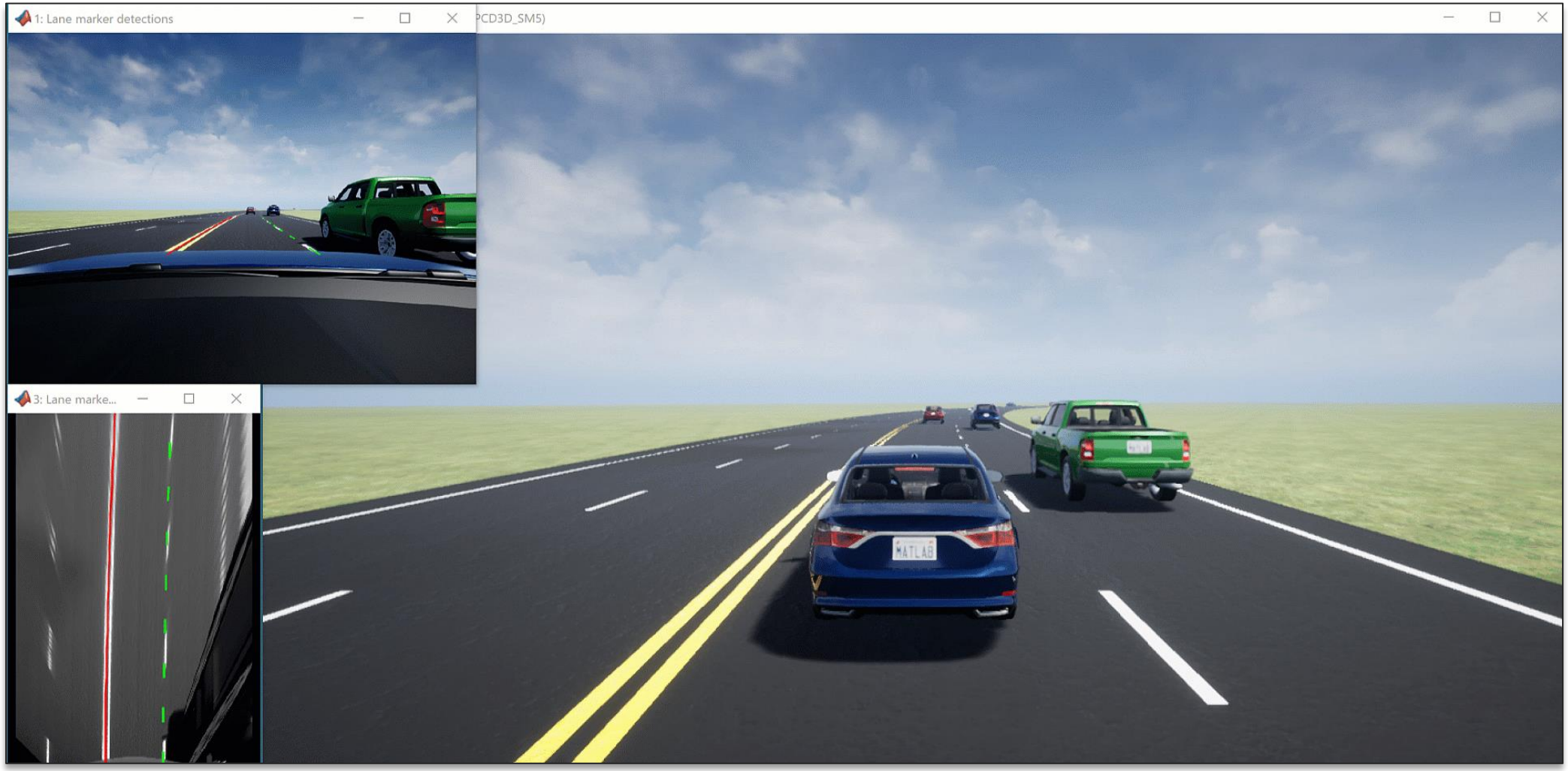
MATLAB EXPO

模型预测控制在自动驾驶中的应用

Wu Jing, MathWorks China

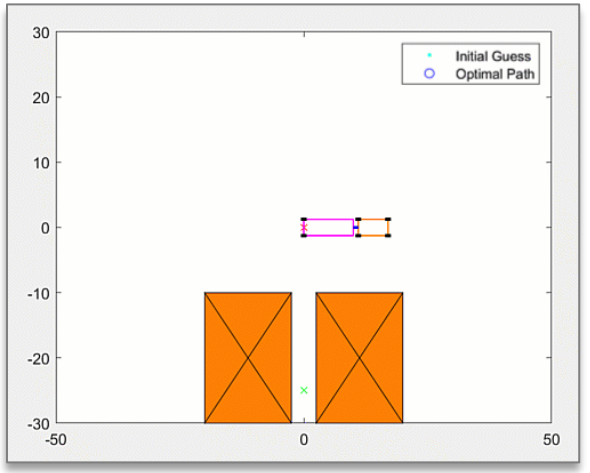
MathWorks®

模型预测控制 (MPC) 广泛应用于自动驾驶算法的开发

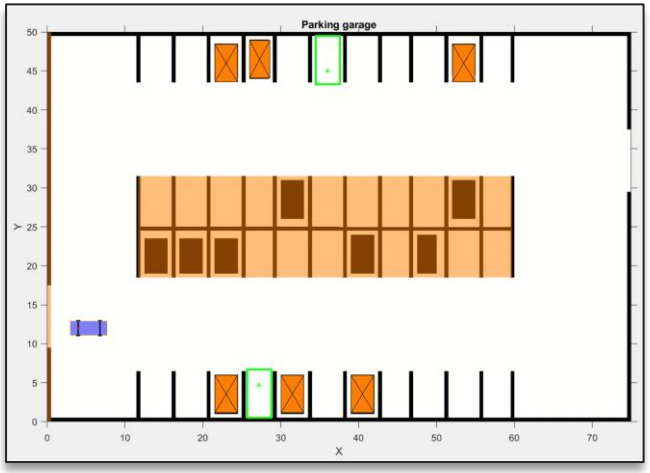


模型预测控制 (MPC) 广泛应用于自动驾驶算法的开发

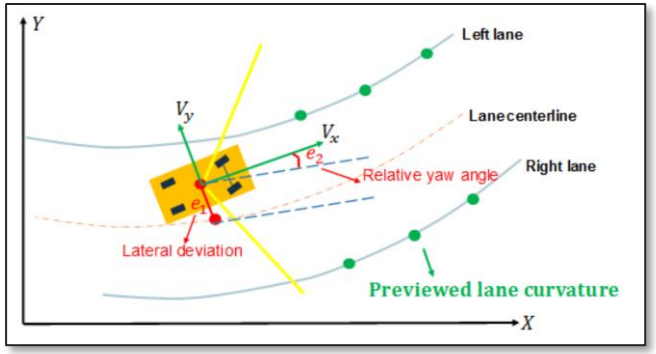
Lane following control



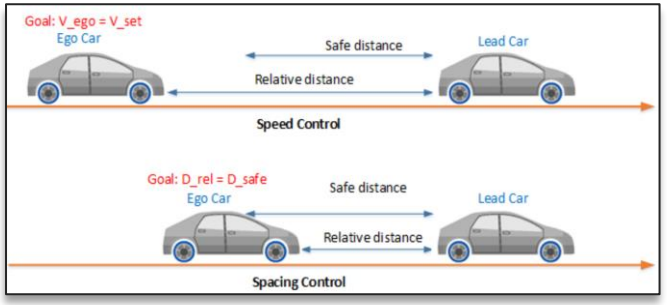
Truck and trailer automated parking



Parking valet



Lane keeping assist



Adaptive cruise control

日程

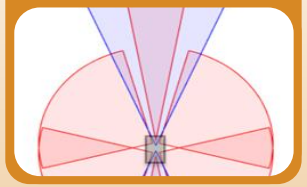
- 使用MATLAB开发ADAS应用的MPC解决方案
- MPC 基础
- Demo
  - 自动驾驶转向系统线性MPC和自适应MPC控制器的设计
- 更多信息

