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Micro-Robot Control and Coordination

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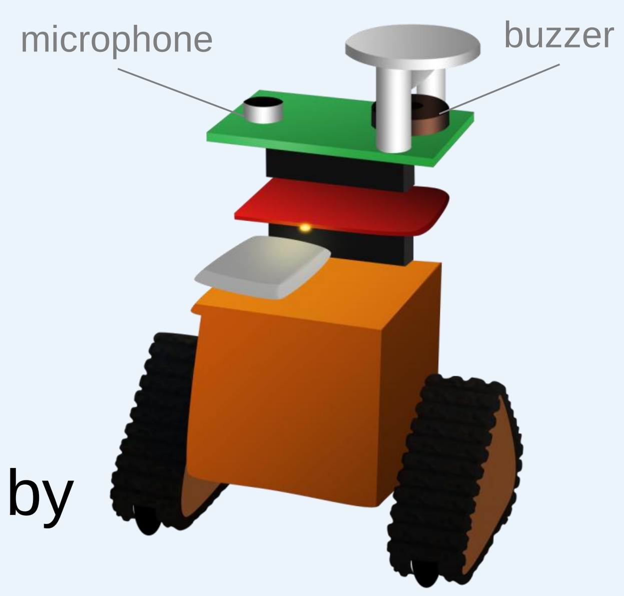
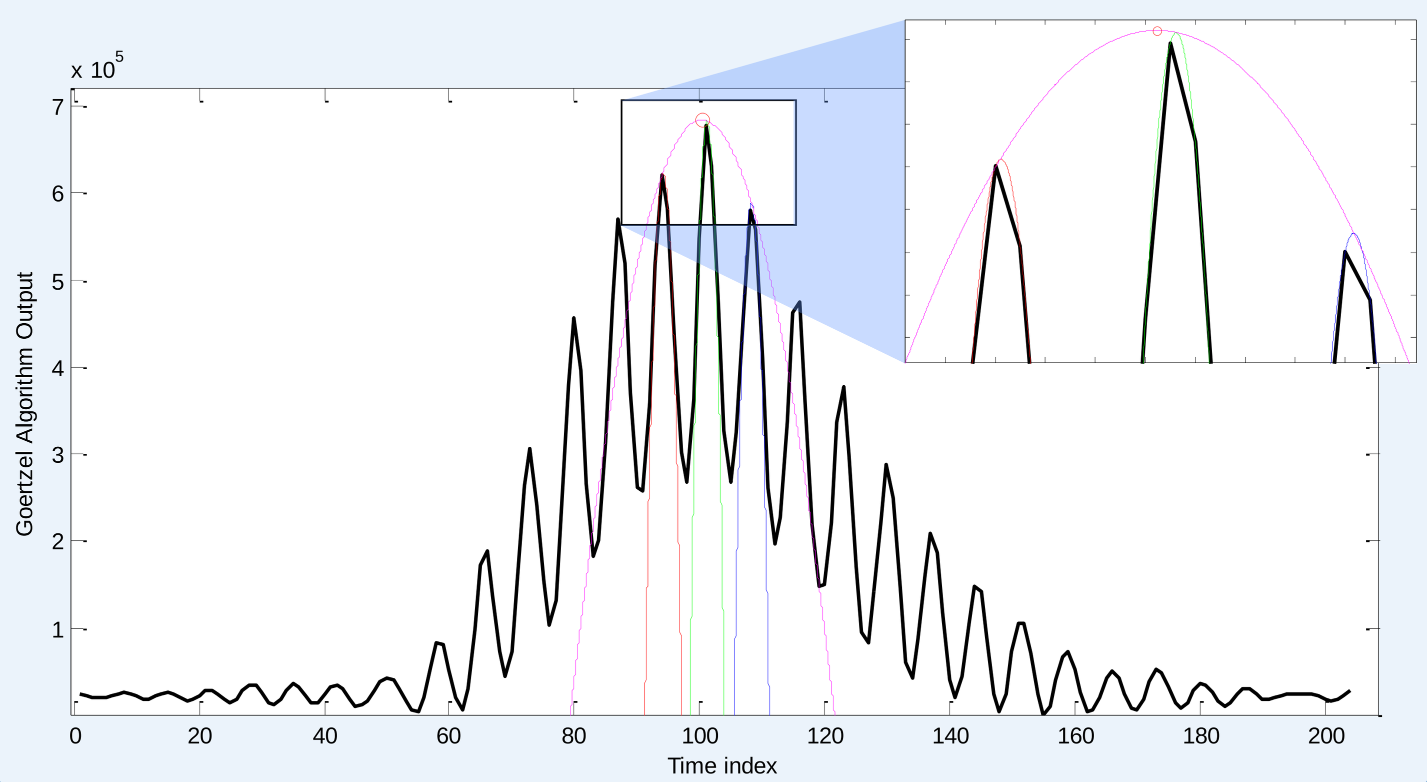
Goals

