UMassAmherst

Cumulative Design Review

Stride

March 7, 2018

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What is the Problem?

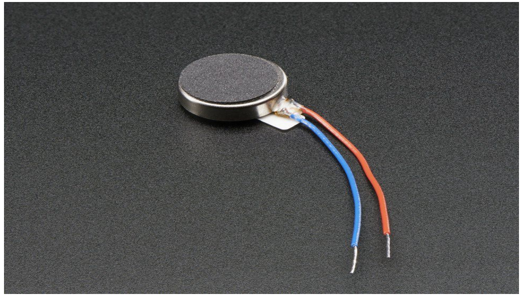
- Parkinson's Disease (PD) makes walking challenging
- Physical therapy and other treatments are expensive
- Limited inexpensive methods of monitoring exercises outside of clinical environment

What is Stride?

- Low cost array of wearable sensors that collects body movement information, designed for those with Parkinson’s Disease
- Provide real-time feedback and track long term performance progress
- Used in home as well as in clinical environment

Neuro Training

- Vibrations on knee to indicate stride length error
    - Patient-specific stride length threshold
    - Two levels of vibrations depending on severity of error (both benign)

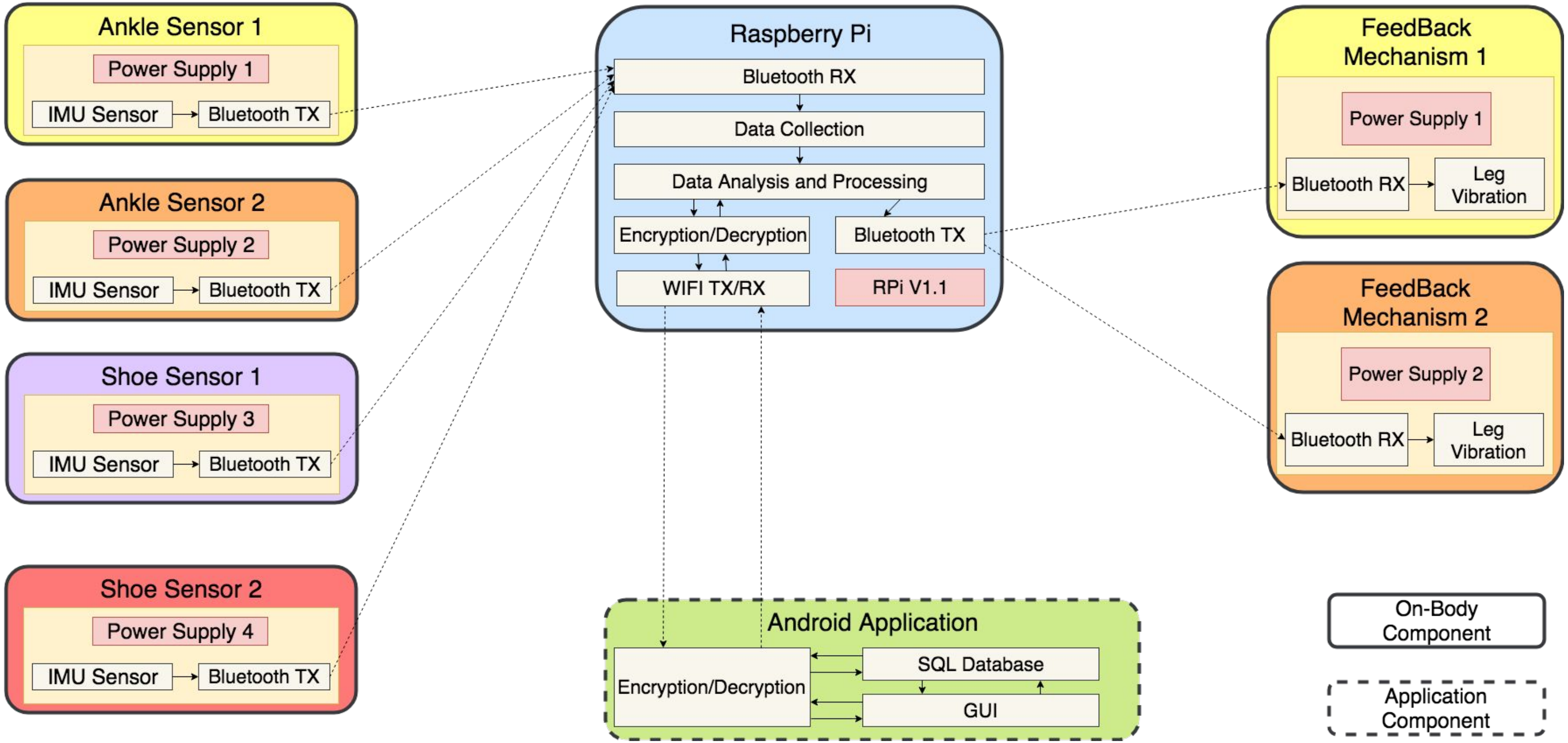


- Auditory Cueing
    - Rhythms played via app to stimulate proper cadence
    - Recommended by a Neurological PT

System Requirements

