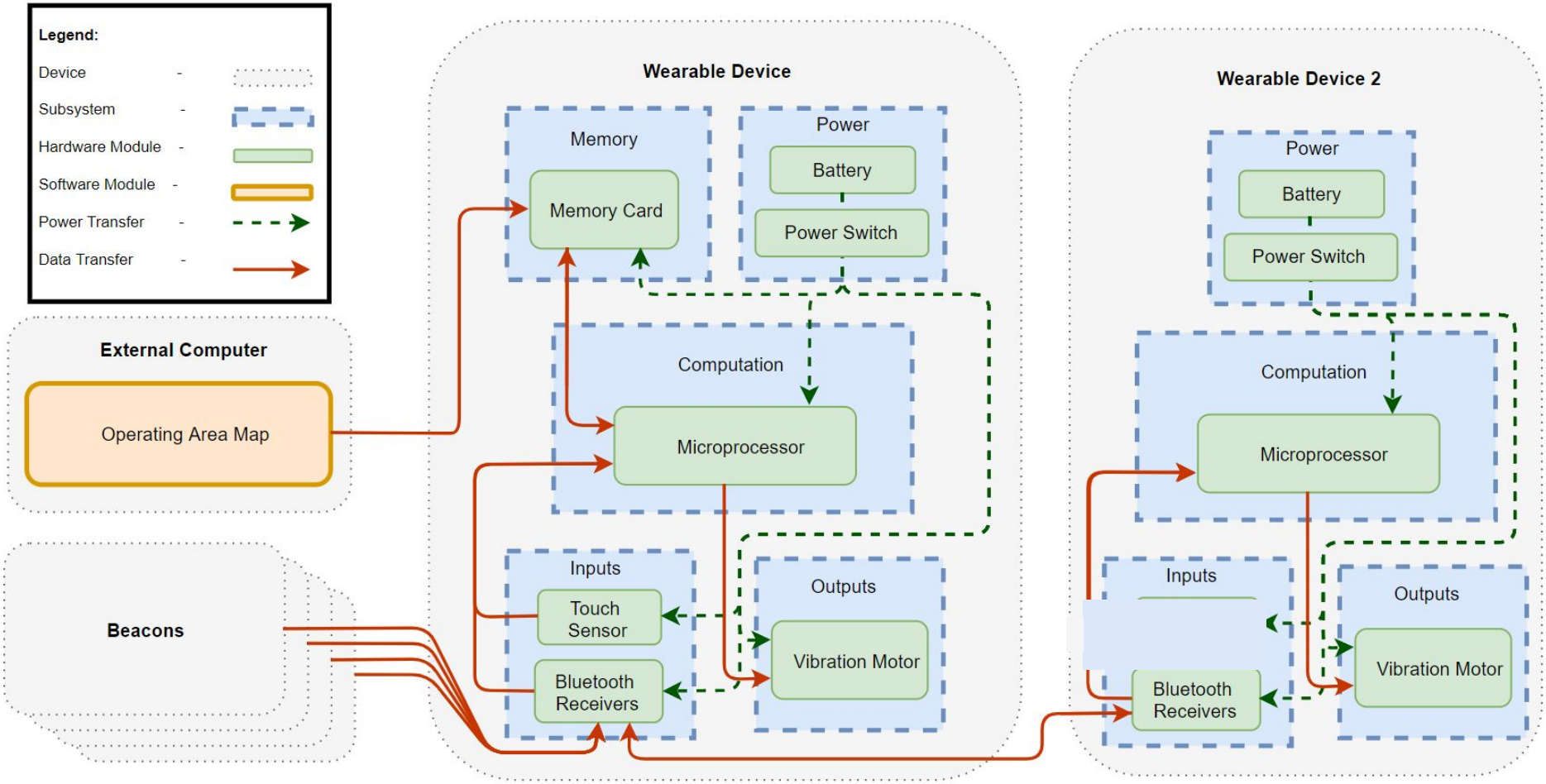


Initial Proposal of the Block Diagram

Revised Proposed Solution

- An **Integrated** product that needs to solve two things:
  - A Localization and Navigation solution to find the user and a ‘way’ to their destination

  - **Convert the ‘way’ to simplified and actionable instructions so the user has zero confusion**


Legend:
Device
Subsystem
Hardware Module
Software Module
Power Transfer
Data Transfer
External Computer
Operating Area Map
Beacons
Wearable Device
Memory
Memory Card
Power
Battery
Power Switch
Computation
Microprocessor
Inputs
Touch Sensor
Bluetooth Receivers
Outputs
Vibration Motor
Wearable Device 2
Power
Battery
Power Switch
Computation
Microprocessor
Inputs
Bluetooth Receivers
Outputs
Vibration Motor

Power

- Battery
  - Lithium Ion
  - 3.7V
  - 1500mAh
- Power Switch
  - Push button
  - Allow user to turn device completely on/off

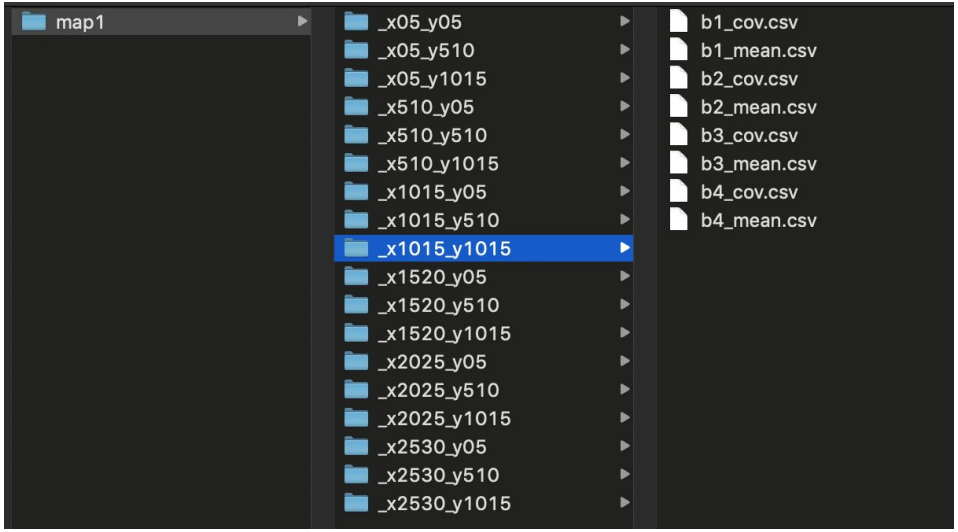
Power

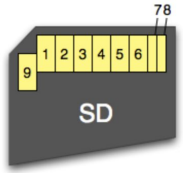
Module	Power Usage (mW)
Microcontroller	4-6
Bluetooth	150-200
SD-Card	150-200
Touch Sensor	1-3
Vibration Motor	150-200
Total	455-609

- Battery:
  - 1500mAh
  - 3.7V
  - 5550mWh
- Device:
  - 455-609mW
- Battery Life:
  - 5550/455 = ~12
  - 5550/609 = ~9
  - ~9-12 hours

Memory

- SD Card
  - Walkability Maps
  - Beacon Maps and Lists
  - Pre-computed GPR values
  - Interfacing with Microcontroller

