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Multi-Objective Optimal Design of a Cascade Control System for a Class of Underactuated Mechanical Systems

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Abstract : This paper presents a multi-objective optimal design of a cascade control system for an underactuated mechanical system. Cascade control structures usually include two control algorithms (inner and outer). To design such a control system properly, the following conflicting objectives should be considered at the same time: 1) the inner closed-loop control must be faster than the outer one, 2) the inner loop should fast reject any disturbance and prevent it from propagating to the outer loop, 3) the controlled system should be insensitive to measurement noise, and 4) the controlled system should be driven by optimal energy. Such a control problem can be formulated as a multi-objective optimization problem such that the optimal trade-offs among these design goals are found. To authors best knowledge, such a problem has not been studied in multi-objective settings so far. In this work, an underactuated mechanical system consisting of a rotary servo motor and a ball and beam is used for the computer simulations, the setup parameters of the inner and outer control systems are tuned by NSGA-II (Non-dominated Sorting Genetic Algorithm), and the dominancy concept is used to find the optimal design points. The solution of this problem is not a single optimal cascade control, but rather a set of optimal cascade controllers (called Pareto set) which represent the optimal trade-offs among the selected design criteria. The function evaluation of the Pareto set is called the Pareto front. The solution set is introduced to the decision-maker who can choose any point to implement. The simulation results in terms of Pareto front and time responses to external signals show the competing nature among the design objectives. The presented study may become the basis for multi-objective optimal design of multi-loop control systems.

Keywords : cascade control, multi-Loop control systems, multiobjective optimization, optimal control
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