HL Klemove

Further topics

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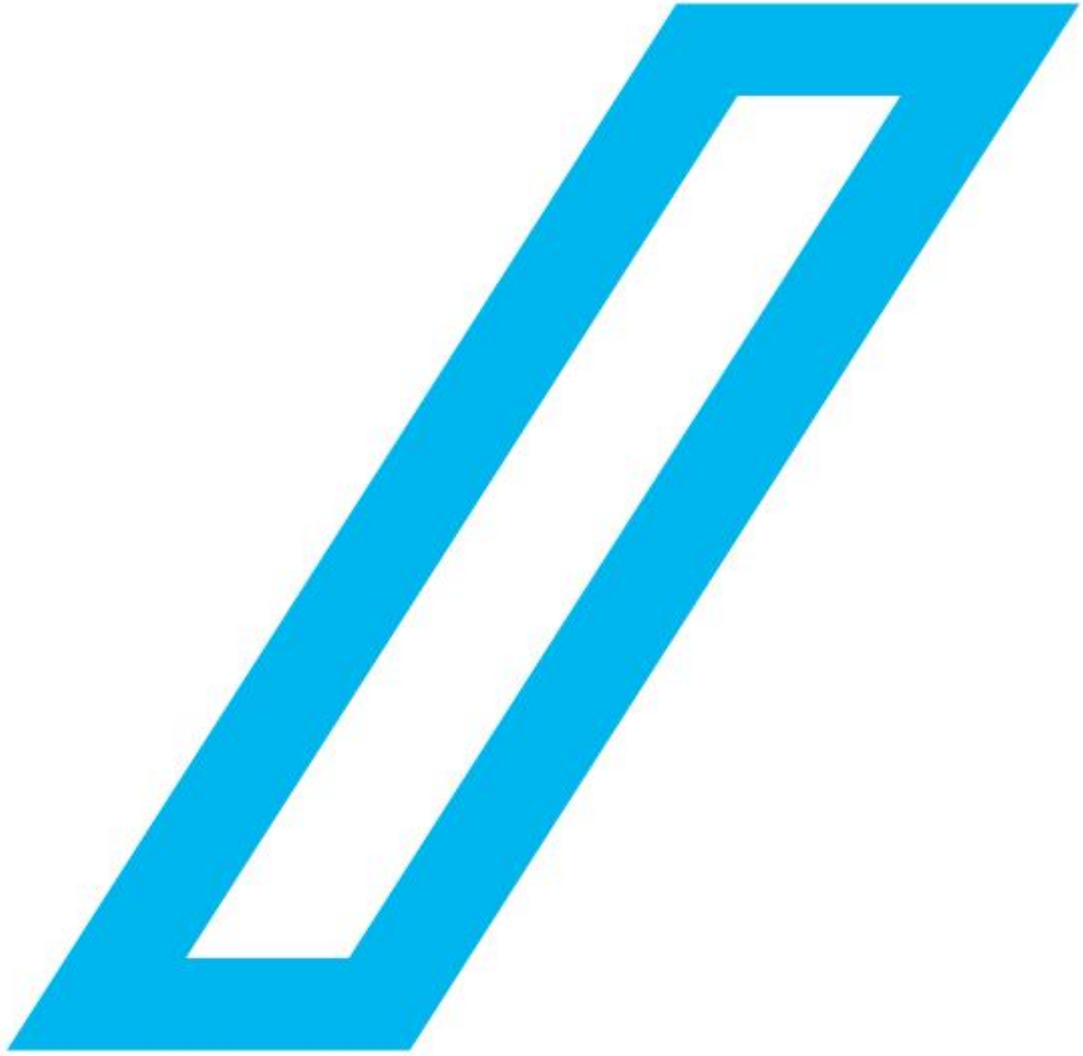


Contents

Prediction

- Main idea
  - How to win a race? : Optimization

Objective:

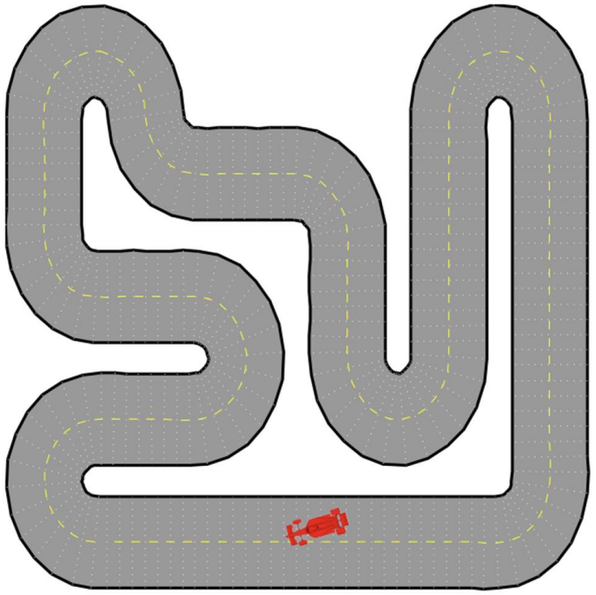
- Minimize lap time

Constraints:

- Avoid other cars
- Stay on road
- Don't skid
- Limited acceleration

Intuitive approach:

- Look forward and plan path based on
  - Road conditions
  - Upcoming corners
  - Abilities of car
  - etc...

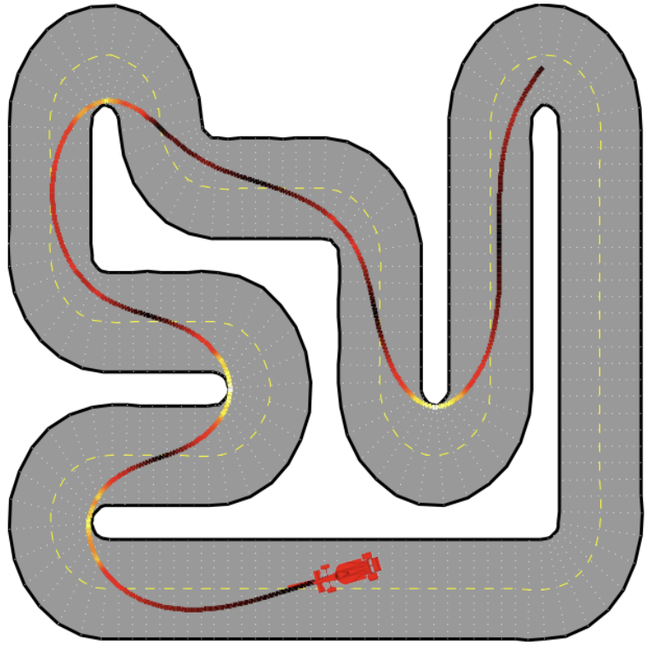


Model predictive control

- Main idea
  - How to win a race? : Optimization

Minimize	(lap time)
while	avoid other cars
	stay on road
	...

