Model Predictive Control of a Ballbot System

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Ballbot forms a spherical inverted pendulum with a car-like structure mounted on top that moves on a ball, see Fig.1. Its performance in cornering and turning is significantly better than conventional wheeled robots. Generally, a ballbot is an under-actuated system; thus, the robot has more degrees of freedom (DOF) than independent control inputs. Actuators directly drive the ball, and the body has no direct control. Therefore, balancing and transferring the ballbot is a challenging control problem.

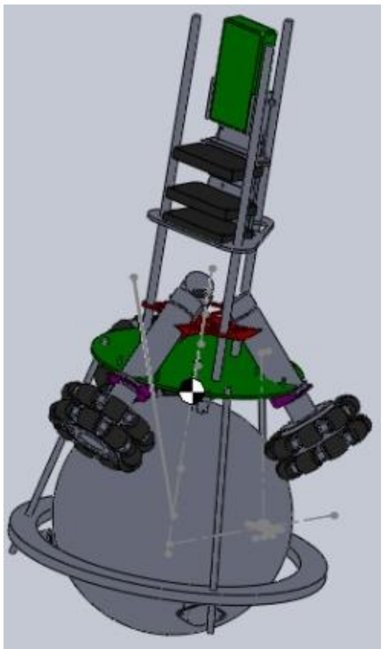

Fig. 1 A ballbot design using Solidworks.

Model predictive control (MPC) is a prime control approach for handling constrainted multivariable systems, its control design is carried out online by optimizing system performance based on predicting its future behaviour over a so-called *prediction horizon*. For practical implementation, MPC based on *linear parameter-varying* (LPV) models is considered for controlling nonlinear systems, where nonlinearities are embedded in a so-called *scheduling parameter* (p), which are employed online to compensate these nonlinearities.

In this project, MPC is considered for controlling a ballbot system in simulation. The main challenge is how to devolve a practical MPC algorithm in terms of online computational burden without sacrificing closed-loop performance. Therefore, LPV-MPC approach as shown in Fig. 2 will be investigated and compared with conventional and nonlinear MPC approaches.

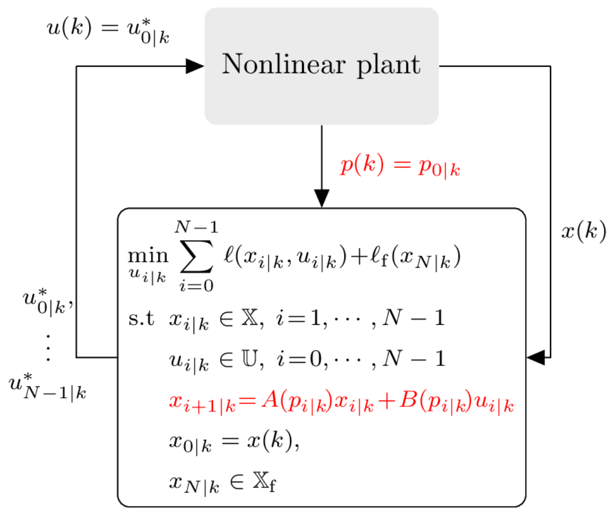

Fig. 2 Closed-loop block clock diagram, the lower block shows the online optimization problem of the LPVMPC approach. The LPV model is in red.

Project activities:

- Understanding the MPC/LPV fundamental concepts
- Understanding different modelling dynamics of the ballbot plant.
- Studying different possibilities of representing the nonlinear dynamics of the ballbot in LPV forms.
- Using quadratic programming (QP) tools to solve the LPVMPC optimization problem.
- Examining computational complexity aspects of implementing LPVMPC algorithms on the ballbot plant and compare with conventional and nonlinear MPC.
- Analysing the stability of the closed-loop system under the LPVMPC and the recursive feasibility of its optimization problem.
- Investigating the application of the LPVMPC onto the ballbot for stabilizing the robot and for motion planning.

<u>Prerequisites:</u> Basic course in automatic control and linear systems theory.