QEA Bridge of Doom

Jackie Zeng

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1 Introduction

In this challenge, I wrote a program that navigates a Neato robot across the "Bridge of Doom" and avoids the dangerous lava below the bridge. All experiments were conducted through an online Neato simulator. The Bridge of Doom is defined by a parametric curve, shown in the position equation below:

$$r(u) = 4 * [0.3960 * cos(2.65(u + 1.4)), 0.99sin(u + 1.4), 0] \; u \in [0, 3.2] \tag{1}$$
$$u = \beta * t$$

One of the requirements for this challenge is that the Neato cannot surpass a speed of 2 m/s in either wheel. Hence, it is not physically possible for the Neato to cross the bridge in u = 3.2 seconds. Hence, we redefine u as $\beta * t$ and adjust β to keep the wheel velocities under 2 m/s.

In addition to programming the robot's movements, I also used plots to visualize the differences between the calculated (theoretical) motion of the Neato and the motion derived from the encoder data from the simulated (experimental) robot.

2 Methods and Visualizations

2.1 Parametric Curve Visualization

To visualize the Bridge of Doom, I plotted the parametric curve it is based on in both 2D and 3D. I also calculated and plotted the unit tangent ($\hat{T}$), unit normal ($\hat{N}$), and unit binormal ($\hat{B}$) vectors at several locations to gain a better understanding of the curve. I used the following equations to find the TNB field:

$$\hat{T} = \frac{dr}{|dr|} \tag{2}$$

$$\hat{N} = \frac{d\hat{T}}{|d\hat{T}|} \tag{3}$$

$$\hat{B} = \hat{T} \times \hat{N} \tag{4}$$

To clarify, the dr is the first derivative of the parametric equation r(u) with respect to time (t).

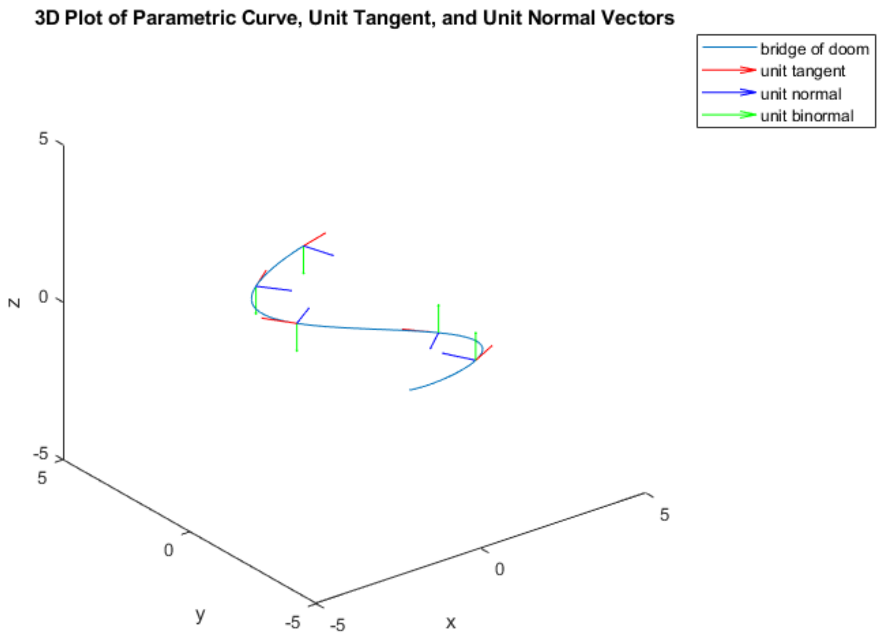

Figure 1: 3D plot of the Bridge of Doom curve with select TNB fields visualized

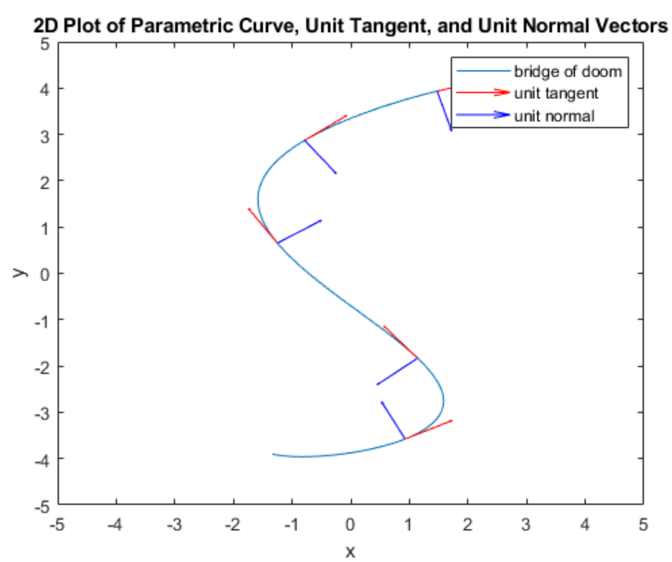

Figure 2: 2D plot of the Bridge of Doom curve with unit tangent and unit normal visualized

2.2 Left and Right Wheel Velocities

To calculate the theoretical left and right wheel velocities for the Neato, I used the following equations:

$$V_{left} = |V| - \frac{\omega * d}{2} \tag{5}$$

$$V_{right} = |V| + \frac{\omega * d}{2} \tag{6}$$

where

$$V = dr \ (linear\ speed)$$

$$\omega = \hat{T} \times d\hat{T} \ (angular\ velocity)$$

To obtain the experimental values, I used the simulation encoder data, which recorded how far each wheel has traveled. I found the velocity of each wheel by calculating the change in distance traveled over the the change in time. I then filtered out the noise in the data by applying a moving average filter with a window size of 10.

