HL Klemove

Path planning

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Contents

Introduction

- Path planning with driving lane

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- Path planning

Path planning

- Path planning with lane
  - Road model
    - Clothoid : 곡률의 변화가 연속적!

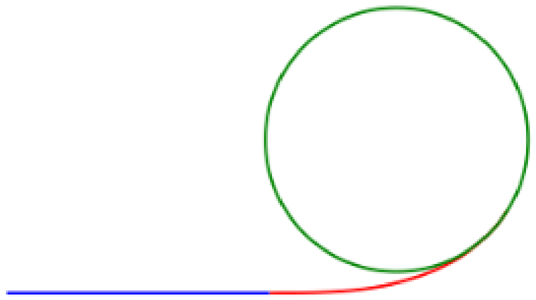
Curvature $\kappa = \frac{1}{R} \approx l$

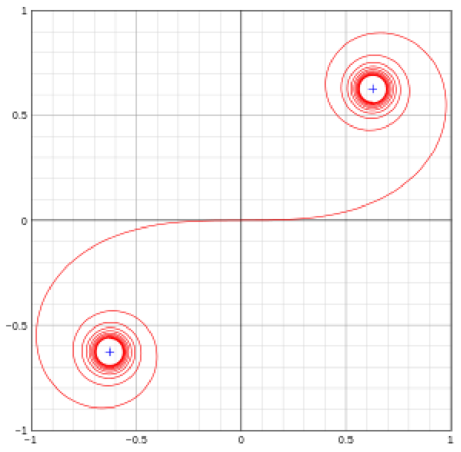
$$x(t) = aC(t) = a\int_0^t \cos\left(\frac{\pi}{2}u^2\right)du$$

$$y(t) = aS(t) = a\int_0^t \sin\left(\frac{\pi}{2}u^2\right)du$$

$$x = \ell - \frac{\ell^5}{40A^4} + \frac{\ell^9}{3456A^8} - \frac{\ell^{13}}{599040A^{12}}\cdots$$

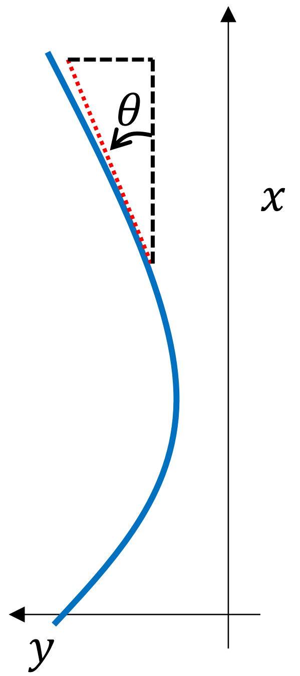
$$y = \frac{\ell^3}{6A^2} - \frac{\ell^7}{336A^6} + \frac{\ell^{11}}{42240A^{10}} - \frac{\ell^{15}}{9676800A^{14}}\cdots$$





Path planning

- Path planning with lane
  - Road model
    - 3rd order polynomial : local coordinate 에서 clothoid를 표현하기에 적합

