한양대학교

Adaptive Model Predictive Control

2019. 11. 05

김정환

한양대학교 전자공학부

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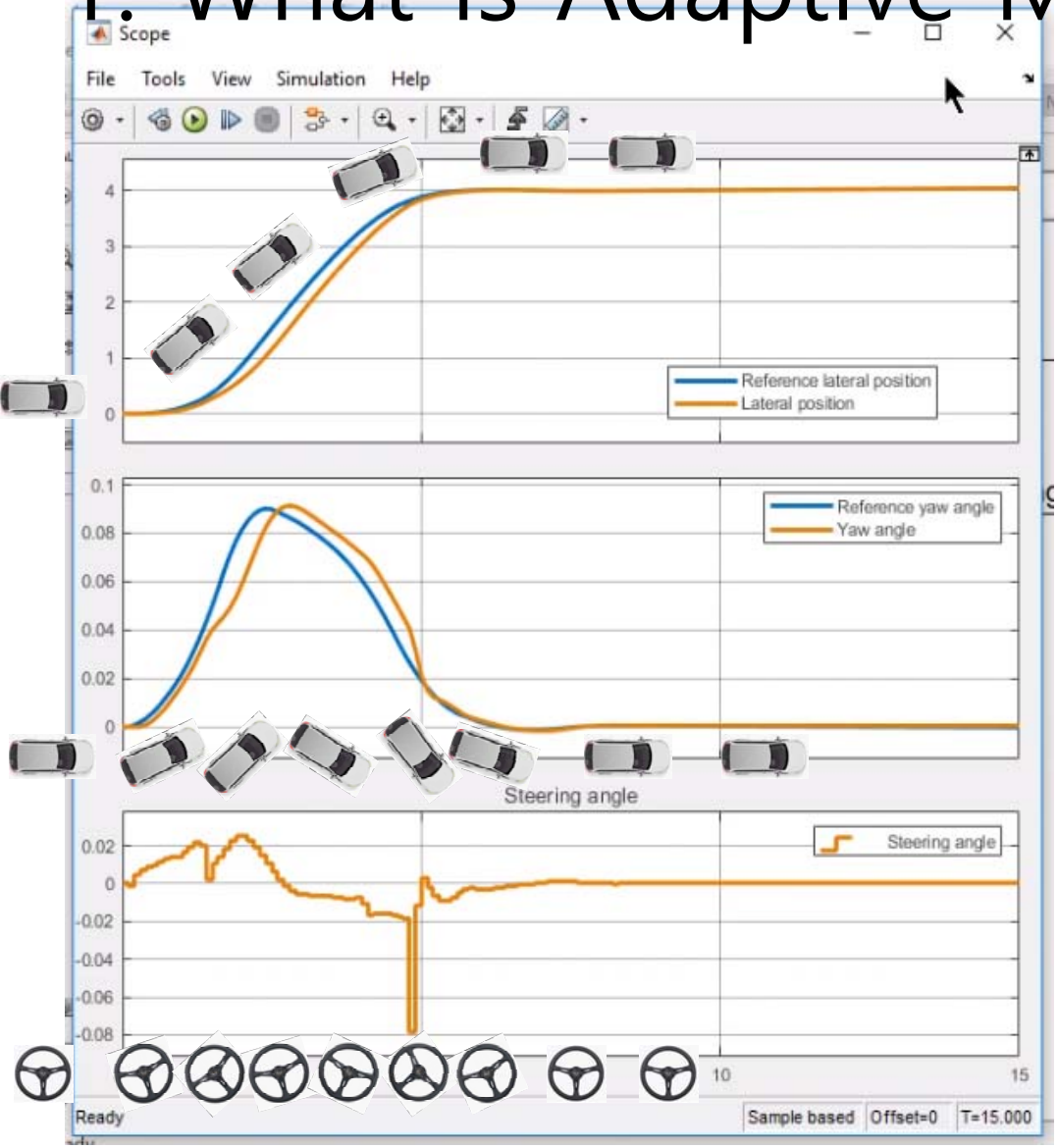
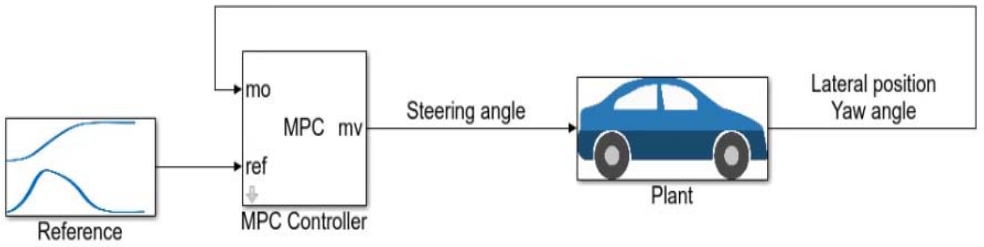
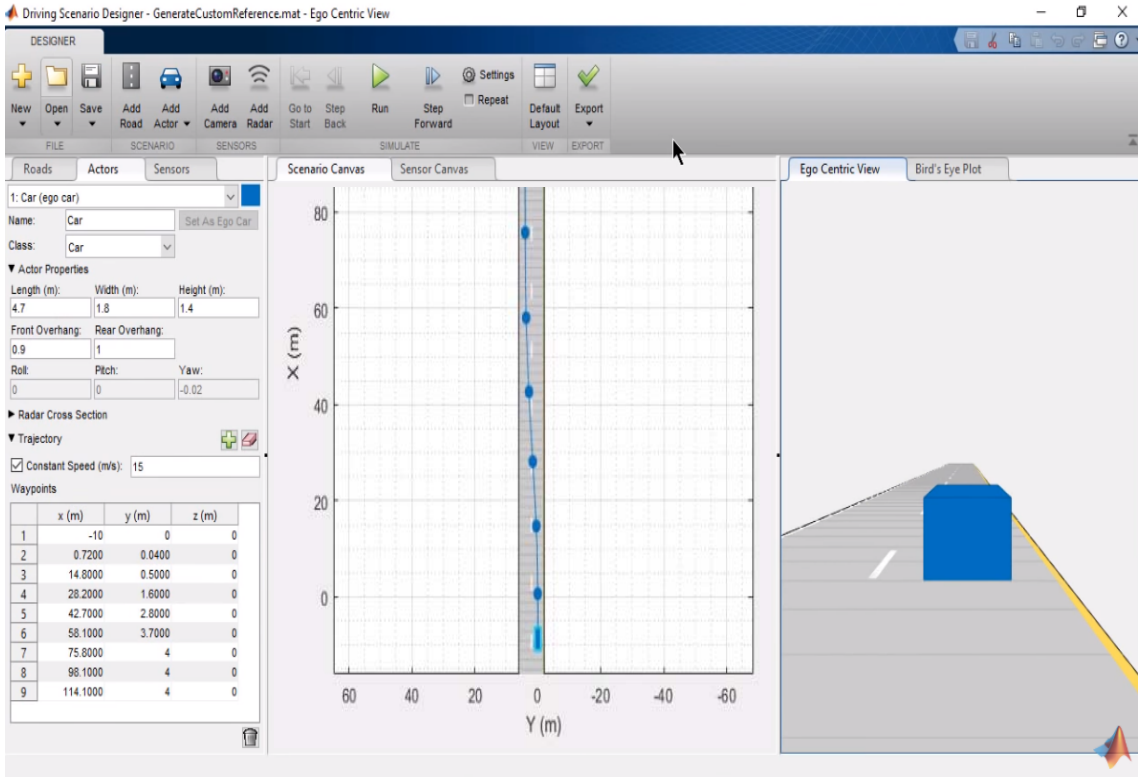
1. What is Adaptive MPC?







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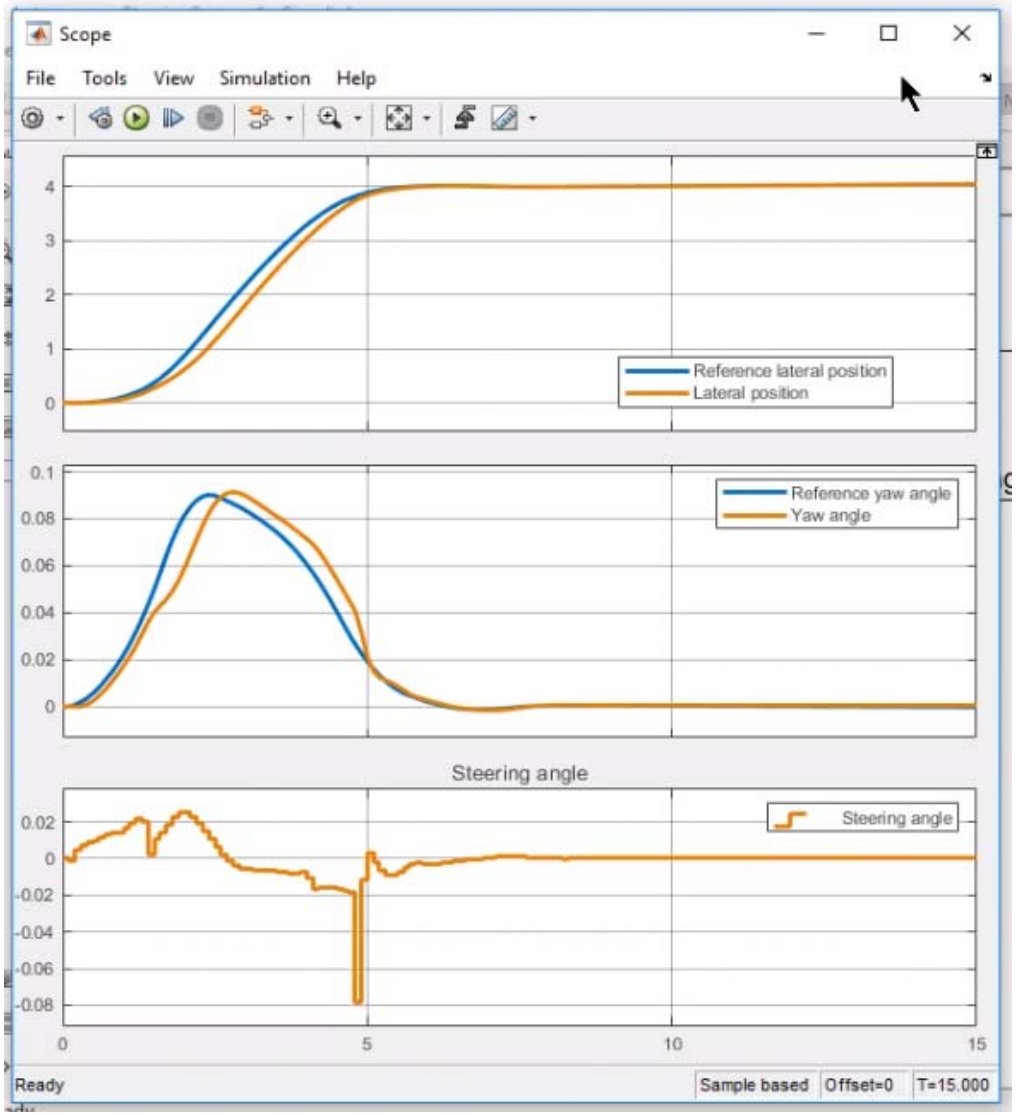

