Micro-Robot Control and Coordination

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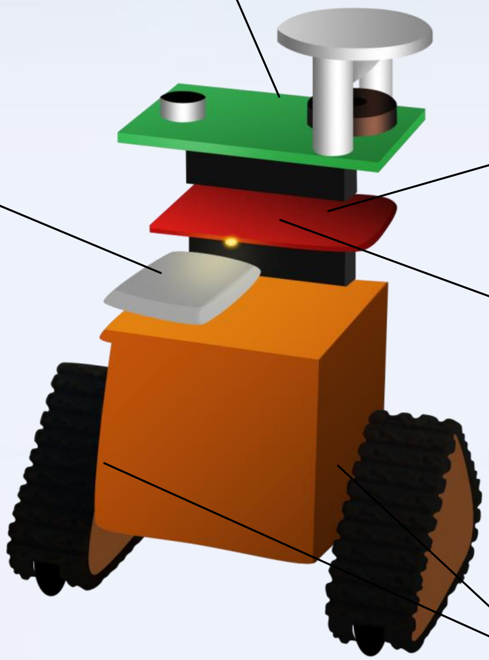
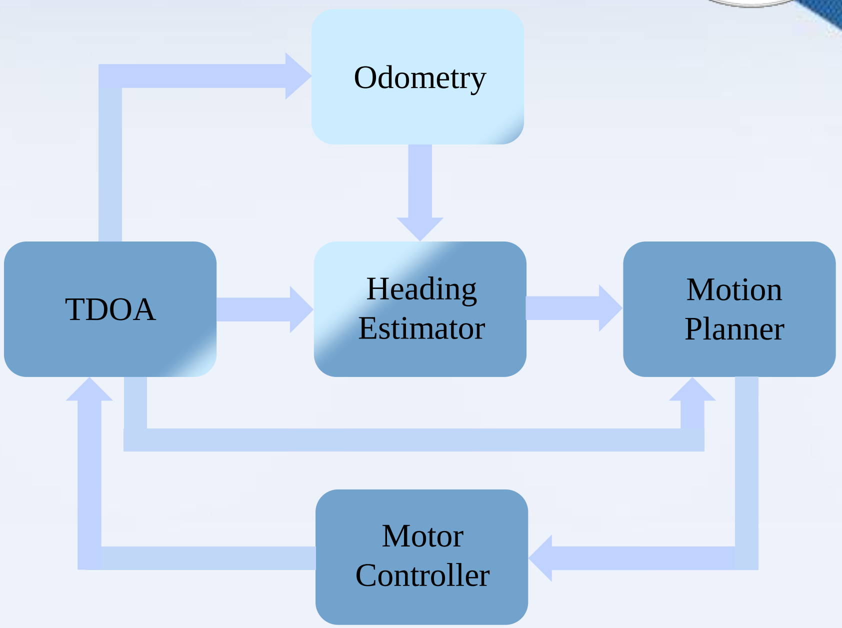
The Wall-E Bots



- Objectives
  - Make bots follow a leader bot by using distance sensing alone
  - Improve motion control and environmental awareness
  - Formation following in a swarm of robots