- Accurately collect movement data to appropriately monitor an individual's:
  - Stride length
  - Cadence
  - Heel-to-toe motion
  - Freezing
- Provide real-time feedback to correct stride length during exercise (less than 100ms)
- Store and display data Android application to track long term patient progress
- Lightweight product that is easy for patient to put on
  - Sensor systems < 1 pound each
  - Waist clip (Raspberry Pi + power supply) < 1 pound
- Sensor systems and Raspberry Pi will have battery life of greater than 2 hours

CDR Block Diagram



Hardware Components

PCB	Shoe (x2)	Knee Sleeve (x2)
Processor	Atmega328p	Atmega328p
Bluetooth	HC-05	HC-05
Battery	Lithium Polymer	Lithium Polymer
Feedback Circuit	No	Yes
IMU	BNO055	BNO055

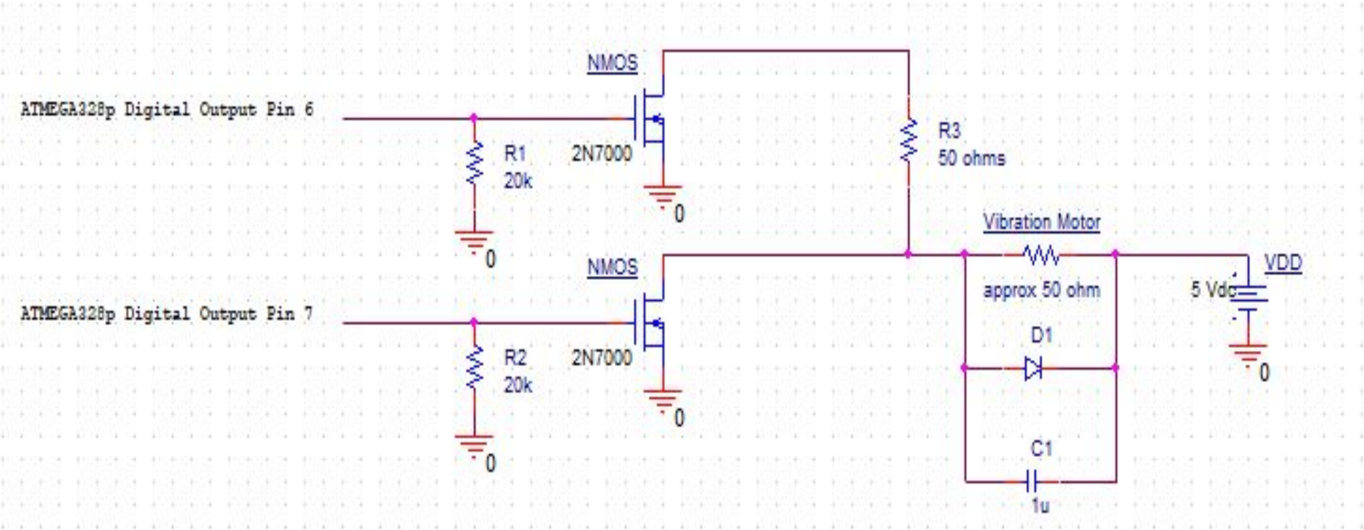
Lithium Polymer Battery

- 5 Identical Batteries
- Rechargable
  - RPi PowerPack V1.1
- 4.3-3.7 V
- 3800 mAh
- Meets all power specs
  - > 6 hrs Raspberry Pi
  - > 12 hrs knee sensor
  - > 20 hrs shoe sensor