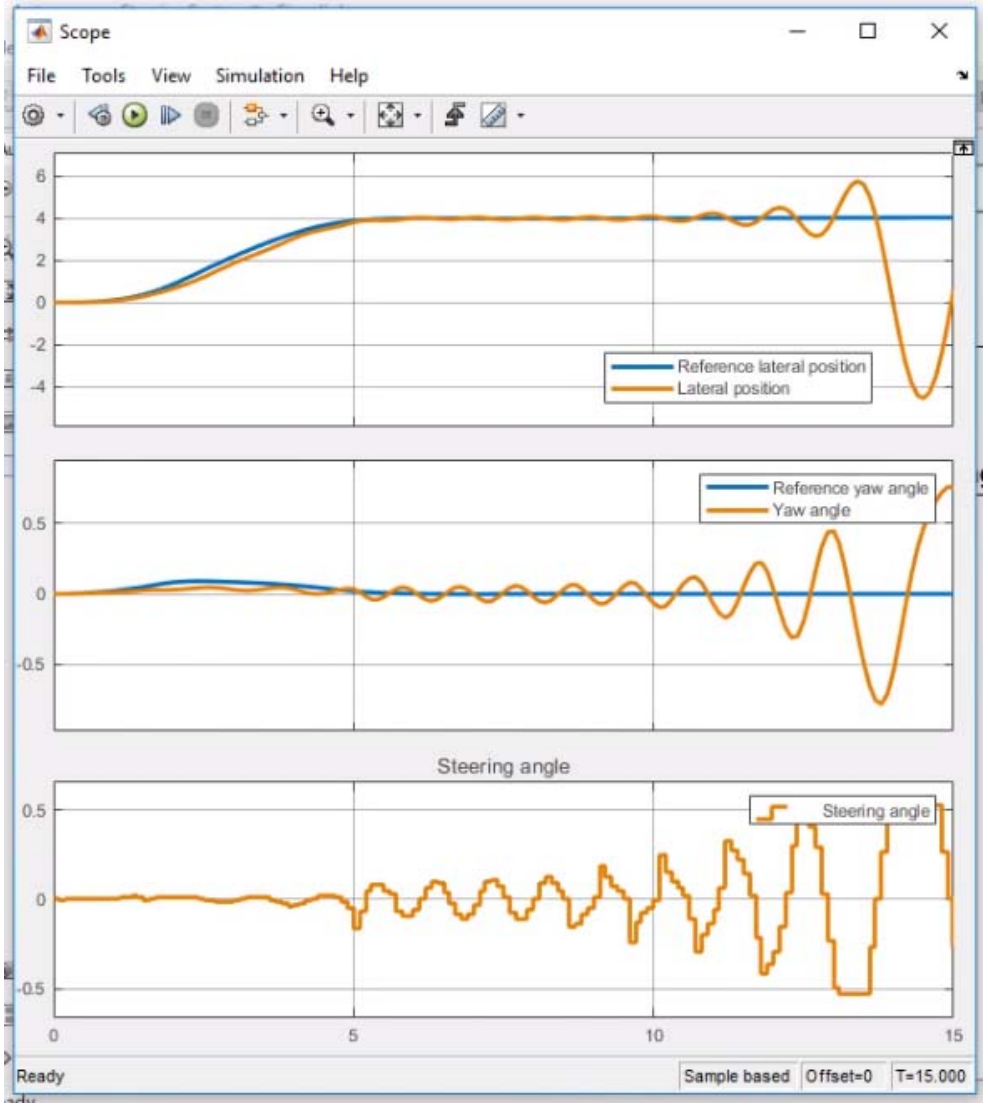

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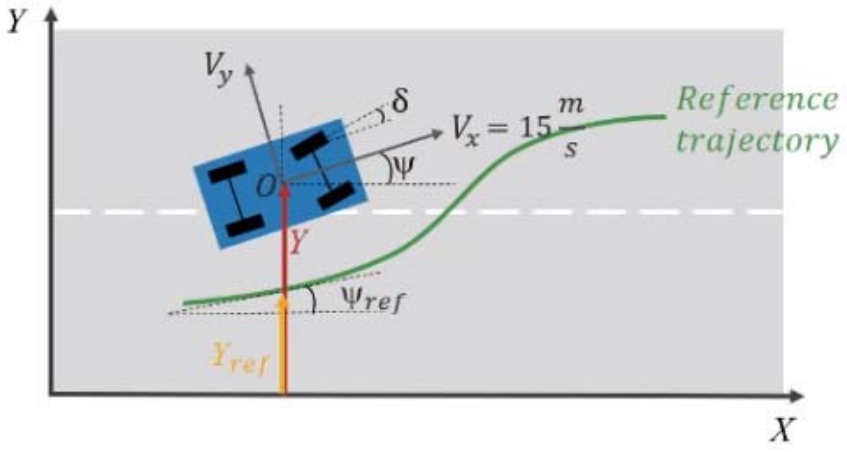


V_y: *Lateral velocity*

V_x: *Longitudinal velocity*

(X, Y): *Vehicle's global position*

ψ: *Yaw angle*

δ: *Front steering angle*

Y_{ref}: *Reference lateral position*

ψ_{ref}: *Reference yaw angle*

- Lateral dynamics:

$$\frac{d}{dt}\begin{bmatrix}\dot{y}\\ \psi\\ \dot{\psi}\end{bmatrix} = \begin{bmatrix}-\frac{2C_{\alpha f}+2C_{\alpha r}}{mV_x} & 0 & -V_x-\frac{2C_{\alpha f}\ell_f-2C_{\alpha r}\ell_r}{mV_x}\\ 0 & 0 & 1\\ -\frac{2\ell_f C_{\alpha f}-2\ell_r C_{\alpha r}}{I_z V_x} & 0 & -\frac{2\ell_f^2 C_{\alpha f}+2\ell_r^2 C_{\alpha r}}{I_z V_x}\end{bmatrix}\begin{bmatrix}\dot{y}\\ \psi\\ \dot{\psi}\end{bmatrix} + \begin{bmatrix}\frac{2C_{\alpha f}}{m}\\ 0\\ \frac{2\ell_f C_{\alpha f}}{I_z}\end{bmatrix}\delta$$

- Global Y position:

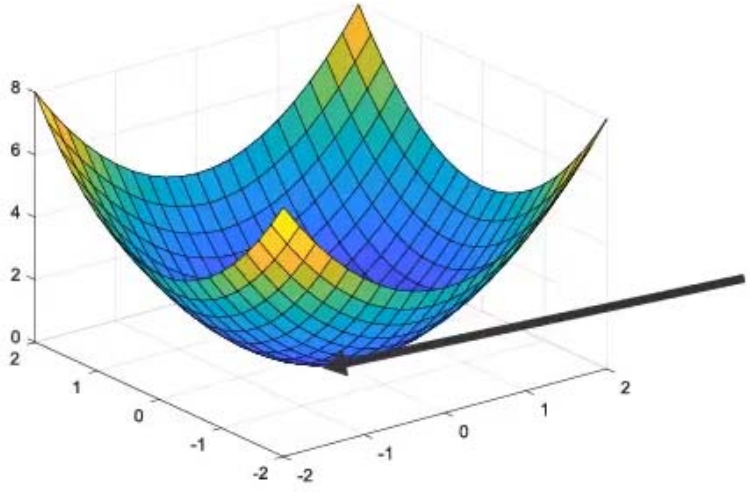
$$\dot{Y} = V_x\psi + V_y$$

V_x	Longitudinal velocity at center of gravity of vehicle
m	Total mass of vehicle
I_z	Yaw moment of inertia of vehicle
l_f	Longitudinal distance from center of gravity to front tires
l_r	Longitudinal distance from center of gravity to front tires
C_α	Cornering stiffness of tire
δ	Front steering angle
y	Lateral position
ψ	Yaw angle

1. What is Adaptive MPC?

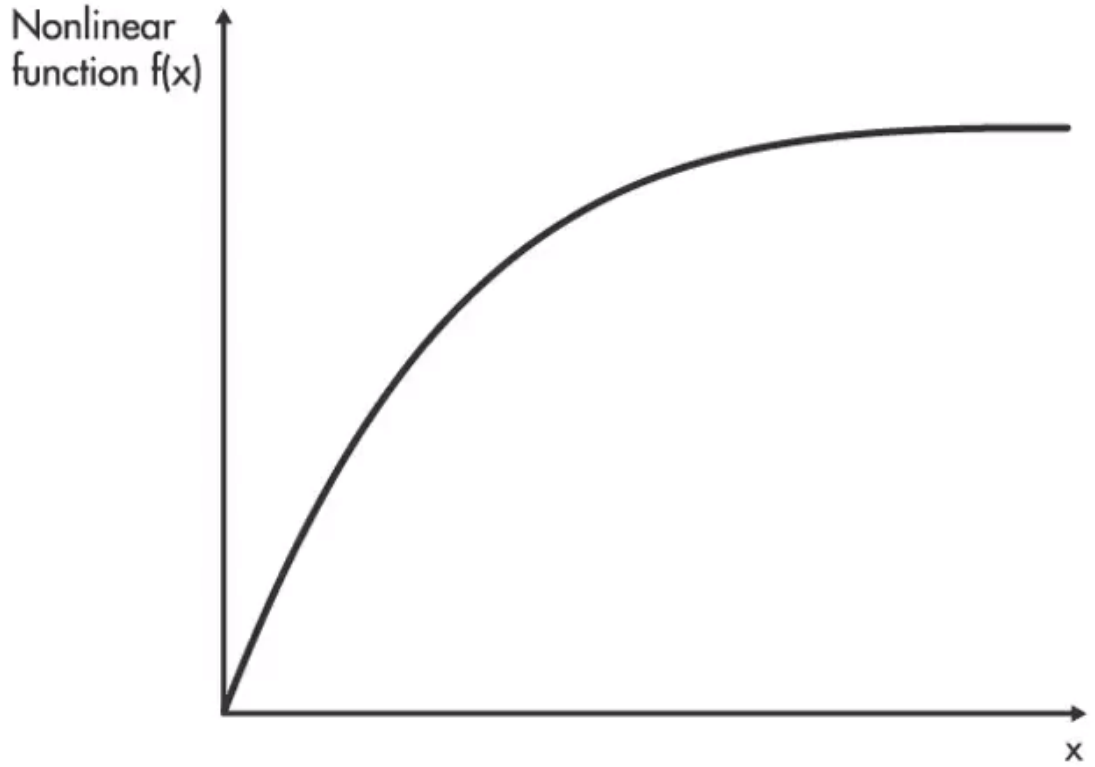
Linear system Linear constraints Quadratic cost function