使用MATLAB工具链开发自动驾驶应用

Virtual Worlds

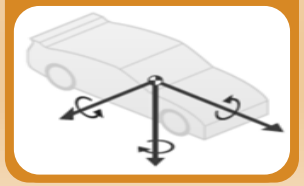
Scenes

Sensors



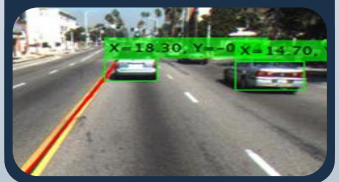
Scenarios

Dynamics

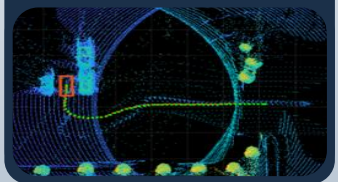


Multidisciplinary Skills

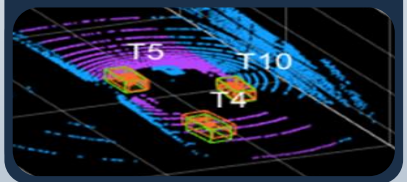
Detection



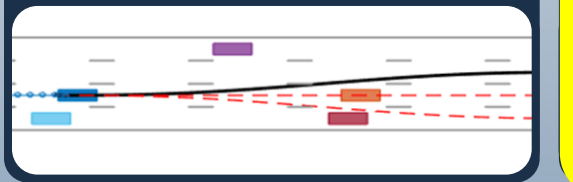
Localization



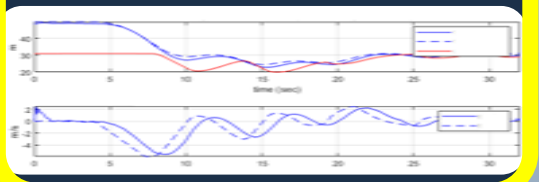
Tracking



Planning



Decision & Controls



Software

Code

C/C++
GPU HDL

Architectures

AUTOSAR
ROS DDS

RoadRunner
product family

MATLAB & Simulink
product family

Polyspace
product family

为什么使用MATLAB工具链进行MPC的设计及实现?

Reference examples

Adaptive cruise control
Path following control
Lane keeping assist
Lane change
Automated Parking

…and more…

Pre-built ADAS blocks

Code generation support

ISO 26262 and MISRA-C compliant

Simulink blocks: Adaptive Cruise Control System, Lane Keeping Assist System, Path Following Control System

Different types of MPCs

Linear (implicit) MPC

Implicit, explicit, adaptive, LTV, gain-scheduled, discrete control set MPC

Nonlinear MPC

Single and multi-stage formulation

Optimization solvers

Built-in deployable solvers

Custom/3rd party solver support

Integration with FORCES PRO
Support for custom QP and NLP solvers

MPC Designer App

Interactive design of linear (implicit) MPCs

Automatic code generation

C/C++, CUDA code,
IEC 61131-3 structured text

MATLAB中模型预测控制的演变

2016 and before

Linear MPC

LTI MPC

Adaptive MPC

LTV MPC

Online constraints

Online weights

Simulink blocks

Code Generation

MATLAB Coder

Simulink Coder

Embedded Coder

App

MPC Designer

2017

Linear MPC

Run-time mixed I/O constraints

Code Generation

Suboptimal solution

Custom QP solver plug-in

2018

Linear MPC

Run-time time-varying weights

Nonlinear MPC

Generic Nonlinear MPC

ADAS Blocks

Adaptive Cruise Control

Lane Keeping Assistant

Code Generation

ACC block

LKA block

2019

Linear MPC

Run-time horizons

Nonlinear MPC

Simulate as Adaptive and LTV MPC

ADAS Blocks

Path Following Control

Code Generation

PFC block

2020

Linear MPC

Interior-Point QP Solver

Run-time time-varying constraints

Code Generation

Generic Nonlinear MPC

Plug in FORCESPRO QP solver

2021

Linear MPC

Run-time horizons

Support “quadprog”

Nonlinear MPC

Multi-stage nonlinear MPC

Hybrid MPC

Discrete Control Set MPC

Code Generation

Multi-stage nonlinear MPC

GPU Coder

ISO 26262 compliance

MISRA C compliance (22a)

Plug-in FORCESPRO NLP solver

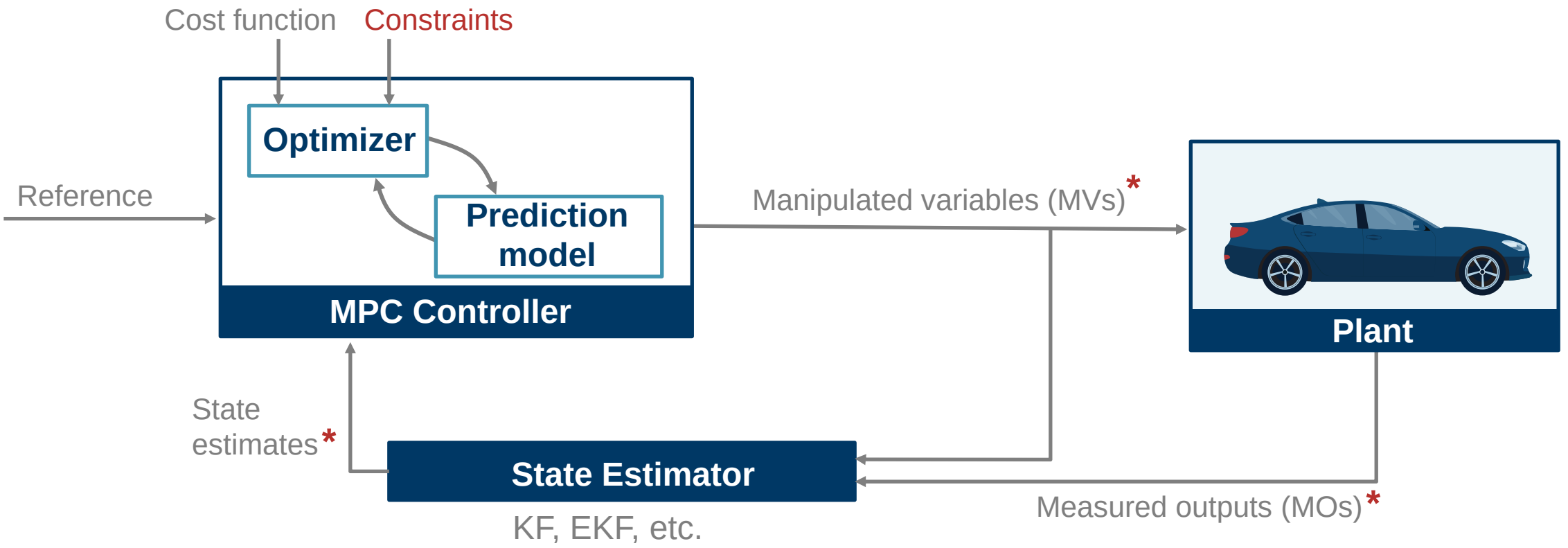
Numerous examples have been added to Model Predictive Control Toolbox in the past releases, especially in the Nonlinear MPC, ADAS and Code Generation areas.

日程

- 使用MATLAB开发ADAS应用的MPC解决方案
- **MPC 基础**
- Demo
  - 自动驾驶转向系统线性MPC和自适应MPC控制器的设计
- 更多信息

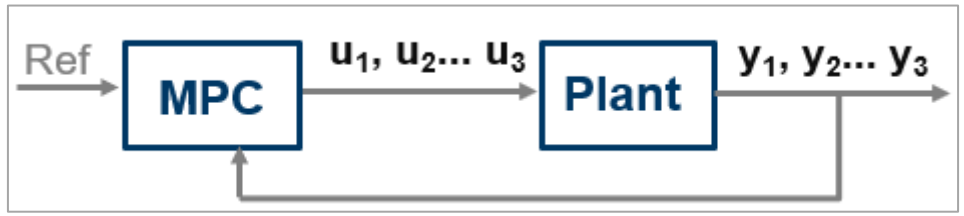
MPC 基础: 什么是MPC?

