Lecture 18 : MPC Variations : Code Generation, Robust, Stochastic

goals:

- Code gen techniques for MPC
- Robust + stochastic MPC

Fast MPC via Code Generation

- MPC : Repeatedly solve open-loop planning problem; often a convex problem

- general parser-solver (e.g. CVX, YALMIP) ok for prototyping, but can do much better using a custom solver in a low-level language (usually C) tailored to problem structure

- useful/necessary when
    - need to run many simulations for performance verification (Monte Carlo)
    - implementation on a real system (e.g. robot w/ low-cost, low-power embedded processor)

Options:

① manually write solver in C code

② use recent <u>code generation</u> techniques to automatically generate custom solvers!

- can exploit problem structure + hardware platform characteristics for speed + reliability

Ex CVXGEN by Mattingly + Boyd (~2012)

- used in SpaceX Falcon 9 landing system

Forces Pro by Embotech GMBH (~2012)

* both have academic licenses

- highlights of Mattingly's CVXGEN slides

<u>Summary</u>

- extremely fast + reliable custom solvers for convex optimization problems

- exploits repeated problem structure, hardware

- appropriate + necessary for extensive simulations, implementation on embedded systems

Robust + Stochastic MPC

- combination of robust/stochastic optimization with model predictive control

Lecture 10

- on research boundary, state-of-the-art (or beyond!) in many application areas

Ex minimize $\sum_{t=0}^{T_h-1} g_t(x_t, u_t) + g_{T_h}(x_{T_h})$

subject to $x_{t+1} = Ax_t + Bu_t + w_t \quad t=0,\dots,T_h-1$

$$\left.\begin{aligned} Fx_t &\le h \\ Gu_t &\le d \end{aligned}\right\} \quad \forall t=0,\dots,T_h, \quad \boxed{\forall w_t \in W}$$

with variables $u_0,\dots,u_{T_h-1}, x_1,\dots,x_{T_h}$

parameters $g_t, A, B, T_h, F, h, G, d, W$

uncertain variable $w_t \in W$

- if W is polytopic, can reformulate exactly using duality w/ linear constraints (see Lecture 10)
- repeatedly solve robust optimization problem
- same idea for different uncertainty sets, or for various types of stochastic constraints