Convex Optimization Problem



Global optimum

1. What is Adaptive MPC?



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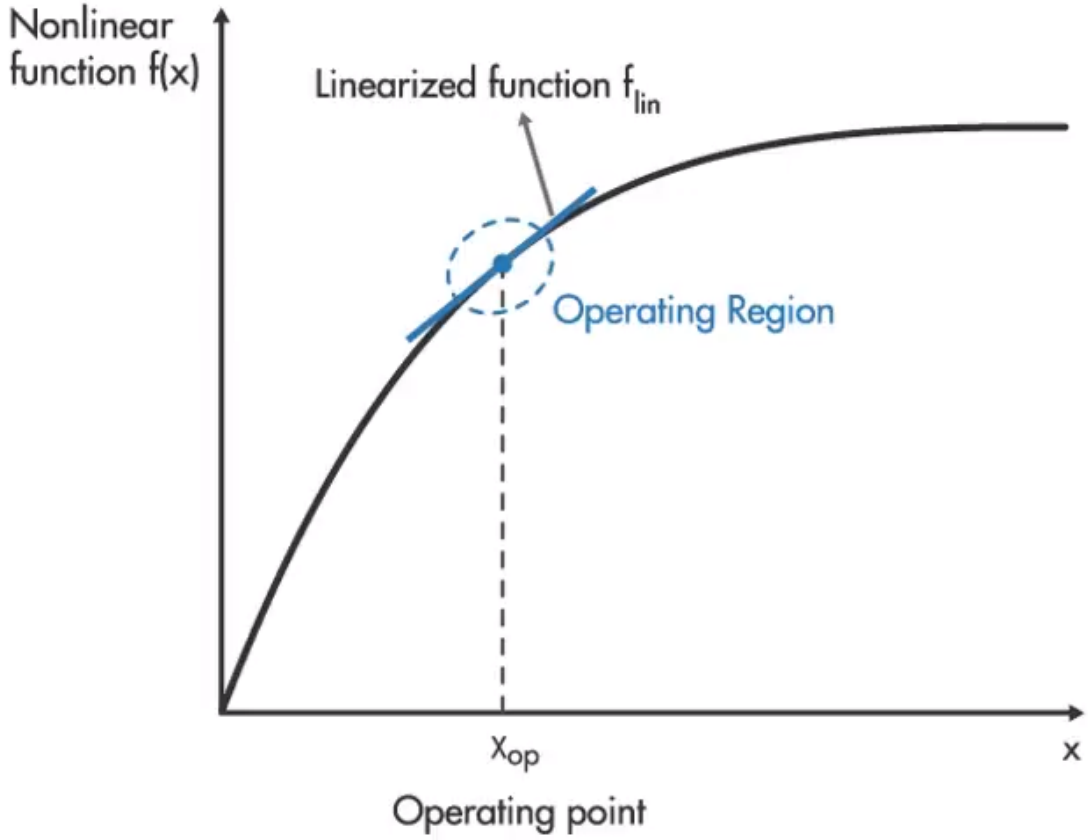

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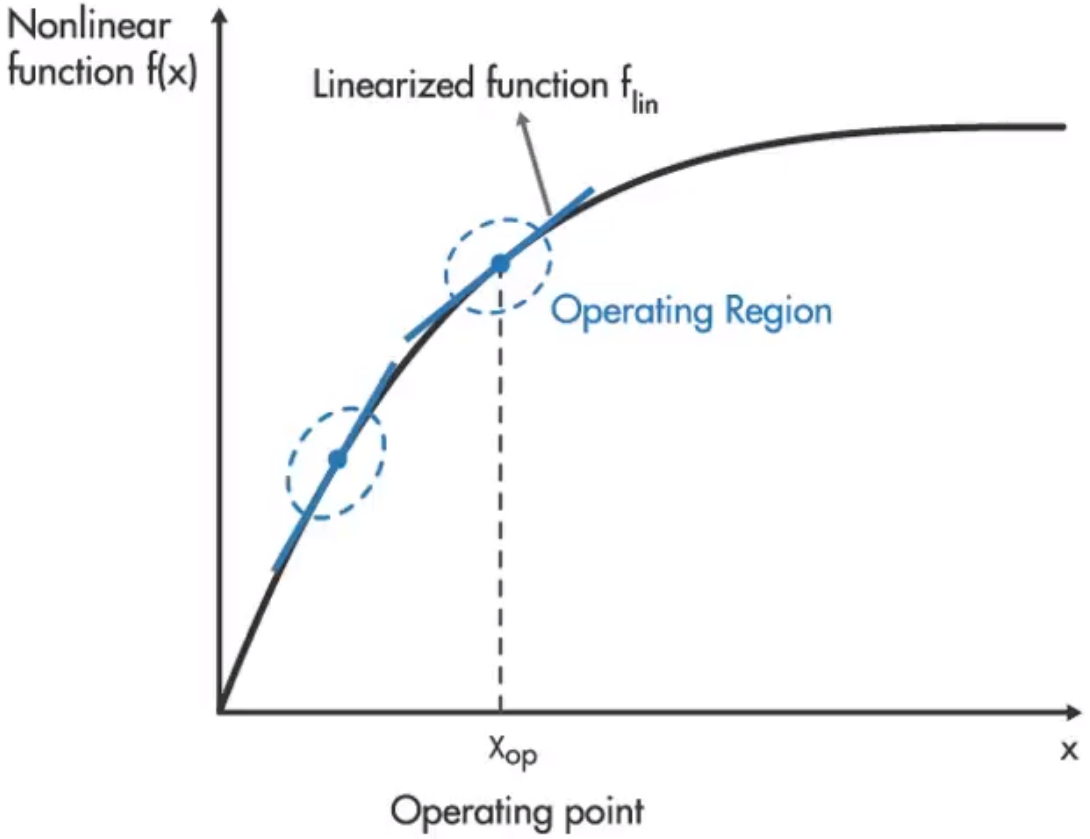

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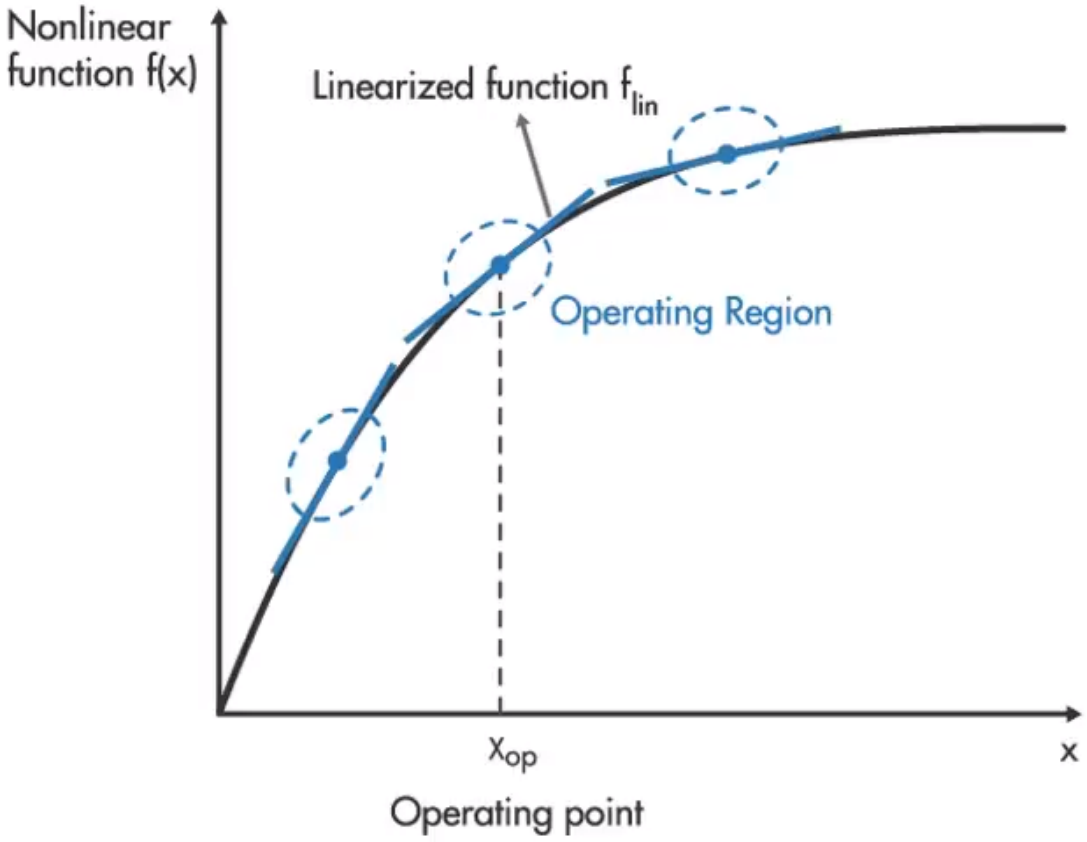

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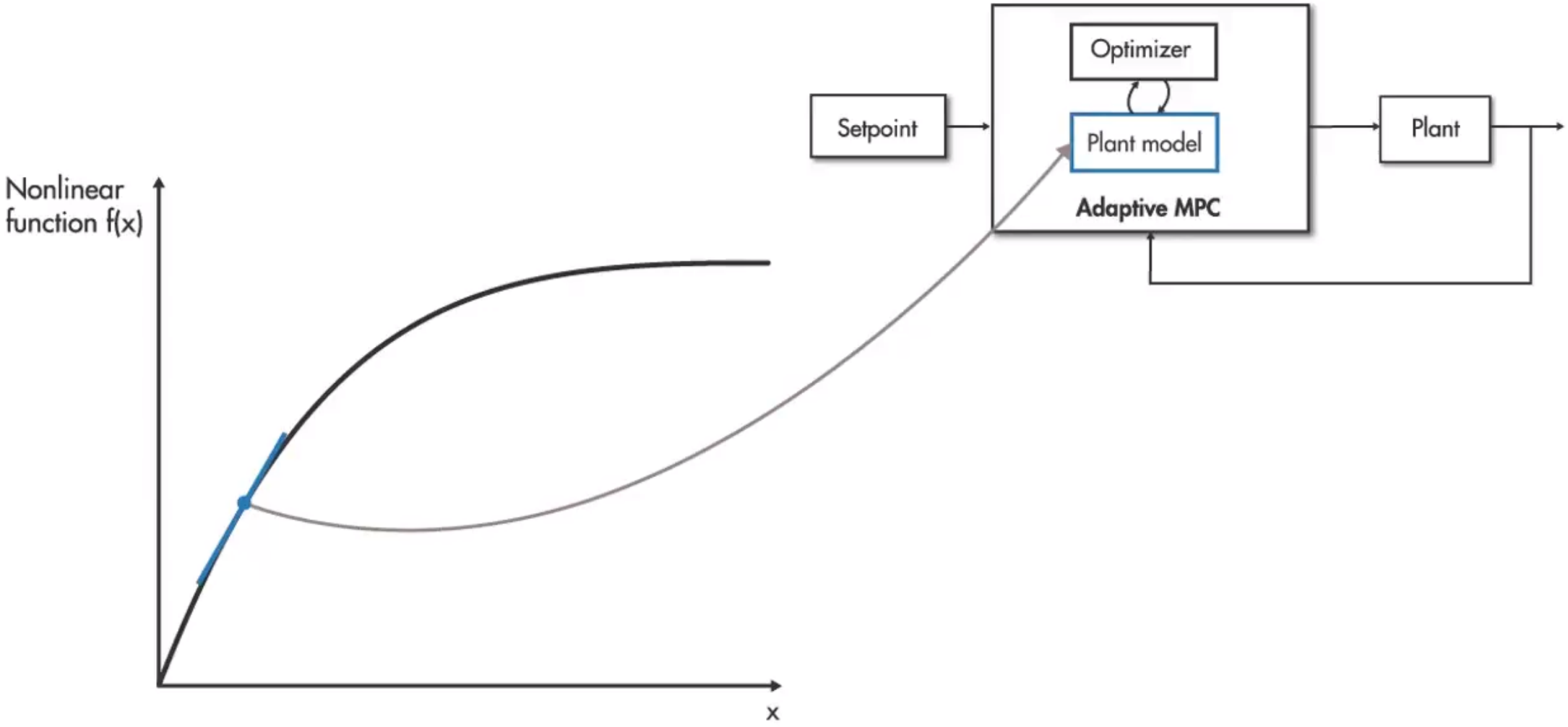