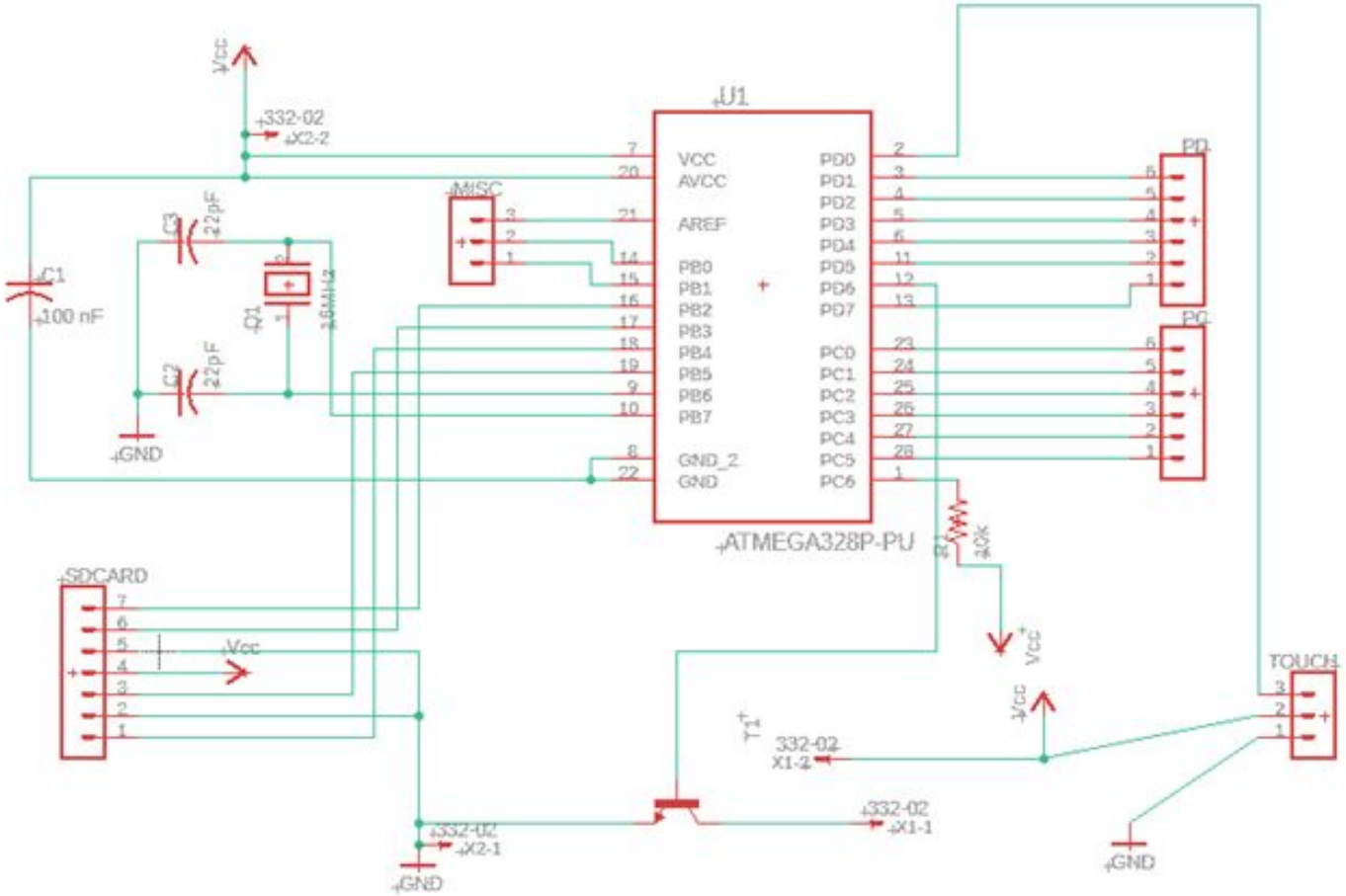


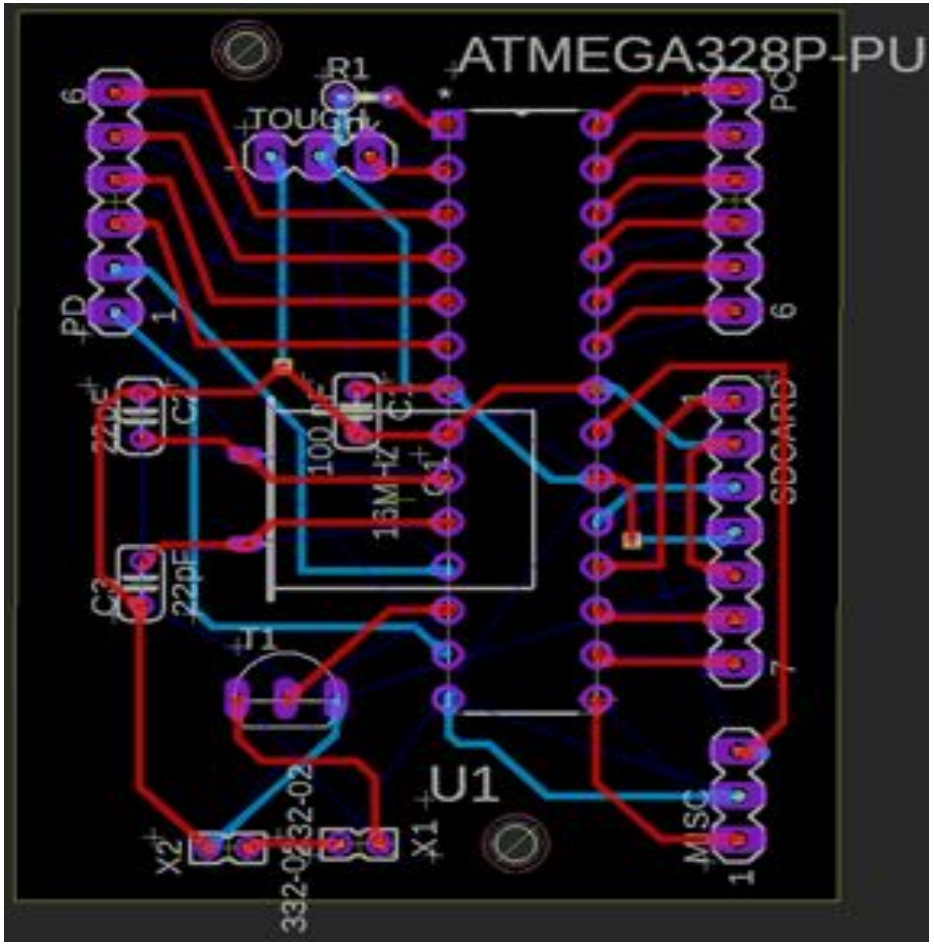


Pin	SD	SPI
1	CD/DAT3	CS
2	CMD	DI
3	VSS1	VSS1
4	VDD	VDD
5	CLK	SCLK
6	VSS2	VSS2
7	DAT0	DO
8	DAT1	X
9	DAT2	X

Processing

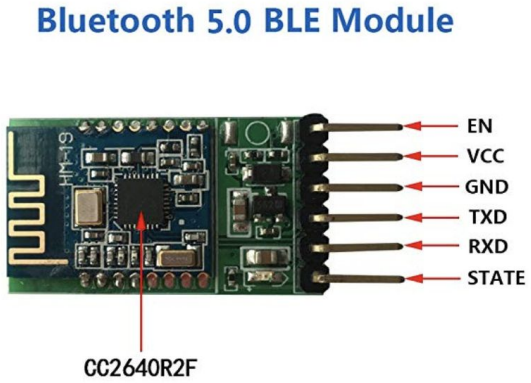
- Microcontroller
  - ATMega328P
  - Interfacing with:
    - SD Card
    - Bluetooth Receivers
    - Touch Sensor
    - Vibration Motors
  - Verification: running C scripts in Arduino to test communication

