IOWA STATE UNIVERSITY

EE/CprE/SE 492

IoT: Automated Inventory Management & Route Optimization

Team: sdmay19-29
Adviser: Goce Trajcevski
Client: Jimmy Paul (Crafty, LLC)

Team Members

David Bis, Adam Hauge, Noah Bix, Hanna Moser, Samuel Guenette, Ben Gruman

Outline

- Motivation and Solution
- Requirements
- Feature Highlights
- Implementation
- Testing Results
- Challenges
- Future Plan

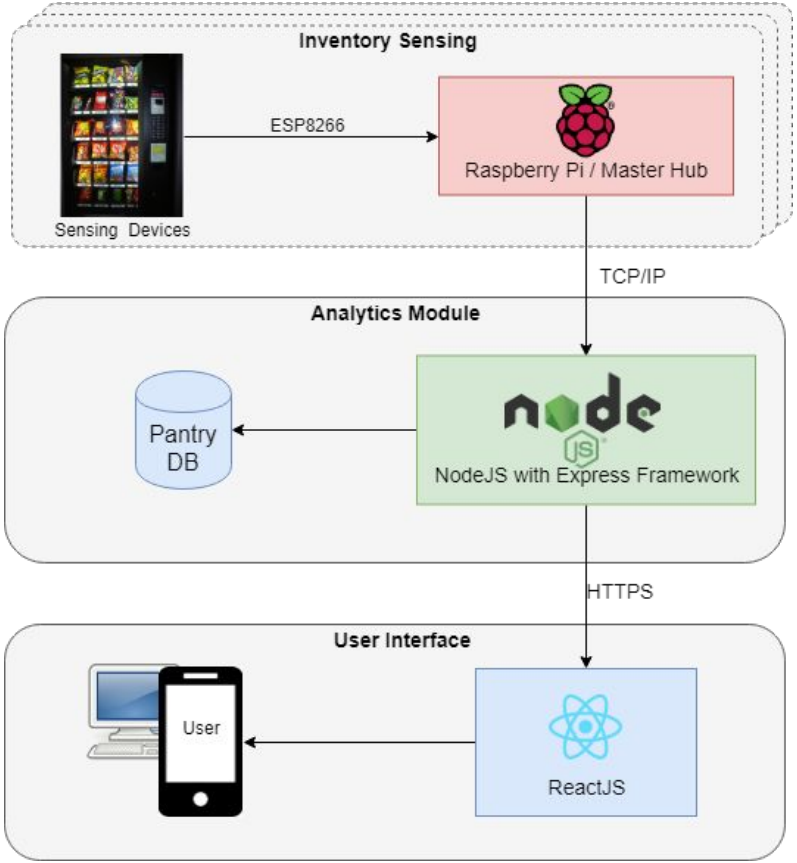
Motivation & Problem Statement

- **Crafty delivers food to office pantries**
  - Crafty employee stationed at each office
    - Keep track of inventory and reorder items
  - Trucks restock multiple offices based on individual orders
- **Issues**
  - Added expense for gas and labor
  - Human error
  - Time inefficiency
  - Route Inefficiency

CRAFTY

Craft A Better Workplace

Block Diagram



Market Survey

- **Impinj** - Automatic inventory management with RFID
- **Barcodes, Inc.** - Inventory management with barcode scanners
- **Route4Me** - Optimal route planning