- Solve **optimization problem** to compute minimum-time path

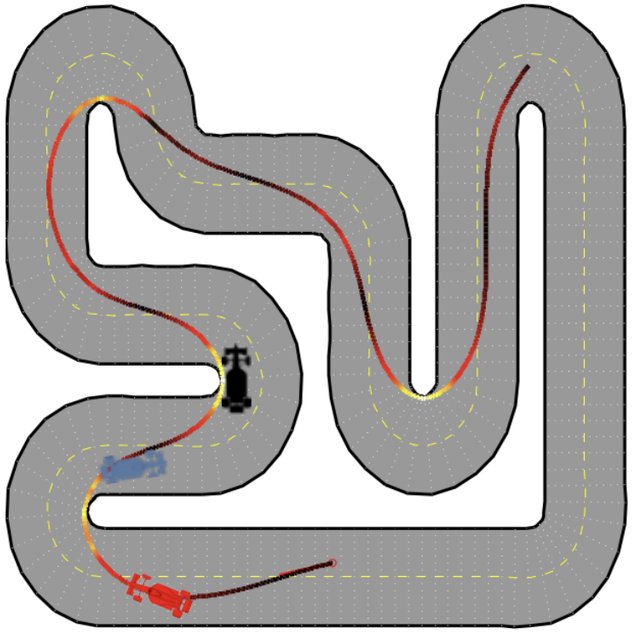


Model predictive control

- Main idea
  - How to win a race? : Optimization

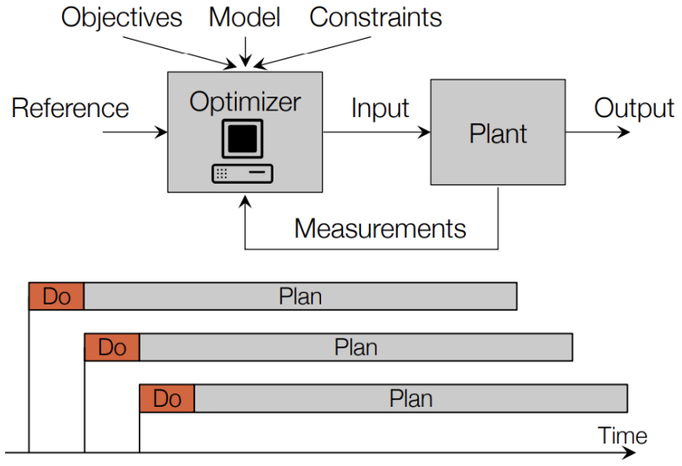
Minimize	(lap time)
while	avoid other cars
	stay on road
	...

- Solve **optimization problem** to compute minimum-time path
- What to do if something unexpected happens?
  - We didn't see a car around the corner!
  - Must introduce *feedback*

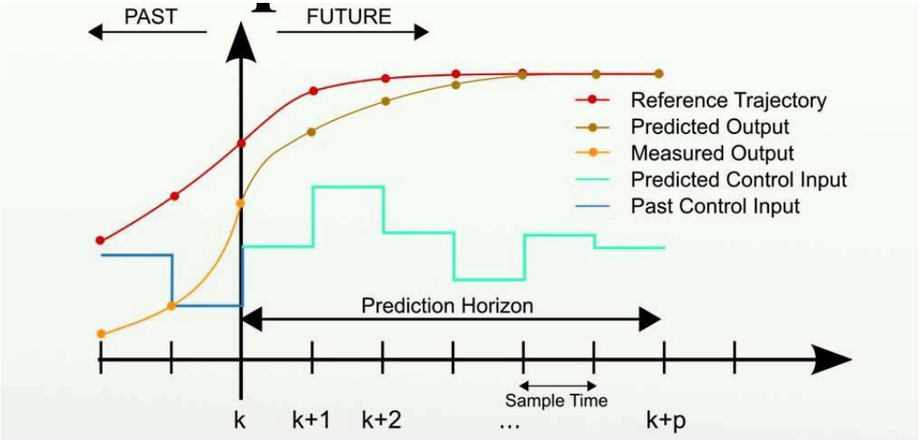


Model predictive control

- Main idea

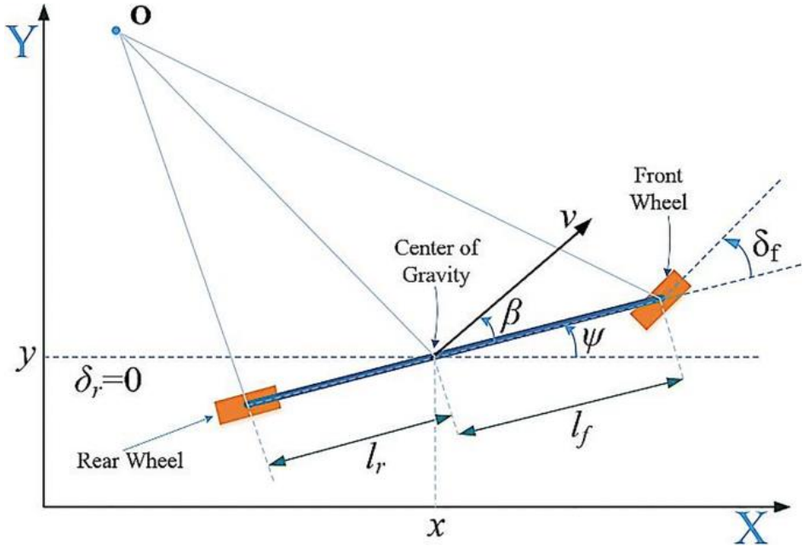


Receding horizon strategy introduces **feedback**.