Feedback Circuit

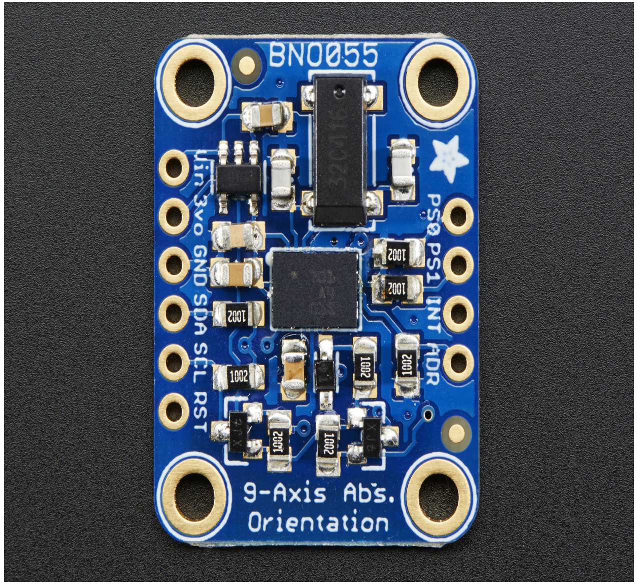
Motor Noise Elimination

- Pulldown Resistors
  - R1,R2
- Flyback Diode
  - D1
- Filtering Capacitor
  - C1



BNO-055 Sensor

- Fuses 3 axis gyroscope, accelerometer, and magnetometer data using an embedded processor
- Data Outputs: Absolute orientation, linear acceleration (100 Hz maximum)
- Advantages over LSM9DOF: Frees space on ATmega for calculations, outputs more reliable and useful data



Data Analysis Overview

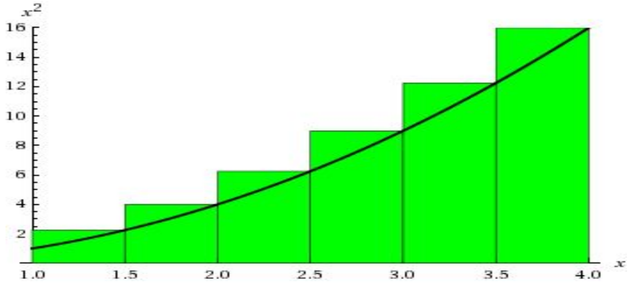
- Calculating Parkinsonian performance metrics
- Use double integration of linear acceleration for stride length
- Use absolute orientation values for heel-to-toe transfer

Table 1: IMU Measurements and Metrics

	Measurements	Metrics
Ankle IMU	Linear Acceleration	Stride length, Cadence
Shoe IMU	Euler Angles (Orientation), Linear Acceleration	Heel-to-toe weight distribution, freezing

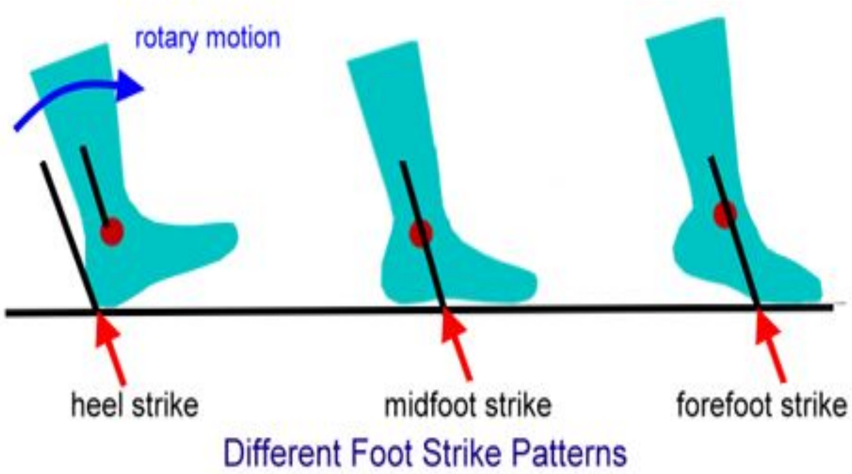
Data Analysis-Ankle

- Linear Acceleration (+X) → $\iint$ → Displacement
- Spike in linear acceleration in Z direction = step complete
- Track time between samples, do successive integrations over this sample period
- Sum of displacements over this time = stride length
- Averaging (Low Pass) Filter: average each acceleration with two nearest neighbors to eliminate noise and outliers