- MIMO 控制技术
- MPC 实时地解决带有约束的优化问题

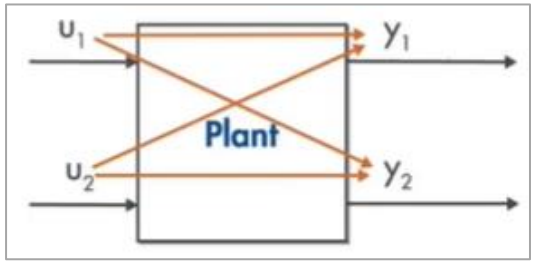


MPC 基础: 为什么用MPC?

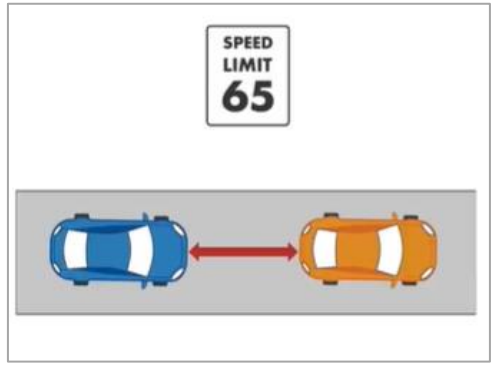
- MIMO 系统的控制



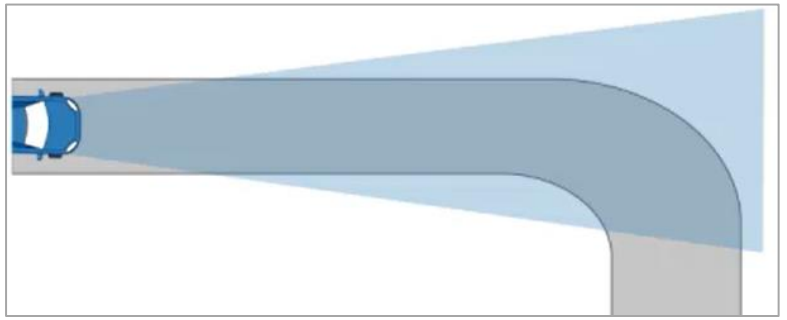
- 系统动态的耦合



- 约束

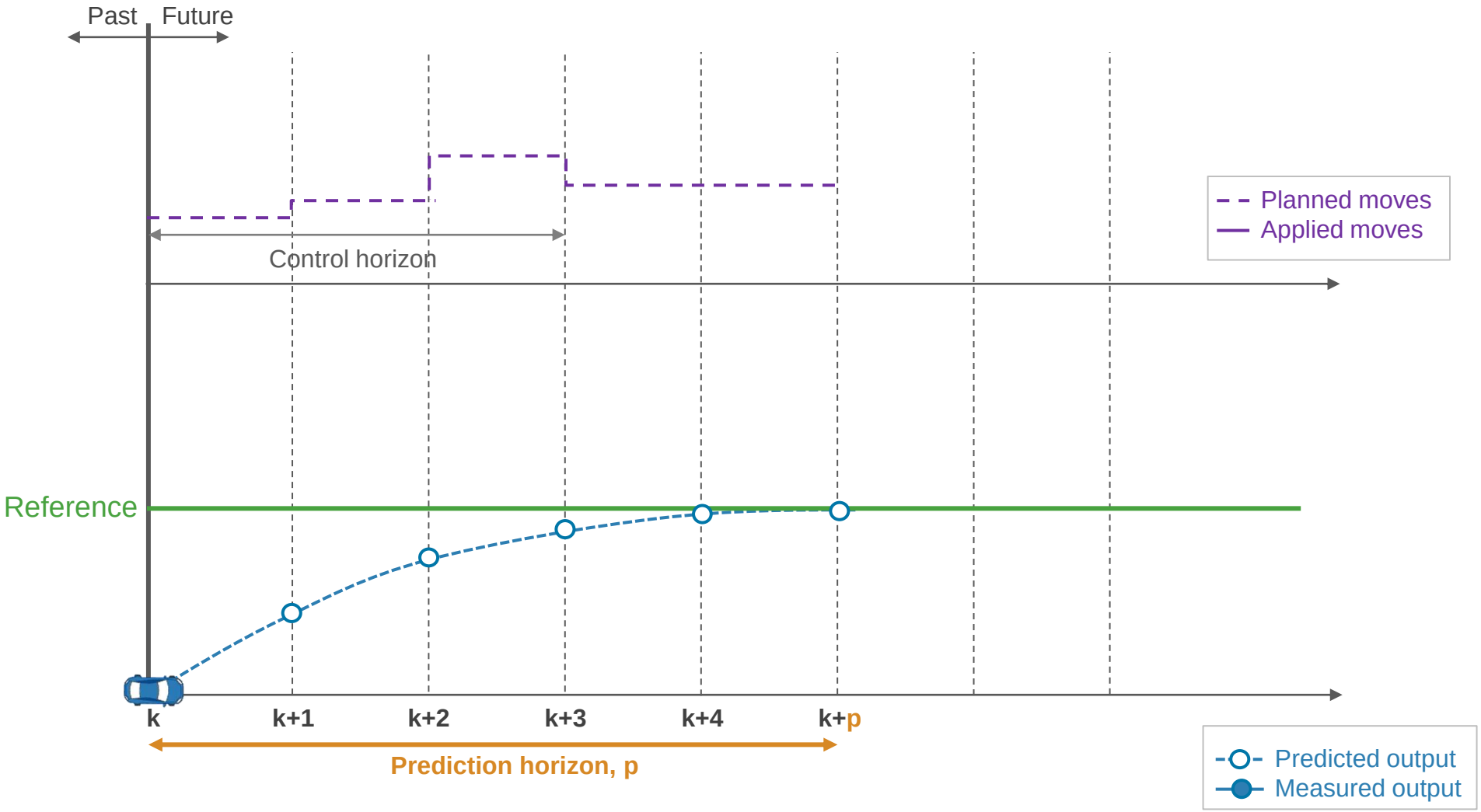


- 预览功能



