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21

Final Project Presentation

AuE 822 Final Project Presentation

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https://www.anl.gov/es/polaris-transportation-system-simulation-tool

Assumptions

- No-slip condition
- Arms, 220mm
- Axle Width, 330mm
- Wheel Diameter 200mm
- Inverse kinematics used unicycle model for placement and lead with arm
- Forward kinematics numerical integration sufficiently accurate for base calculations.

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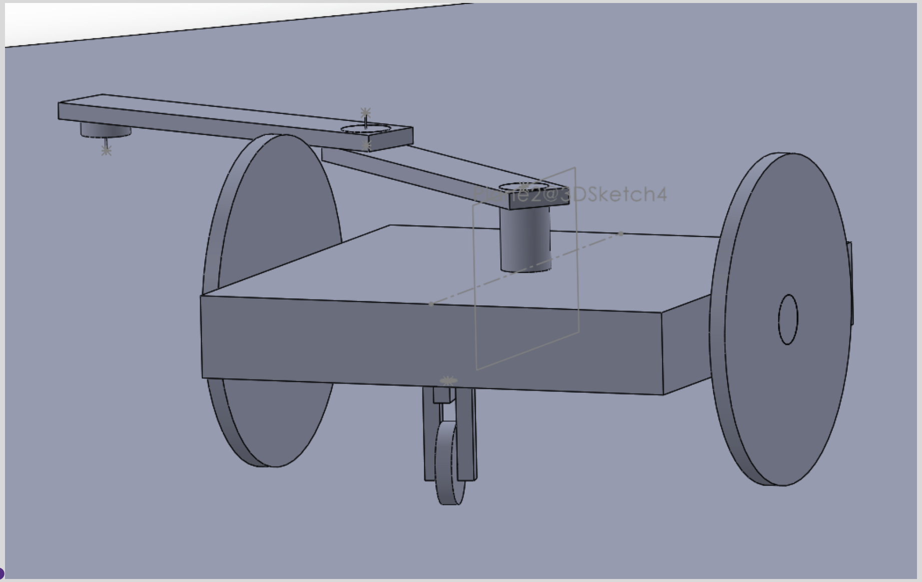
Approach

Methods



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Jacobian Structure

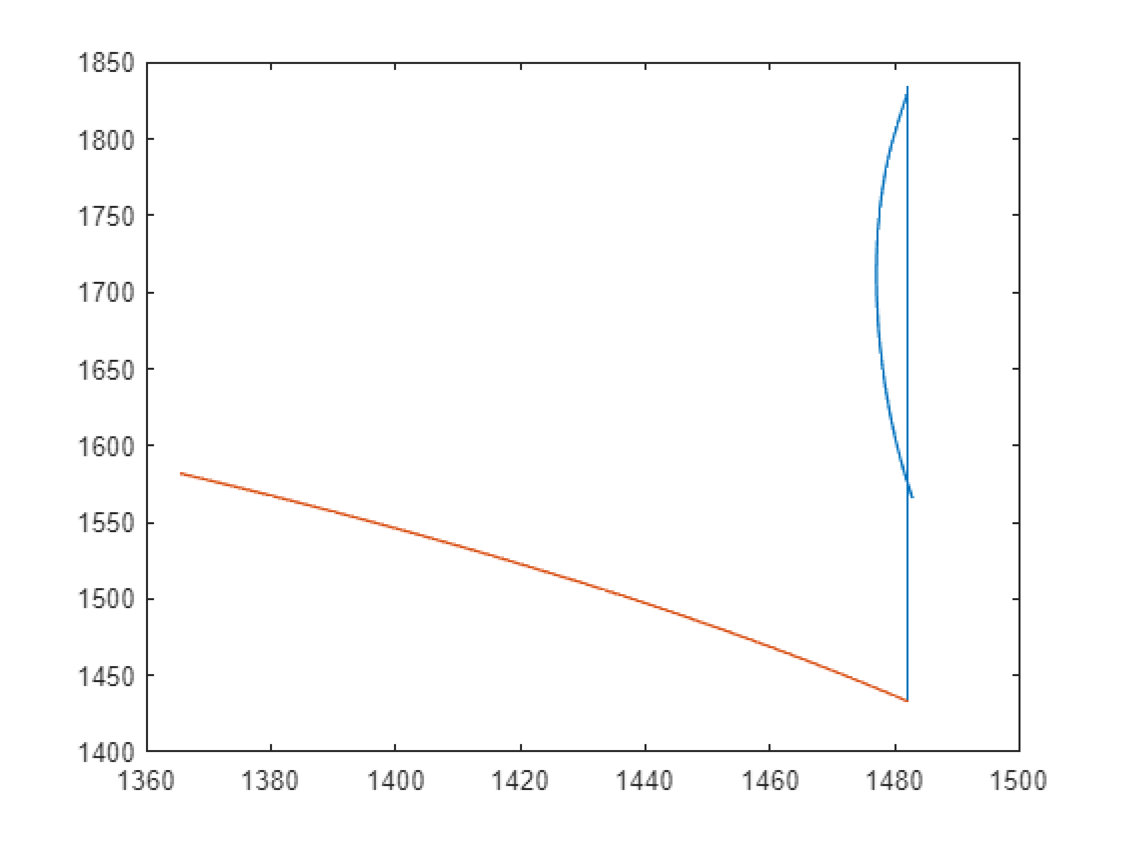
- 2 Redundancies, however, important to identify Phi Base because it appears in both the arm and base Jacobians
- 2WDD can be modeled by unicycle model whose path has a unique algebraic solution at every point
  - For elliptical model, just have vehicle trace ellipse, lead arm ahead
  - For Square model, have vehicle trace circle within arms reach of the square
- Utilizing unicycle model eliminates 2 redundancies due to the robot being forced to attempt to follow the path exactly