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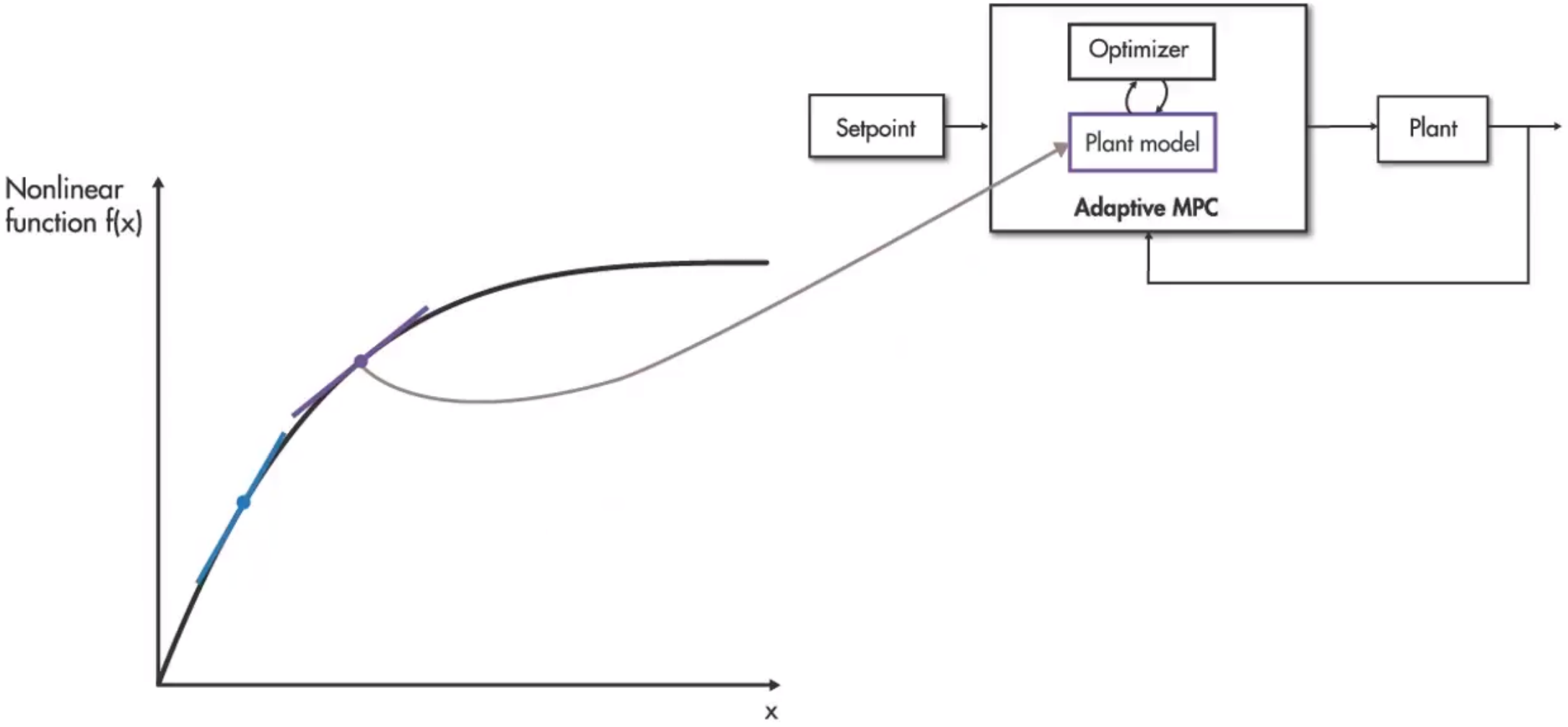

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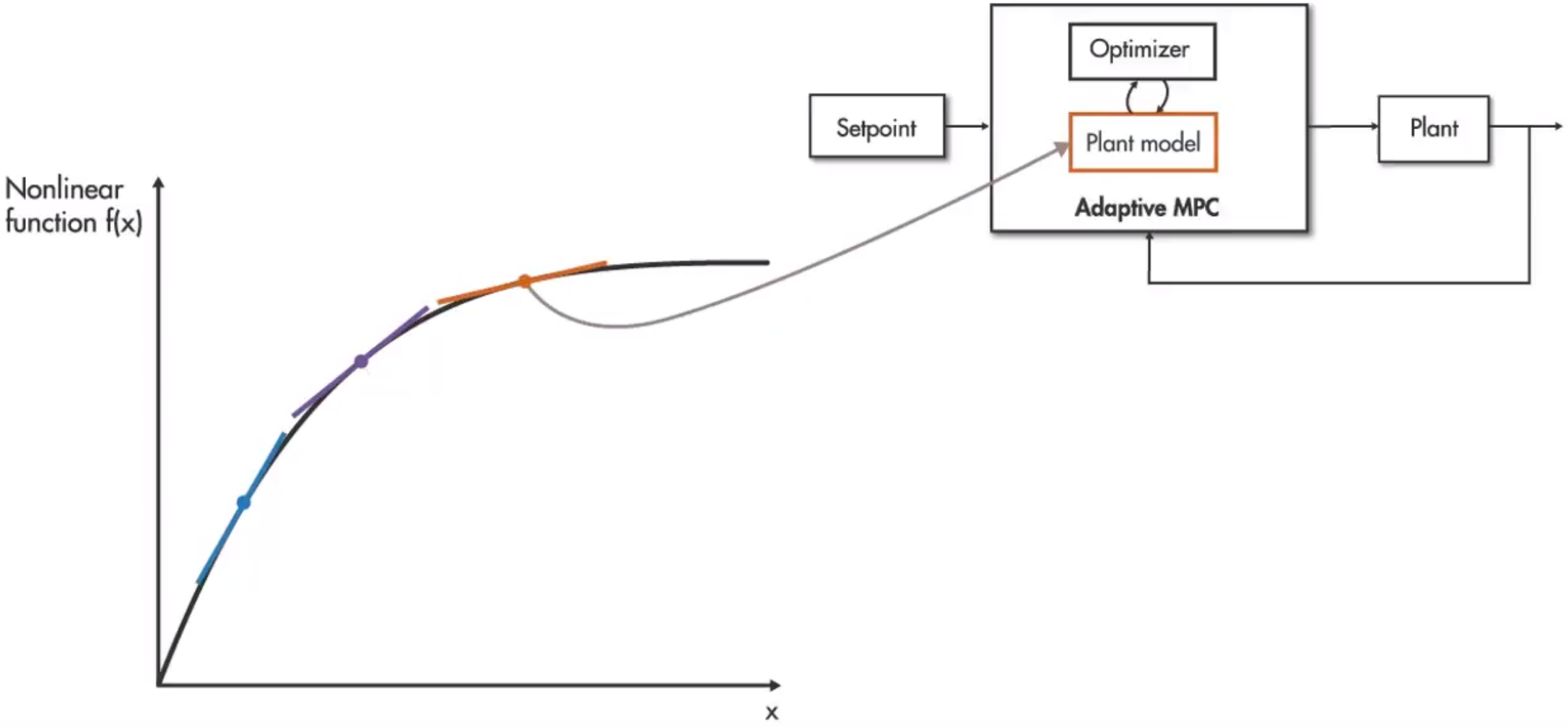

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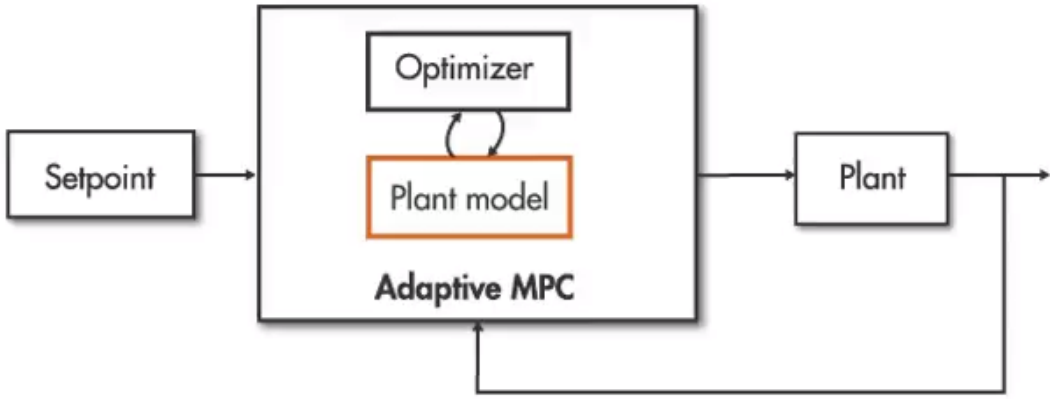
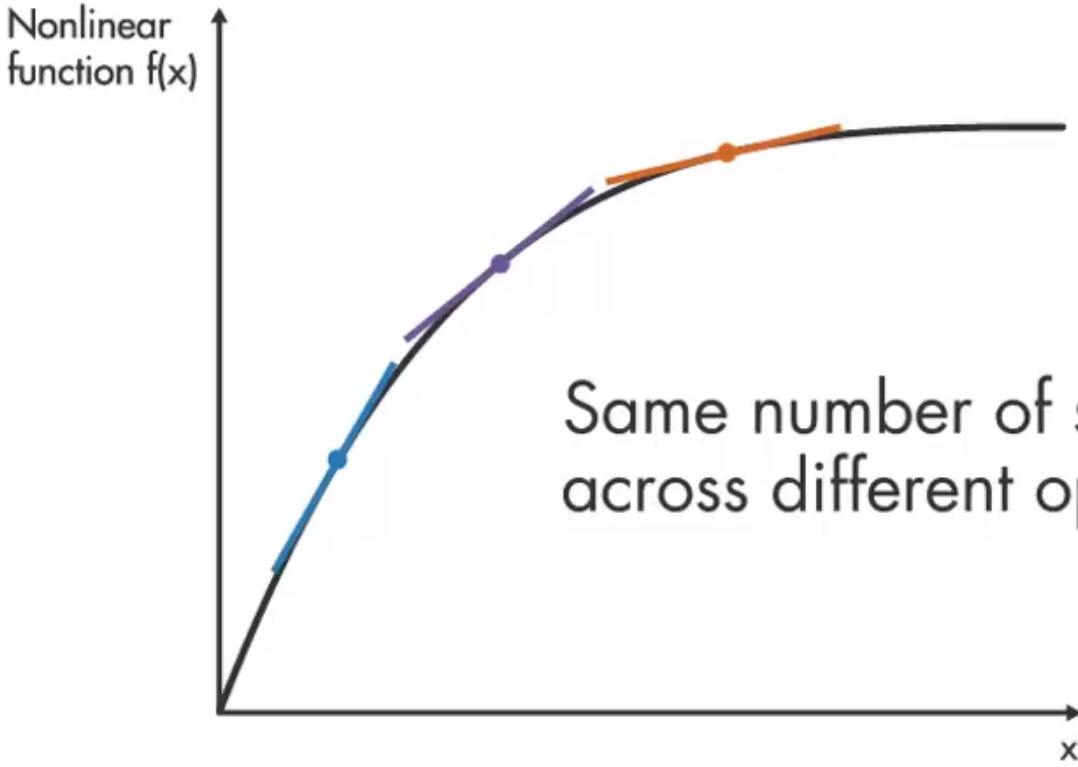
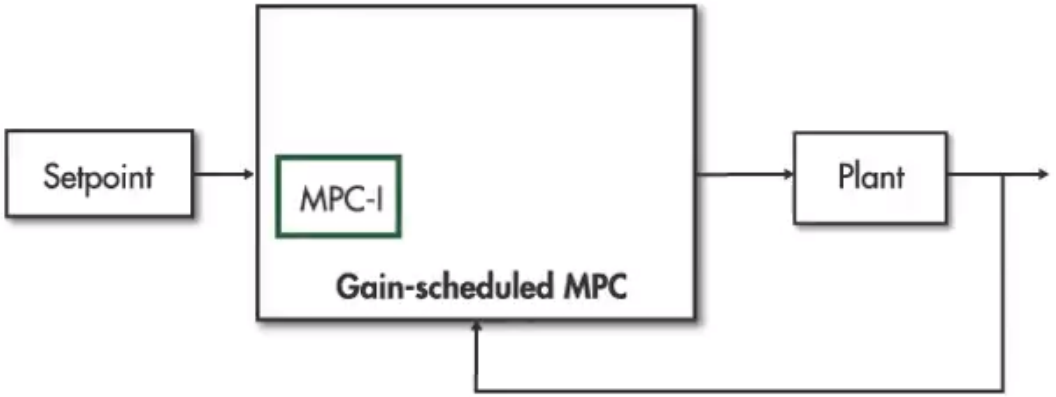
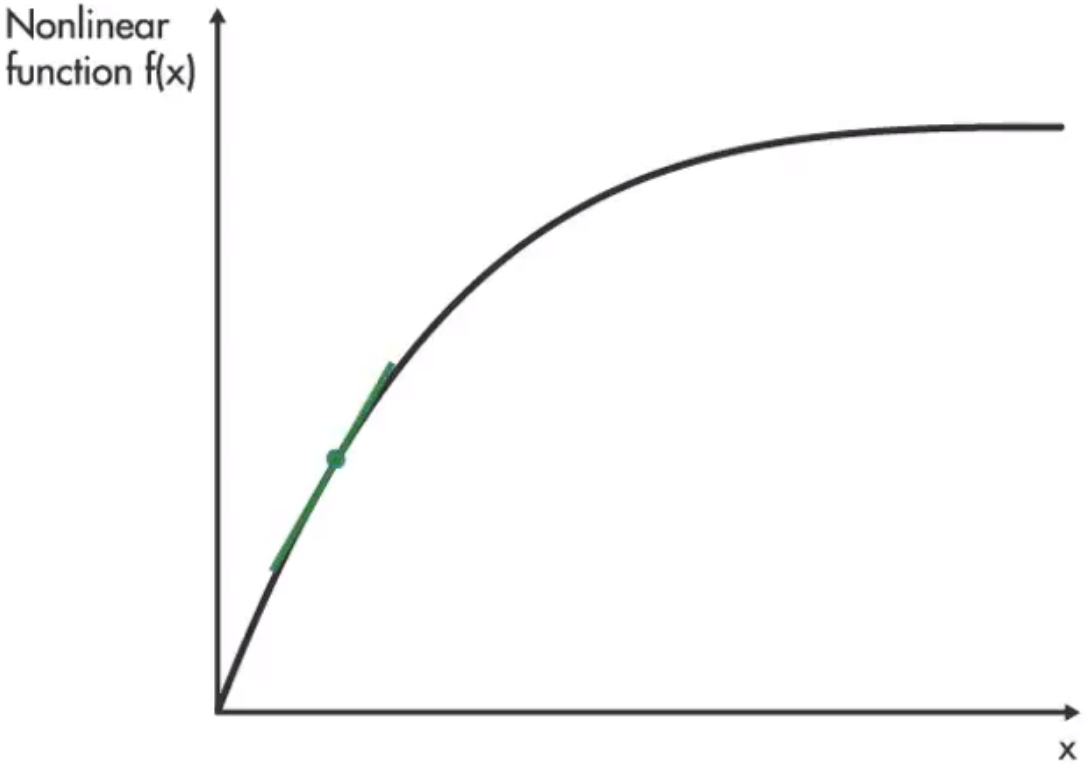