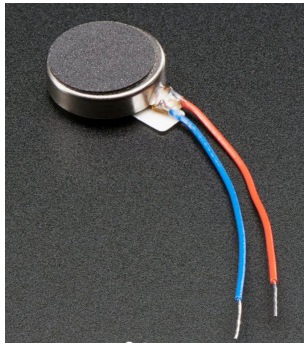

Vcc
+332-02
+X2-2
+U1
VCC
AVCC
AREF
PB0
PB1
PB2
PB3
PB4
PB5
PB6
PB7
GND_2
GND
PD0
PD1
PD2
PD3
PD4
PD5
PD6
PD7
PC0
PC1
PC2
PC3
PC4
PC5
PC6
+ATMEGA328P-PU
+MISC
PD
PC
C1
+100 nF
C3
22pF
C2
22pF
Q1
+16MHz
+GND
R1
10k
+SDCARD
+Vcc
TOUCH
T1
332-02
X1-2
+332-02
+X1-1
+332-02
+X2-1
+GND
+GND


ATMEGA328P-PU
R1
TOUCH
PD
PC
SDCARD
MISC
C1
C2
C3
22pF
22pF
100 nF
16MHz
J1
U1
X1
X2
332-0232-02

Input/Output Interface

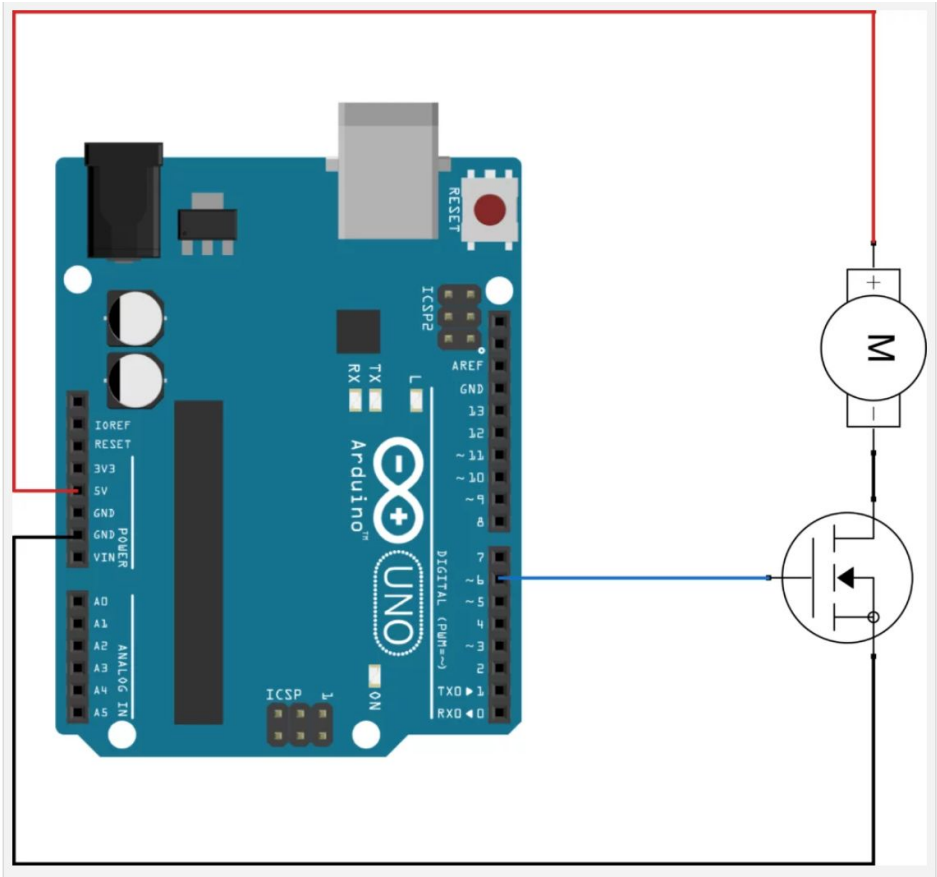
- Touch Sensor
  - Capacitive Touch Breakout Board
- Vibration Motor
  - 3V
  - 10000 RPM
- Bluetooth Receiver
  - HM-19
  - 5.0 BLE