$$\begin{aligned} v_d(t) &= \pm\sqrt{\dot{x}_d^2(t)+\dot{y}_d^2(t)} \\ \omega_d(t) &= \frac{\ddot{y}_d(t)\dot{x}_d(t)-\ddot{x}_d(t)\dot{y}_d(t)}{\dot{x}_d^2(t)+\dot{y}_d^2(t)}, \end{aligned}$$

$$\hat{q}_k = \begin{bmatrix} \hat{x}_k \\ \hat{y}_k \\ \hat{\theta}_k \end{bmatrix} = \hat{q}_{k-1} + \begin{bmatrix} \cos\bar{\theta}_k & 0 \\ \sin\bar{\theta}_k & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \Delta s \\ \Delta\theta \end{bmatrix},$$

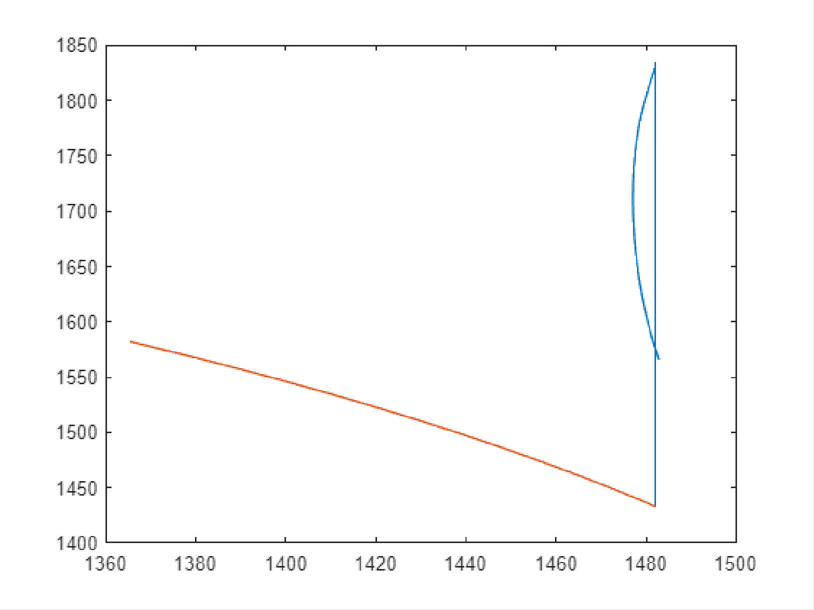
$$\theta = \mathrm{ATAN2}\left(\dot{y}, \dot{x}\right) + k\pi, \qquad k = 0, 1,$$

Unicycle Model, Deluca, 2001.



ns

- …) constantly move
- …f the increase
- …nplex shapes
- …vith ODE45,
- …ds before arms
    - I think this is because the near perfect tracing of the trajectory made the end point highly sensitive to small movements
- Pros
    - Very simple derivation of phi_base
    - Very smooth travel with base of vehicle
    - No need for additional constraints



