<u>MPC Based Minimization of Peak Base Torque For 2 Wheel Self-Balancing Mobile Manipulators</u>

2-wheel self-balancing robots are not passively stable, and their stability needs to be actively controlled. This necessity for active stability control is both a boon and a bane when it comes to mobile manipulation. Despite raising the complexity of control, active stability helps us make the platform more agile towards handling manipulation. A passively stable mobile platform mounted with a manipulator needs to find an ideal position to set up the base in, for the arm to perform the manipulation. This ideal position is not always available due to accessibility and obstacle constraints. Whereas, In the case of a self-balancing 2-wheel base, just like humans, the robot can adjust its pitch (or vertical incline) to provide leverage for the arm mounted on it, to complete the task. Simultaneously, this torque generated along the pitch of the robot needs to be minimized in order to not cause any failures in the robot's stability and balancing. In this paper we propose a Model Predictive Control based scheme that will compute the optimal control inputs to minimize the robot's peak base torque whilst avoiding obstacles and enforcing the motion plan for executing the task.

We will first develop the self-balancing double inverted pendulum mathematical model and then a path/motion controller is developed using NMPC. The conditions for optimality and the constraints are derived and incorporated into the algorithm to solve the problem. This will be compared to a standard (or other published) motion controller to demonstrate a general maneuver.

Step 1: Dynamics model of the robot

Step 2: NMPC formulation - Minimize deviation from equilibrium (deviation in pitch from central axis) and minimize the torque at base (not a direct input because it's a passive joint, so considered as a disturbance input).

Step 3: Model a nonlinear plant using a multibody dynamics software (ADAMS, MAPLESIM) for controller validation.

Step 4: Build a parameter-state estimation scheme to be fed into the controller.