ECE 495 Autonomous Vehicles Tutorial 7 Overview

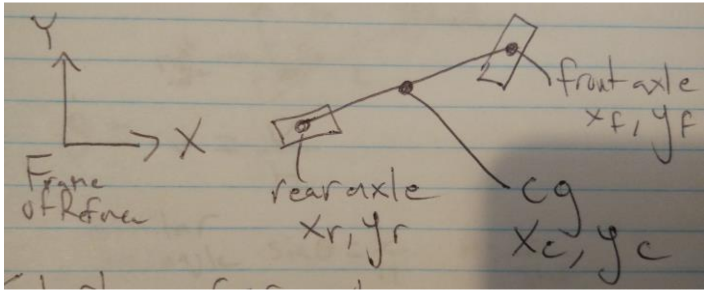
- Before starting
- Goals
- A7
  - Part 1
  - Part 1 Output
  - Part 2
  - Part 2 Output

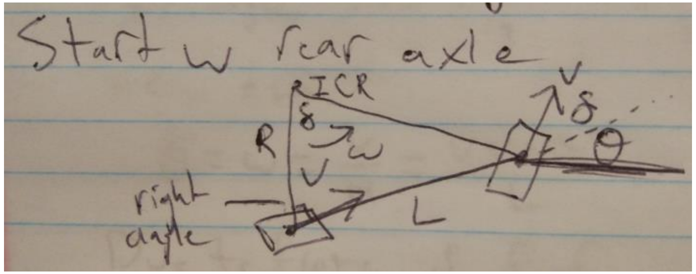
Before starting

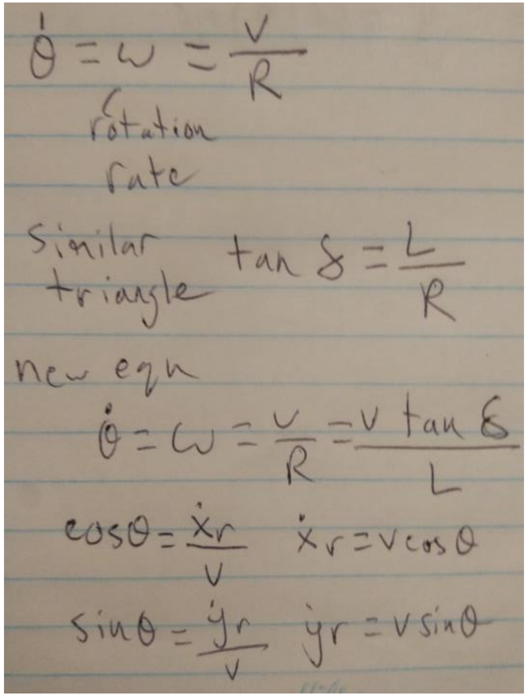
- We are implementing a kinematic bicycle model
  - Simple compared to dynamic vehicle model
  - Works at low speeds
  - CG (center of gravity) bicycle model
    - w10-1_vehicle_modeling
      - slides 25 & 26
    - Let's go through the derivation

Before starting – Rear bicycle model

- Theta: heading
- L: length between the two wheel axis
- Delta: steering angle measured from theta
- V: velocity pointing from wheel
- ICR: Instantaneous center of rotation