Functional Requirements

Sensor Network

FR.1: Transmit product quantities individually

FR.2: Sensor arrays fit all stockrooms

Analytics Software

FR.3: Create optimal delivery routes

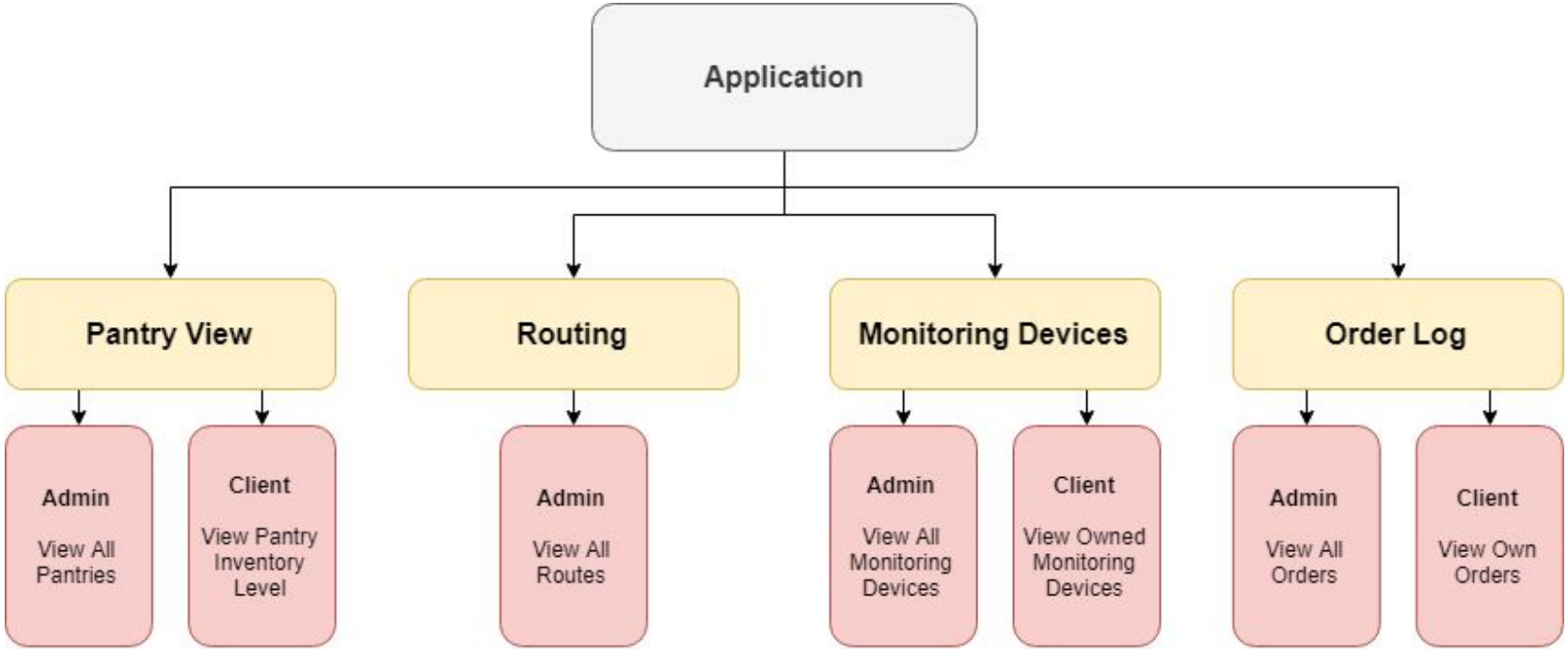
FR.4: Display & monitor the stockroom inventory data

Non-Functional Requirements

- **Scalability** - The sensor nodes should fit into multiple pantries
- **Data Integrity** - Sensors should be accurate and consistent over their lifetime
- **Availability** - Inventory should update at least once every weekday
- **Deployment** - New sensor devices should automatically detected by master
- **Usability** - User interface should be intuitive
- **Resilience** - Sensor network should be protected from typical motions of pantry inventory