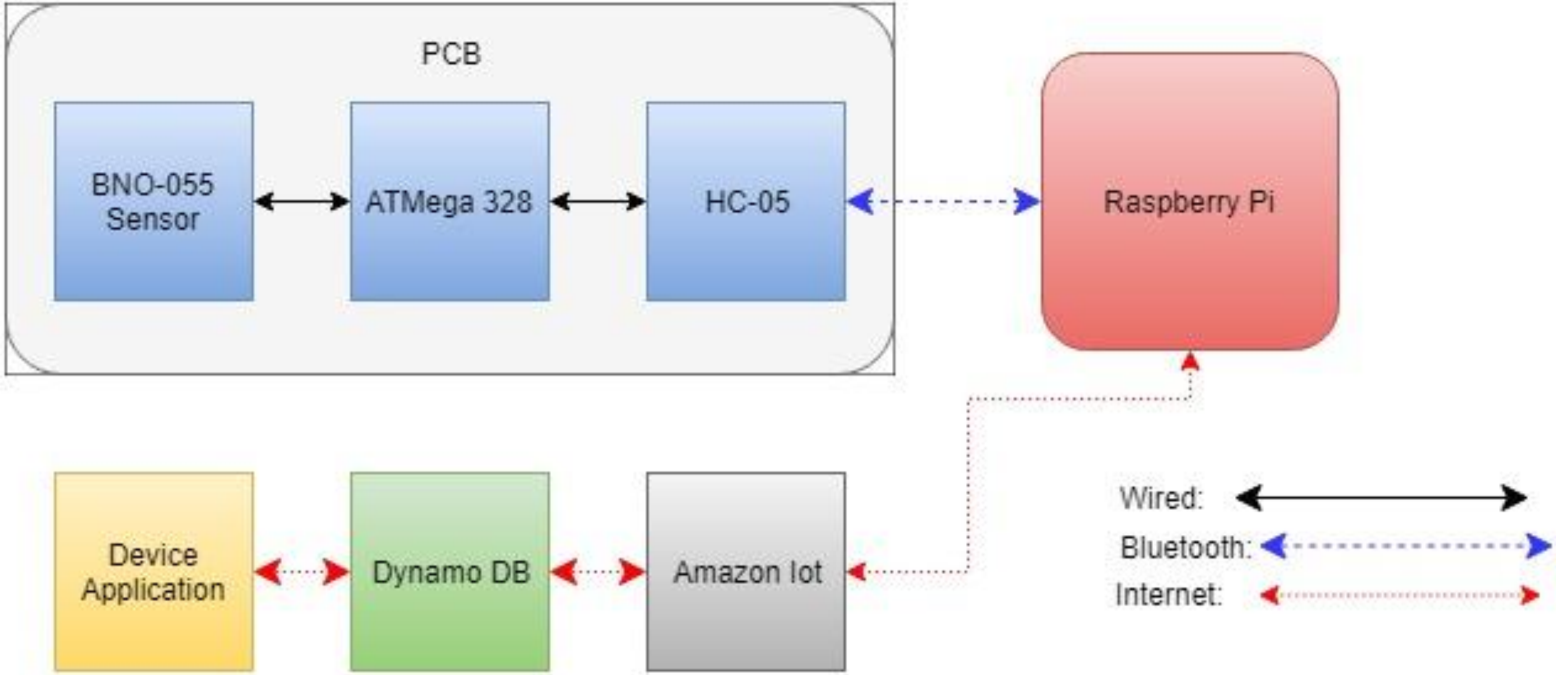


Data Analysis-Shoe

- New step = spike in linear acceleration on Z axis
- Record range of angular orientation values upon each new step
- Larger range of Euler angle from heel-strike to toe-off means greater degree of heel-to-toe weight transfer
- Understand acceptable values through experimentation
- Track this data long term