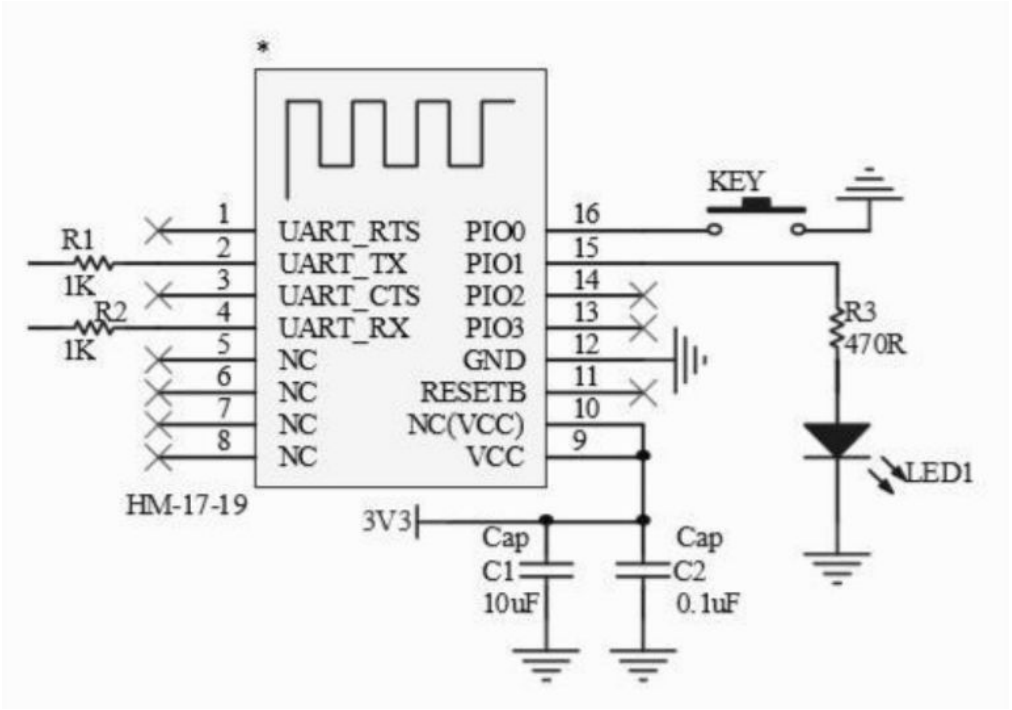
Input/Output Interface

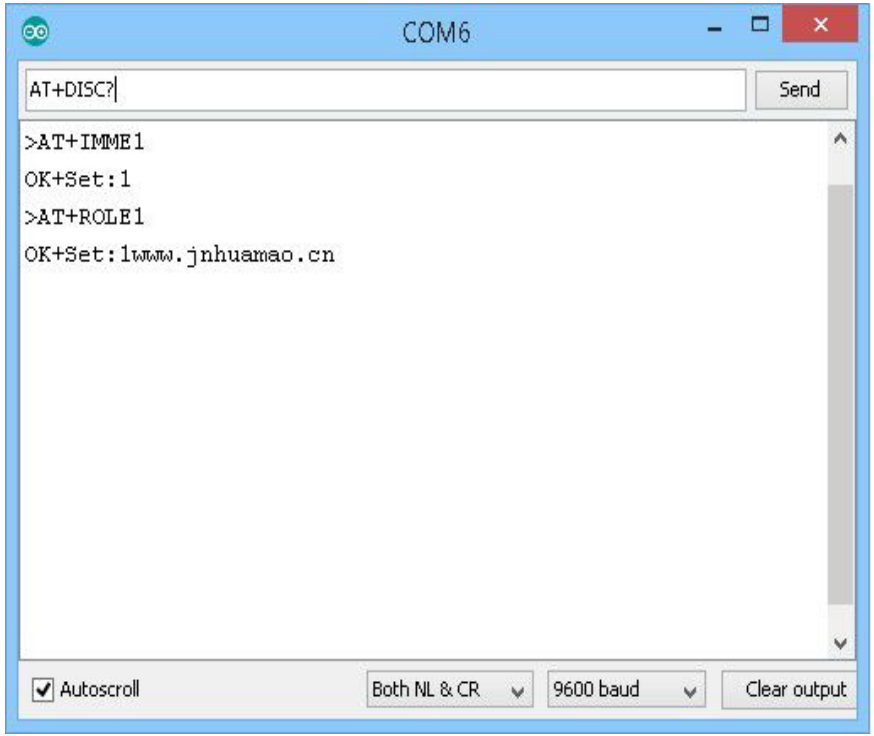
- Vibration Motor
  - Transistor Circuit
  - PWM Input
  - 80% Duty Cycle
    - 3 V Motor
    - 3.7 V Power Supply
    - (3/3.7) ~ 80%

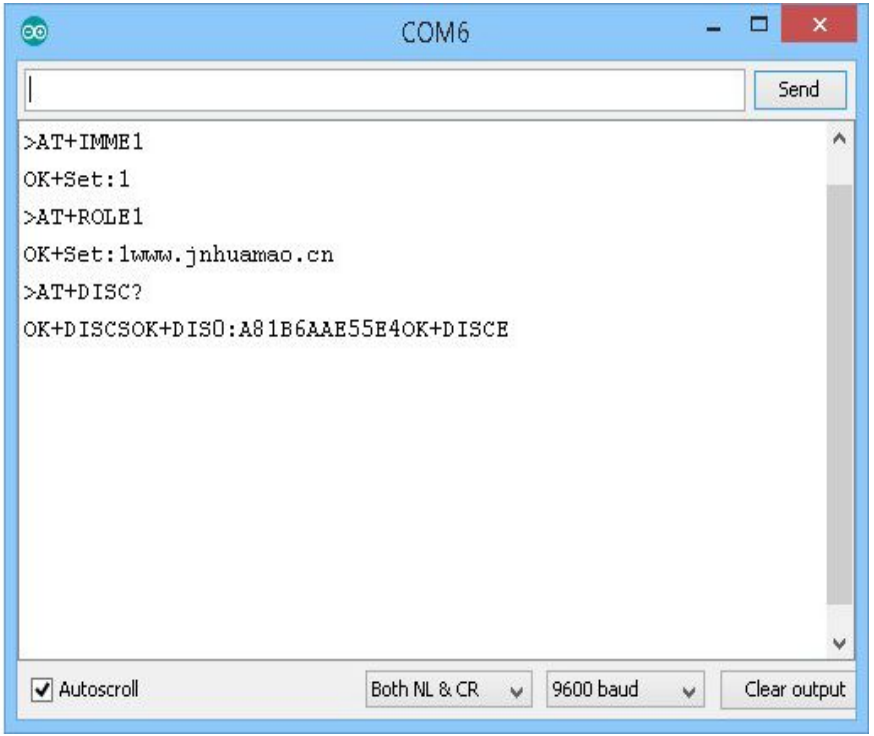


Input/Output Interface

- Bluetooth Receiver
  - “AT” commands
    - “AT”
    - “AT+DISC?”
    - “AT+ROLE?”
    - “AT+IMME?”
    - “AT+START”
    - “AT+CONN”

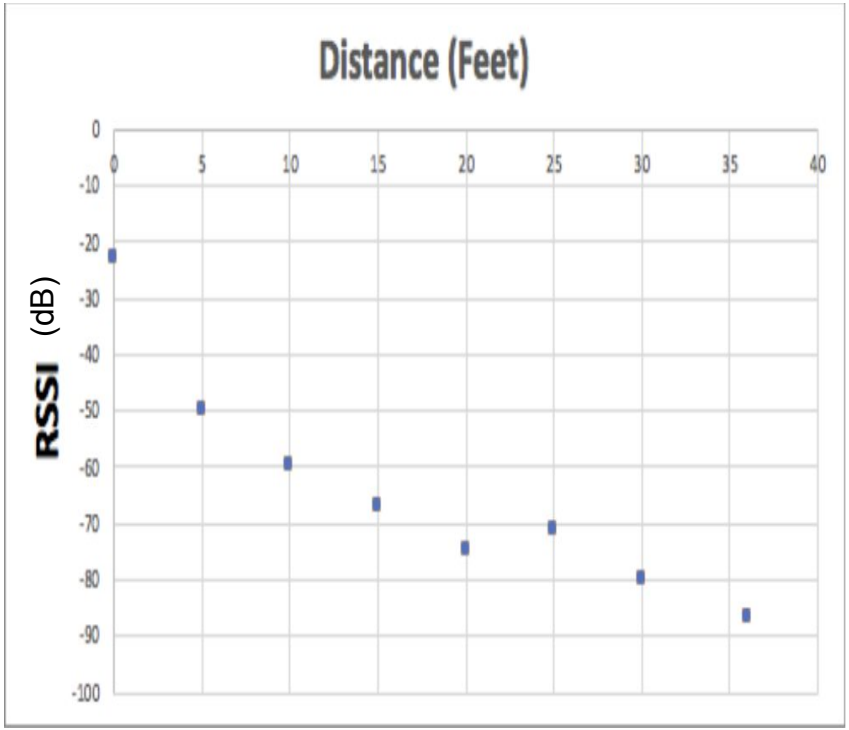



COM6
AT+DISC?
Send
>AT+IMME1
OK+Set:1
>AT+ROLE1
OK+Set:1www.jnhuamao.cn
Autoscroll
Both NL & CR
9600 baud
Clear output