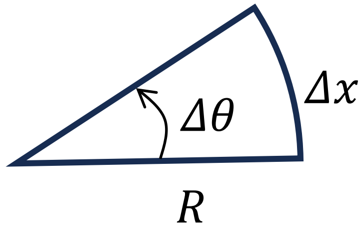


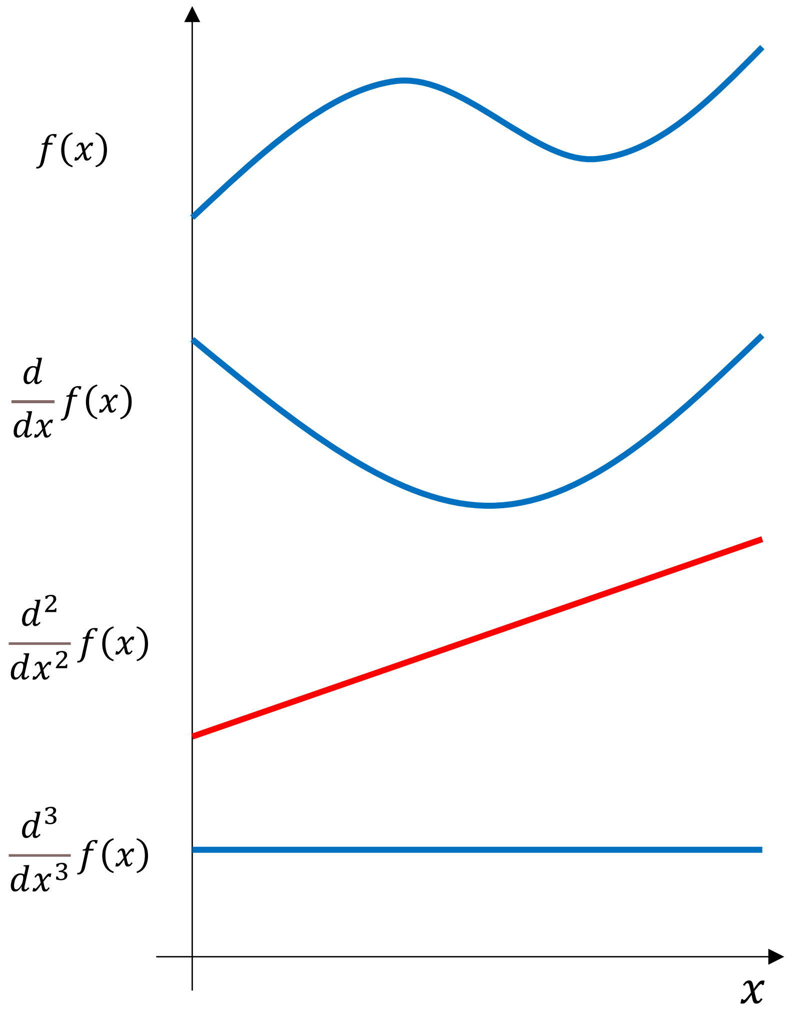
$$y = f(x) = c_3 x^3 + c_2 x^2 + c_1 x + c_0$$

$$\theta \approx \tan(\theta) = \frac{dy}{dx} = \frac{d}{dx} f(x)$$

$$\frac{d\theta}{dx} = \kappa = \frac{1}{R} = \frac{d^2}{dx^2} f(x)$$

$$\frac{d\kappa}{dx} = \frac{d^3}{dx^3} f(x)$$

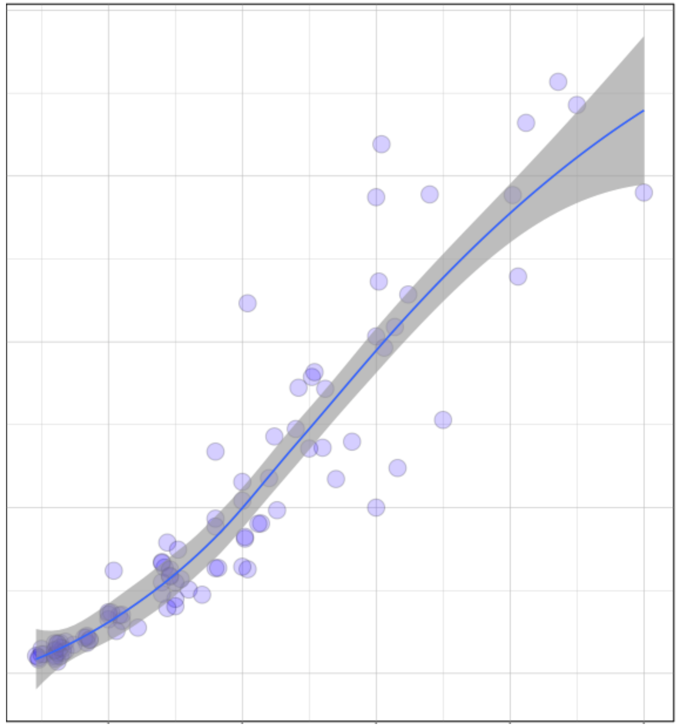




Path planning

- Path planning with lane
  - Road model
    - Fitting to 3rd order polynomial : least square

$$\begin{bmatrix} (x_1, y_1) \\ (x_2, y_2) \\ \vdots \\ (x_m, y_m) \end{bmatrix} \Rightarrow \quad y = f(x) = c_3 x^3 + c_2 x^2 + c_1 x + c_0$$



$$\begin{bmatrix} x_1^3 & x_1^2 & x_1^1 & x_1^0 \\ x_2^3 & x_2^2 & x_2^1 & x_2^0 \\ \vdots & \vdots & \vdots & \vdots \\ x_m^3 & x_m^2 & x_m^1 & x_m^0 \end{bmatrix} \begin{bmatrix} c_3 \\ c_2 \\ c_1 \\ c_0 \end{bmatrix} \approx \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{bmatrix}$$