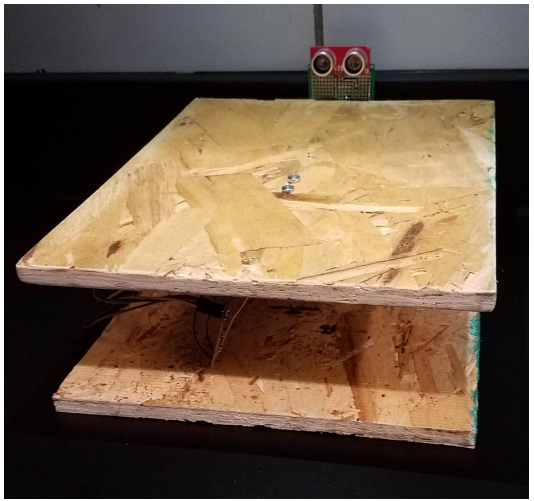
Feature Highlights

Functional Decomposition - Website



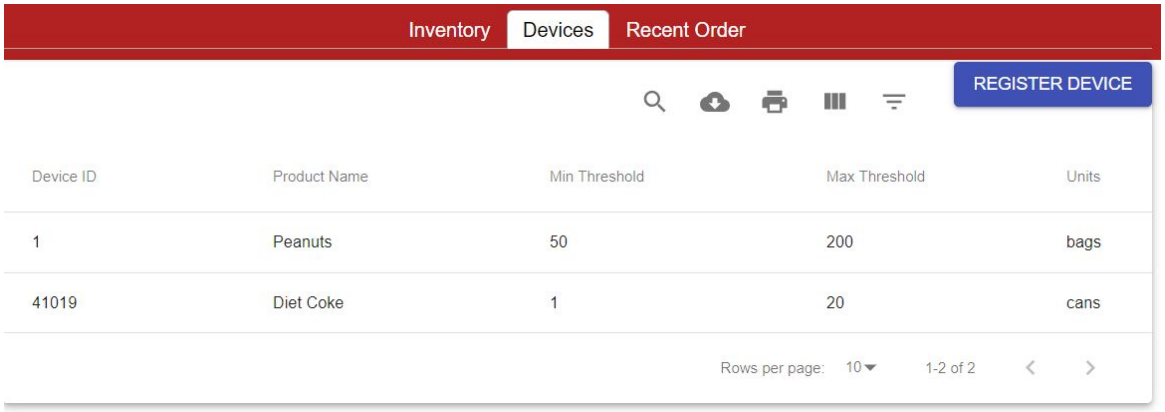
Monitoring Devices

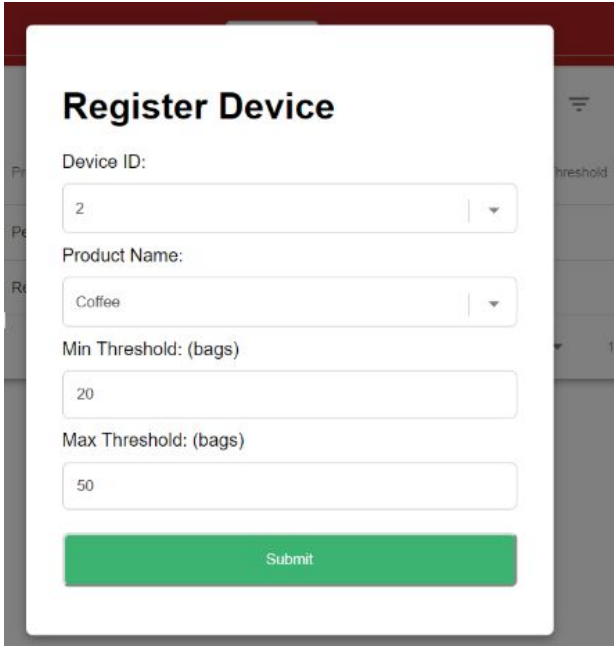
- Monitors product weight and sonar (distance)
- Master Raspberry Pi collects and communicates sensor data to server
- Each monitoring device powered by ESP8266



Device Registration

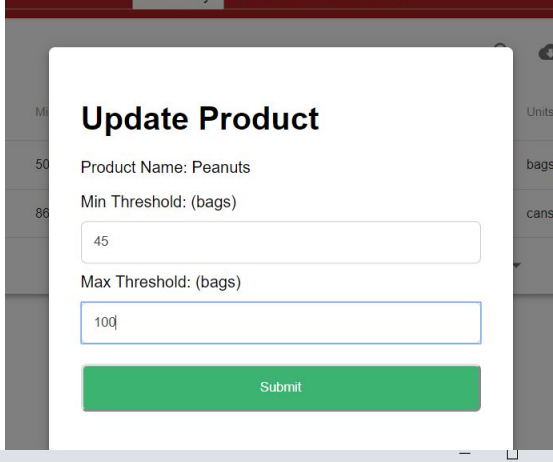
- Add monitoring devices
- Modify monitored product per device