Model predictive control

- How to predict?
  - Model of a system
    - 2D kinematic bicycle model (rear wheel reference point)
    - State: x, y, v, ψ, δ
    - Input: $a, \dot{\delta}$



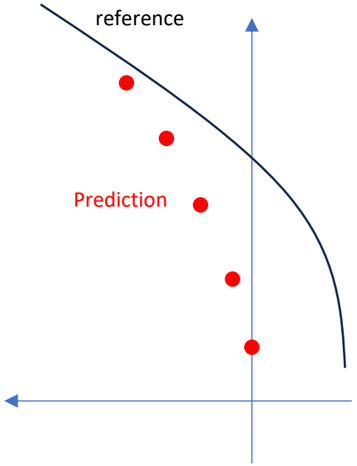
$$x_{k+1} = Ax_k + Bu_k$$

$$y_k = Cx_k$$

$$x_{k+2} = A(Ax_k + Bu_k) + Bu_{k+1}$$

$$y_{k+1} = C(Ax_k + Bu_k)$$

$$\vdots$$



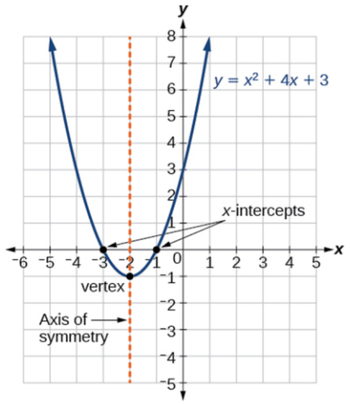
$$Minimize(J)$$

$$J = \sum(\Delta y)^2 = \sum(y_{ref} - y_k)^2$$

Model predictive control

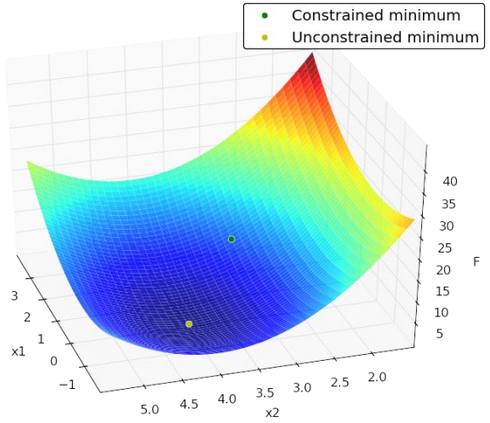
- Optimization problem
  - How to optimize

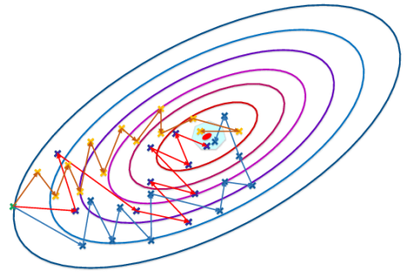
Variables: $u_k, u_{k+1}, u_{k+2}, \cdots u_{k+l}$



$$\begin{aligned} \underset{x}{\text{minimize}} \quad & f(x) \\ \text{subject to} \quad & g_i(x) \leq 0, \quad i = 1, \ldots, m \\ & h_j(x) = 0, \quad j = 1, \ldots, p \end{aligned}$$

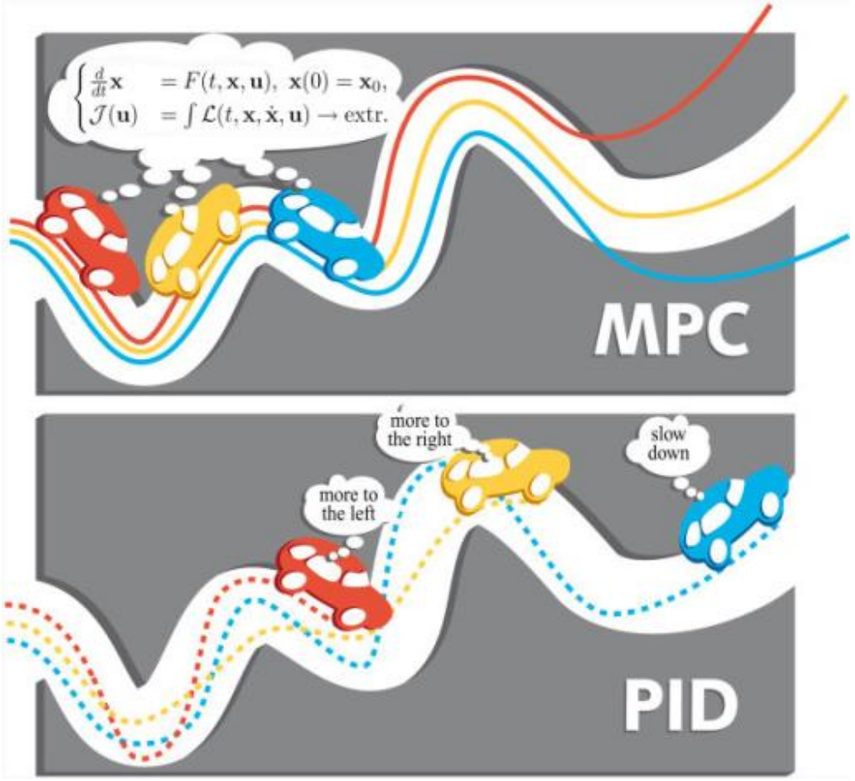
- $f : \mathbb{R}^n \to \mathbb{R}$ is the **objective function** to be minimized over the n-variable vector x,
- $g_i(x) \leq 0$ are called **inequality constraints**
- $h_j(x) = 0$ are called **equality constraints**, and
- $m \geq 0$ and $p \geq 0$.