$$XC \approx Y$$

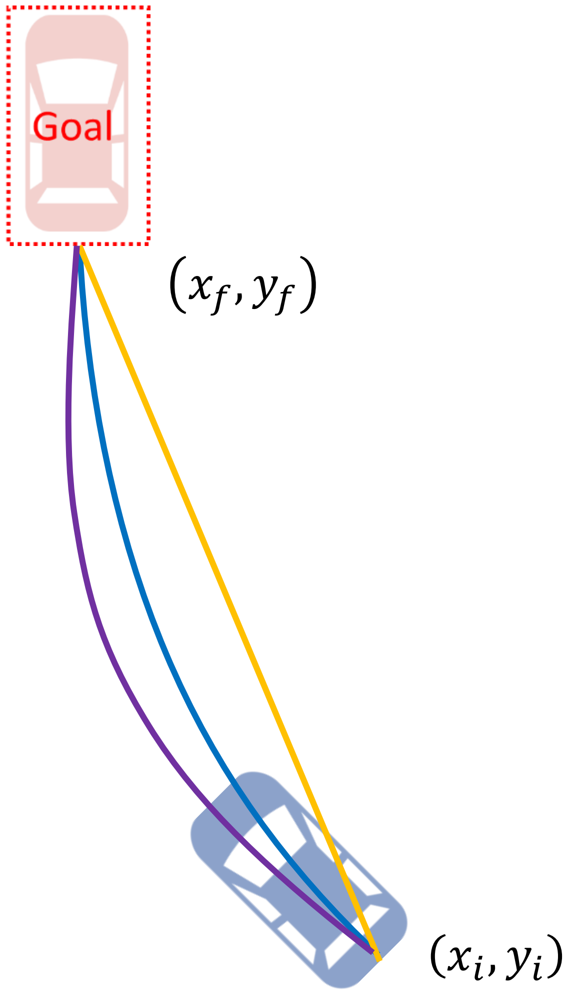
$$C = inv(X^T X) X^T Y$$

Path planning

- Path planning with lane
  - Both lane detected
    - Use mean value of each lane
  - Either lane detected
    - Make virtual lane
    - Lane width estimation

Path planning

- Path planning without lane
  - With goal destination



$y = f(x) = c_1 x + c_0$: 2 known information

$y = f(x) = c_2 x^2 + c_1 x + c_0$: 3 known information

$y = f(x) = c_3 x^3 + c_2 x^2 + c_1 x + c_0$: 4 known information

$\vdots$

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Path planning

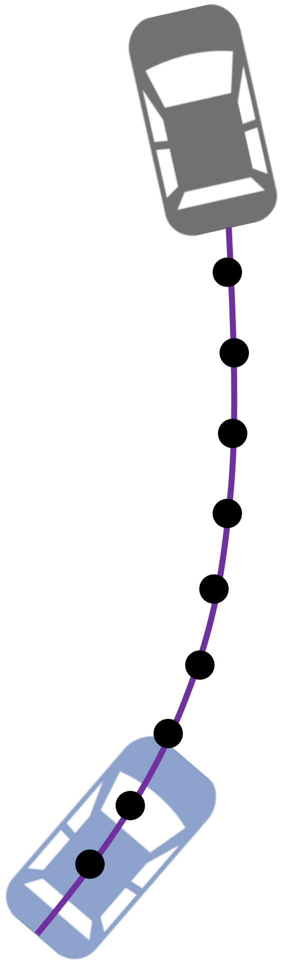
- Path planning without lane
  - With leading vehicle

$$y = f(x) = c_1 x + c_0 \text{ : 2 known information}$$

$$y = f(x) = c_2 x^2 + c_1 x + c_0 \text{ : 3 known information}$$

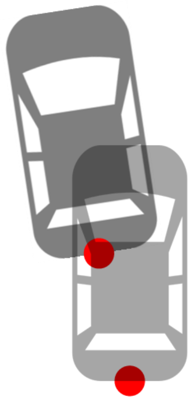
$$y = f(x) = c_3 x^3 + c_2 x^2 + c_1 x + c_0 \text{ : 4 known information}$$

