UCI Samueli School of Engineering
Department of Mechanical and Aerospace Engineering

The Optimal Hopper Height

Experimental Verification #2

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Objective & Hypothesis

- **Objective:**
  - To determine the optimal resting height of the hopper hinge point to maximize forward velocity (or distance traveled per actuation).
- **Hypothesis:**
  - I hypothesize that the lowest hinge point will provide the best balance between stride length and stability. Too low will cause drag; too high will cause instability.
- **Performance Metric:**
  - distance traveled per 5 hops.

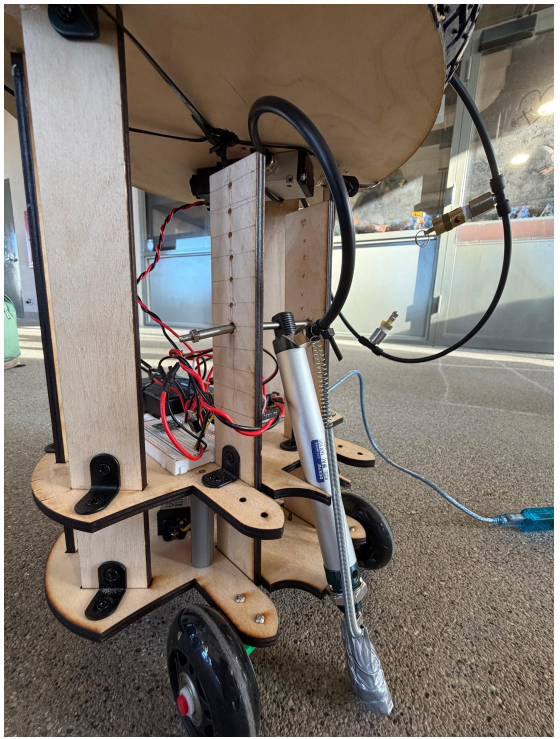

Figure 1: Hopper height adjustment system

Experimental Setup

- **Independent Variable:** Hopper hinge point height (measured from the hinge point to the ground).
- **Dependent Variable:** Distance traveled (measured from start line to rear axle).
- **Constants** (Controlled Variables):
  - Pressure: Regulated to 30 psi for every run.
  - Actuation: 5 Hops per run.
  - Timing: Solenoid fires every 1 second.

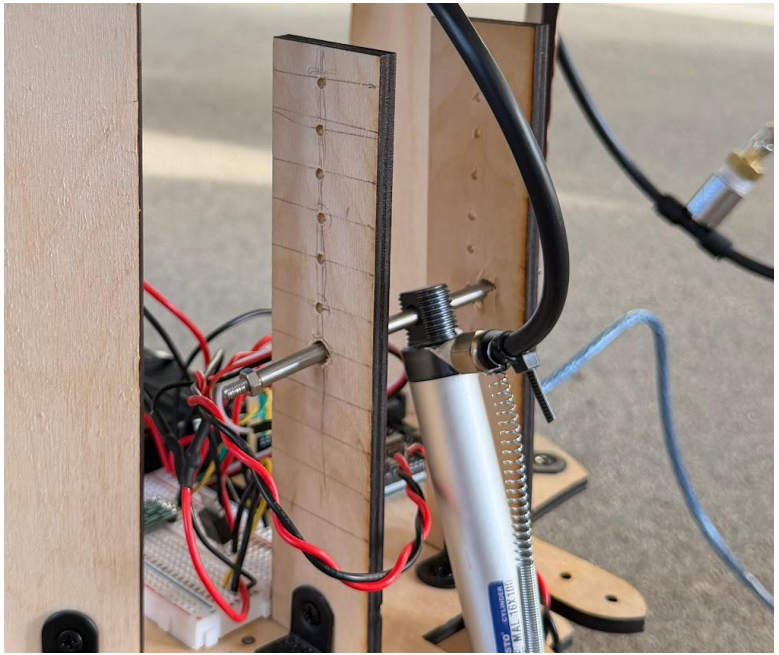

Figure 2: Bolts can be removed to adjust hopper height.