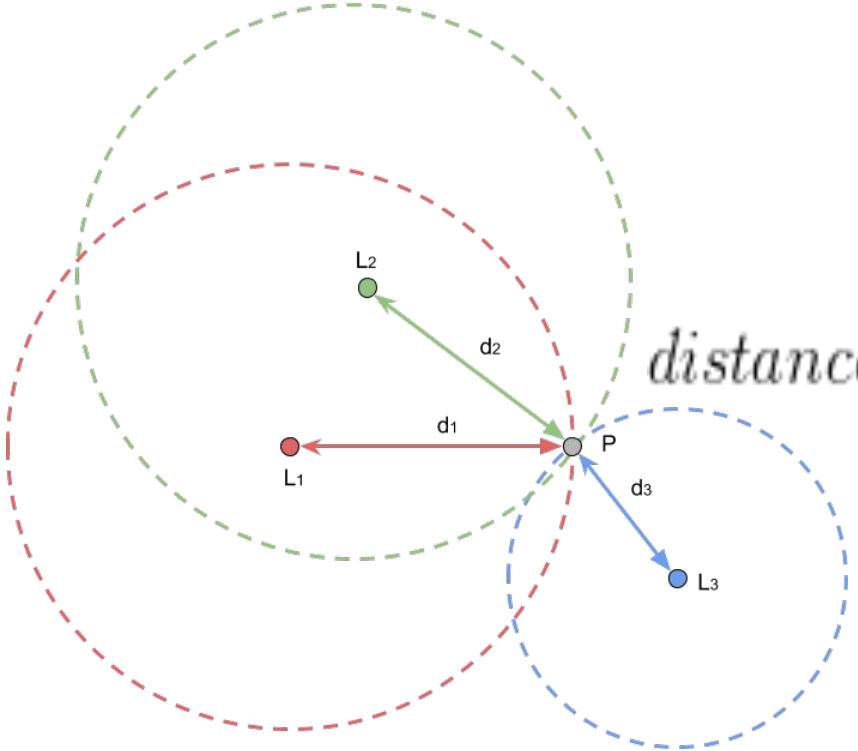

COM6
Send
>AT+IMME1
OK+Set:1
>AT+ROLE1
OK+Set:1www.jnhuamao.cn
>AT+DISC?
OK+DISCSOK+DIS0:A81B6AAE55E4OK+DISCE
Autoscroll
Both NL & CR
9600 baud
Clear output

Beacon Signal Interpretation

- Should receive signal strengths from at least three beacons at any given point
  - Used Feasycom app to initialize beacons
  - Further characterization