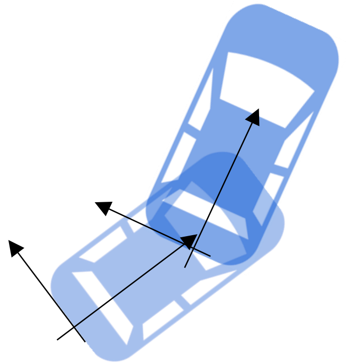
$$\vdots$$



Path planning

- Path planning without lane
  - With leading vehicle
    - CTRV(등속 선회운동)

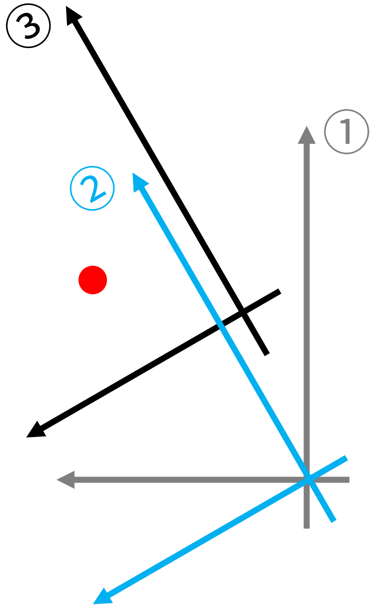




$$(x_1, y_1) \rightarrow (x_2, y_2) \rightarrow (x_3, y_3)$$

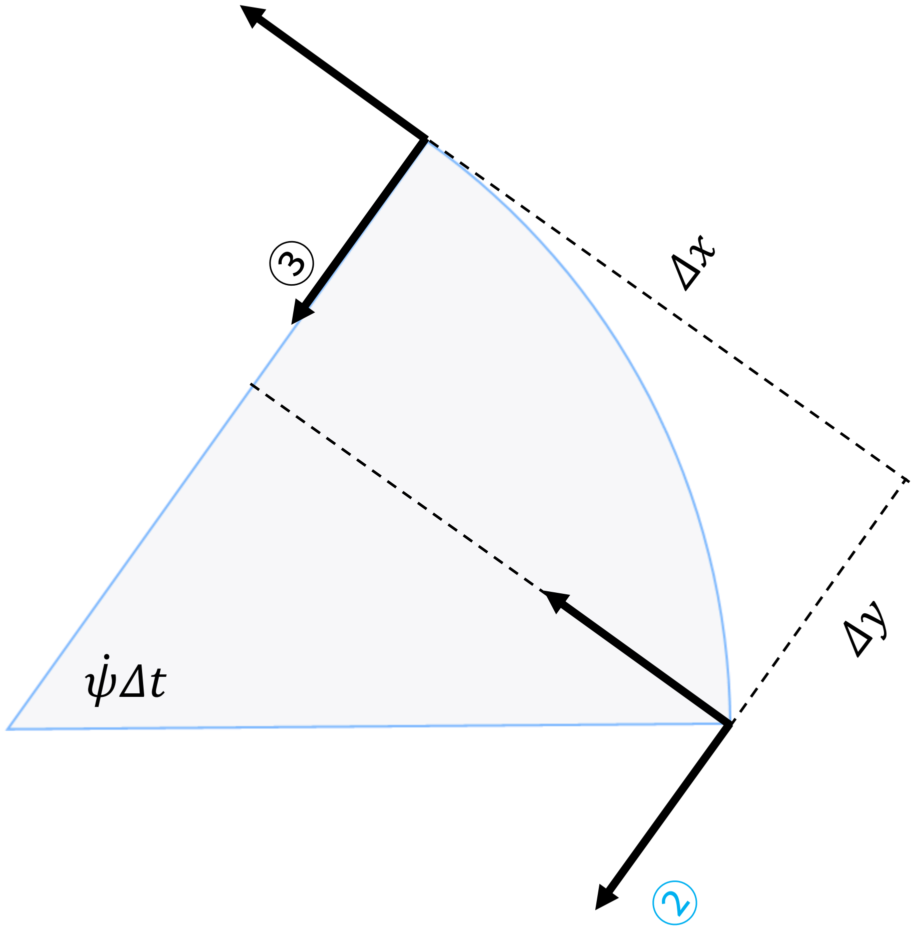
Step 1. ①→②좌표계 회전 : $-\dot{\psi}\Delta t$

$$\begin{pmatrix} x_2 \\ y_2 \end{pmatrix} = \begin{pmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{pmatrix} \begin{pmatrix} x_1 \\ y_1 \end{pmatrix}, \qquad \theta = -\dot{\psi}\Delta t$$