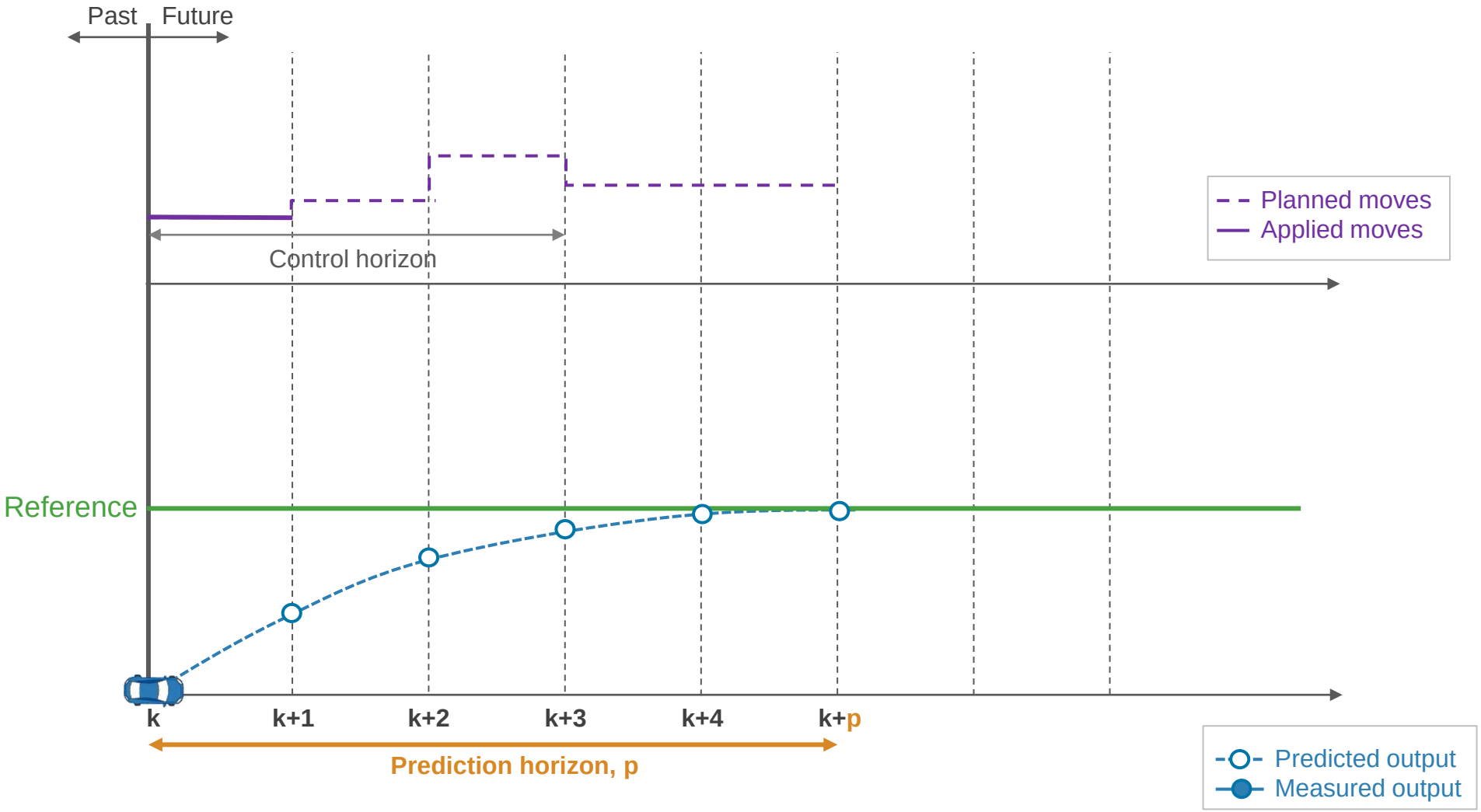
MPC 基础: MPC 如何工作?

- 在时间步K求解优化问题



MPC 基础: MPC 如何工作?

- 控制器采用第一个控制动作，并丢弃其余的部分



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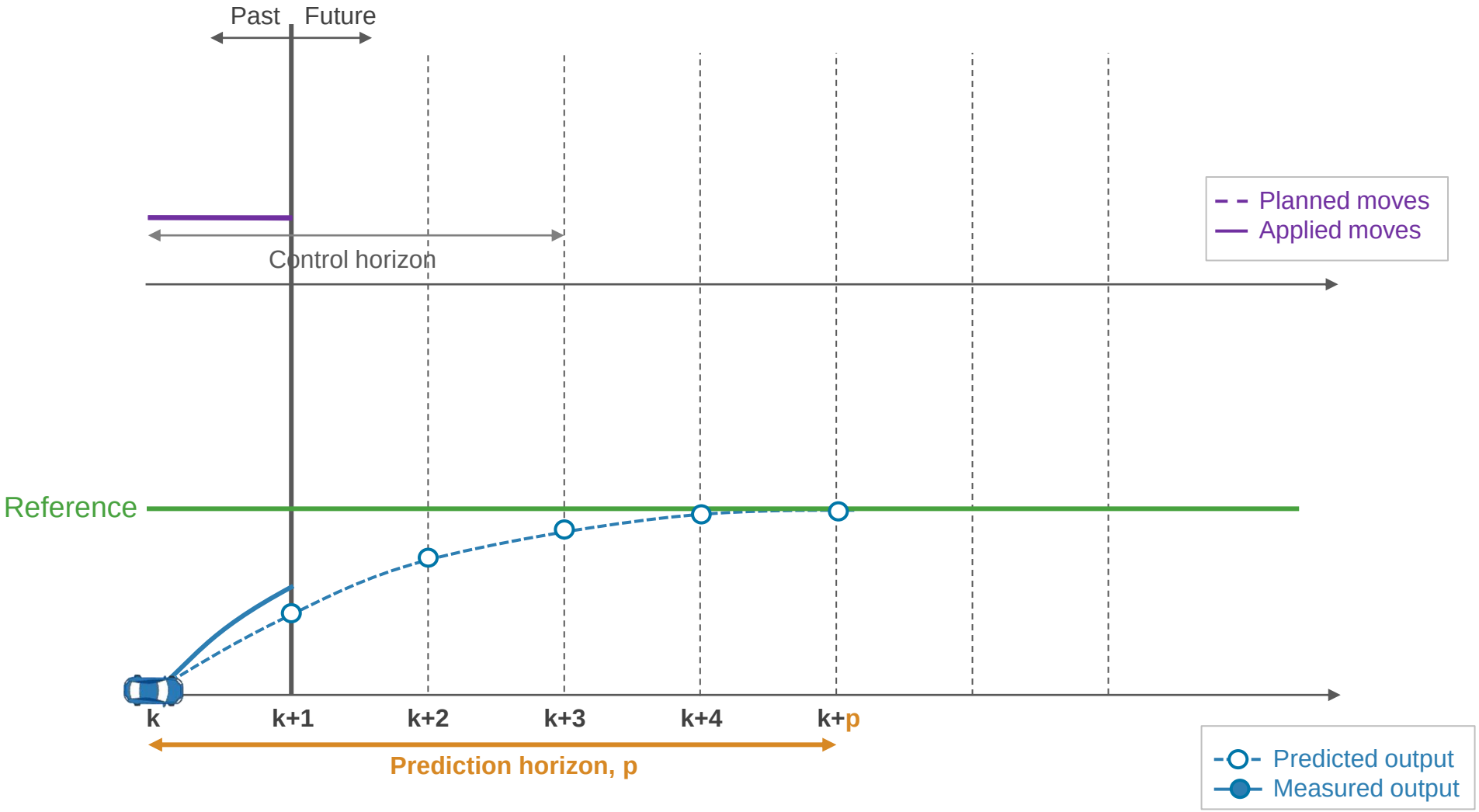
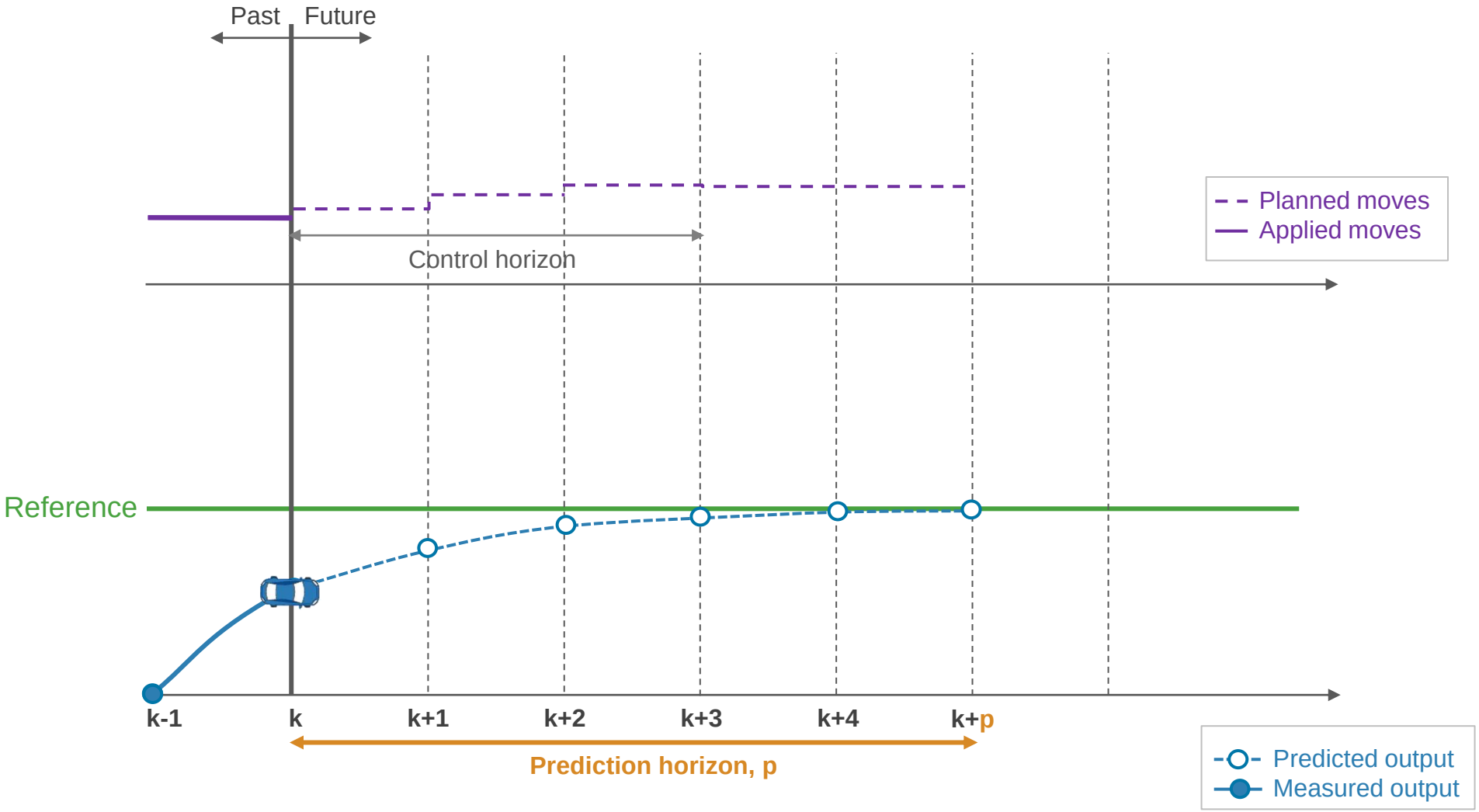


