Micro-Robot Control and Coordination

Franklin Nouketcha
Susana Galicia
MERIT Students

Michael Kuhlman
Graduate Student Mentor

Dr. Pamela Abshire
Faculty Mentor
The Wall-E Bots

- **Distance sensor**
  - microphone/buzzer

- **Power supply**
  - 3.7 V rechargeable battery

- **Microcontroller**
  - MSP430

- **Radio chip**
  - CC2500

- **Motors with gearbox**

**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

<table>
<thead>
<tr>
<th>Method</th>
<th>Interpolation basis</th>
<th>Mean resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goertzel, 4 parabolas</td>
<td>Lagrange</td>
<td>0.88cm</td>
</tr>
<tr>
<td>Goertzel, 1 parabola</td>
<td>Lagrange</td>
<td>0.86cm</td>
</tr>
<tr>
<td>Goertzel, 1 parabola</td>
<td>Monomial</td>
<td>0.84cm</td>
</tr>
<tr>
<td>Goertzel</td>
<td>none</td>
<td>1.06cm</td>
</tr>
</tbody>
</table>
Motor Calibration and Odometry

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

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

- $P_L = \text{left pulse}$
- $P_R = \text{right pulse}$

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

\[
v = R \frac{(\omega_L + \omega_R)}{2} \\
\omega = R \frac{(\omega_L - \omega_R)}{D}
\]
Motor Calibration (continued)

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

\[
\begin{bmatrix}
\nu \\
\omega
\end{bmatrix} = A \begin{bmatrix}
P_L \\
P_R
\end{bmatrix}
\]

**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**

<table>
<thead>
<tr>
<th>Calibration Technique</th>
<th>SVD: Circle fit</th>
<th>Odometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \nu )</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>( \omega )</td>
<td>0.3</td>
<td>1.08</td>
</tr>
</tbody>
</table>
Odometry

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

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

\[
\begin{bmatrix}
    x' \\
    y' \\
    \theta'
\end{bmatrix} = \begin{bmatrix}
    \nu \cos \theta \\
    \nu \sin \theta \\
    \omega
\end{bmatrix}
\]

- 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

$x$ and $y$ position of the minibot trajectory over time PWM value = (0, 50)

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

Acknowledgements

• Dr. Pamela Abshire, Michael Kuhlman, George Sineriz, Gary Sullivan and the rest of the ANTBOTSB team
• National Science Foundation OCI award #1063035