

Title	拘束条件を有する制御系の解析および設計に関する研究
Author(s)	平田, 研二
Citation	
Issue Date	1999-03
Type	Thesis or Dissertation
Text version	author
URL	http://hdl.handle.net/10119/869
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Description	Supervisor: 藤田 政之, 情報科学研究科, 博士

Analysis and Design of Feedback Control Systems subject to State and Control Constraints

Kenji Hirata

School of Information Science,
Japan Advanced Institute of Science and Technology

February 15, 1999

Abstract

Recent development in the linear robust control theory provides many systematic control design procedures which solve stabilization, tracking, robustness, noise reduction problems. However none of these is able to cope with *constraints*. Nowadays one of the most important practical and theoretical open problem in control is the analysis and design of feedback controllers for systems with *state and control* constraints. Constraints on the inputs and often also on the state are present inherently in all real physical systems. The former are dictated by physical limitations of the actuators; the latter by the necessity to keep some plant variables within safe limits. If constraints are not properly accounted for in the design procedure, this would lead to serious *performance deterioration* and even *instability*.

This dissertation includes contributions on the analysis and design of control systems subject to pointwise-in-time state and control constraints. First, the necessary and sufficient condition for *safe operation* of constrained systems is derived. This result is obtained by constructing a certain subset in the state space such that avoiding constraint violation is equivalent to restricting the state dynamics to this subset. This fundamental result has important applications in the area of stability analysis and controller design.

Many control specifications, stability, performance, robustness, are required of control system design. This makes complicate or even impossible to design a single special feedback controller which satisfies required specifications as well as attempts to handle the effects caused by constraints. Therefore despite its importance in practice, various problems associated with control of constrained systems still remained unsolved. However in *constraint free* case, systematic techniques are available to solve design problem and provide efficient conventional feedback controllers. Even in *constrained* case, there is no necessity to replace a conventional techniques with completely new one which attempt to

satisfy many control specifications and also constraints handling at the same time. Alternatively, introducing a higher hierarchical level mechanism which utilizes conventional feedback controllers also attempts to handle constraints would have potential benefits.

Control system design techniques utilizing hierarchical structures are proposed. Switching control scheme which includes fixed structure controllers and a *supervisor*. Where supervisor selects the highest performance controller which is *safe* for the current state of the plant. Because supervisor avoids constraint violation, controlled system remains stable and controller switching improves control performance. The other method consists of adding to a primal closed-loop system a nonlinear device called *reference governor* which manipulates the *desired reference signal* in order to avoid constraint violation. This control scheme is proved to fulfill the constraints and tracking requirements. All resulting control systems has separation structure: first stabilize the system and improve performance by using the conventional feedback controller in the absence of constraints; then adding switching mechanism or reference governor those operate at a higher hierarchical level for constraints fulfillment.

Key Words: state and control constraints, switching control, reference governor, robust control, discrete-time systems