Methodology

- **Procedure:**
  - Robot placed at marked start line.
  - Arduino performs automated 5-hop routine.
  - Distance measured with tape measure.
  - Repeated 10 times for each of the 5 height settings (Total = 50 data points).
- **Statistical Analysis:**
  - Calculated Mean x_bar for central tendency.
  - Calculated Standard Deviation sigma to quantify consistency/reliability.
  - Identify highest mean for each height.

Height Test: 210 [mm]

Run #	1	2	3	4	5	6	7	8	9	10
Dist [m]	2.6	3.1	2.9	1.9	3.0	3.0	2.8	2.7	2.9	3.4

Table 1: Distance traveled wrt 210 mm hinge height

Height Test: 225 [mm]

Run #	1	2	3	4	5	6	7	8	9	10
Dist [m]	2.7	2.4	2.3	2.4	2.8	2.6	2.4	2.4	2.7	2.6

Table 2: Distance traveled wrt 225 mm hinge height

Height Test: 240 [mm]

Run #	1	2	3	4	5	6	7	8	9	10
Dist [m]	1.4	1.6	1.6	1.7	1.5	1.5	1.4	1.3	1.4	1.5

Table 3: Distance traveled wrt 240 mm hinge height

Height Test: 255 [mm]

Run #	1	2	3	4	5	6	7	8	9	10
Dist [m]	1.0	0.9	0.5	0.7	0.5	0.6	0.8	0.7	0.5	0.6

Table 4: Distance traveled wrt 255 mm hinge height

Height Test: 270 [mm]

Run #	1	2	3	4	5	6	7	8	9	10
Dist [m]	0.4	0.6	0.3	0.1	0.5	0.3	0.2	0.1	0.2	0.3

Table 5: Distance traveled wrt 270 mm hinge height

Overall Results

Hinge Height [mm]	Mean Distance [m]	SD Distance [m]	Notes
210	2.83	0.39	The best
225	2.53	0.17	Moved
240	1.49	0.12	Kind of moved
255	0.68	0.18	Barely moved
270	0.30	0.16	Barely moved

Table 6: Run results summary across hinge heights

Plot of Results

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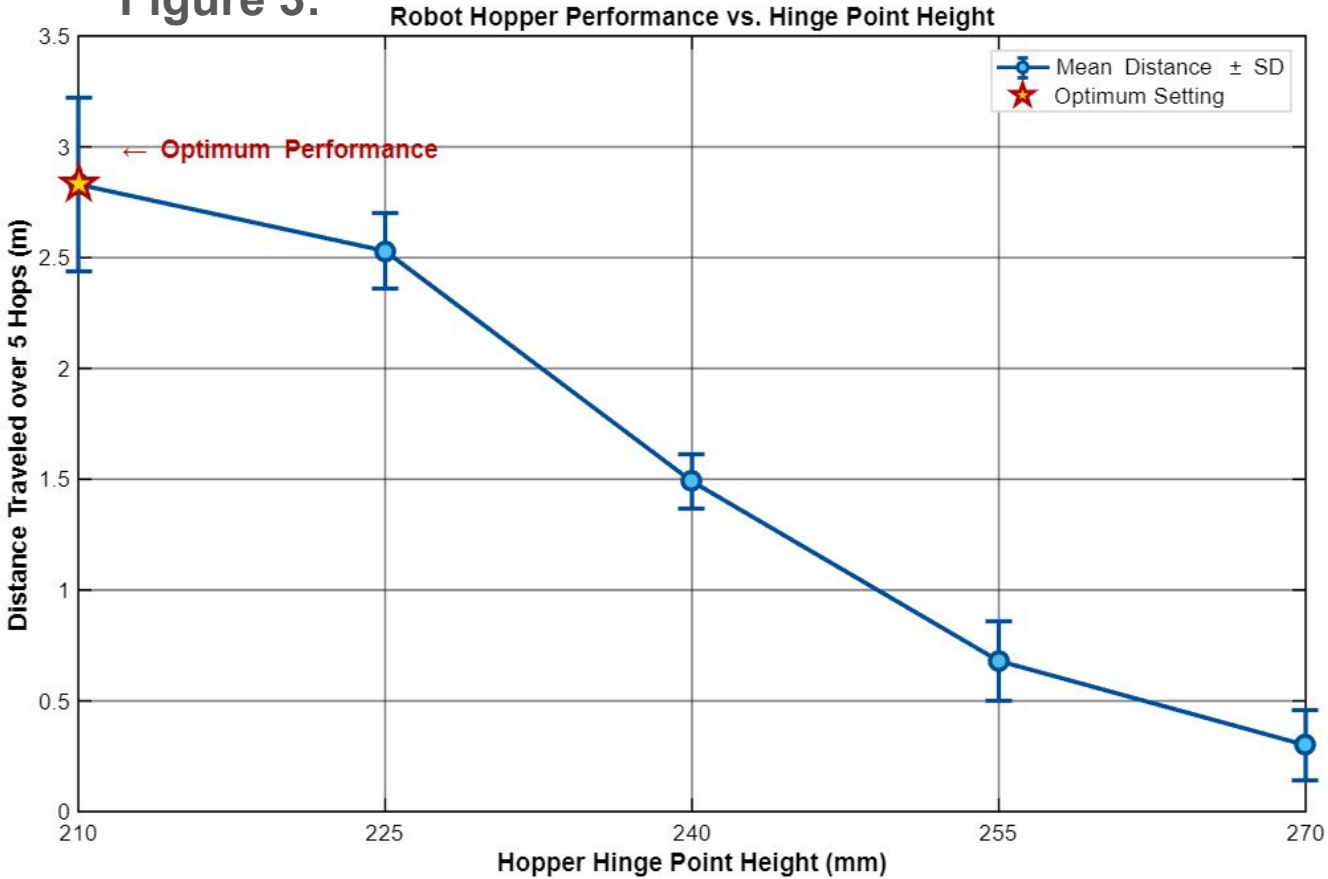
Figure 3:

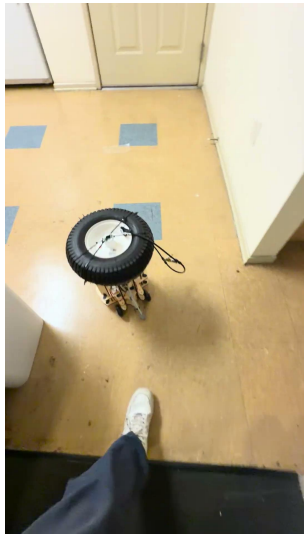


Code for Plot

```
% Data from the experiment table
heights = [210, 225, 240, 255, 270];
means = [2.83, 2.53, 1.49, 0.68, 0.30];
std_devs = [0.39, 0.17, 0.12, 0.18, 0.16];

% Create a new figure
figure('Name', 'Experimental Verification #2 Plot', 'Color', 'w');
% Plot the mean and standard deviation
errorbar(heights, means, std_devs, '-o', 'Color', [0, 0.3, 0.6], 'LineWidth', 2.5, ...
    'MarkerSize', 10, 'MarkerEdgeColor', [0, 0.3, 0.6], ...
    'MarkerFaceColor', [0.3, 0.75, 0.93], 'CapSize', 15);
hold on;
% Find the location of the optimum
[max_mean, max_idx] = max(means);
optimum_height = heights(max_idx);

% optimum point with a star
plot(optimum_height, max_mean, 'p', 'MarkerSize', 20, ...
    'MarkerEdgeColor', [0.7, 0, 0], 'MarkerFaceColor', [1, 0.84, 0], 'LineWidth', 2);

% Add text pointing to the optimum location
text(optimum_height + 2, max_mean + 0.15, '\leftarrow Optimum Performance', ...
    'FontSize', 14, 'FontWeight', 'bold', 'Color', [0.7, 0, 0]);

% Add title and axis labels, FORCE the text color to BLACK ('k')
title('Robot Hopper Performance vs. Hinge Point Height', 'FontSize', 18, 'FontWeight', 'bold', 'Color', 'k');
xlabel('Hopper Hinge Point Height (mm)', 'FontSize', 14, 'FontWeight', 'bold', 'Color', 'k');
ylabel('Distance Traveled over 5 Hops (m)', 'FontSize', 14, 'FontWeight', 'bold', 'Color', 'k');

% Force the axes and tick marks to be visible on a white background
grid on;
set(gca, 'XTick', heights);
set(gca, 'FontSize', 13, 'GridAlpha', 0.5, 'LineWidth', 1.2);
set(gca, 'Color', 'w'); % Force inner plot background to white
set(gca, 'XColor', 'k', 'YColor', 'k'); % Force axis lines and tick numbers to black

% Add a legend and force its text to be black and background white
lgd = legend('Mean Distance \pm SD', 'Optimum Setting', 'Location', 'northeast', 'FontSize', 13);
set(lgd, 'TextColor', 'k', 'Color', 'w');

hold off;
```