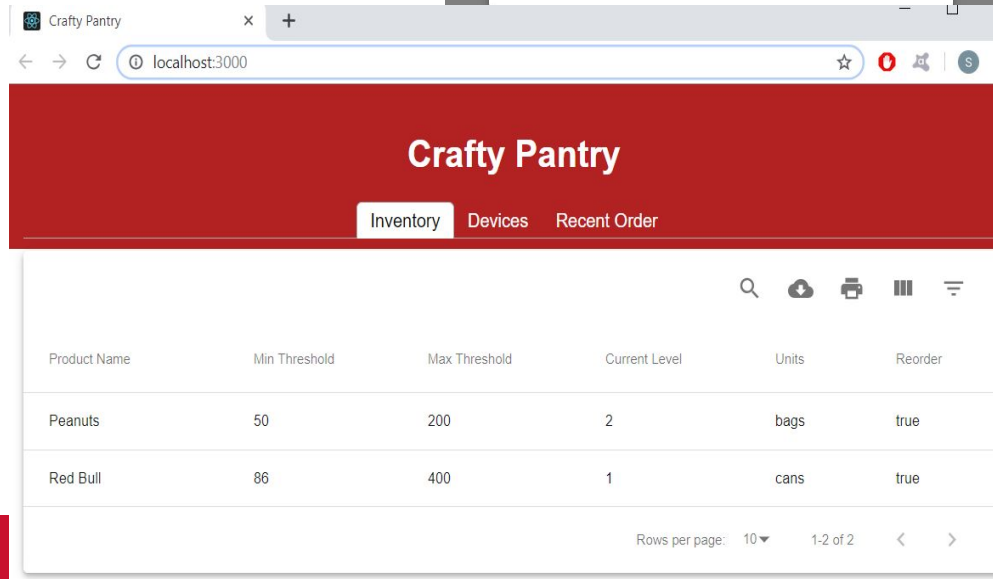




Pantry Inventory

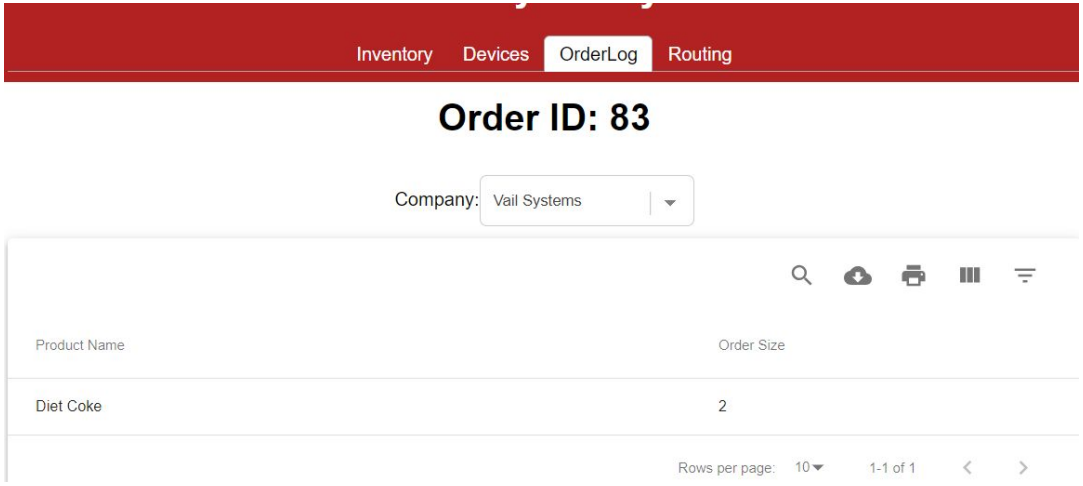
- Display product levels
- Adjust product thresholds

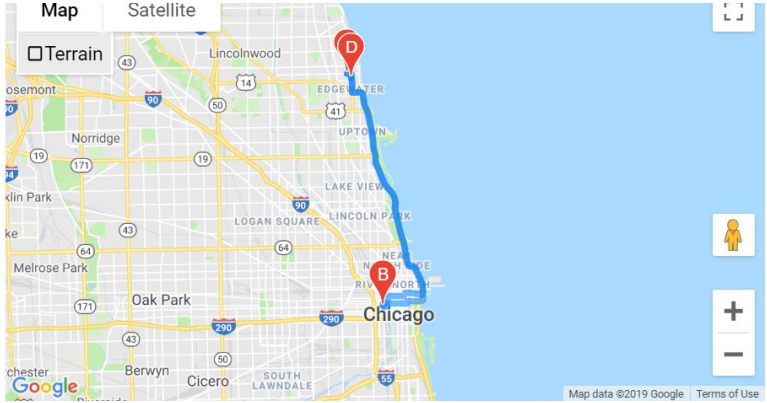




Route Optimization

- Based on most recent order, optimal route for fleet of trucks is calculated
- New route is automatically generated each day





