Optimal Rendezvous Control
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Description:

Cooperative control deals with the problem of controlling two or more dynamically separated systems to work together to fulfill a common goal. The areas where multi-agent control has applications are many, and it is growing with increased availability of wireless sensor technologies. In this work, optimal rendezvous of two heterogeneous agents is considered. In particular, a system consisting of an Unmanned Aerial Vehicle (UAV) and an Unmanned Ground Vehicle (UGV) is considered. Examples of applications to such a system can be found in high altitude pseudo satellites, cooperative air/ground surveillance, and autonomous delivery of consumer products. The objective with this work is to look at how MPC can be used to improve the performance of a cooperative landing system.

Background & Motivation

This work is the continuation from results collected in a previous project on autonomous landings of high altitude solar panel powered UAVs. These UAVs offer the user a highly flexible system for deploying communication or surveillance networks. Because the UAV is very lightweight and might lack traditional landing gear, alternative methods for landing it are required. The project conducted at the German Aerospace Center DLR focused on proving feasibility of landing a UAV on a cooperating ground vehicle by demonstration. For lateral and longitudinal control, a PID controller was used, and for the vertical control a hybrid control structure was implemented based on the safety constraints of the system. Although it was shown that a fully autonomous landing was possible using this control strategy, several limitations with the setup were identified. In particular, the vertical controller was insufficient. Being practically open loop controlled at times, it failed to correct for position errors before initiating landing, resulting in failed landing attempts.

Research Goal & Questions

Previous work is extended based on the possible improvements that were identified from the resulting data. The goal is to make the control system good enough for use in practice. To this end, the overall control need to be improved for the landing to be faster and safer. In particular the vertical control needs to change. The way that this is done here is with the use of Model Predictive Control. A question that will need to be answered is what demands MPC puts on the communication and computation of the system. Another question is how to include the nonlinear constraints that depend on more than one agent into the optimization problem and still make it computationally efficient.

Methods & Preliminary Results

The objective is to make the agents rendezvous at some unknown point, while minimizing a cost function J subject to the system dynamics and the constraints posed by actuator limitations and safety requirements:

$$\begin{aligned} &\text{minimize} && J(x,u) \\ &\text{subject to} && \dot{x}_1 = f_1(x_1,u_1) \\ & && \dot{x}_2 = f_2(x_2,u_2) \\ & && g(x,u) \leq 0 \end{aligned}$$

This type of control problem is often solved using model predictive control, a control strategy which at every time step solves an optimization problem with respect to a control input vector u, and then applies only the first control input. The problem has been expressed in MATLAB using YALMIP for the optimization. Simple nonlinear models have been derived for the two system agents, and a more extensive model has been made in Simulink for the simulation. Preliminary tests have shown good results, although the optimization formulation still needs to be improved. The current setup uses a centralized controller, a more efficient solution might be to solve the problem distributed instead.

Roadmap & Milestones

The first step has been to pose the problem in the Model Predictive Control form. From here, it will be explored how the different constraints can be includes, and how solving the problem in different ways might affect the performance. Different types of distributed MPC algorithms will be implemented and tried out. If the simulations show good results, the controller will be implemented on a real system.

Figure 1. The setup of the landing scenario. The UAV approaches the UGV from behind, and the UGV starts accelerating to reach the same velocity as the UAV.