Figure 4: Plot code for matlab

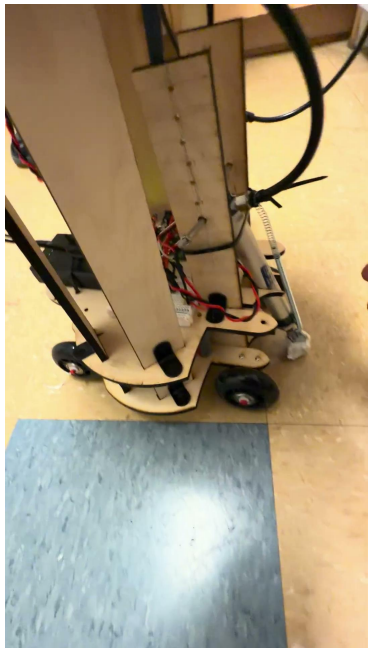
Videos of Suboptimal Hinge Height Performance



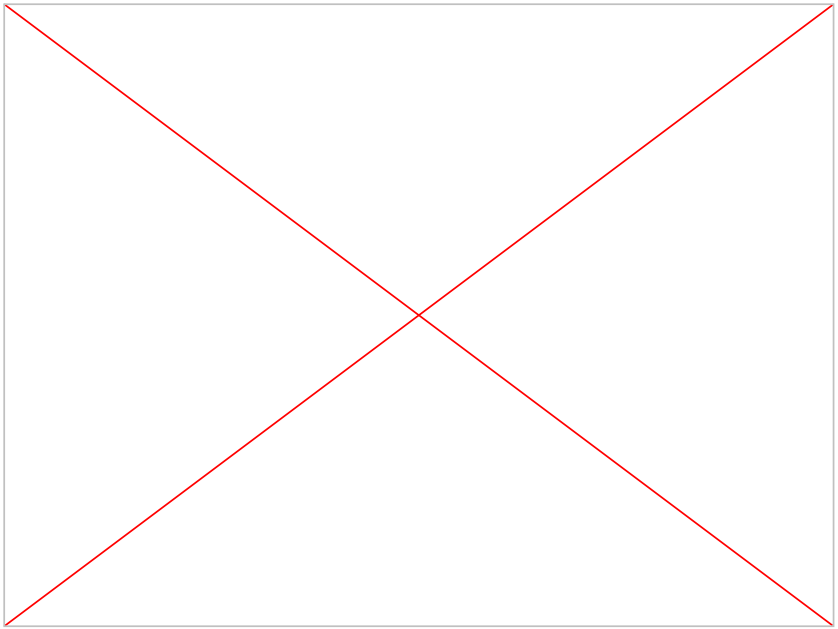
Video 1: Run 5 240 mm

Video 2: Run 10 255 mm (misspoke in video)

Videos of Optimal Hinge Height Performance



Video 3: The best, run 10 210 mm



Video 4: run 1 225 mm

Key Takeaways

- Optimal Setting Identified:
  - The lowest tested hinge height (210 mm) is the optimal configuration for maximum efficiency and forward velocity.
- Performance Peak:
  - At 210 mm, the robot traveled an average of 2.83 m per 5 hops, significantly outperforming higher hinge placements.
- Hypothesis Confirmed:
  - The lower center of gravity and optimized stride angle provided the best balance of stability and distance, minimizing the drag and instability seen at higher settings (like the 0.30 m average at 270 mm).
- Final Design Decision:
  - The robot's hopper hinge will be permanently locked at 210 mm moving forward to maximize overall performance.