Contents

1 Kinematic Model

State vector of the model

$$x, y, \psi, v$$

where x and y are the global coordinates of the characteristic point, ψ is the orientation of the car, v is the velocity

Actuators

$$\delta, a$$

This reduces the vehicle to two actuators, which we'll denote as δ for steering angle and a for acceleration (throttle/brake combined).

Here it is: \[$\begin{array}{rcl} x_{t+1} & = & x_t + v_t \cos(\psi_t) dt \\ y_{t+1} & = & y_t + v_t \sin(\psi_t) dt \\ \psi_{t+1} & = & \psi_t + \dfrac{v_t}{L_f} \tan \delta_t dt \\ v_{t+1} & = & v_t + a_t dt \end{array}$ \]

2 Kinematic model with errors

The state is $[x, y, \psi, v, cte, e_\psi]$

3 Model realization

`https://github.com/udacity/CarND-MPC-Quizzes/blob/master/mpc_to_line/solution/MPC.cpp`

4 One step

4.1 Received step data

```
ptsx <- c(-32.161729999999999, -43.491729999999997, -61.090000000000003, -78.29171999999
ptsy <- c(113.361, 105.941, 92.884990000000002, 78.731020000000001, 65.34102, 50.57938

px <- -40.619999999999997
py <- 108.73
psi <- 3.7336510000000001
v <- 0.43800909999999998

plot(ptsx, ptsy, 'b')
arrows(px, py, px + 10 * cos(psi), py + 10 * sin(psi), col='red')
```

4.2 Transformed points to the local vehicle's reference systems

```
xy <- mapply(function(x, y) c(x*cos(psi) + y*sin(psi), -x*sin(psi) + y*cos(psi)), x = p
print (xy)
plot(xy[1,], xy[2,], 'b', ylim=c(-1, 12))
arrows(0, 0, 10, 0, col='red')

paste(c("X: ", xy[1,]) ,collapse=' ')
paste(c("Y: ", xy[2,]) ,collapse=' ')
```

4.3 Fitting a cubic polynomial

```
coeffs <- lm(formula = xy[2,] ~ xy[1,] + I(xy[1,]^2) + I(xy[1,]^3))
print(coeffs)
track <- function(x) coef(coeffs)[1] + coef(coeffs)[2] * x + coef(coeffs)[3] * x^2 + co

plot(xy[1,], xy[2,], 'b', ylim=c(-1, 12))
xx <- seq(min(xy[1,]), max(xy[1,]), length=50)
lines(xx, lapply(xx, track), type="l", col="red")
arrows(0, 0, 10, 0, col='red')
```

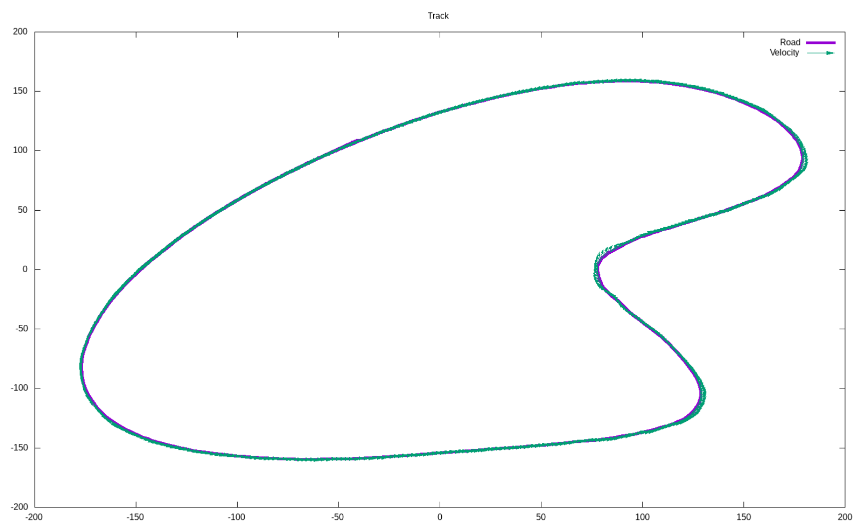
5 Results

5.1 First try with $v_{\mathbf{ref}} = 20$ m/s and $V_{\mathbf{max}} = 26.3$ mph

Cost function

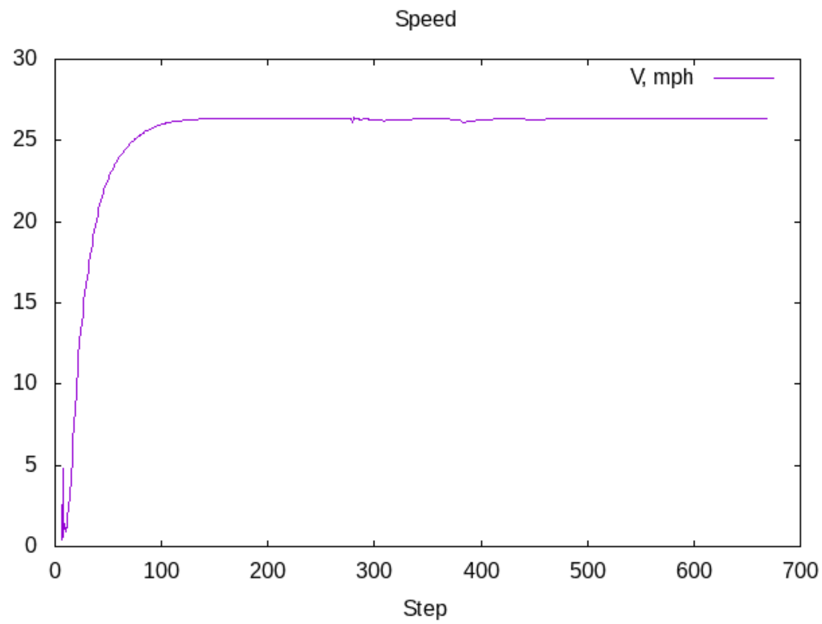
$$C = \left[\sum_{i=0}^{N} cte_i^2 + e\psi_i^2 + (v_i - v_{\text{ref}})^2\right] + 100\left[\sum_{i=0}^{N-1} \delta_i^2 + a_i^2\right] + 100\left[\sum_{i=0}^{N-2} (\delta_{i+1} - \delta_i)^2 + (a_{i+1} - a_i)^2\right]$$

```
reset
set terminal png size 1600,1000
set title "Track"
set xlabel "x"
set xlabel "y"
plot 'data/first.data' using ($1):($2) with lines lw 5 title 'Road', \
     'data/first.data' using 1:2:($4*cos($3)):($4*sin($3)) with vectors head filled lt
```