Result of .3 seconds of simulation time for unicycle model. Desired path in red, resultant in blue. In this scenario, theta 1 and theta 2 are fixed, forcing the vehicle to attempt to trace the circle just with x_dot, y_dot, theta_dot

Other Approaches Attempted

- Traditional Jacobian

- Pros
  - Higher degree of flexibility
    - Implemented constraints for;
      - Combined arm travel angle
      - Arm lockout
      - Gradient function optimization
      - Traditional Pseudoinverse solution
  - Not constrained to single path
- Cons, difficult to prevent vehicle from undertaking movements that although technically are allowed, are non optimal
  - Sticking point

$$\begin{pmatrix} -\sigma_1 - 210\sin(\theta_1+\theta_b) & -\sigma_1 & 50\cos(\theta_b) & 50\cos(\theta_b) \\ 210\cos(\theta_1+\theta_b) - \sigma_1 & -\sigma_1 & 50\sin(\theta_b) & 50\sin(\theta_b) \\ 1 & 1 & 0 & 0 \end{pmatrix}$$

where

$$\sigma_1 = 210\sin(\theta_1+\theta_2+\theta_b)$$

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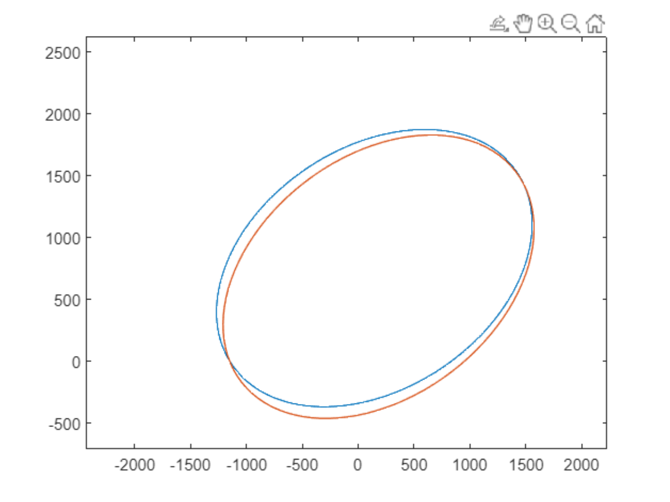
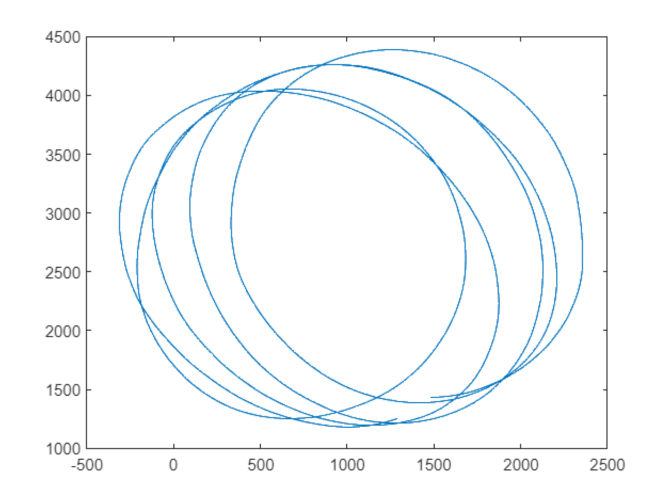
Closed Loop Approaches

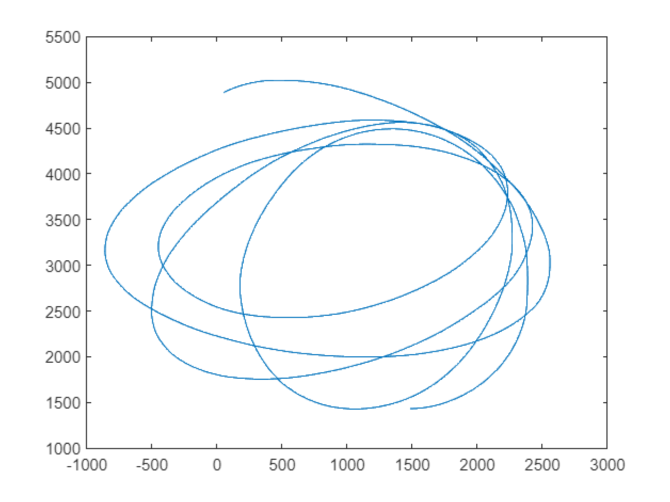
- Utilized WDD model only
- Since unicycle model can follow path perfectly, necessary to add noise to data via error distribution in order to attempt to counter effects
- Model did not respond as expected to closed look control solutions, possible due to nature of unicycle model being modeled differently than traditional Jacobian