Route Details

1) CRAFTY WAREHOUSE: 6056 N Broadway, Chicago, IL 60660

2) Vail Systems: 2 N Riverside Plaza, Chicago, IL 60606

3) Apple Inc: 1315 W Granville Ave, Chicago, IL 60660

4) CRAFTY WAREHOUSE: 6056 N Broadway, Chicago, IL 60660

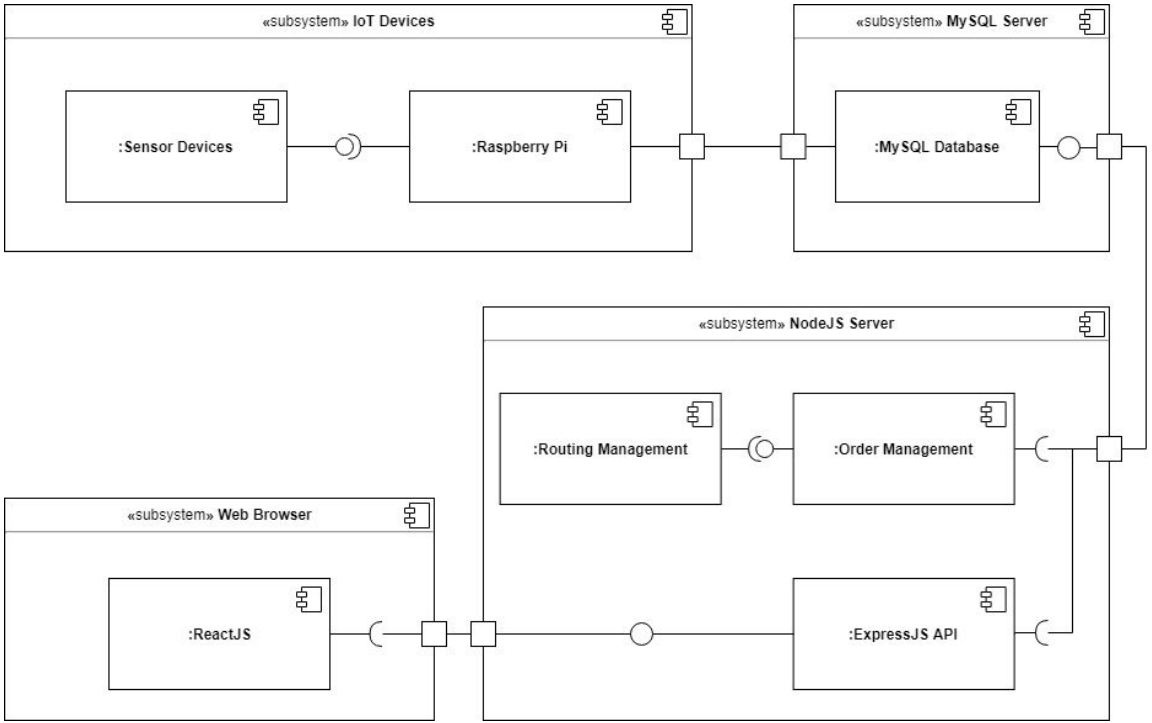
Routing Algorithm

- Improved Clarke-Wright Savings Algorithm
  - Destinations are added into a route starting from greatest “savings” to least “savings”
- Considers following constraints:
  - Maximum truck capacity
  - Expected daily traffic variance
  - Route time estimation limit
- Generates automatically based on most recent order data
- Improved Savings Equation:

$$Savings(i,j) = [\ dist(1,i) + dist(j,1) - dist(i,j)\ ] * trafficFactor(mergedRouteDistance)$$