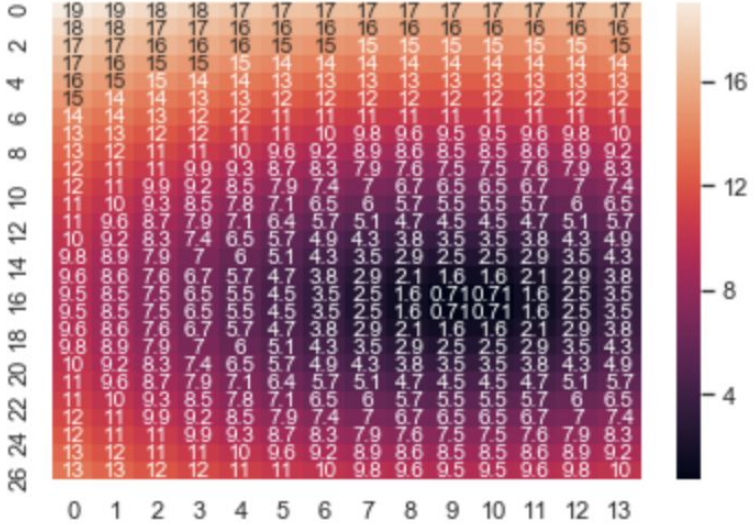


Initial Localization Technique and Failures

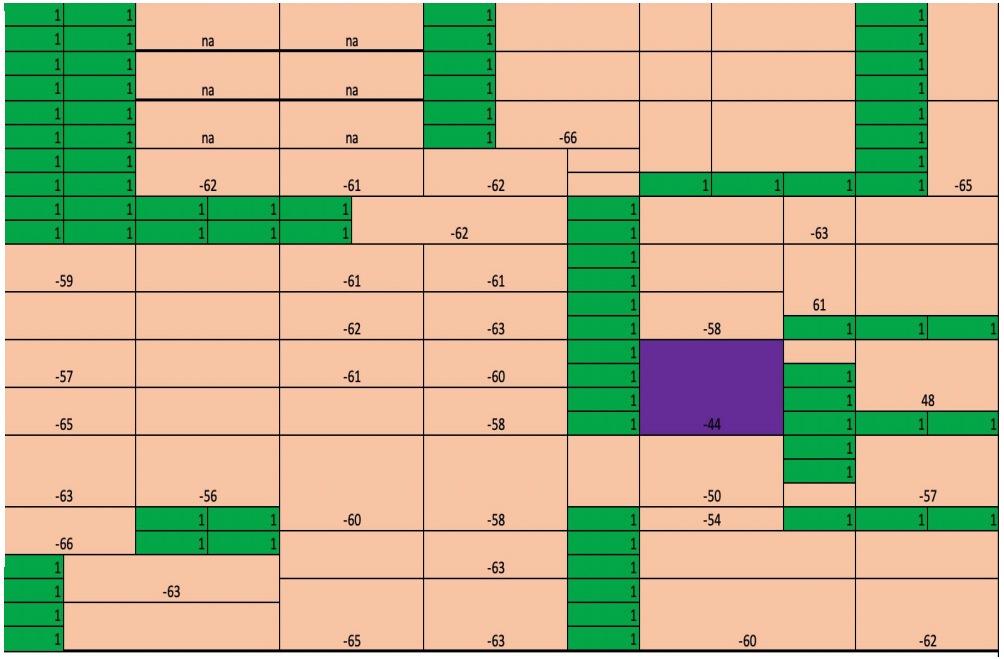


$$distance = 10^{\left(\frac{(RSSI_1 meter - RSSI)}{10 * N}\right.}$$

Initial Environment Characterization

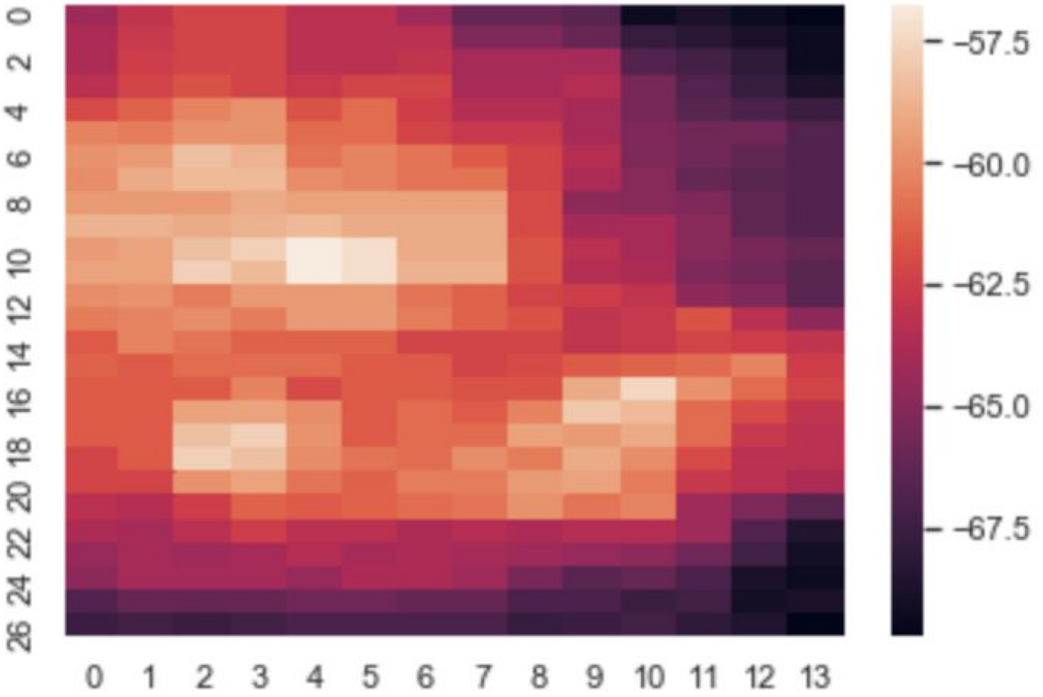


Deciding Beacon Placement:
Distance map from beacon A6 to point

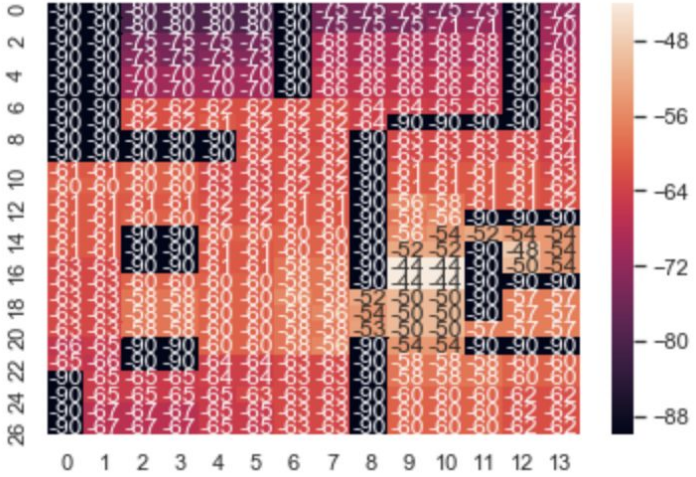


Manual Data Collection across the apartment:
RSSI (dB) values at each location

Environment Characterization- GP Regression Model

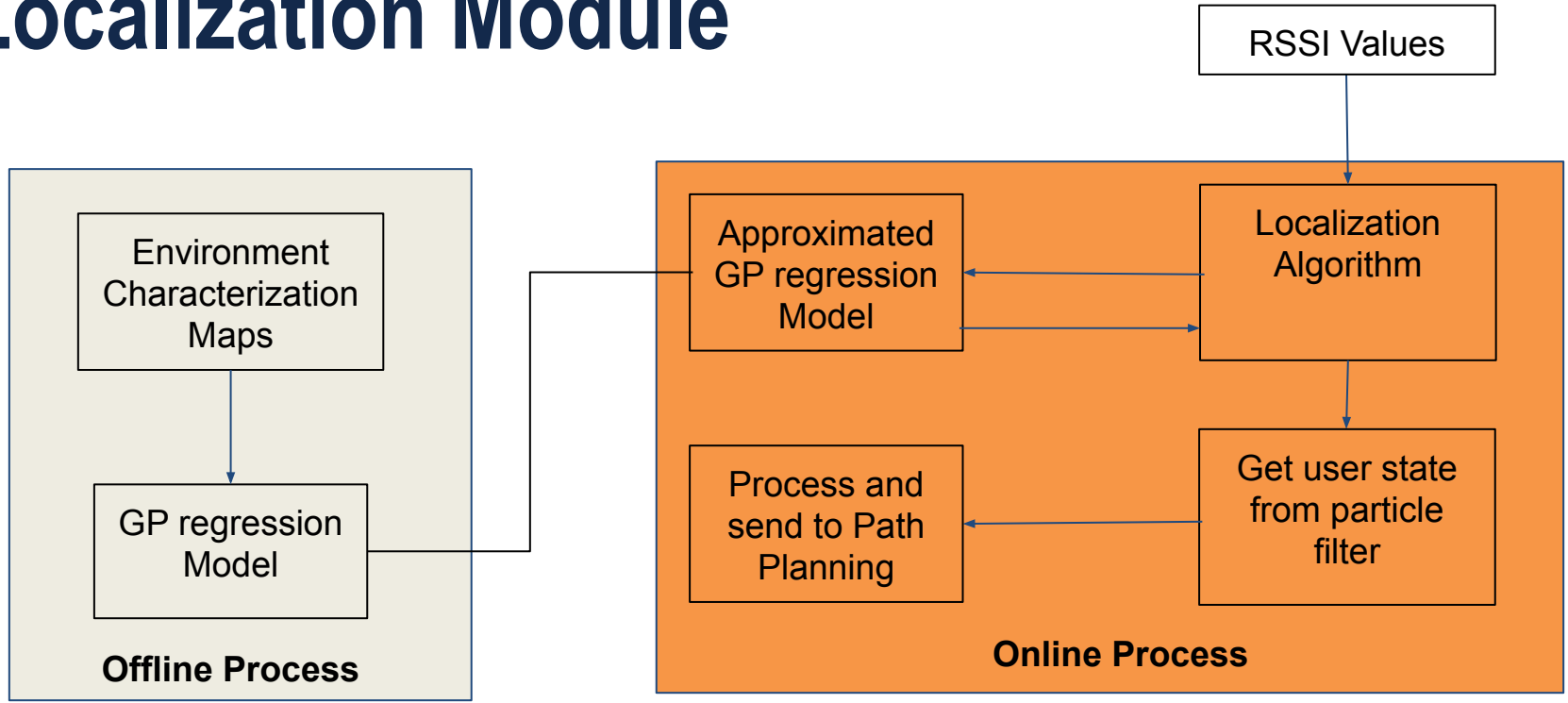


Coverage Map of the Apartment

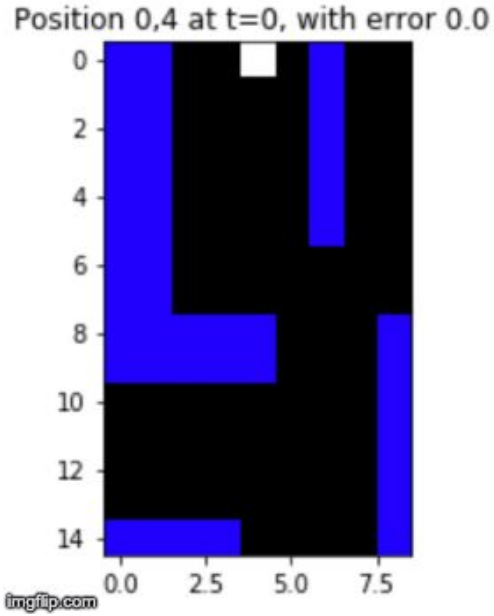


Final Beacon Maps:
Example of a beacon characterization map optimized to be only used by the localization module