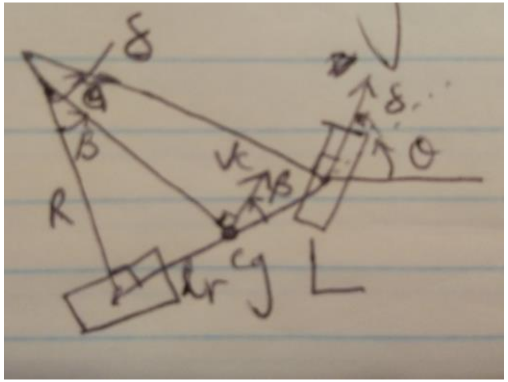


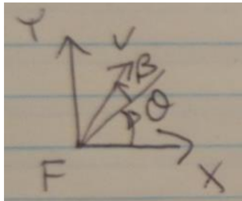




Before starting – CG bicycle model

- lr: distance from rear axle to cg
- Beta: Vehicle slip angle





$$\frac{\dot{X}}{V_c} = \cos(\theta+\beta)$$

$$\dot{X} = V_c\cos(\theta+\beta)$$

$$\frac{\dot{Y}}{V_c} = \sin(\theta+\beta)$$

$$\dot{Y} = V_c\sin(\theta+\beta)$$

for rear

for rear

$$\dot{\theta} = \omega = \frac{V_r \tan\delta}{L}$$

Vc angle β Vr

$$\cos(\beta) = \frac{V_r}{V_c} \qquad V_r = V_c\cos(\beta)$$

for cg $$\dot{\theta} = \omega = \frac{V_c\cos(\beta)\tan(\delta)}{L}$$

$$\tan\beta = \frac{l_r}{R} \qquad \tan\delta = \frac{L}{R}$$

$$R = \frac{L}{\tan\delta}$$

$$\tan\beta = \frac{l_r\tan\delta}{L}$$

$$\beta = \tan^{-1}\left(\frac{l_r\tan\delta}{L}\right)$$

A7 Goals

- Implement step (update) function for the CG (center of gravity) bicycle kinematic model
- Find control inputs to the step function in order to steer the bicycle in a figure 8 loop

A7 – Part 1

- Bicycle class values
  - Max turn rate of 1.22 rad/sec (self.w_max)
  - Wheel base length of 2 m (self.L)
  - Length from rear axle to center of mass is 1.2 (self.lr)
- Implement the step function within the Bicycle class
  - Arguments
    - v– bicycle velocity
    - w – steering angle rate

A7 – Part 1

- Calculate values for:
  - xc_dot, yc_dot, theta_dot, delta_dot
  - ***Remember to properly clamp w***

$$
\begin{aligned}
\dot{x}_c &= v\cos(\theta + \beta) \\
\dot{y}_c &= v\sin(\theta + \beta) \\
\dot{\theta} &= \frac{v\cos\beta\tan\delta}{L} \\
\dot{\delta} &= \omega
\end{aligned}
$$

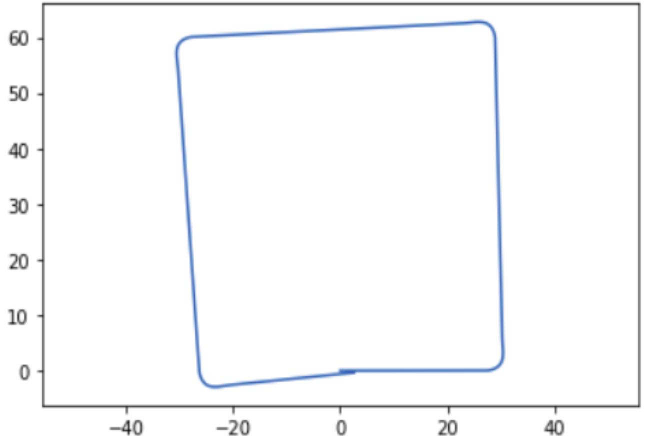
A7 – Part 1

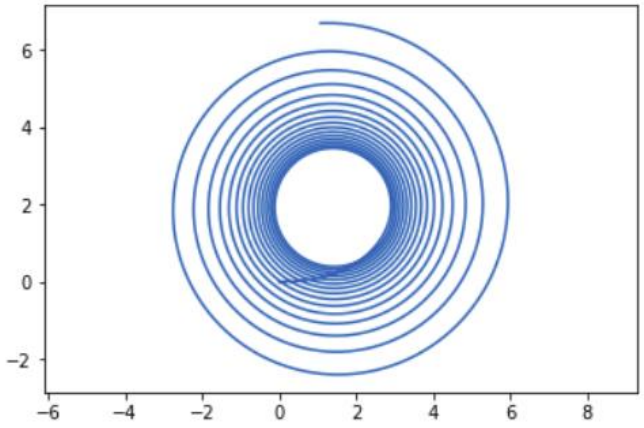
- Update variables
  - Use the calculated values and self.sample_time
    - self.xc, self.yc, self.delta, self.theta
  - Use Beta equation
    - self.beta