- Have a swarm of mini-robots follow a leader using distance-only sensors
- Refine distance sensor resolution through signal envelope interpolation
- Improve spatial awareness by incorporating odometry



Distance Sensing

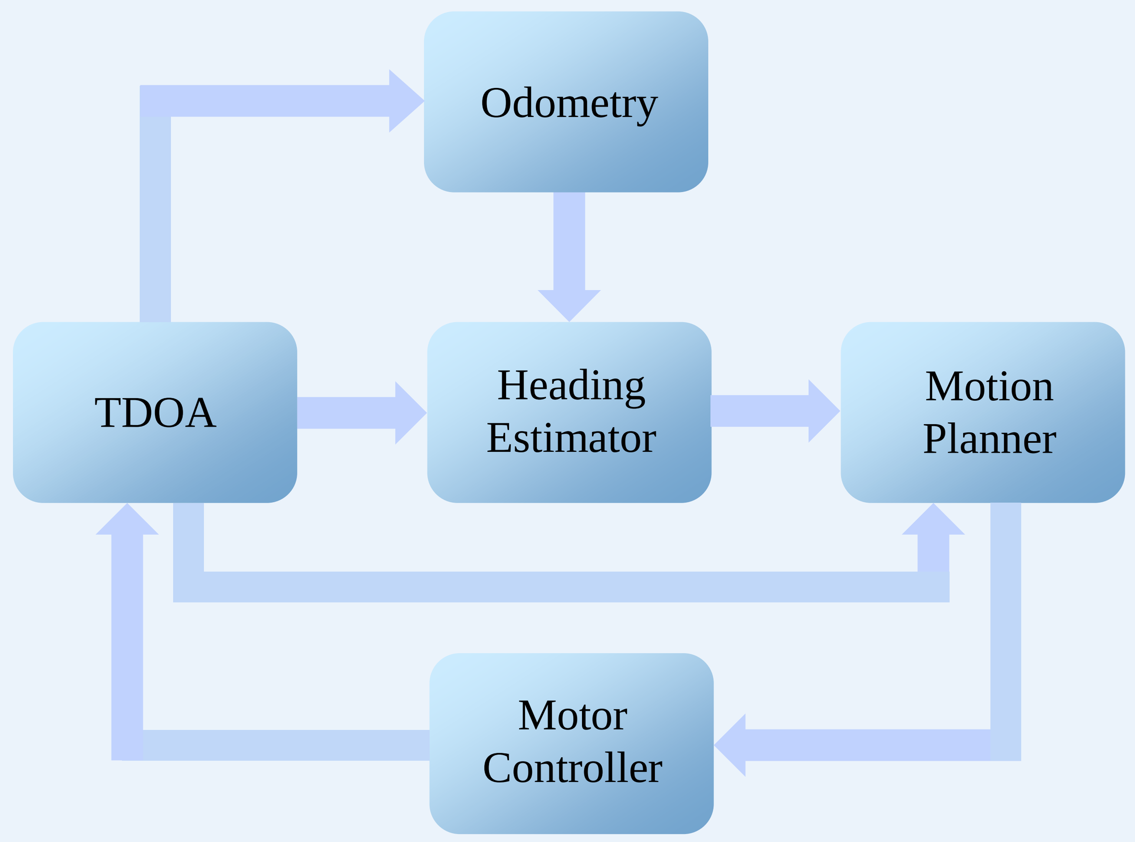
- **Time Difference of Arrival (TDOA)**
  - **Transmission**: leader robot emits a 12kHz sound pulse and a RF packet simultaneously
  - **Reception**: RF packet reaches the follower and instructs the microphone to start listening for pulse
  - **Filtering**: Goertzel algorithm detects the frequency of interest in the audio signal
  - **Interpolation** (Goertzel waveform): allows a better estimate for the time index at which the pulse occurred (peak of parabola)



Goertzel output interpolation using three peaks.

System Overview

- **Time Difference of Arrival (TDOA)**: estimates how far away the leader is located
- **Odometry**: keeps track of the robot's position over time
- **Heading Estimator**: uses the Law of Cosines to estimate the angle between the follower and the leader
- **Motion Planner**: concerned with planning the path in terms of angle and distance
- **Motor Controller**: drives the motors according to the planned motion



Conclusions

- Integrating interpolation in peak detection yields a better distance sensor resolution.