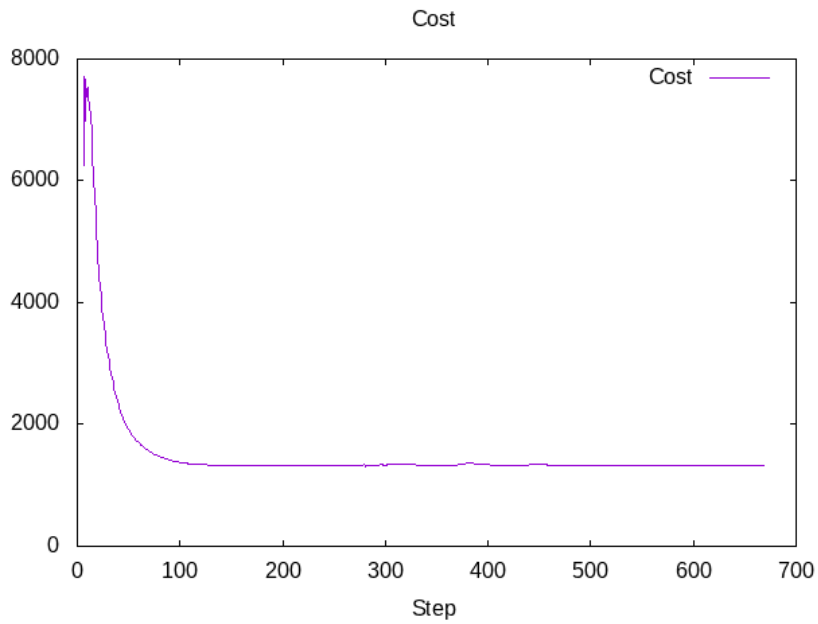
Vehicle's speed settled at ≈ 26.3 mph.

```
reset
set terminal png size 640,480
set title "Speed"
set xlabel "Step"
set yrange [0:30]
set ytics 0,5,30
plot 'data/first.data' using 0:($4*3600/1609.34) with lines title 'V, mph'
```



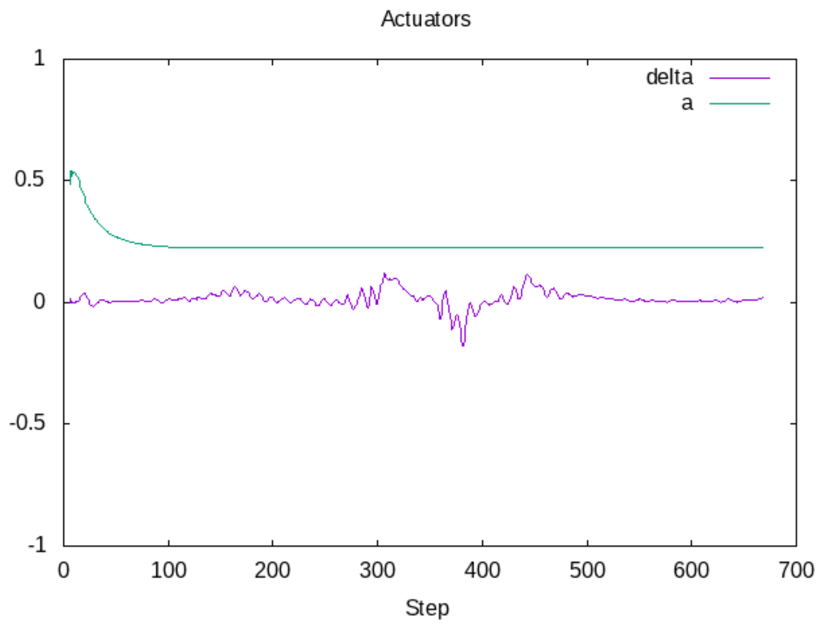
and the cost function at ≈ 1300

```
reset
set terminal png size 640,480
set title "Cost"
set xlabel "Step"
set yrange [0:8000]
set ytics 0,2000,8000
plot 'data/first.data' using 0:($5) with lines title 'Cost'
```



so acceleration value a is almost constant at 0.225

```
reset
set terminal png size 640,480
set title "Actuators"
set xlabel "Step"
set yrange [-1:1]
set ytics -1,0.5,1
plot 'data/first.data' using 0:($6) with lines title 'delta', \
     'data/first.data' using 0:($7) with lines title 'a'
```



Link to video file `https://raw.githubusercontent.com/oxidase/CarND-MPC-Project/master/doc/video/first.mp4`]]