MPC 基础: MPC 如何工作?

- 移动预测时域，测量更新的输出，在第K步求解优化问题



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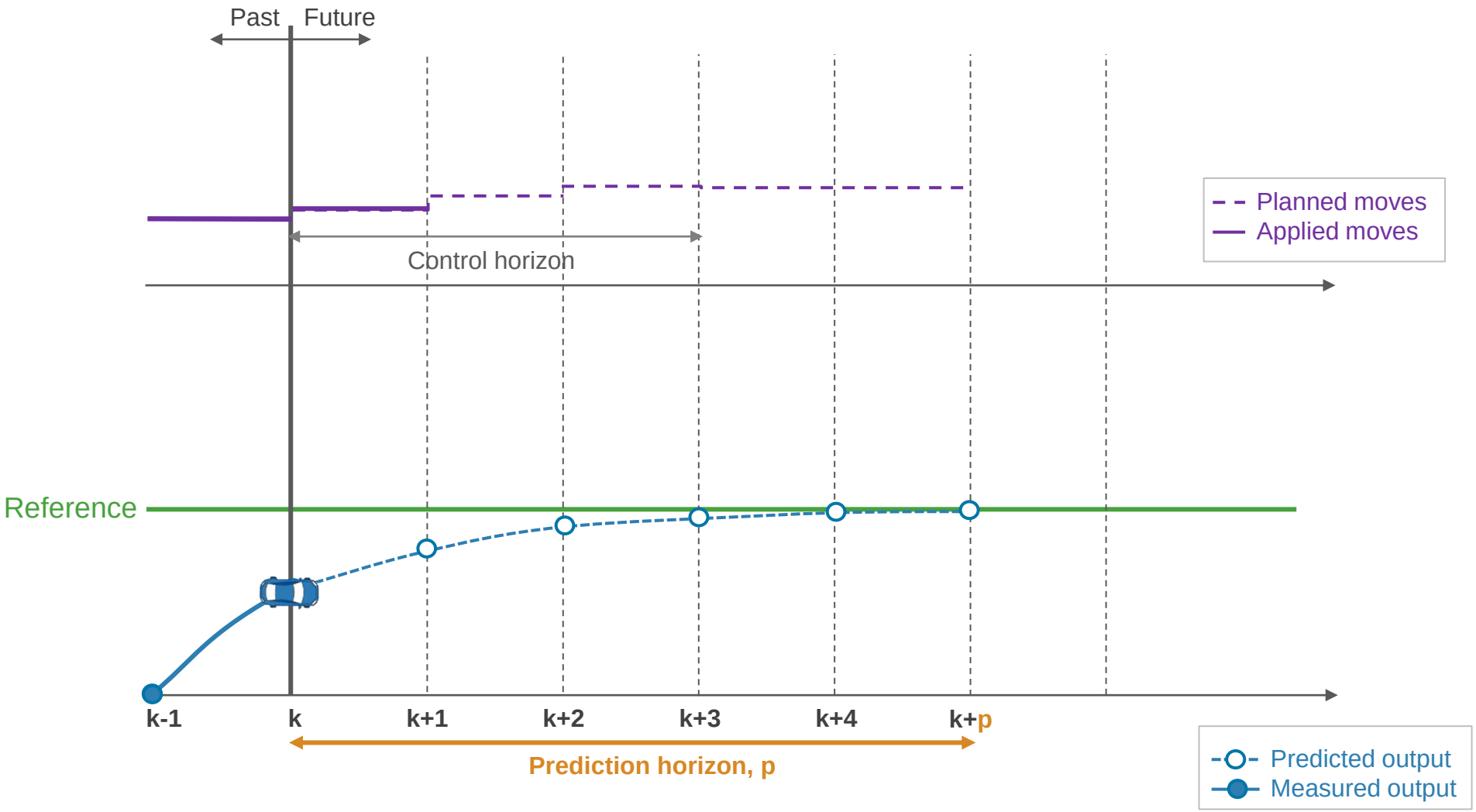