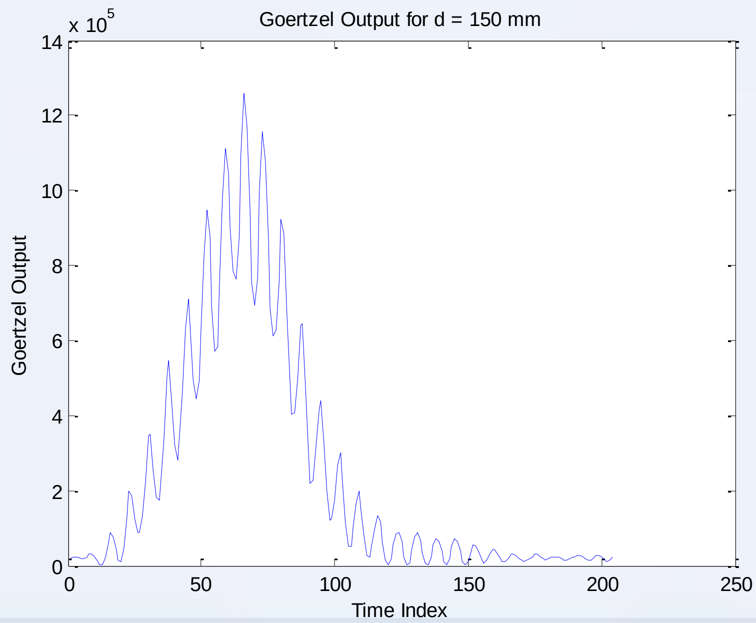
System Overview

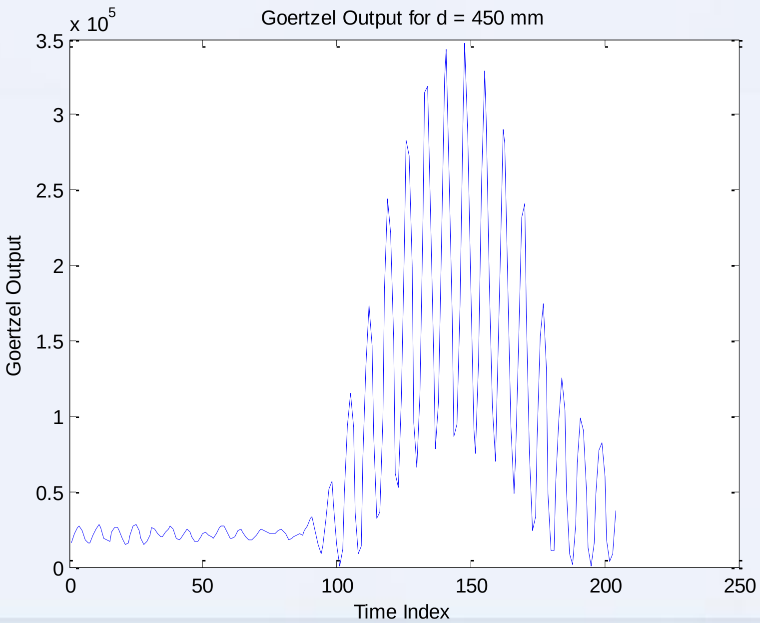
- Time Difference Of Arrival (TDOA)
  - Distance measurement
- Odometry
  - Position tracking
- Heading Estimator
  - Uses TDOA to determine the angle of rotation required
- Motion Planner
  - Uses TDOA and heading information to plan a route
- Motor Controller
  - Executes motion according to the planner



TDOA

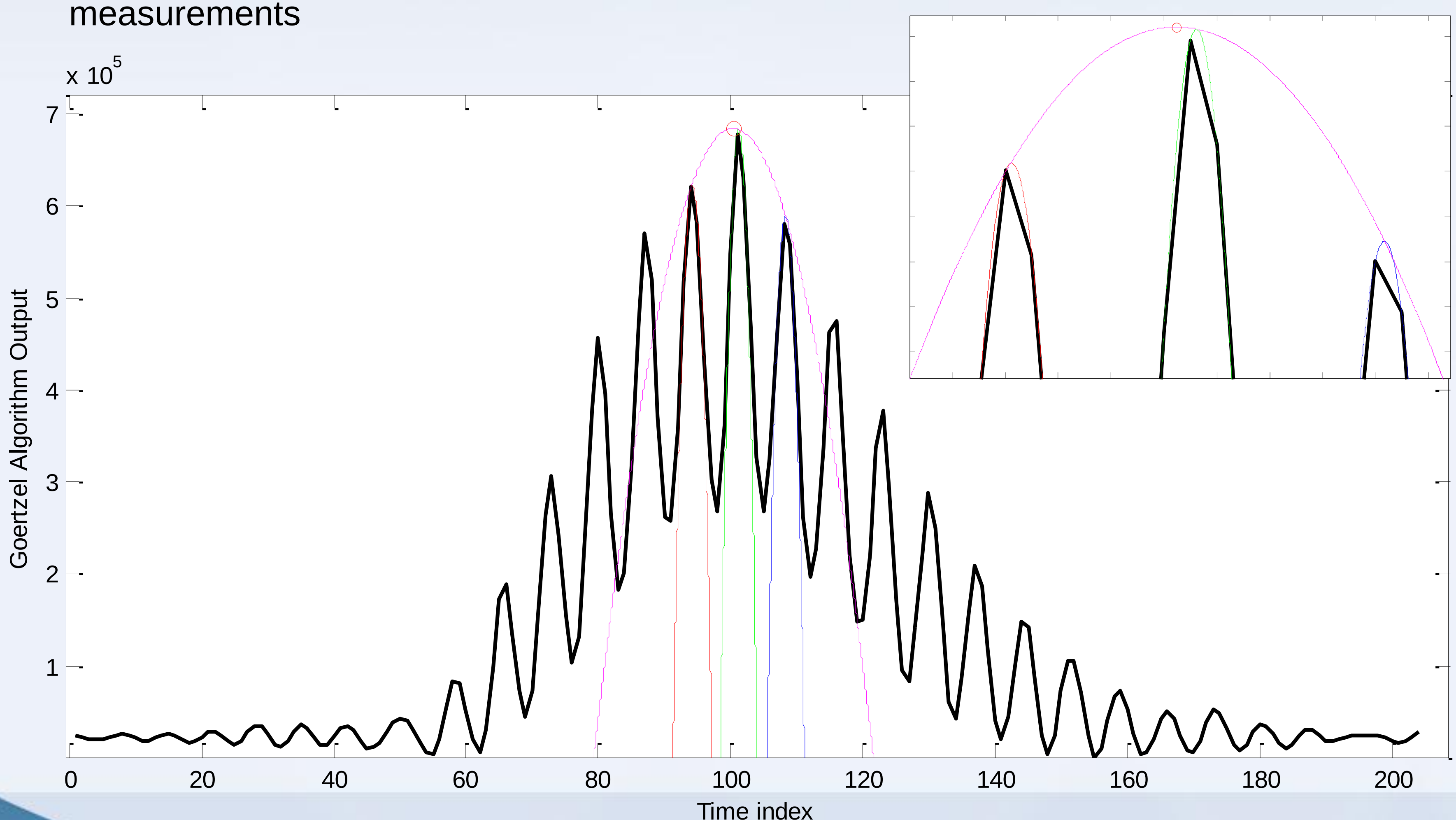
- Filtering: Goertzel algorithm
  - Signal processing technique, similar to Fast Fourier Transform (FFT)
  - Detects the presence of specific frequencies
- Feature extraction: Peak of signal vs. signal envelope
  - Peak of signal envelope estimated through interpolation