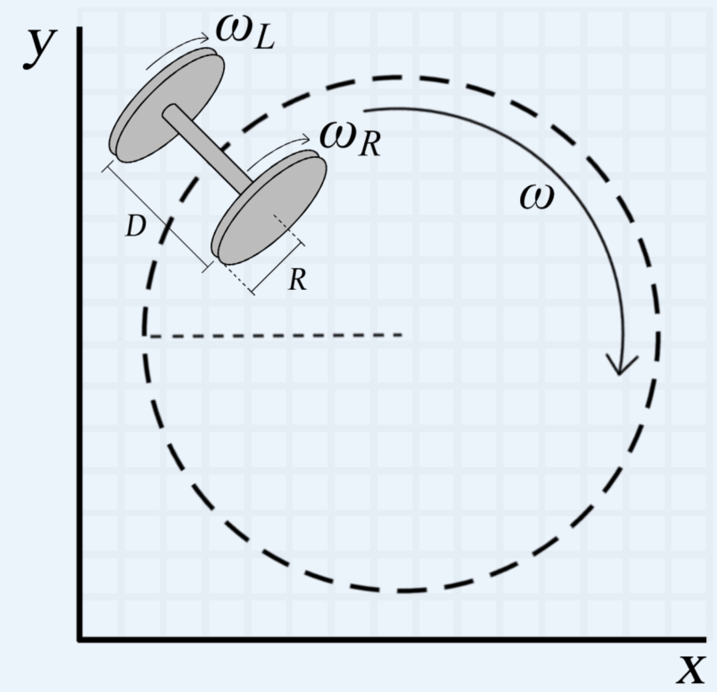
Method	Mean Resolution
No Interpolation	1.06 cm
Interpolation	0.84 cm

- Even though the robot is limited to a distance sensor only, it is possible to control its motion and position over time.

Motor Calibration

$$\omega = R\frac{(\omega_L - \omega_R)}{D}$$

$$v = R\frac{(\omega_L + \omega_R)}{2}$$



- **Calibration**: finding the linear relationship between the applied voltage and the resulting angular and forward velocities (twist)

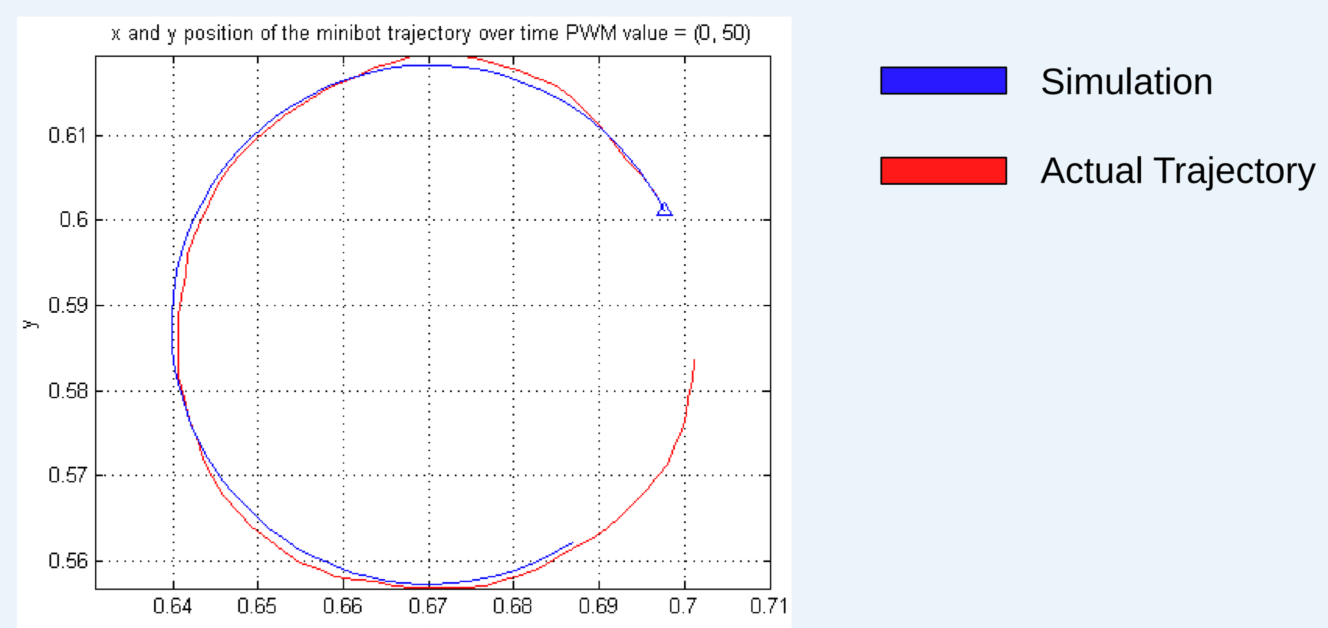
$$\begin{bmatrix} v \\ \omega \end{bmatrix} = A\begin{bmatrix} \omega_L \\ \omega_R \end{bmatrix}$$

- Matrix A is found by tracking the robot's trajectory for a given voltage input

Odometry

- **Odometry**: describes the final position of the robot for a specific command
- Allows control and prediction of the robot's motion for heading estimation
- The equations of motion are:

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} v\cos(\theta) \\ v\sin(\theta) \\ \omega \end{bmatrix}$$



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