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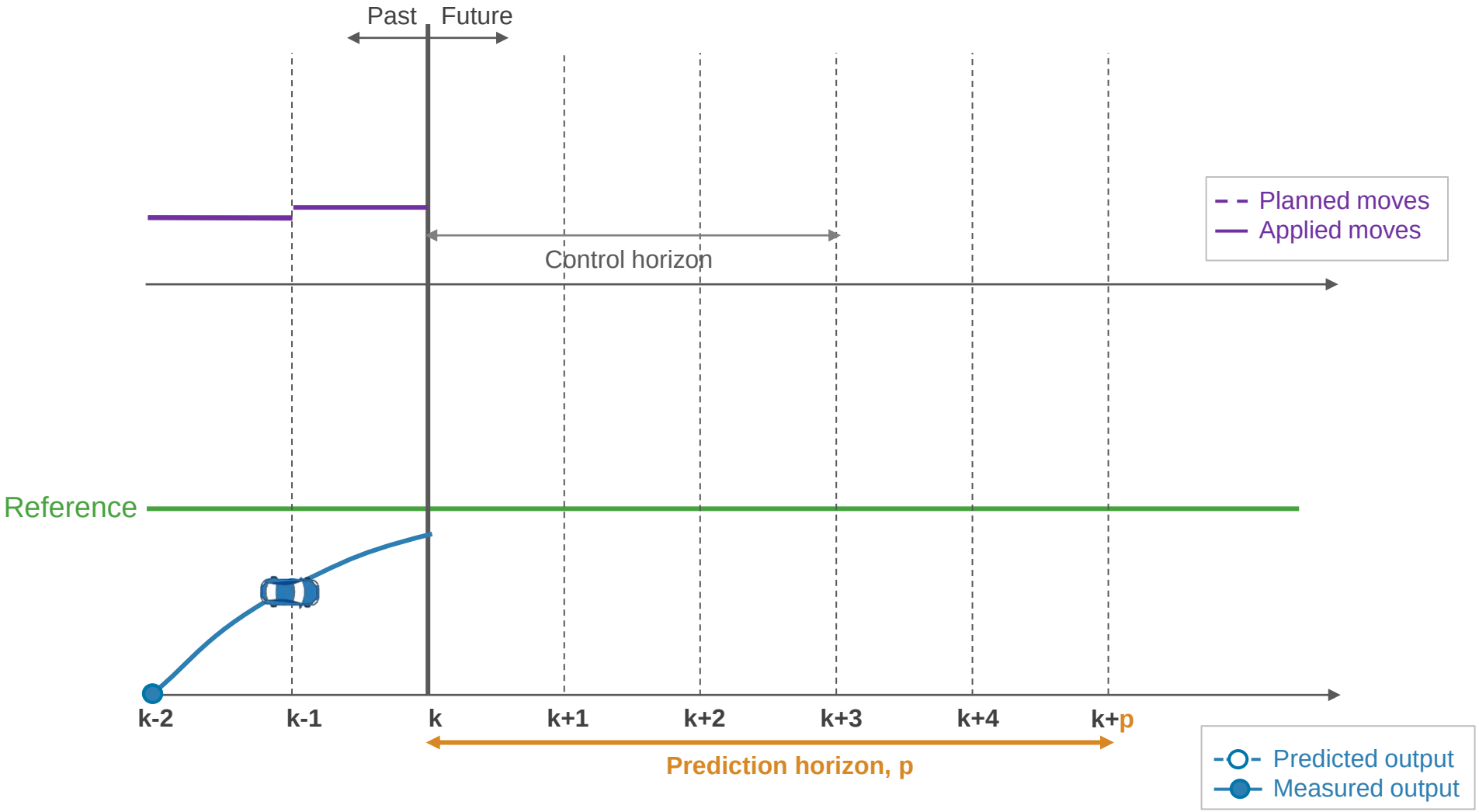
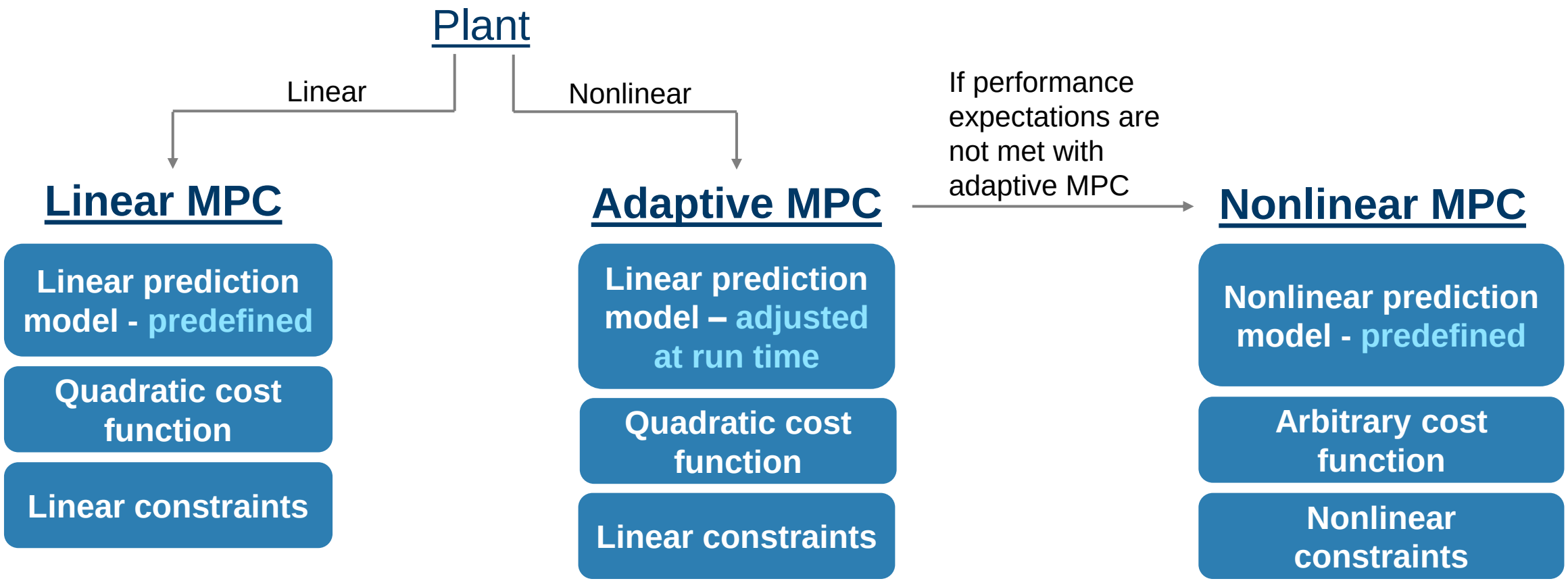


MPC 的类型及使用场景



日程

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- MPC 基础
- **Demo**
  - 自动驾驶转向系统线性MPC和自适应MPC控制器的设计
- 更多信息

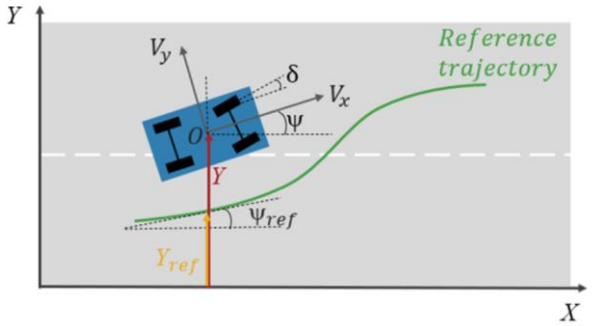
MPC实现工作流

MPC design in MATLAB and Simulink

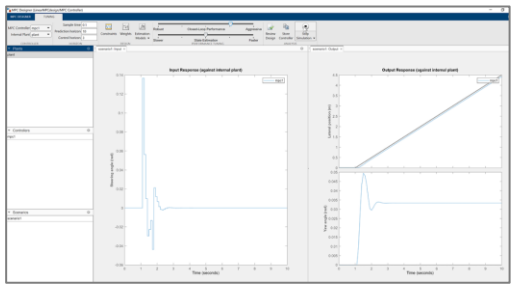
Closed-loop desktop simulation

Deployment to CPUs, GPUs

Demo: 为自动驾驶转向系统设计线性和自适应 MPC



Autonomous vehicle steering system



MPC Designer App

MPC Design → Closed-loop desktop simulation → Code generation and deployment

Linear MPC design using MPC Designer app:

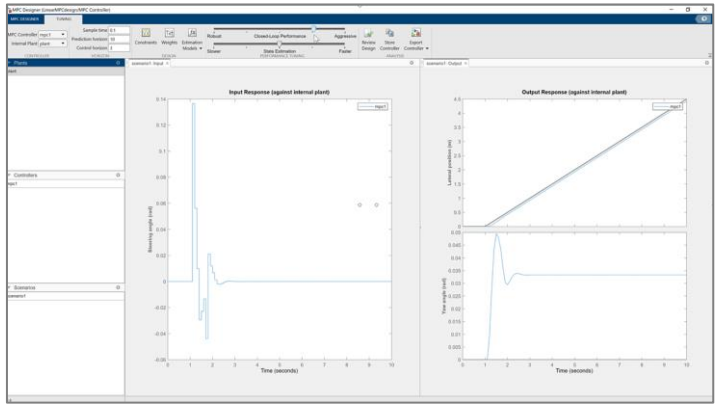
- Import LTI internal plant model
- Specify controller sample time
- Specify prediction & control horizon
- Specify constraints & weights & scale factors

Adaptive MPC design :

- Design linear mpc for the average operating conditions
- Update internal plant model and operating conditions