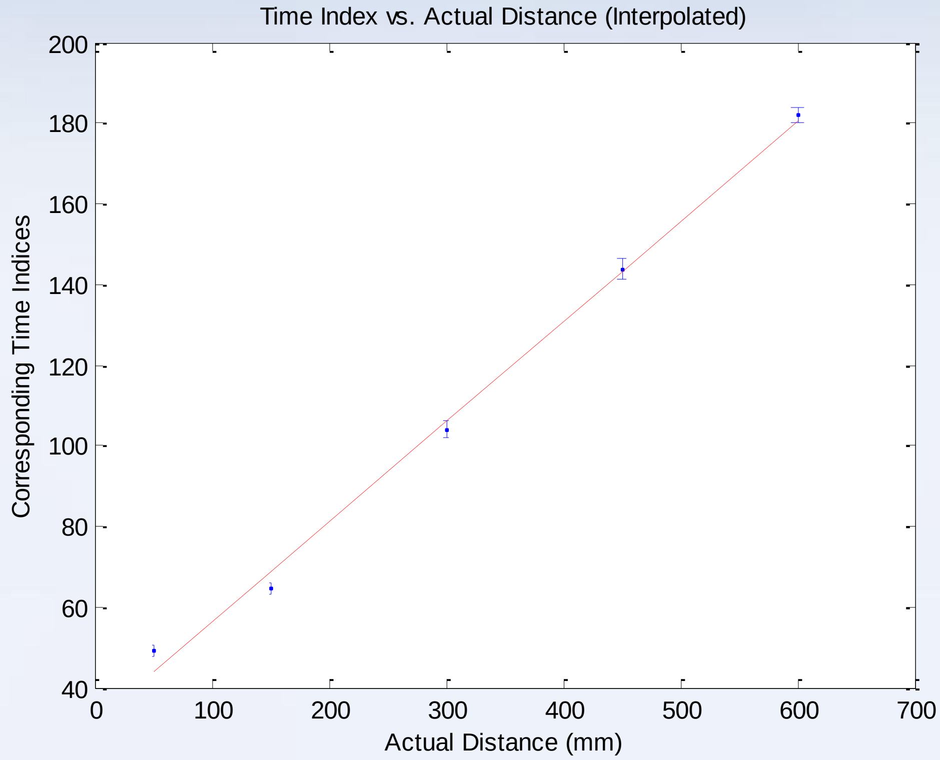


4-Parabola Interpolation

Approximating signal envelope using interpolation yields more accurate distance measurements



TDOA Calibration



Method	Interpolation basis	Mean resolution
Goertzel, 4 parabolas	Lagrange	0.88cm
Goertzel, 1 parabola	Lagrange	0.86cm
Goertzel, 1 parabola	Monomial	0.84cm
Goertzel	none	1.06cm