Same number of states and constraints
across different operating conditions

2. What is Gain-Scheduled MPC?





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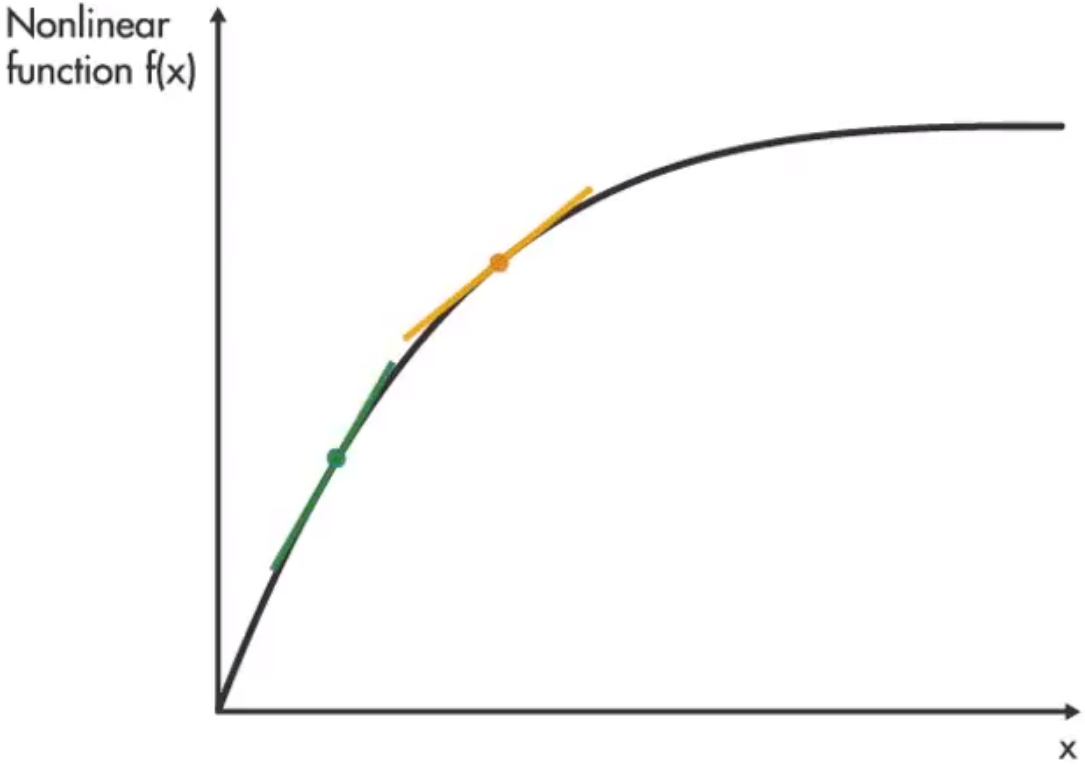