Demo 总结：为自动驾驶转向系统设计线性和自适应 MPC

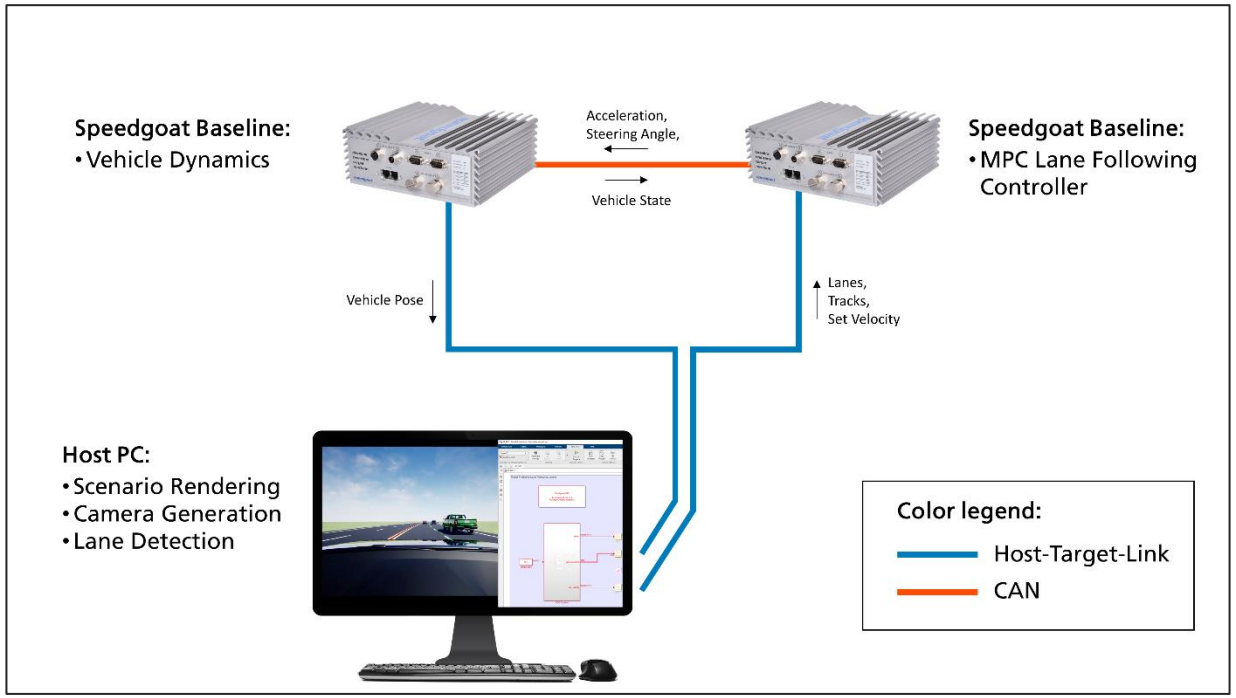
MPC Design → Closed-loop desktop simulation → Code generation and deployment



- 使用 **MPC Designer App**进行交互式线性MPC的设计
- 基于设计的线性MPC实现**Adaptive MPC**
- 使用设计好的MPC控制器进行**闭环桌面仿真**

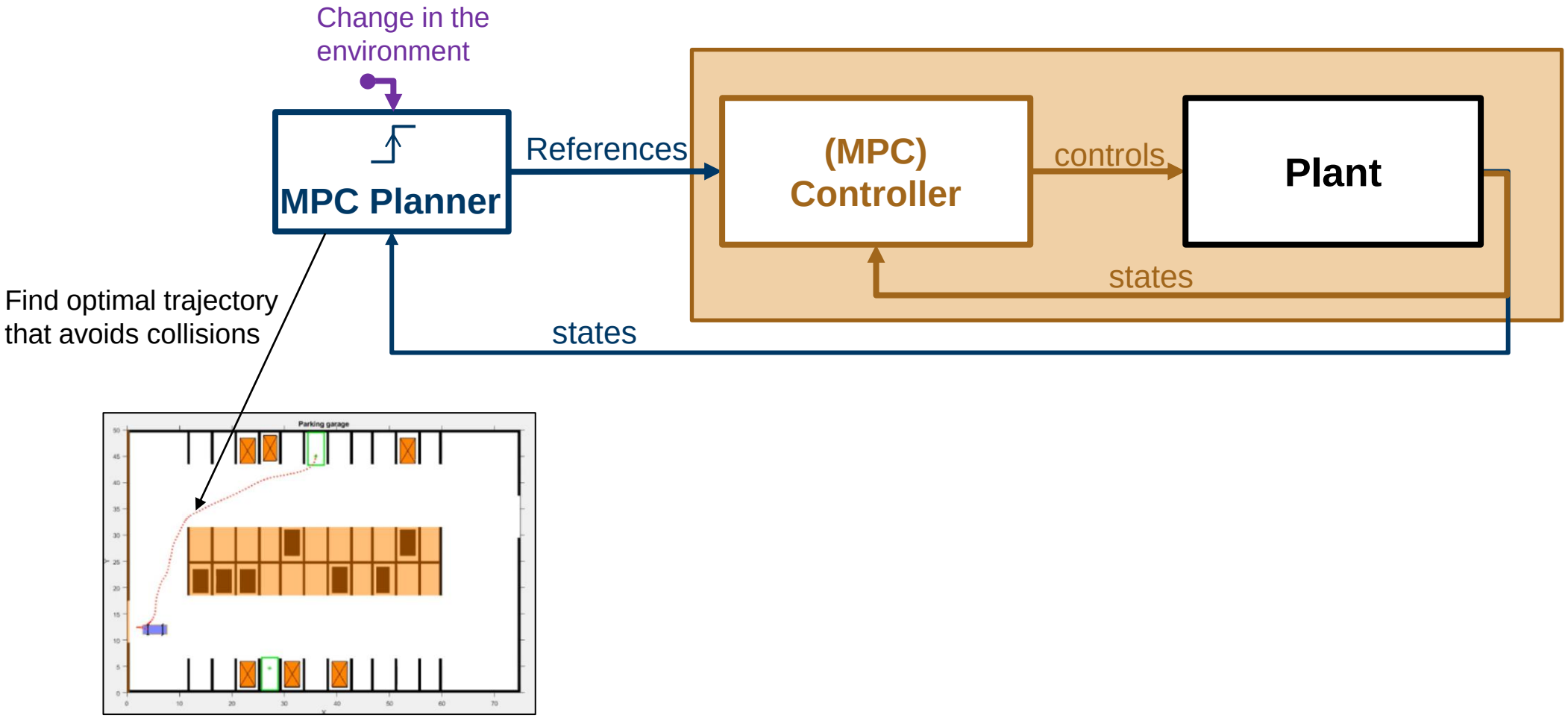
实时测试

Partitioning lane following control algorithm into multiple modules for real-time testing



Real-time testing with Speedgoat hardware and driving simulator

MPC：路径规划+轨迹跟踪



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日立汽车系统：使用MBD为自适应巡航控制开发MPC控制器

挑战

为走走停停的交通场景开发高性能自适应巡航控制系统

解决方案

使用 Simulink， 设计、仿真和调节模型预测控制器，并使用 Embedded Coder 生成高效代码

结果

- 控制器开发时间减半
- 免除了数月的手工编码时间
- 测试速度和效率提高

Testing the ACC algorithm using model predictive control on a public road.

"We were able to conduct multiple parameter studies via simulation in Simulink to tune our controller and reduce its computational load. Simulation gives us deep insight into the internal details of the design, which contributes to improved accuracy and time savings when adjustments are needed."

