CONTROLLER SYNTHESIS VIA HUMAN GENERATED TRAJECTORIES

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ABSTRACT

As technology advances, the control systems that are used to drive devices are growing more and more complicated. In many situations the PID controllers of the past are replaced with complicated high-level controllers that allow systems to follow intricate trajectories. It is important to have methods for designing controllers that are able to perform these tasks safely.

Our research focuses on the task of safety controller synthesis, that is, designing a controller that will take the system from any point within a compact set of initial states to a point inside a set of acceptable goal states, while never entering any state that is deemed unsafe. To do this we introduce the control autobisimulation function, which is the analog of the control Lyapunov function for approximate bisimulation. We use this function to determine a set of admissible feedback control laws that guarantee trajectory robustness, a property that ensures that any trajectory of the closed-loop system that is initialized within some neighborhood of a nominal trajectory will stay within some tube of the nominal trajectory when given the same input. This feedback control and input can be used as the controller for some subset of the initial states. If we have a method of generating feasible trajectories, we can create a set of trajectories such that for any allowable initial state there is a trajectory whose feedback law and input will safely control the system to an allowable goal state.

As systems become more complicated, either by adding nonlinearities or becoming higher order, generating feasible trajectories becomes more difficult. Where a computer trying to find a solution using brute-force methods may fail, a human may be able to succeed using heuristics and high-level thinking. We solve this problem by having humans generate feasible trajectories via video game simulations to use in the controller synthesis process. This provides a method of generating safe controllers in situations where classical controller synthesis techniques may fail to efficiently find a solution. Our research applies this to linear affine systems, input-output linearizable systems, and differentially flat systems, and examines techniques for dealing with input bounds.

We then develop an optimal control method based on iterative local optimization of the trajectories with respect to a known cost function. We use this method as a means for both improving the feasible trajectories that compose the controller and generating new feasible trajectories from nearby trajectories to cover the set of initial states. This

could easily be extended to inverse optimal control, which aims to define an underlying cost function that describes a set of initial conditions. In this case the cost function can be used to automate the process of trajectory generation in designing a controller.