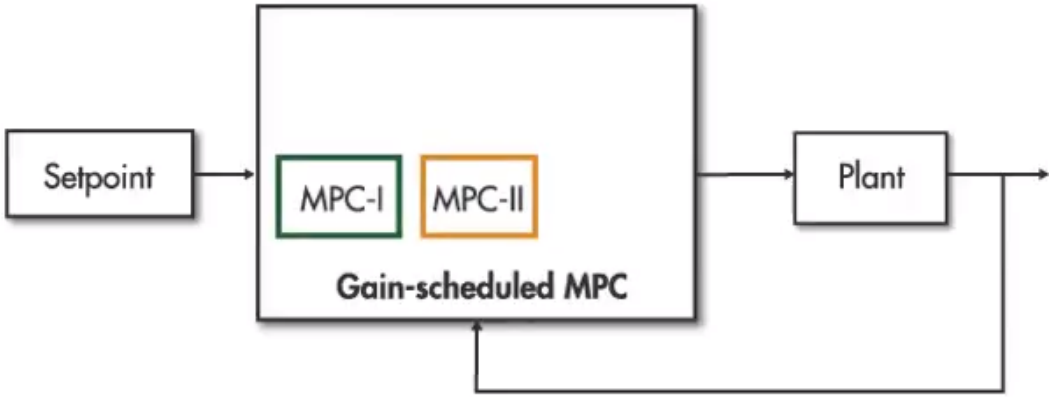

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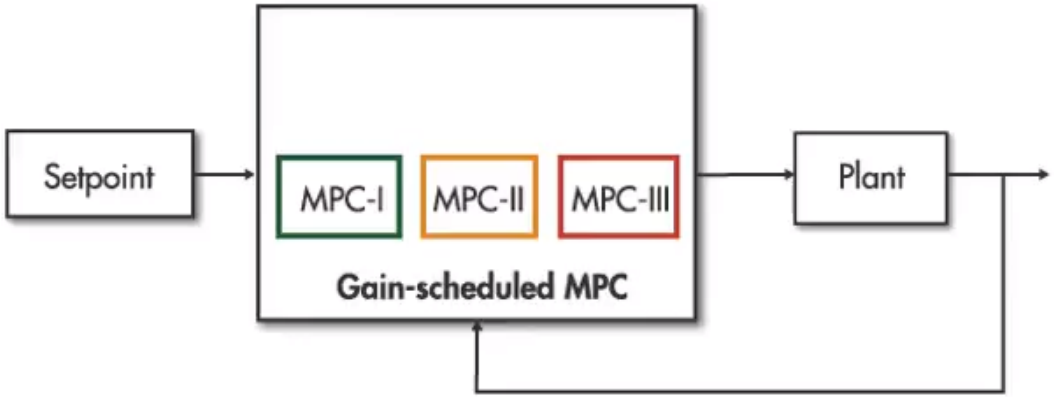
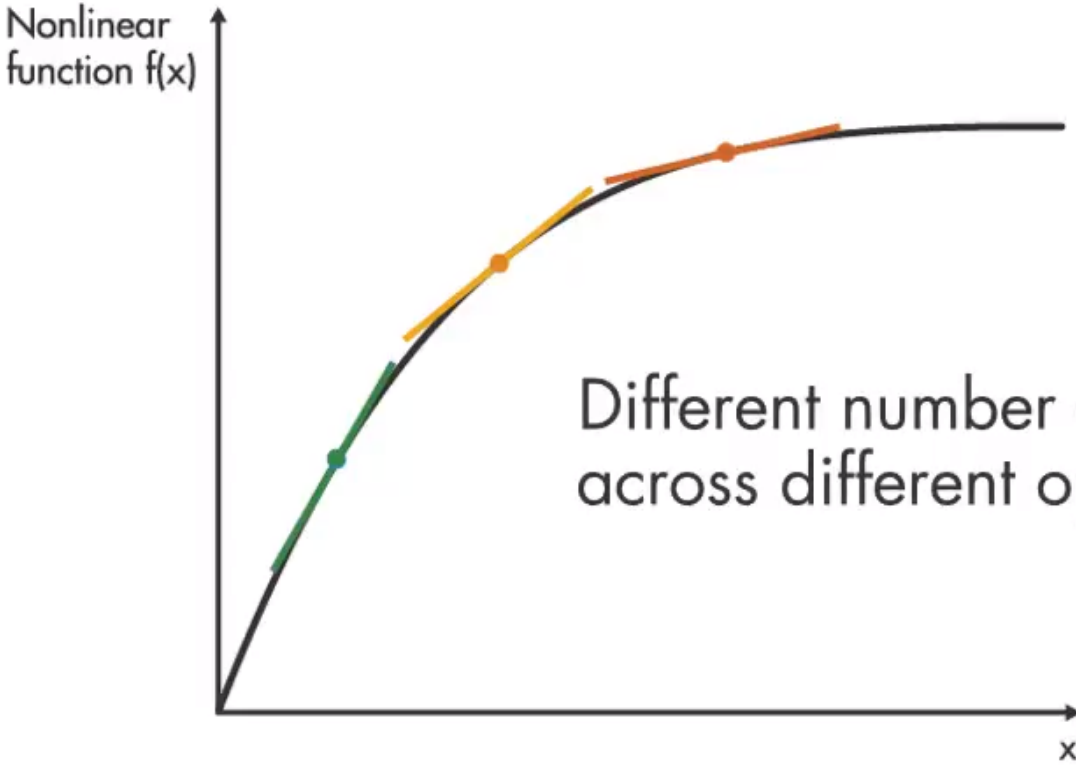
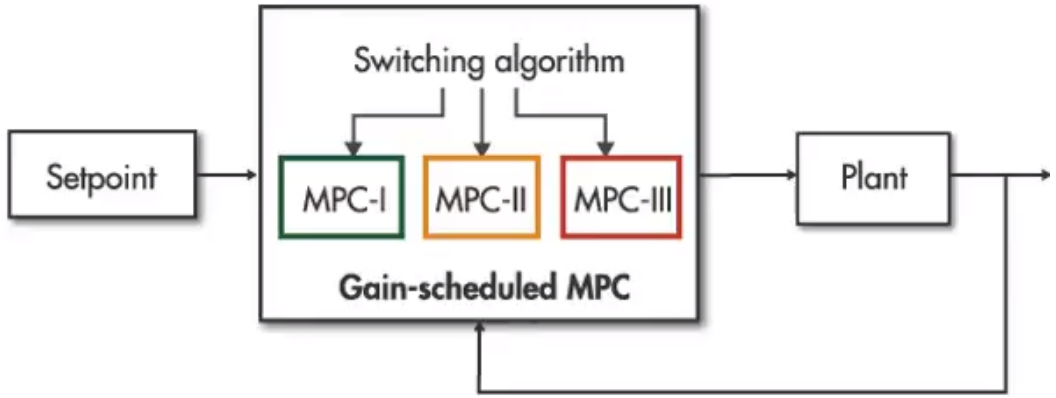
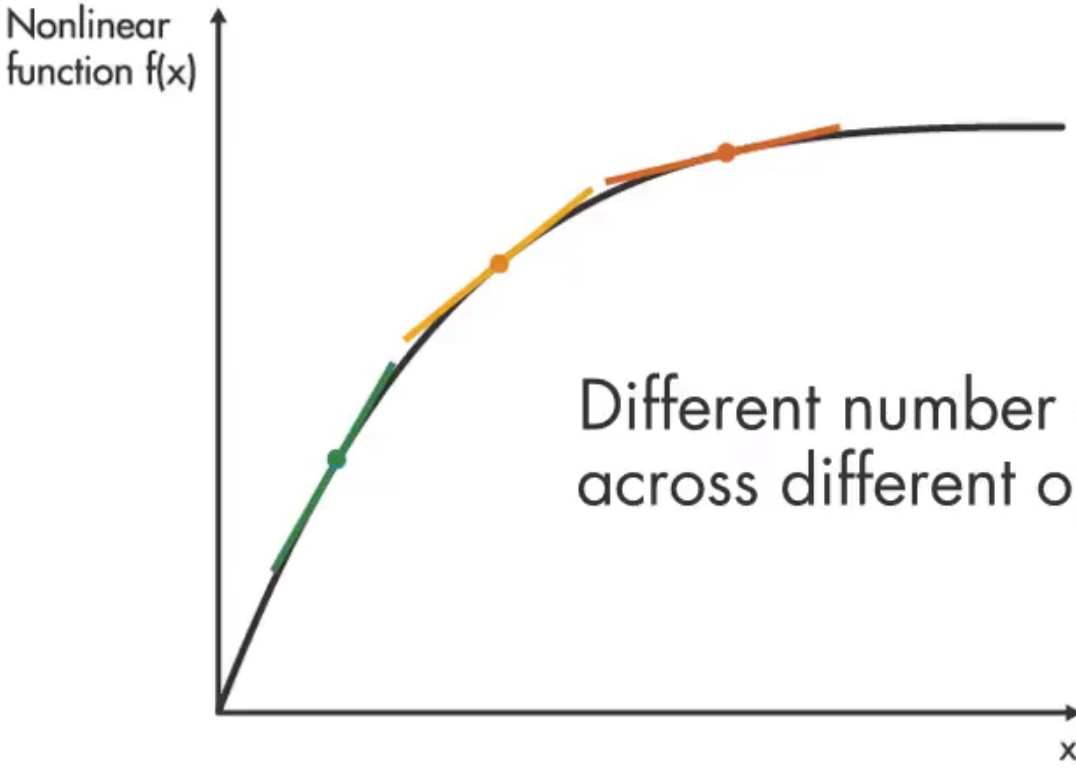




Different number of states and constraints
across different operating conditions

2. What is Gain-Scheduled MPC?



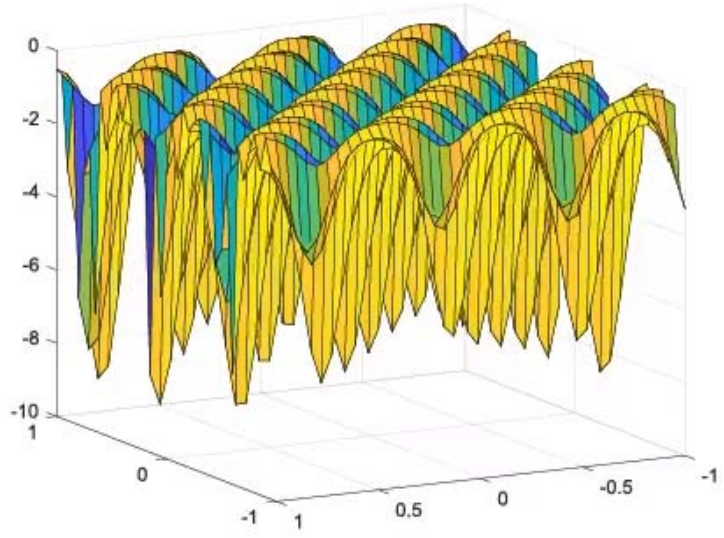


Different number of states and constraints
across different operating conditions

3. What is Nonlinear MPC?

Nonlinear system Nonlinear constraints Nonlinear cost function

Non-convex Optimization Problem



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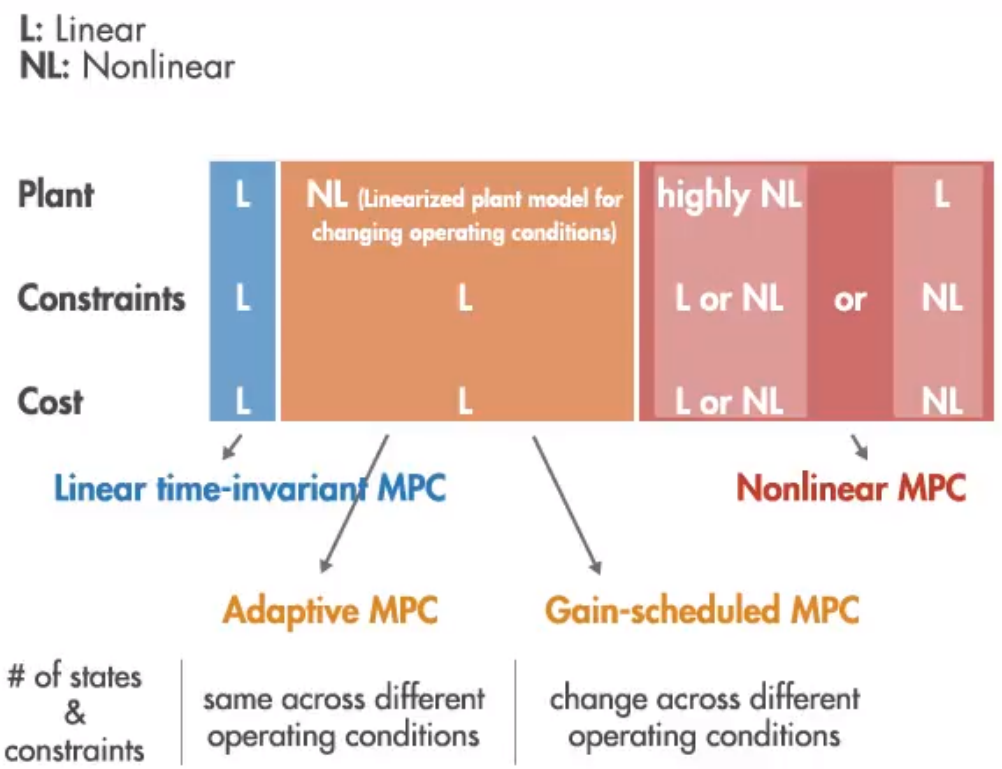
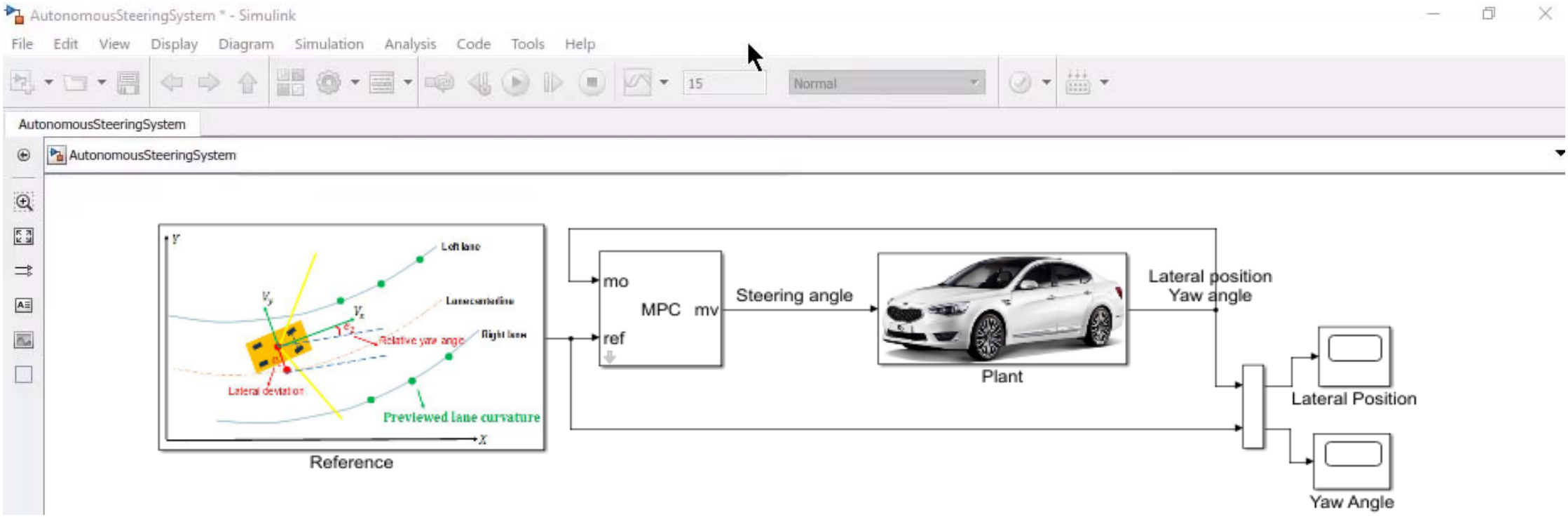