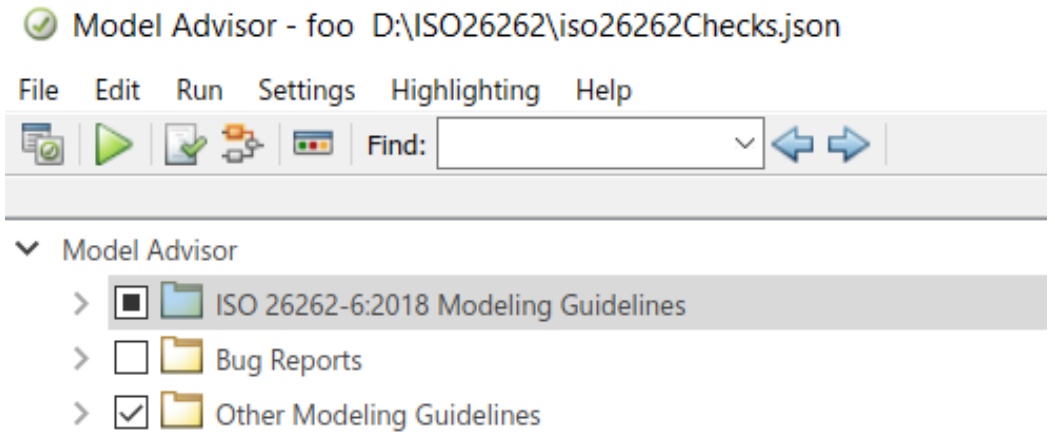
- Taku Takahama, Hitachi Automotive Systems

Link to user story

符合ISO 26262 和 MISRA C:2012

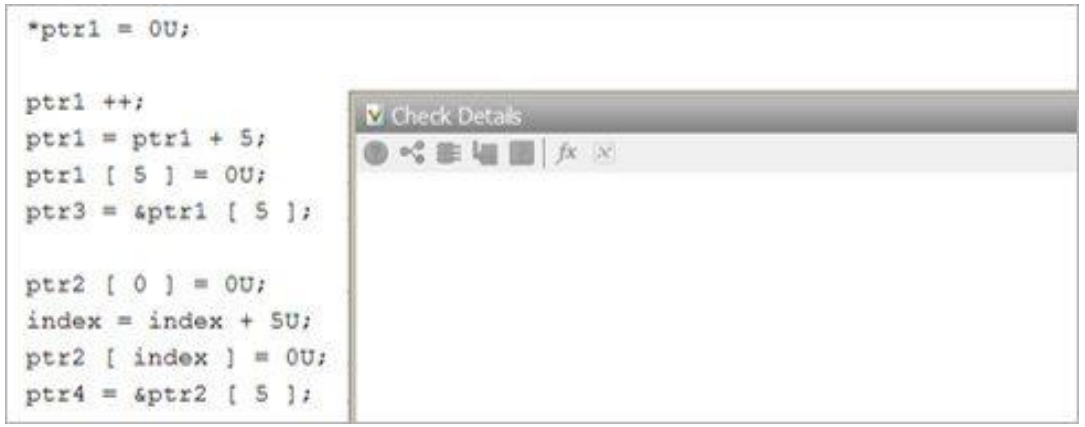
2022

Simulink中使用线性MPC以及ADAS模块做控制器时，符合ISO 26262 和 MISRA C:2012的标准



以下模块符合ISO 26262- 和 MISRA C:2012- 标准:

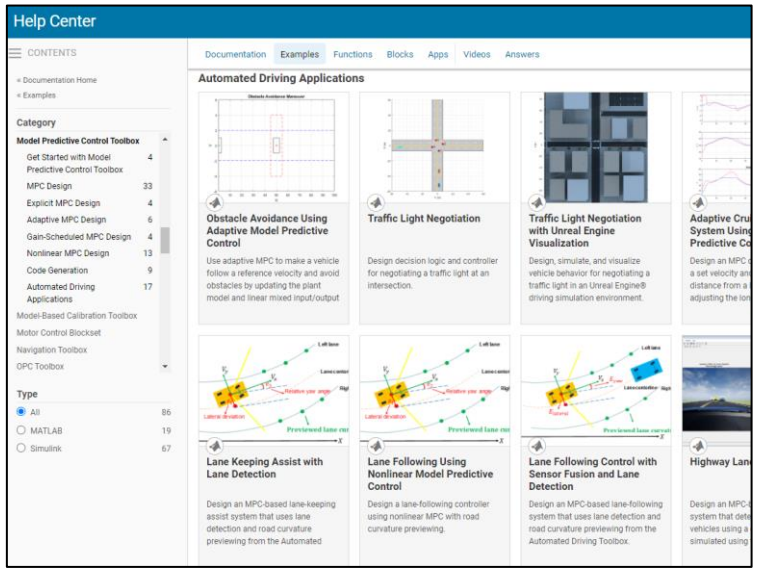
- MPC Controller
- Adaptive MPC Controller
- Explicit MPC
- Multiple MPC Controllers
- Adaptive Cruise Control System
- Lane Keeping Assist System
- Path Following Control System



关于MPC的更多信息

[Model Predictive Control Toolbox]

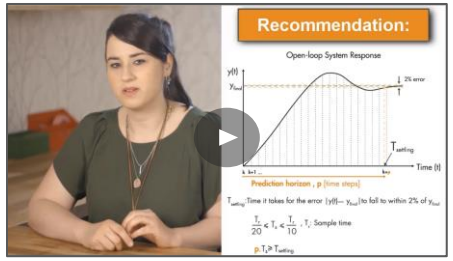
[Automated Driving with MATLAB, Simulink and Roadrunner]



[Automated Driving Reference Applications]

关于MPC的更多信息

Learn how to select MPC design parameters:

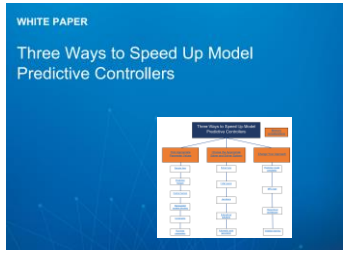


[MATLAB Tech Talk: MPC Design Parameters]

[How to Design MPCs]

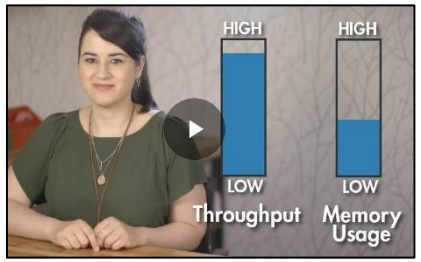
Dr. Alberto Bemporad
Co-author of Model Predictive Control Toolbox

Check out tips & tricks for implementing MPCs:



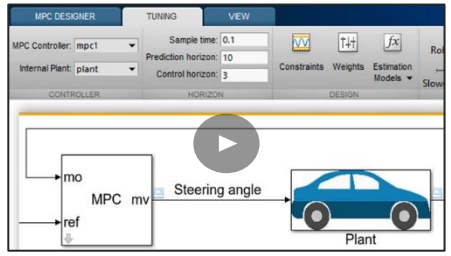
[Whitepaper: 3 Ways to Speed Up MPCs]

[How to Implement MPCs]

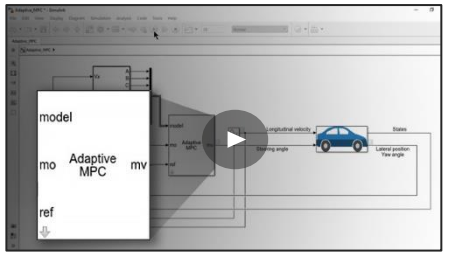


[MATLAB Tech Talk: How to Run MPC Faster?]

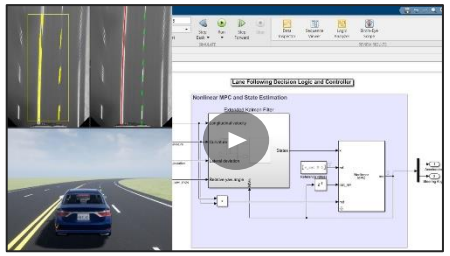
Learn how to design and implement linear, adaptive and nonlinear MPCs:



[MATLAB Tech Talk: How to Design Linear MPCs]



[MATLAB Tech Talk: How to Design an Adaptive MPC]



[MATLAB Tech Talk: How to Design a Nonlinear MPC for Lane Following]

MATLAB EXPO

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