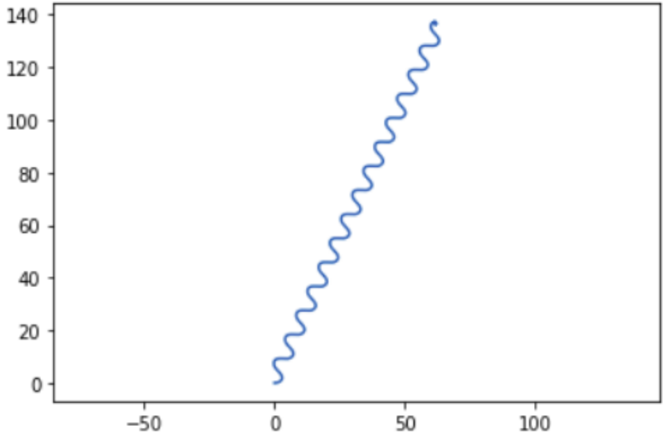
$$\beta = \tan^{-1}\left(\frac{l_r \tan\delta}{L}\right)$$

A7 – Part 1 Output

- Uncomment different code blocks to test output
  - Square, spiral, wave pattern

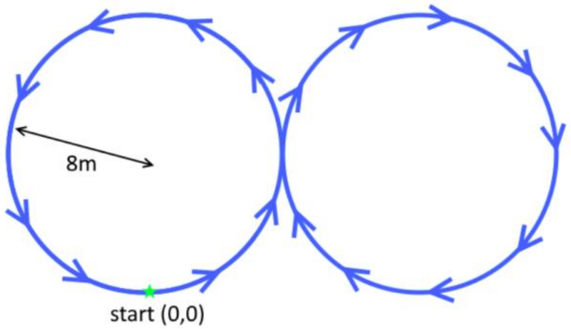






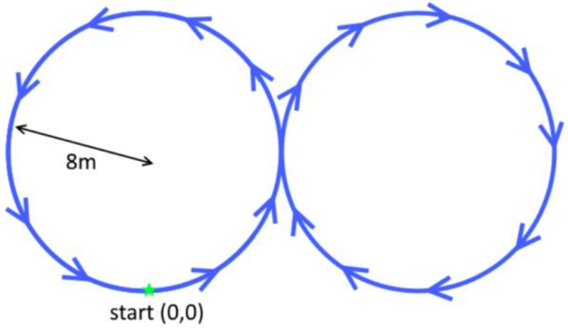
A7 Part 2

- Program the control inputs to have the bicycle create a figure 8 trajectory
- Requirements:
  - Both circles have a radius of 8 m
  - Finish following the trajectory in 30 s



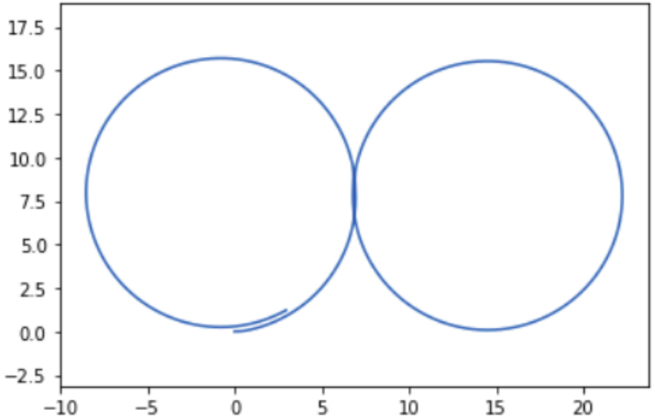
A7 Part 2 Hints

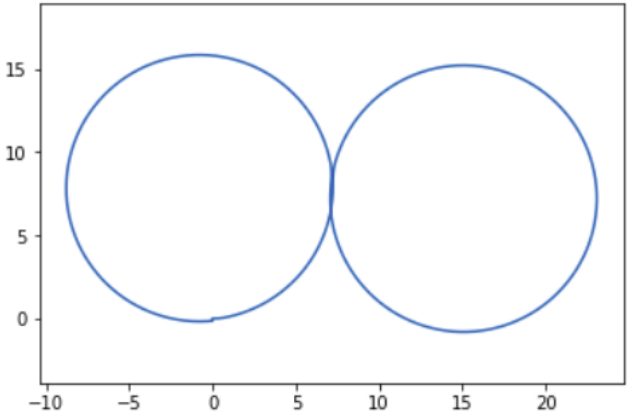
- I recommend reading over the code and math in the assignment to have the bicycle ride in a circle
- Calculating v
  - 2 circles, radius = 8 m, must traverse in 30 seconds
- Calculate desired delta, set w to steer to it
- Three turns: left, right, left
  - Test angles for when to start next turn



A7 Part 2 Output

- Example solution outputs





A7 tutorial

- Finished