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Energy Optimal Point-to-point Motion of A Badminton Robot Using Model Predictive Control

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1 Abstract

This presentation discusses energy optimal point-to-point motion using Model Predictive Control (MPC). MPC [1] is a model-based control approach that predicts the future behaviour of the system and the control signals over a prediction horizon are calculated by solving an optimization problem while taking into account system constraints. The considered system is the linear motor based first axis of FMTC's badminton robot. This robot has to perform energy optimal point-to-point motion and arrive at a given set point within a required time. Energy optimality is achieved by setting the object function of the MPC optimization problem equal to the system's energy losses. The key issue is to utilize the strategy of the prediction horizon to ensure that the motion time is exactly equal to the required motion time.

2 Problem Description

The badminton robot of FMTC shown in Figure 1 is a 3 degree of freedom robot equipped with a badminton rocket. The robot controller receives estimation of the interception position and time in real-time from a central computer. This presentation discusses the application of MPC to the first axis of the badminton robot, in order to arrive at the in real-time generated interception position and time in an energy optimal way. It is assumed that linear motor is a perfect velocity controlled system so that the system can be regarded as an integrator. The input and the output are the velocity and the position of the robot respectively. According to the limitations of the system, the considered limits on position, velocity and acceleration are: $\pm 5[m], \pm 3[m/s]$ and $\pm 30[m/s^2]$ respectively.

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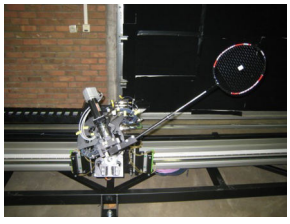

Figure 1: Badminton robot

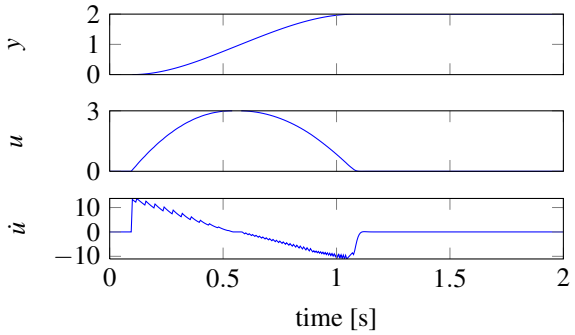

Figure 2: position (y), velocity (u) and acceleration ($\dot{u}$)

3 Energy Optimal MPC Approach

The developed energy optimal MPC approach is based on Time Optimal MPC [2]. Assuming that friction forces are negligible, the motion energy losses are copper losses in the motor and hence proportional to square of the motor current, which is taken as the object function of the MPC. An important constraint to consider in this optimal control problem is the given time of arrival at the interception position or the motion time T. If the system arrives at the interception point early, more energy is consumed, hence the solution won't be energy optimal. If the system arrives late, there's a chance the robot can't hit the shuttle.

4 Simulation results and conclusion

Figure 2 shows the simulation result for a motion of $2[m]$ and $T = 1[s]$, requested at time $0.1[s]$. The non-smooth acceleration is caused by the blocking [2]. The blocking is required to achieve prediction horizons that are sufficiently long to allow large displacements with a limited number of control variables.

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