Path planning

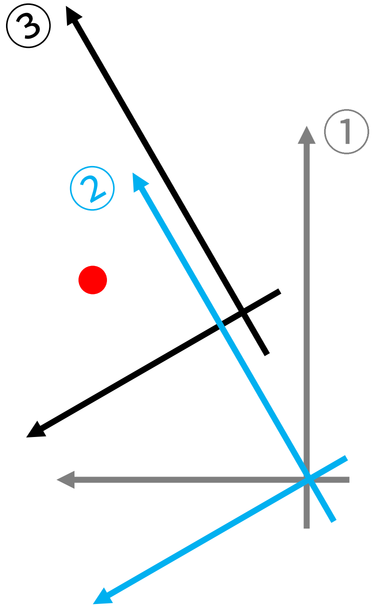
- Path planning without lane
  - With leading vehicle
    - CTRV(등속 선회운동)



Step 2.②→③좌표계 회전 : $-\dot{\psi}\Delta t$

$$\Delta x = R\sin(\dot{\psi}\Delta t), \qquad \Delta y = R\left(1-\cos(\dot{\psi}\Delta t)\right)$$

$$\begin{pmatrix} x_3 \\ y_3 \end{pmatrix} = \begin{pmatrix} x_2 \\ y_2 \end{pmatrix} + \begin{pmatrix} -\Delta x \\ \Delta y \end{pmatrix} = \begin{pmatrix} x_2 \\ y_2 \end{pmatrix} + \begin{pmatrix} -R\sin(\dot{\psi}\Delta t) \\ R\left(1-\cos(\dot{\psi}\Delta t)\right) \end{pmatrix}$$



Path planning

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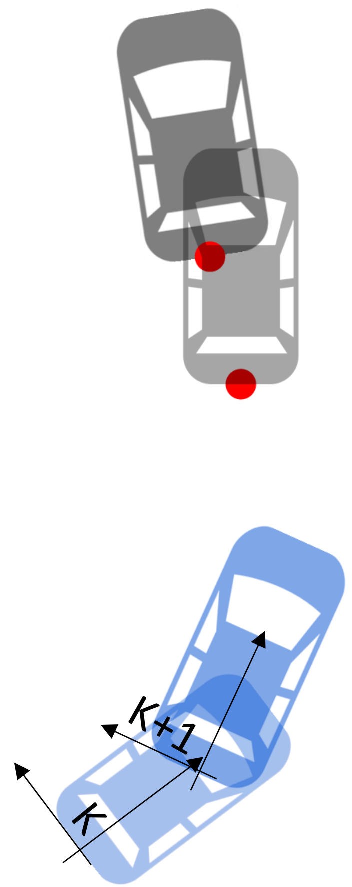
        - CTRV(등속 선회운동)



$$\begin{pmatrix} x_{k+1} \\ y_{k+1} \end{pmatrix} = \begin{pmatrix} \cos(\dot{\psi}\Delta t) & \sin(\dot{\psi}\Delta t) \\ -\sin(\dot{\psi}\Delta t) & \cos(\dot{\psi}\Delta t) \end{pmatrix} \begin{pmatrix} x_k \\ y_k \end{pmatrix} + \begin{pmatrix} -R\sin(\dot{\psi}\Delta t) \\ R\left(1-\cos(\dot{\psi}\Delta t)\right) \end{pmatrix}$$

$$\boldsymbol{P_{k+1}}^{\boldsymbol{T}} = \begin{pmatrix} \boldsymbol{\cos(\dot{\psi}\Delta t)} & \boldsymbol{\sin(\dot{\psi}\Delta t)} \\ \boldsymbol{-\sin(\dot{\psi}\Delta t)} & \boldsymbol{\cos(\dot{\psi}\Delta t)} \end{pmatrix} \boldsymbol{P_k}^{\boldsymbol{T}} + \begin{pmatrix} \boldsymbol{-R\sin(\dot{\psi}\Delta t)} \\ \boldsymbol{R\left(1-\cos(\dot{\psi}\Delta t)\right)} \end{pmatrix}, \quad P_k = \begin{pmatrix} (x_1, y_1) \\ (x_2, y_2) \\ \vdots \\ (x_n, y_n) \end{pmatrix}$$