Initial attempt to add noise



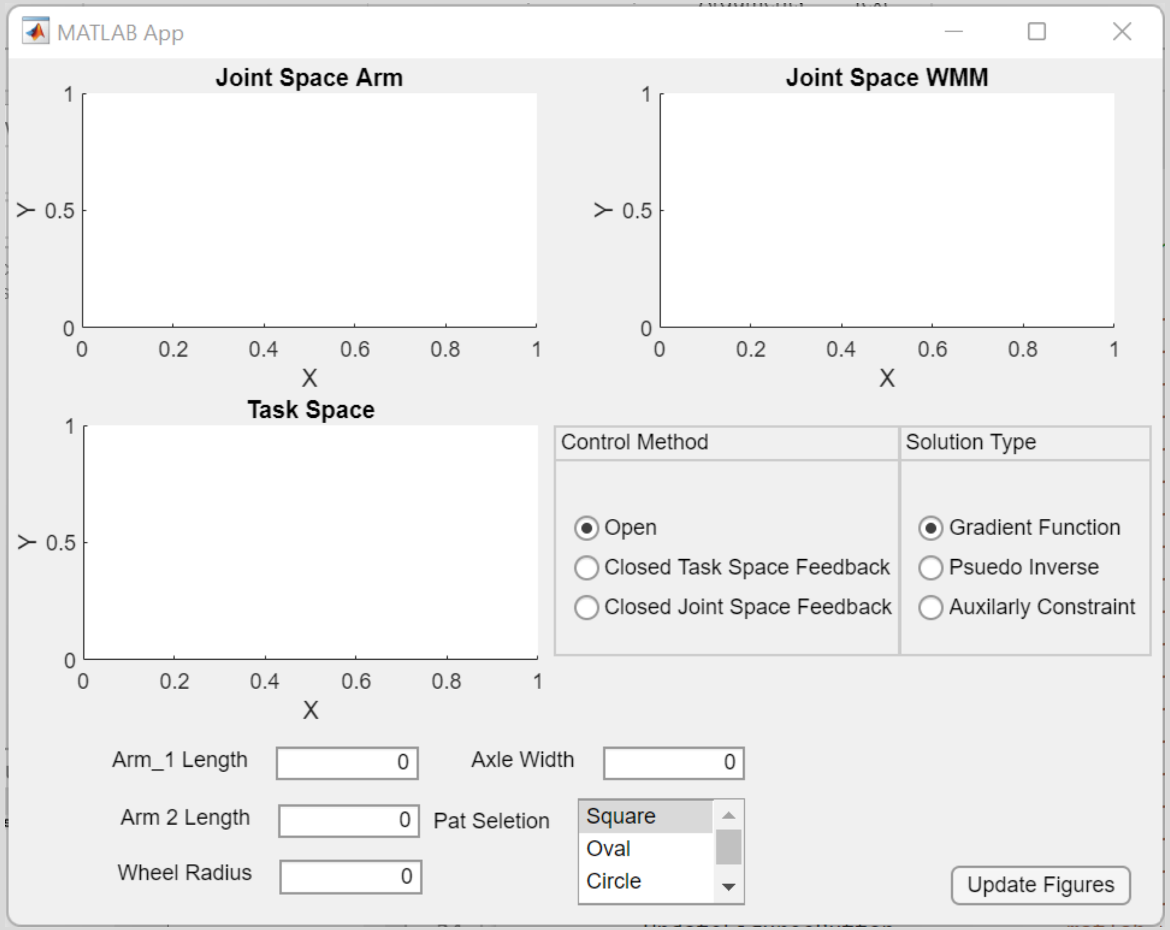
Example addition of artificial noise to assess filterability. Noise added via normal distribution with a mean. Drift displayed clearly.



Filter corrected drift but seemed to introduce rotational error.