4. Adaptive MPC Design with Simulink



4. Adaptive MPC Design with Simulink

AutonomousSteeringSystem * - Simulink

File Edit View Display Diagram Simulation Analysis Code Tools Help

AutonomousSteeringSystem

AutonomousSteeringSystem

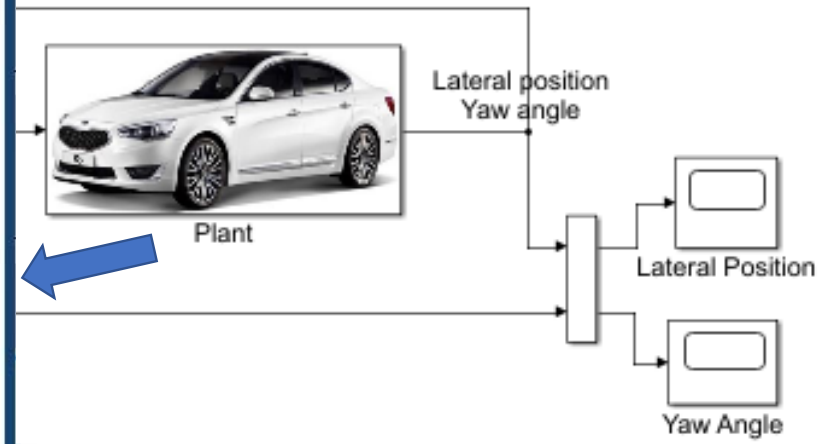
- Lateral dynamics:

$$\frac{d}{dt}\begin{bmatrix}\dot{y}\\ \psi\\ \dot{\psi}\end{bmatrix} = \begin{bmatrix}-\frac{2C_{\alpha f}+2C_{\alpha r}}{mV_x} & 0 & -V_x-\frac{2C_{\alpha f}\ell_f-2C_{\alpha r}\ell_r}{mV_x}\\ 0 & 0 & 1\\ -\frac{2\ell_f C_{\alpha f}-2\ell_r C_{\alpha r}}{I_z V_x} & 0 & -\frac{2\ell_f^2 C_{\alpha f}+2\ell_r^2 C_{\alpha r}}{I_z V_x}\end{bmatrix}\begin{bmatrix}\dot{y}\\ \psi\\ \dot{\psi}\end{bmatrix} + \begin{bmatrix}\frac{2C_{\alpha f}}{m}\\ 0\\ \frac{2\ell_f C_{\alpha f}}{I_z}\end{bmatrix}\delta$$

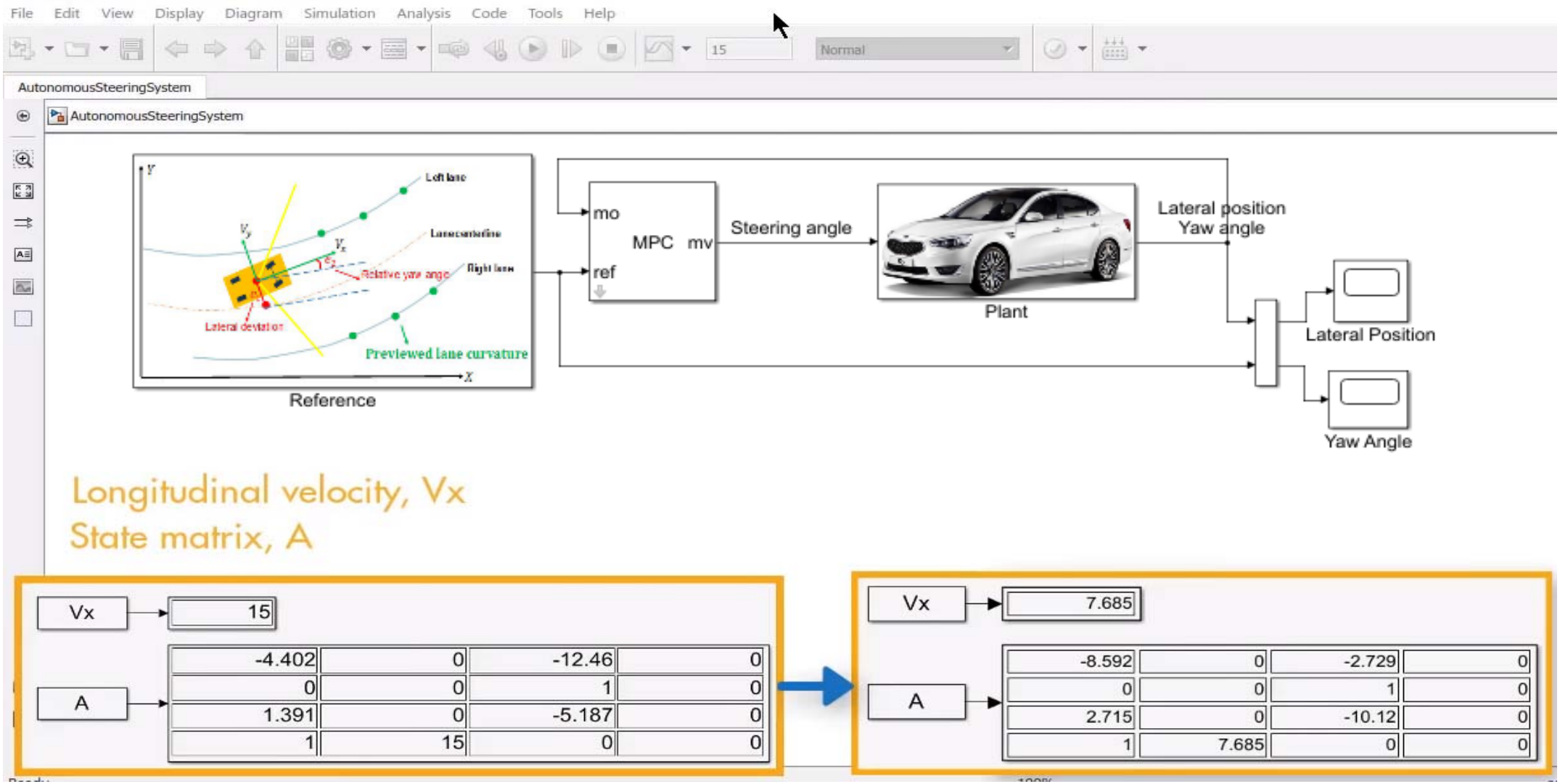
- Global Y position:

$$\dot{Y} = V_x\psi + V_y$$

V_x Longitudinal velocity at center of gravity of vehicle → 15 m/s
m Total mass of vehicle
I_z Yaw moment of inertia of vehicle
l_f Longitudinal distance from center of gravity to front tires
l_r Longitudinal distance from center of gravity to front tires
C_α Cornering stiffness of tire
δ Front steering angle
y Lateral position
ψ Yaw angle



4. Adaptive MPC Design with Simulink



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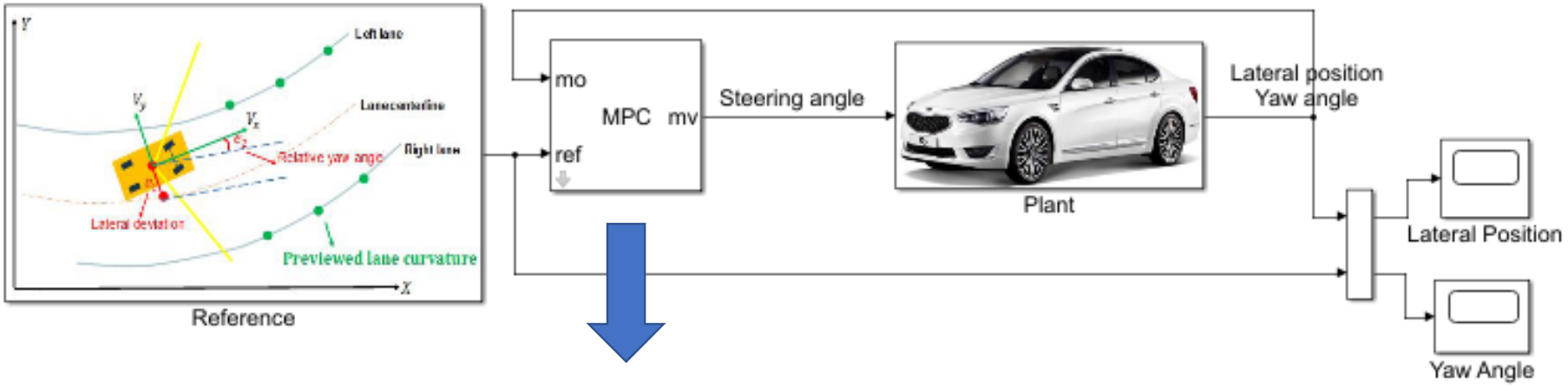
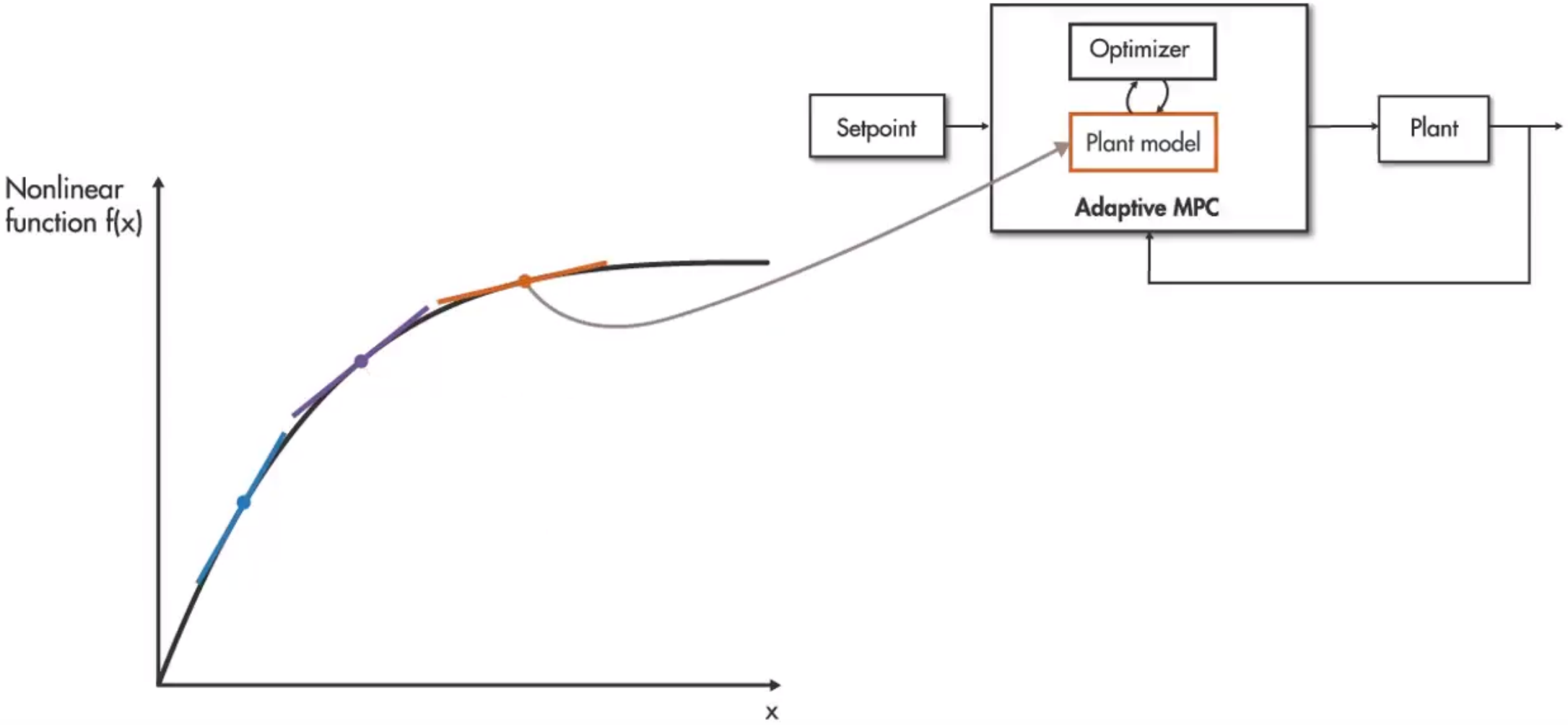


The internal plant model used for predictions is constant.