Motor Calibration and Odometry

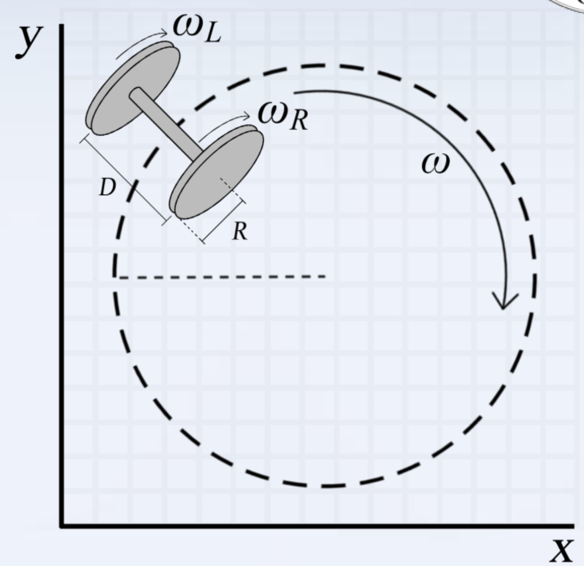
- **Calibration**
  - Used to find the relationship between applied voltage (PWM) and resulting velocities (twist)

$$\begin{bmatrix} v \\ \omega \end{bmatrix} = A \begin{bmatrix} P_L \\ P_R \end{bmatrix}$$

Twist PWM

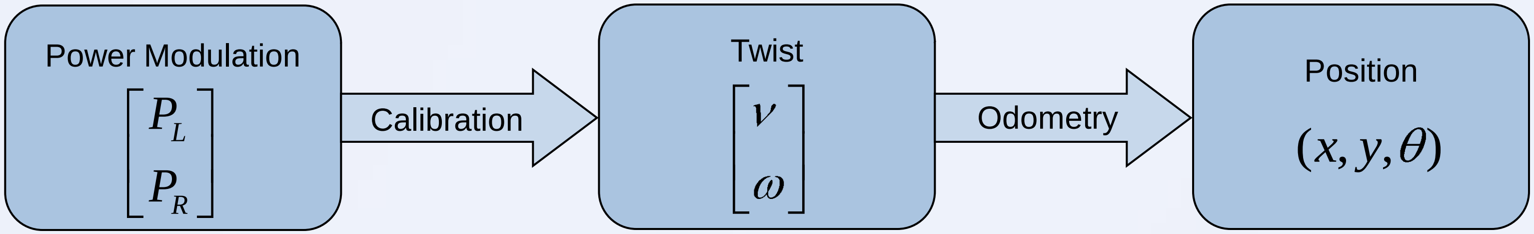
P_L = *left pulse*

P_R = *right pulse*



- **Odometry**
  - Used to identify where the robot is located after a specific motion

$$v = R\frac{(\omega_L + \omega_R)}{2} \qquad \omega = R\frac{(\omega_L - \omega_R)}{D}$$



Motor Calibration (continued)

- Calibrating means finding the relationship between power applied and resulting velocities.
- The twist is linearly proportional to motor power modulation (PWM).

$$\begin{bmatrix} v \\ \omega \end{bmatrix} = A \begin{bmatrix} P_L \\ P_R \end{bmatrix}$$

Steps

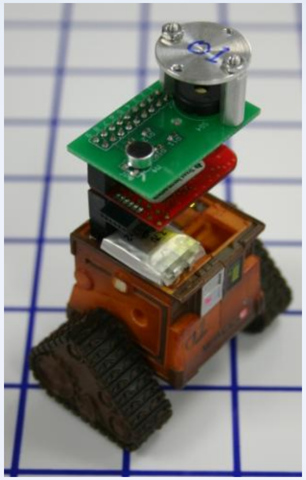
1. Command assignment (e.g. f 50, 00) and trajectory tracking
2. Computation of forward and rotational (twist) velocities from the trajectory
3. Use of experimental twist and initial pulses to find the 2x2 matrix

Error Results

Calibration Technique			
SVD: Circle fit		Odometry	
v	ω	v	ω
0.12	0.3	0.12	1.08

Odometry

- Odometry allows the estimation of the traveling robots' position in Cartesian coordinates.