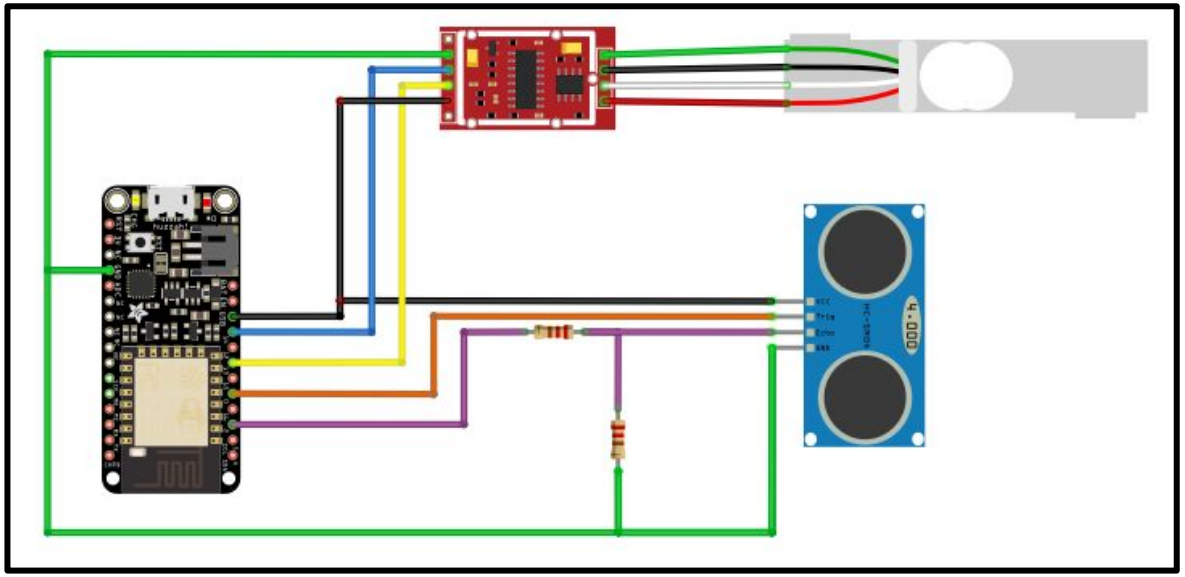
Implementation

Implementation Diagram

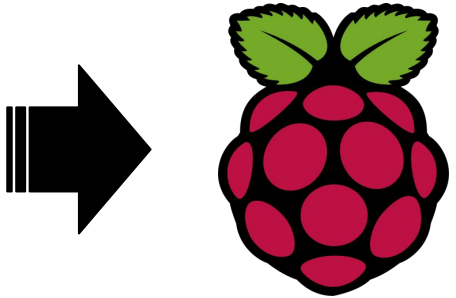


Detailed Design - Sensor Network

Sensor Module Components

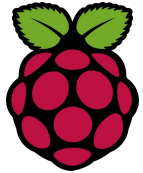
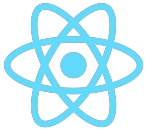


Raspberry Pi



Hardware/Software/Tech Platforms

- **Sensors**
  - Weight sensor
  - HC-SR04 Ultrasonic distance sensor
- **Monitoring Device**
  - Raspberry Pi 0W (Master Component)
  - ESP8266 (Slave Component)
  - Python
- **Web Component**
  - ReactJS
  - NodeJS Backend Processing
    - Sequelize API to Query Database
    - ExpressJS for REST API
  - MySQL Database
  - Redhat 7 Server



Resources and Cost Estimation

- **Sensor Network**
  - Master Microcontroller: $30
  - Sensor Array: $50 / module
- **Analytics Software**
  - All used software is free of charge
- **Labor Resources**
  - Required for sensor network maintenance

Functional Test Results

- The Mocha Testing Framework and Postman produce expected results
  - Unit tests exist for all relevant business logic code blocks
- Routing algorithm tested run-time based on *n* destinations
  - Expected input size will be no greater than *n* = 100

Routing Algorithm Stress Testing

n	Time (s)
10	0.003
100	23.1
200	543.9

Non-Functional Test Results

- **Scalability** - All sensors successfully detected through the system
- **Data Integrity** - Both *.csv* files are equivalent
- **Availability** - Order delivery routes successfully generated
- **Deployment** - All new sensor modules discoverable by the network
- **Usability** - Automated time less than a minute
- **Resilience** - Sensor devices remain accurate after a semester of use

Demo Video

Challenges

- Interdisciplinary team required collaboration for solution
- Routing problem is derivative of Vehicle Routing Problem (NP-Hard)
- Managing an ad-hoc sensor network of variable sizes

What We Learned

- API and language conventions
- Managing IoT communication
- Various route optimization algorithms
- Interdisciplinary teamwork

Future Plans

- The project will be handed back to Crafty LLC for further development
  - Improve Scale Construction
  - Improve Device Registration
  - Improve Routing Algorithm
    - Traffic Abnormalities
    - Fine Resolution in Traffic Variance

Task Responsibility/Individual Contributions

David Bis — Back-end Developer, Meeting Facilitator

Sam Guenette — Back-end Developer, Public Relations

Hanna Moser — Front-end Developer, Meeting Scribe

Adam Hauge — Network Architect, Report Manager

Ben Gruman — Hardware Architect, Resource Acquisition

Noah Bix — Hardware Architect, Documentation Manager

Questions