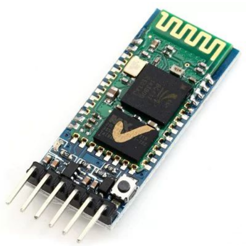


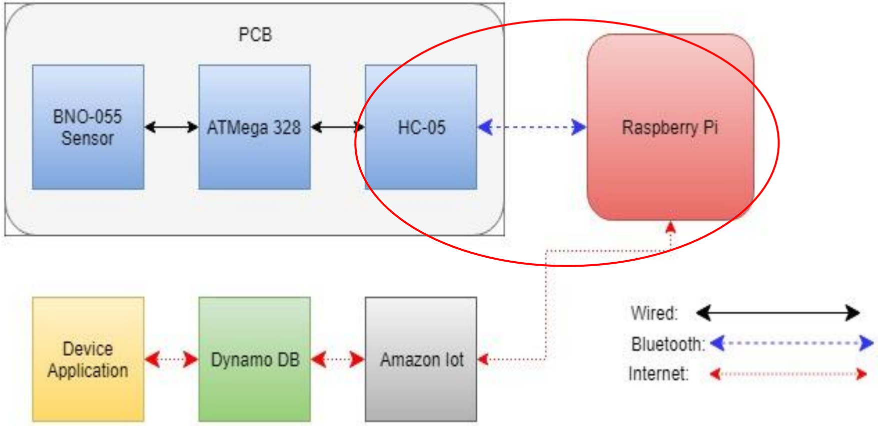
Data Movement



Data Movement: PCB to Raspberry Pi

- HC-05 transmits data outputted by Atmega over serial Pi connection
- Auto-Pair and Start Functions
- Python program on Raspberry Pi program, then listens and formats the received bytes