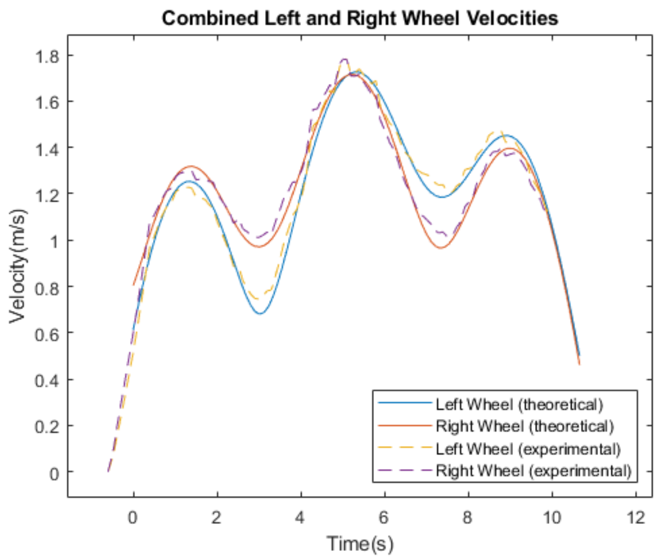

Figure 3: Left and right wheel velocities of the Neato over time

2.3 Linear Speed and Angular Velocity

I have already covered the equations used to calculate the theoretical linear speed and angular velocity in the above section. For the experimental values, I used the following equations

$$V_{exp} = \frac{V_{right,exp} + V_{left,exp}}{2} \tag{7}$$

$$\omega_{exp} = \frac{V_{right,exp} - V_{left,exp}}{d} \tag{8}$$

where $V_{left,exp}$ and $V_{right,exp}$ are experimental left and right wheel velocities calculated in the above section and d is the distance between the two wheels on the wheel base. For the Neato, $d = 0.235$. I filtered this data as well with a moving average filter of window size 10.

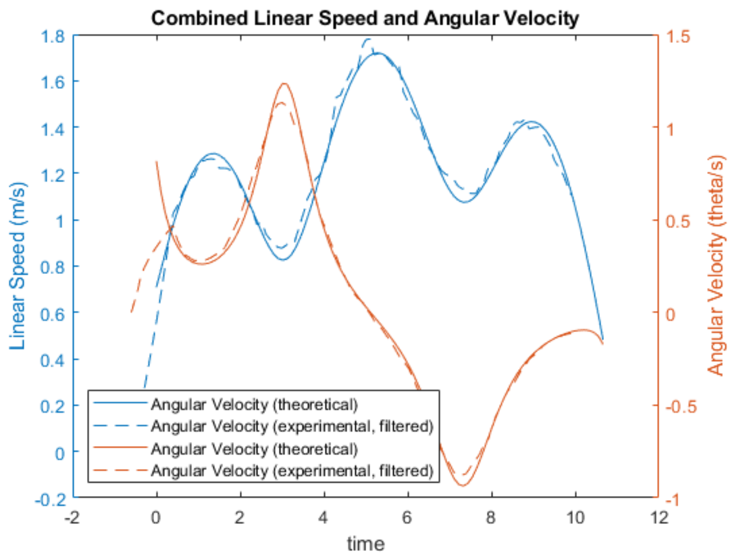

Figure 4: Linear speed and angular velocity of the Neato over time

2.4 36.5 Path of Neato

The theoretical path for the Neato is simply the parametric curve r(u) defined at the very beginning. I found the experimental path by using $V_{exp} and \omega_{exp}$.

$$\omega_{exp} = \frac{V_{right,exp} - V_{left,exp}}{d} \tag{9}$$

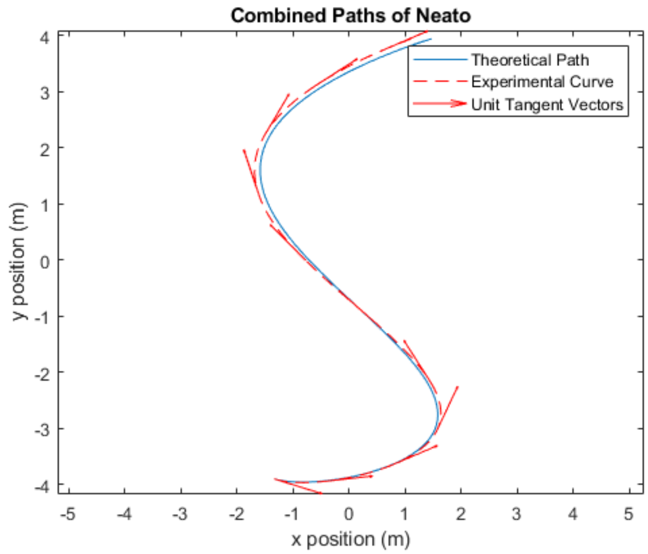

Figure 5: Theoretical vs experimental paths of the Neato

3 Neato in Action

Click here to see a live action film of my Neato making the trek across the Bridge of Doom.