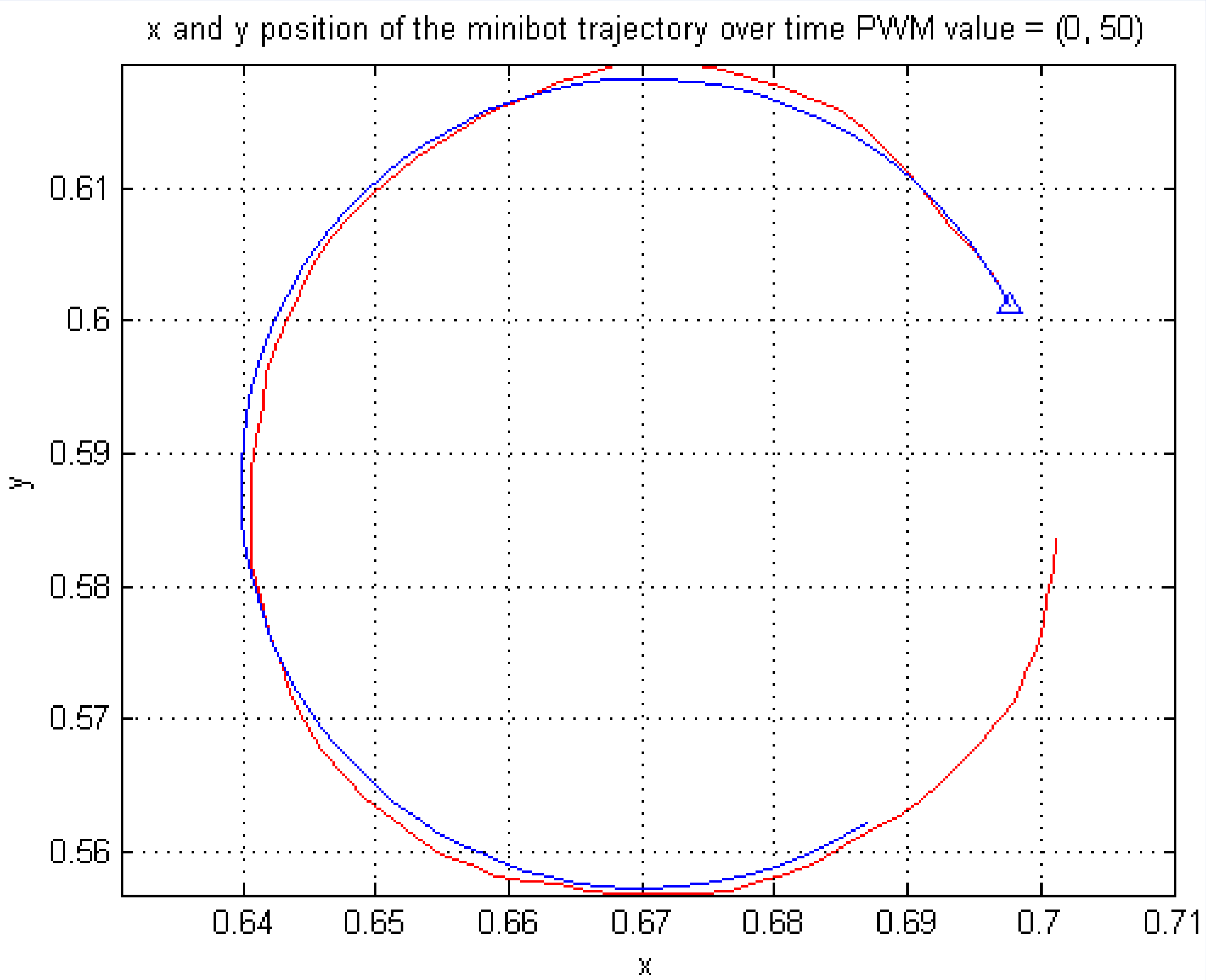
- The motion of micro-bot can be modeled as:

$$\begin{bmatrix} x' \\ y' \\ \theta' \end{bmatrix} = \begin{bmatrix} v\cos\theta \\ v\sin\theta \\ \omega \end{bmatrix}$$

- Solving the system of equations gives a prediction about the trajectory of the robot for a specific command.

- The Cartesian coordinates of the robot depend on its angular and forward velocity, which also depend on the given pulse.

Experimental and Simulated Trajectories



Simulation

Actual Trajectory

Future Work

- TDOA Distance Sensing
  - Explore additional interpolation methods
  - Consider using Received Signal Strength Indicator (RSSI) for shorter distances

- Motor Calibration and Odometry
  - Estimate the error between the predicted and experimental trajectory of the mini-robot and try possible corrections
  - Improve the calibration of the Walle-bots

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