Data Movement: Raspberry Pi to Amazon Iot

- Pi runs program to format data into MQTT, JSON format
- Amazon IoT Topic

dataTopic Dec 8, 2017 10:41:44 AM -0500 Export Hide


```
{
  "sessionID": "1_49",
  "magnetometerz": "0.66",
  "accelerometer x": "-3.18",
  "user": "rhartnett",
  "accelerometer z": "8.61",
  "magnetometer x": "0.26",
  "magnetometer y": "1.03",
  "gyroscope x": "-0.42",
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  "gyroscope z": "-7.84",
  "accelerometer y": "-2.02"
}
```
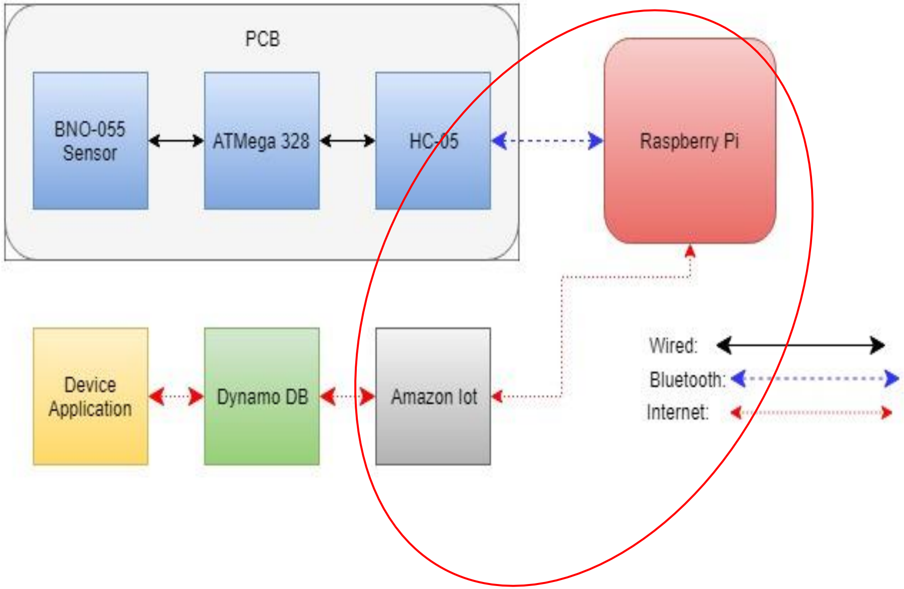
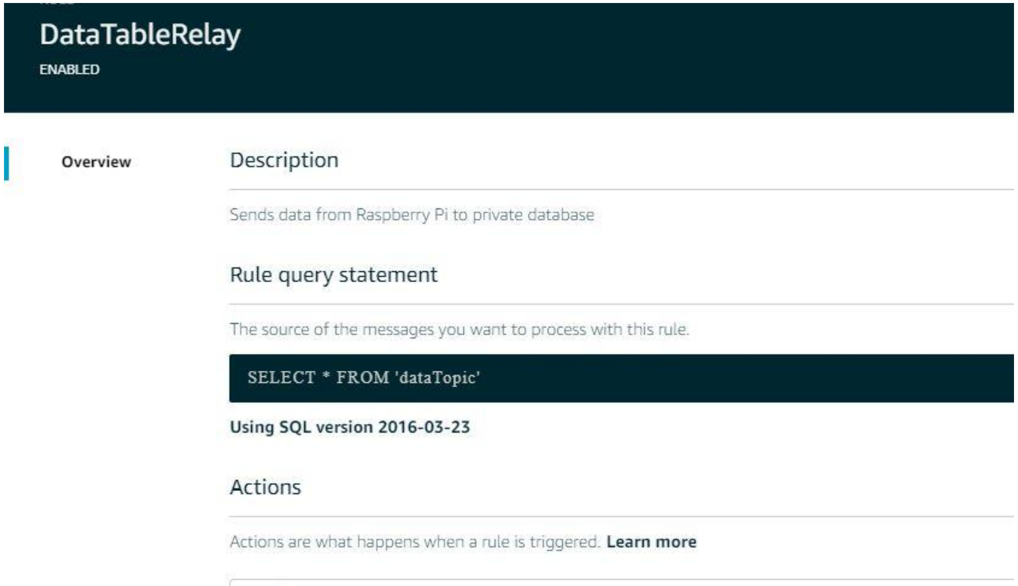
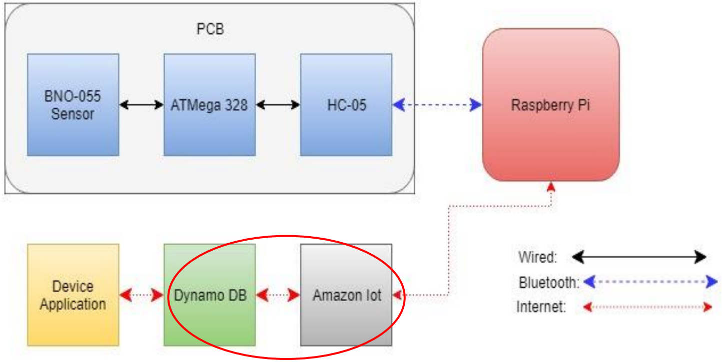




Data Movement: Amazon Iot to DynamoDB

- Rules that react to Topics
- Permissions for Certified Users





Application Backend

- Used AWS Mobile Hub to integrate backend with Android Application

- Created multiple NoSQL database tables to store application data

- Database consists of 5 tables
  - User Information
  - Patient List for Therapist
  - Patient Workout List
  - Overall Workout Performance
  - Session Workout Performance

Application

- Android application designed in Android Studio
- Functionality:
  - Patient/Therapist Login
  - Therapist can program workouts for specific patient
  - Therapist can view patients session performance
  - Patient can view session performance
  - Patient can view and perform programmed workouts
  - Patient workout auditory queuing

Proposed CDR Deliverables

- Complete design of knee sleeve with functional IMU (no feedback)
  - Completed data analysis
- Functioning prototype of shoe with no data analysis
  - Data passed through the pipeline of system
- Simultaneous bluetooth connection between IMU systems and Raspberry Pi
- Implement auditory cueing on Android Application and exercise programming

FDR Deliverables

- Fully functional knee and shoe sensor with data analysis
- Breadboard → PCB
- Real-time feedback incorporated into data analysis
- Fully functional and polished application
  - Be able to start workout from application

Goals of Demo

- Show basic data analysis using knee sensor system and view data received by the Raspberry Pi over BlueTooth
- Show data movement through all systems
  - BNO055 → Atmega328 → HC-05 → Raspberry Pi → AWS backend → Android Application
- Show simultaneous sensor data transfer
- Show feedback system functionality
- Show application design and functionality
  - login/create account
  - Therapist side
  - Patient side

Thank You

Questions?