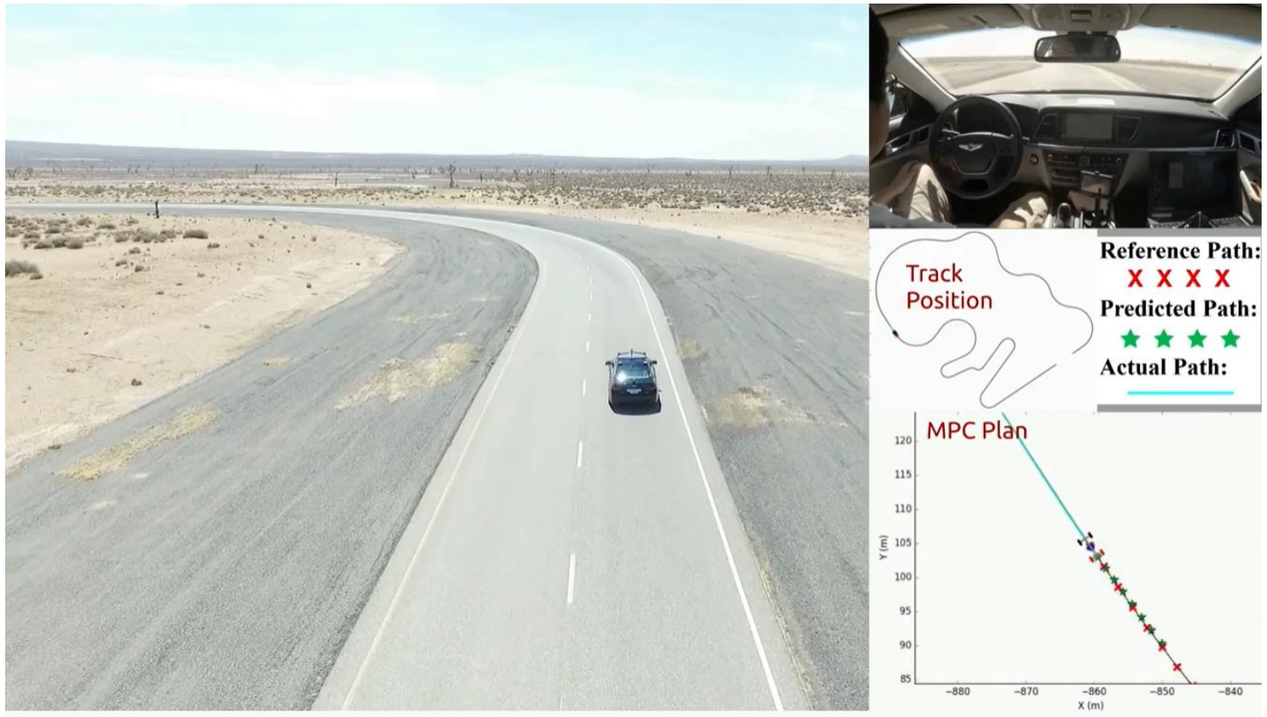
Model predictive control

- MPC vs PID



Model predictive control

- Example
  - Blog: https://automatedcars.space/home/2018/11/28/differential-gps-for-mpc-based-path-following
  - Video: https://youtu.be/WT43DCK7sf8
  - Code: https://github.com/MPC-Berkeley/genesis_path_follower (ROS, Python)



Model predictive control

- Example
  - Video: https://youtu.be/32v-e3dptjo
  - Paper: “Robust Sampling Based Model Predictive Control with Sparse Objective Information” (RSS 2018)
  - http://www.roboticsproceedings.org/rss14/p42.pdf

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Thank You