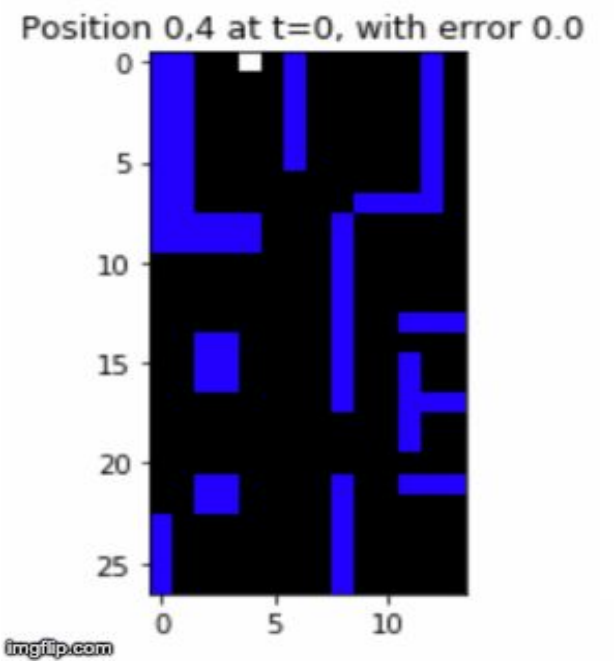
Localization Module



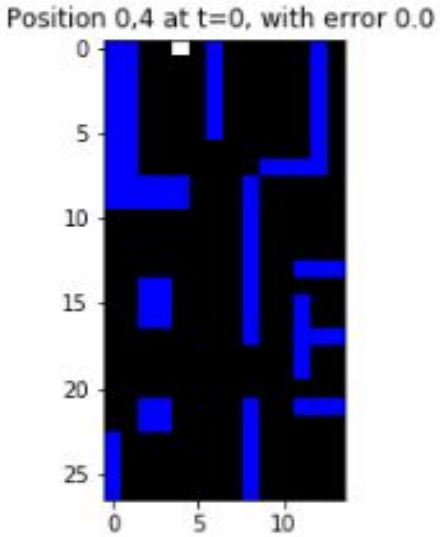
Localization Module



Localization RV Testing meets criteria: CE85 100%



Good Output of the Localization Module

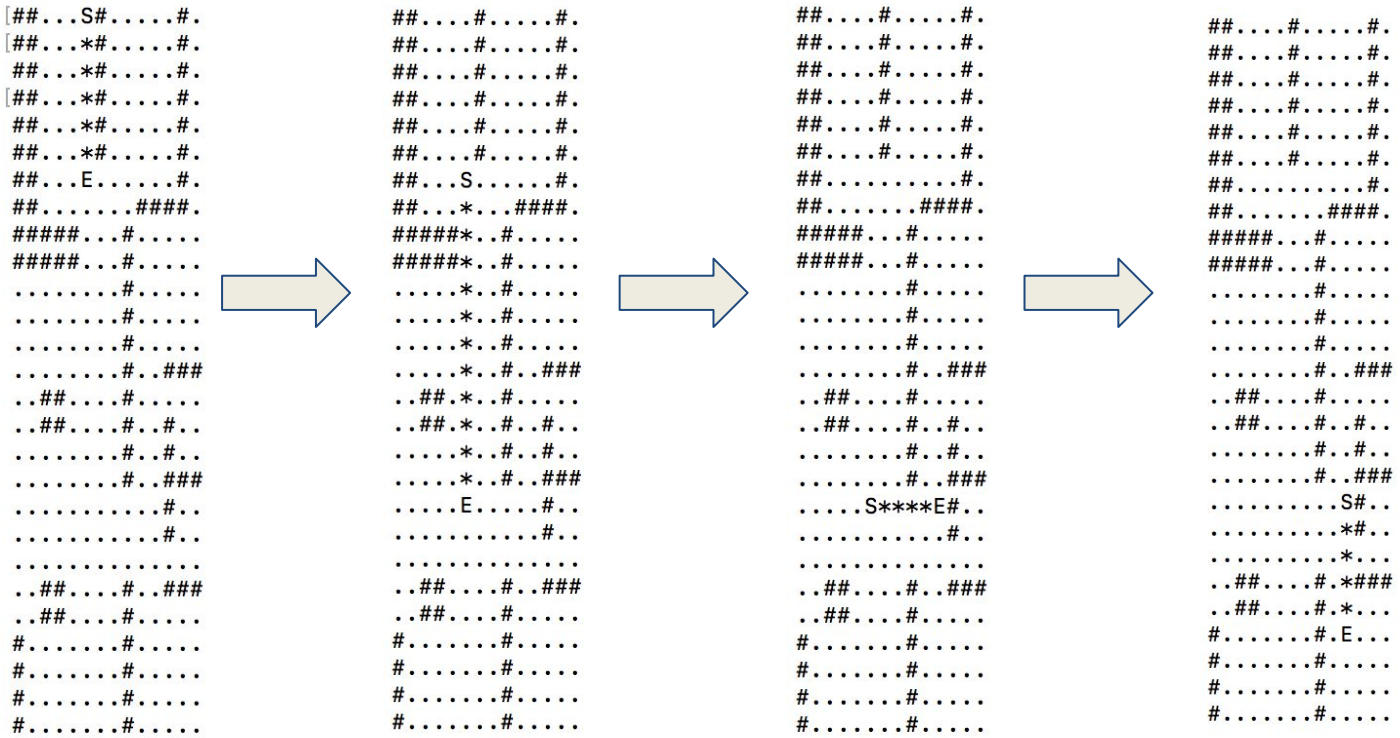


Example where User doesn't follow the path but localization module adjusts itself