GUI Draft

- Allows a convenient way to interact with the code without manual manipulation needed
- Ability to control different aspects of the code and specify unique constrain combinations
- Would be interesting challenge to prevent failures when parameters cause mapping failures



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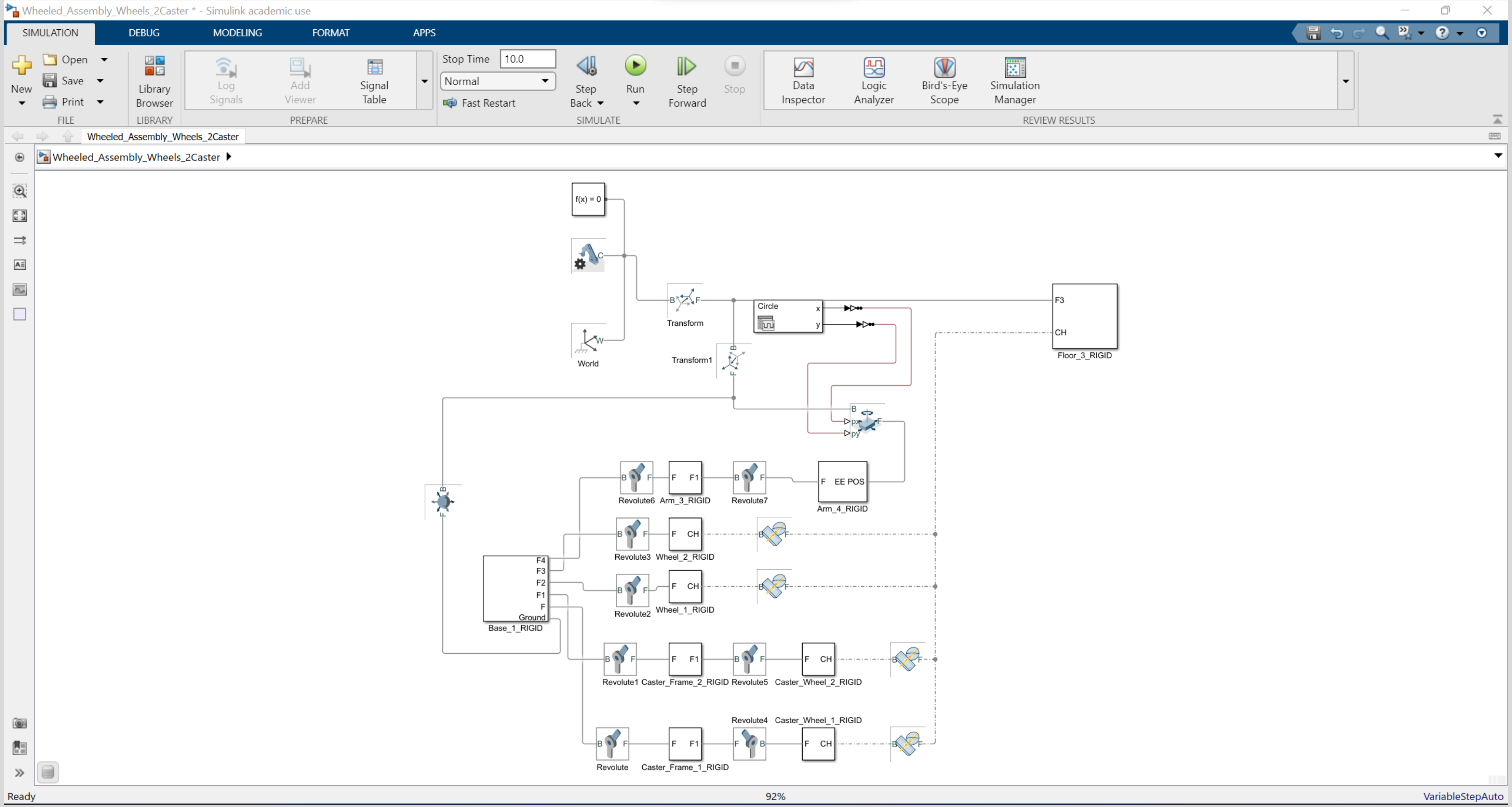
Simulink Model



Simulink Model

- Decided to model in Simulink to explore how effective kinematic models are at modeling dynamic behaviour

Conclusions

- ODE45 can be very sensitive to bad initial parameters and requires significant oversight especially when dealing with angles > |360|
- Working with high degree of freedom systems can be very difficult especially without known redundancy handling methods
- Redundancy allows significantly more flexibility but comes with increase setup, computing, and other costs over simpler systems.