4. Adaptive MPC Design with Simulink



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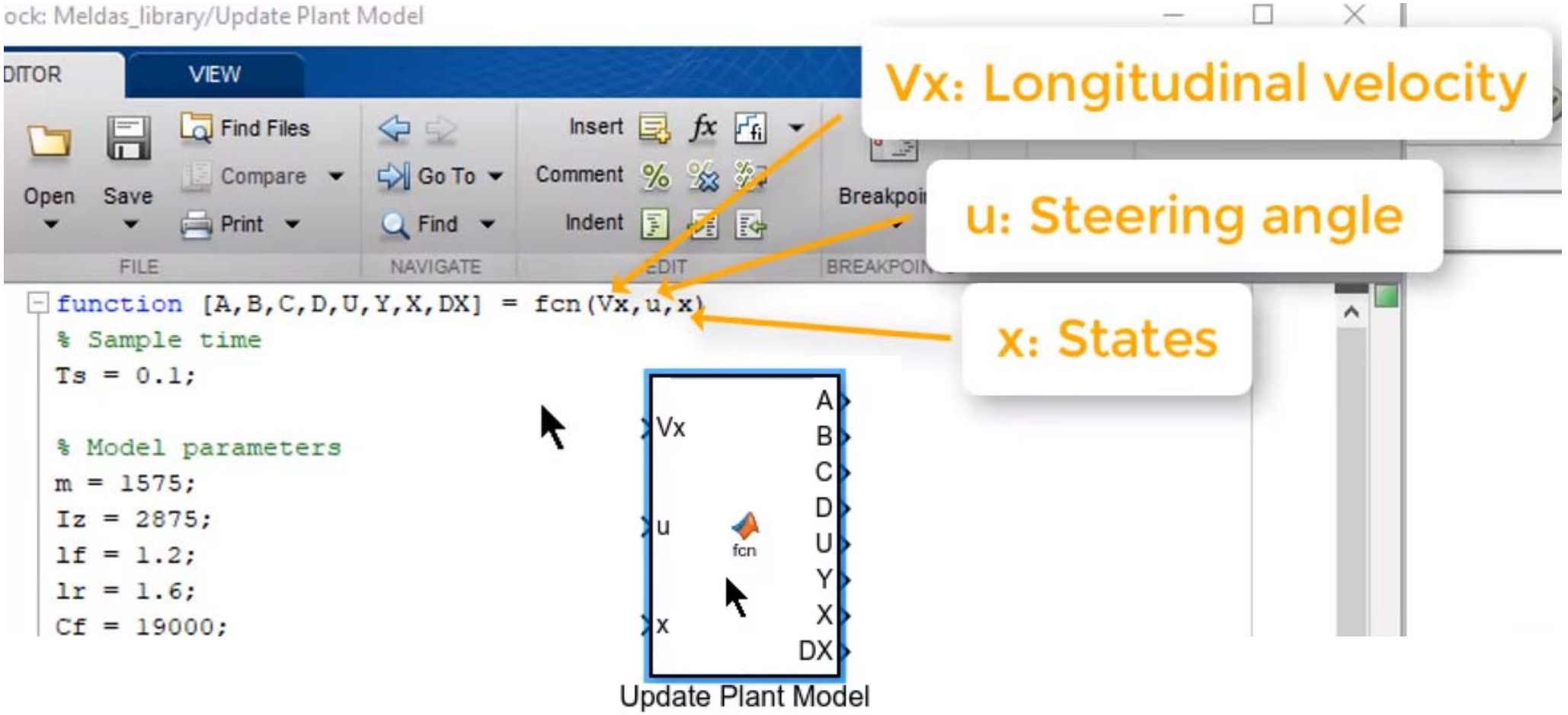

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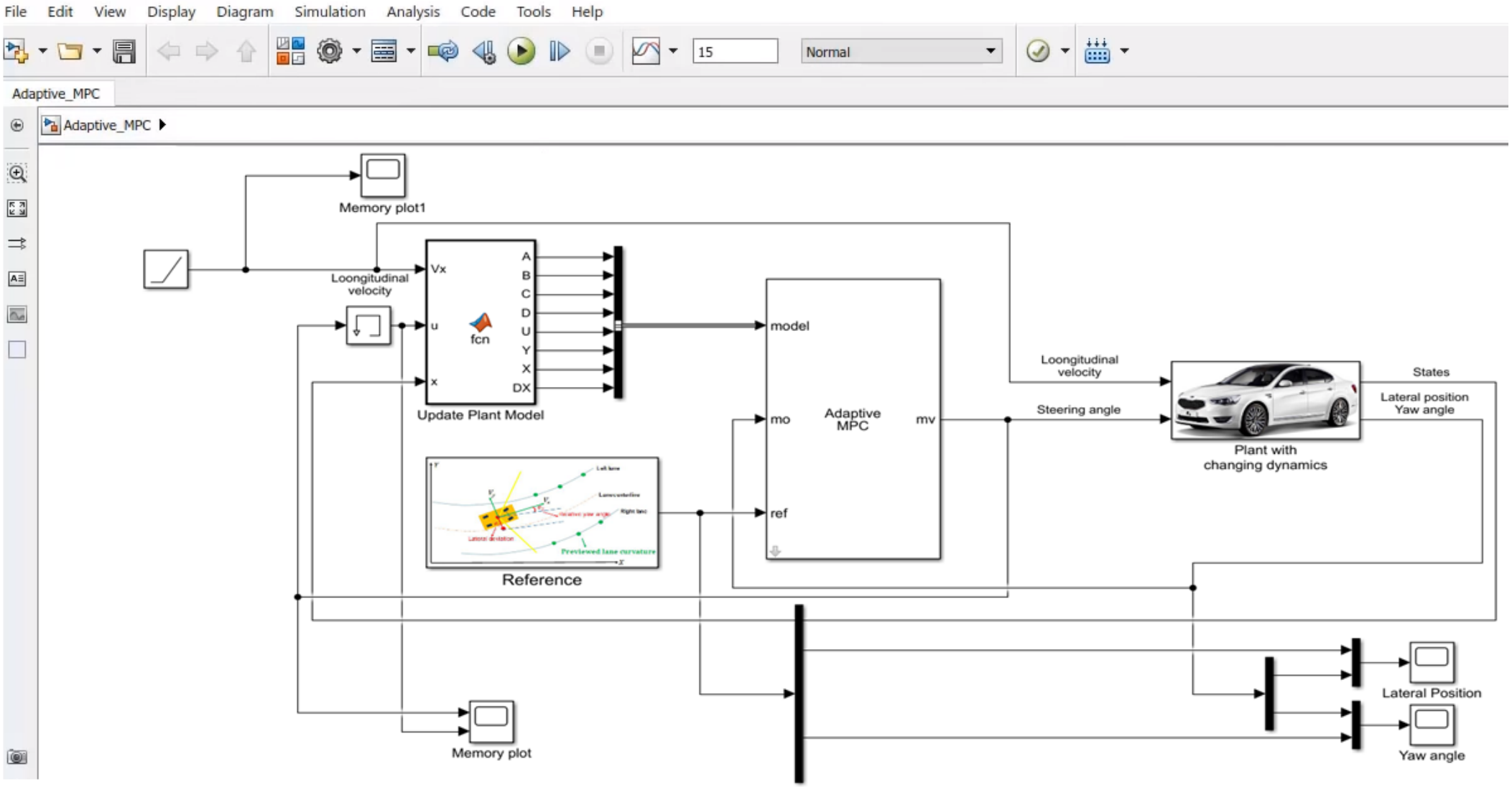

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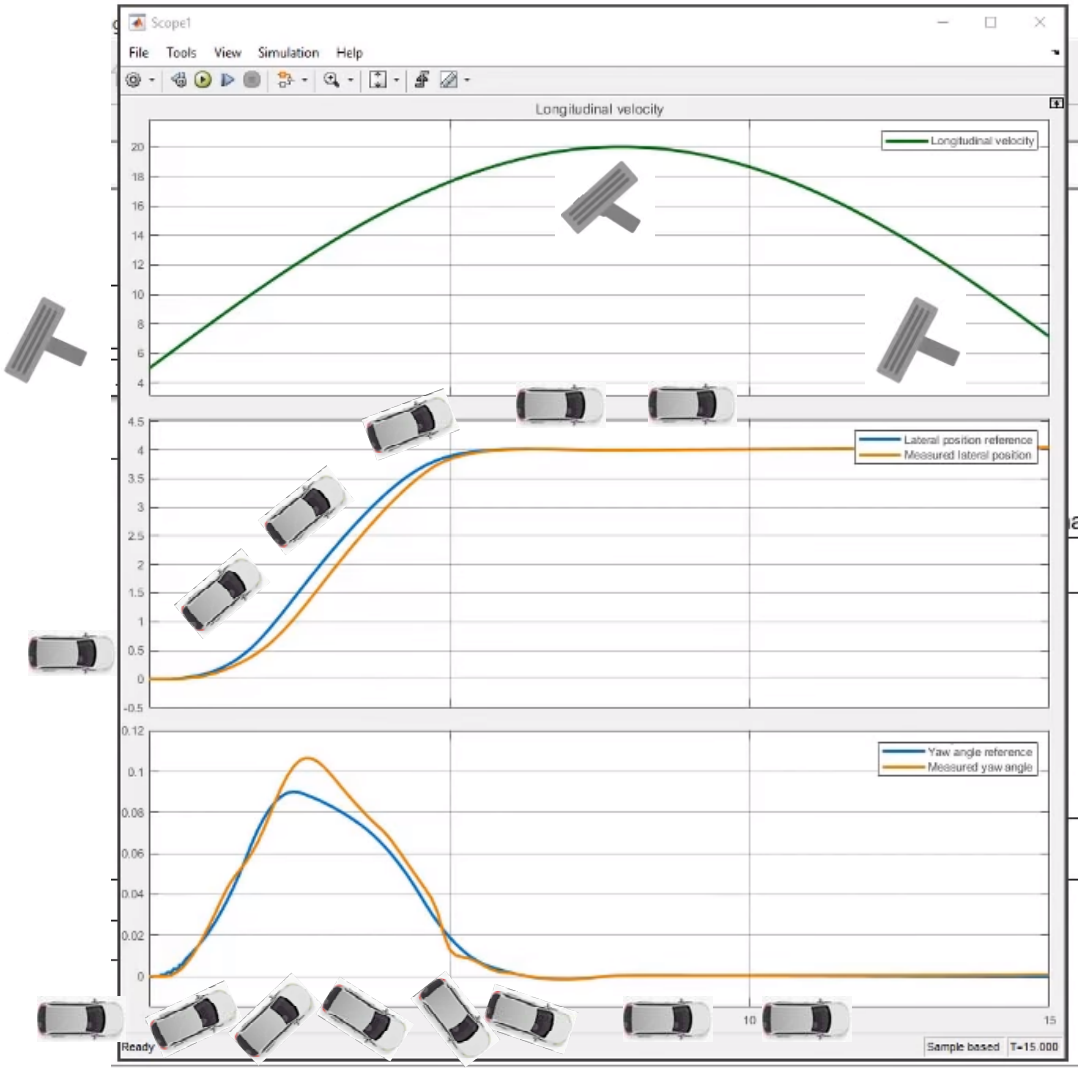

Longitudinal Velocity

Lateral Position

Yaw Angle

4. Adaptive MPC Design with Simulink