Actual Position

User

Path Planning

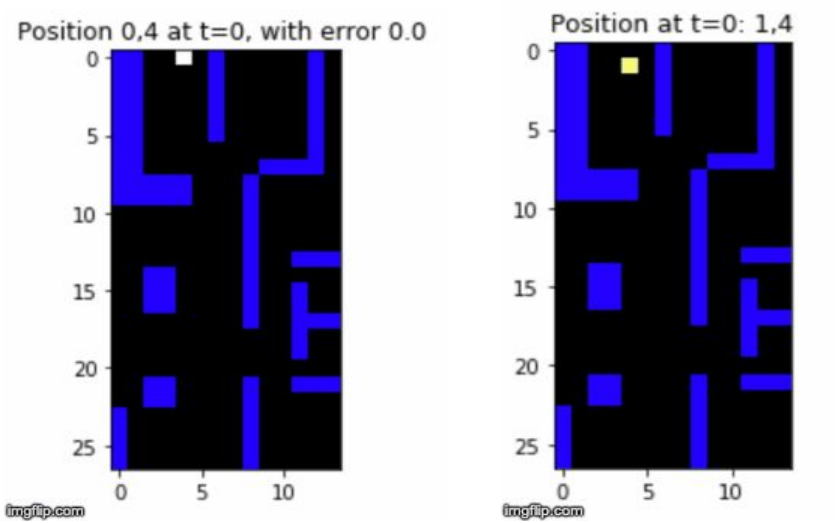


Successes

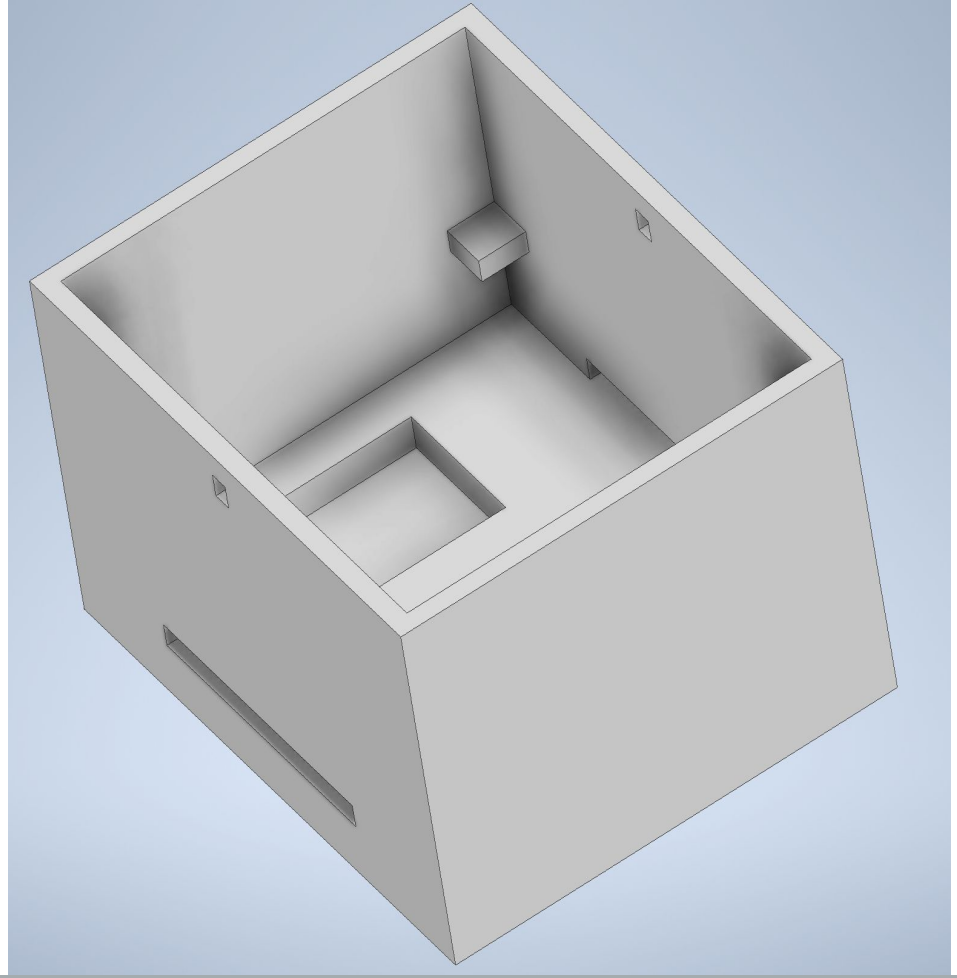
- Bluetooth communication
- Path planning
- Localization via the Particle Filter Implementation
- Modular Design
- Integration of system into wearable device

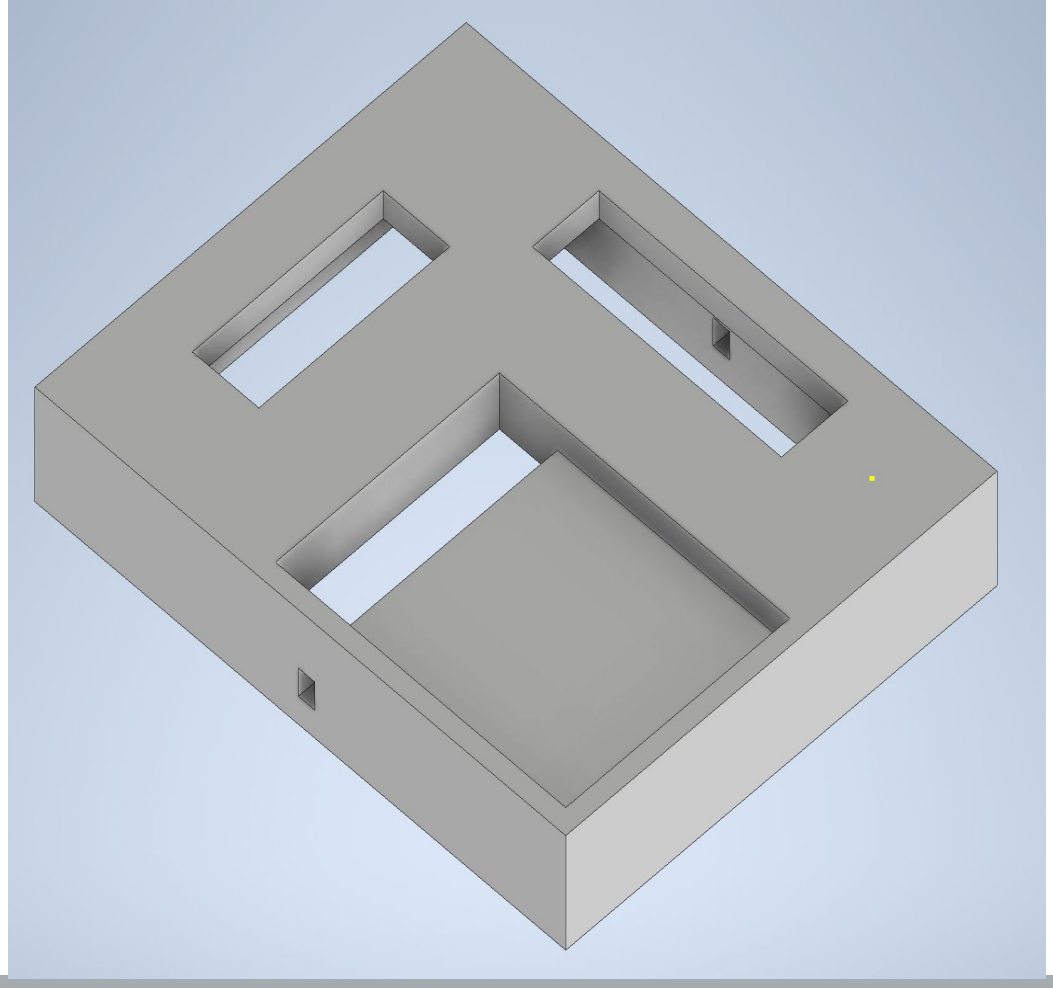
Challenges

- Limited dynamic memory on ATMega328P
- Issues with hardware reliability
- Bluetooth signal interference



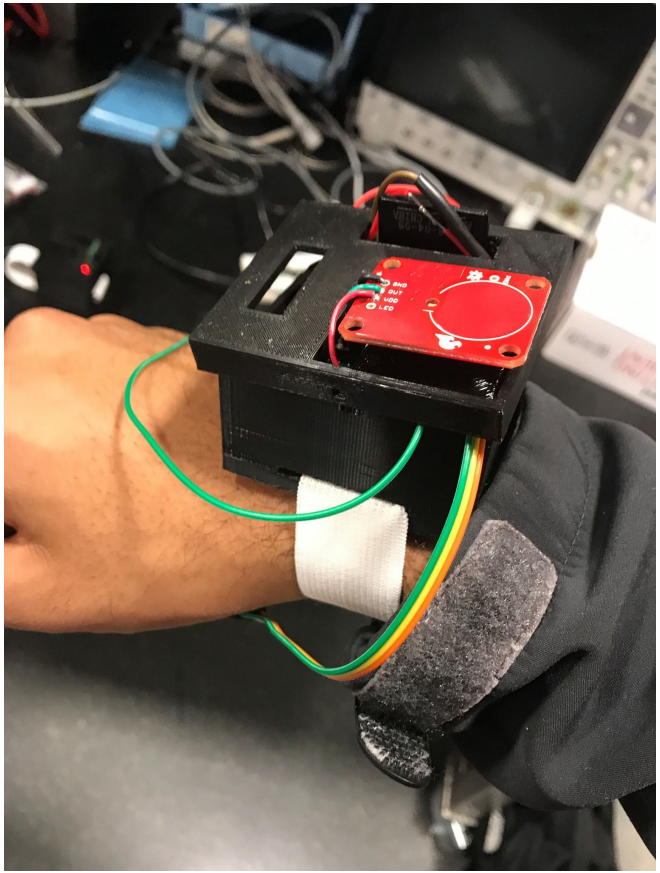
Left to Right: Example of Python Output (800 particles), ATMega328P Output (5 particles) with the same path





Future Work Opportunities

- Implement audio input/output
  - Integration with Alexa library
- Shift to larger public locations
  - Test in malls, airports, etc.
- Standard procedure for creating map data
- Convert to smaller size hardware
- Integrate with Apple Watch



Questions?