別紙様式８

研　究　主　論　文　抄　録

論文題目

Design of Observer-based Guaranteed Cost Controllers for Uncertain Systems

（不確かなシステムに対するオブザーバに基づくコスト保証制御器の設計）

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主論文要旨

《本文》

This thesis contributes to the design method of guaranteed cost controller with an observer for uncertain systems. The aim of the guaranteed cost control method is to achieve the stability of the closed-loop systems and guarantee an adequate level of their performance. In the practical use, it is difficult to measure all system states that are needed for controller design because of some reasons such as poor plant knowledge, costing problem, sensors availability, etc. We consider a full order and a minimal order observer to avoid these difficulties. The observers could be embedded in the control systems that do not have their available states from directly measurement. The problem scopes considered here to be solved include non-delay, time-delay and discrete-time multi-rate systems. An LMI approach is used to obtain the feasible solutions of the observer-based state feedback guaranteed cost controller. Because the problems contain some variables that must satisfy the inverse relations, this thesis adopts an iterative algorithm.

Firstly, this thesis deals with a minimal order observer-based guaranteed cost controller for uncertain systems. The uncertainties are assumed to be norm-bounded. The initial state is assumed unknown but their mean and covariance are assumed known. Further, an application to a 3-DOF nonlinear model helicopter is discussed. One of main difficulties in designing a feedback controller for the helicopter is that the model includes nonlinearities. To avoid the difficulty, these nonlinearities are considered as the uncertainty. By using Taylor's expansion, the state equation of a nonlinear 3-DOF model helicopter is changed to the form of a continuous-time uncertain system. The

robust controller design is achieved by guaranteed cost control method.

Secondly, the thesis conducts the uncertain systems with a full order observer. An output estimator and a minimal order observer construct the full order observer. In some results with a full order observer, an observer gain is restricted, but this thesis does not restrict it. We begin in designing a minimal order observer-based guaranteed cost controller and extend it to a full order observer-based one without any restriction.

Thirdly, we extend the problems of a minimal order observer-based guaranteed cost control design to the time-constant and time-varying delay systems. As comparison, a time-varying delay system with a full order observer is also explained and it is shown that in this situation, the observer gain without any restrictions is extremely large.

Most previous results on time-varying delay situation have a constraint in the derivative of time delay, i.e. less than one. It means that the method is suitable only for slow time-varying delay. In this thesis, we relax the constraint of a minimal order observer-based guaranteed cost control problem for uncertain time-varying delay systems such that it is allowed for either slow or fast time-varying delay situation.

The last discussion concerns on the discrete-time multi-rate systems. Multi-rate control systems are those that use more than one sampling rate. This situation seems to occur when it is impossible to sample all physical system variables at a single-rate. Although the single-rate control systems using the slowest sampling rate for the measurement sampling rate and the control update rate are often considered for simpler design, in many practical cases, the control input should be updated at a higher rate to achieve an improved performance. For example, in the chemical process of a continuous stirred tank reactor, the cooling water flow is updated at a faster rate by means of a pneumatic valve than the reactor temperature. Hence, the multi-rate controllers which enable to provide faster input moves based on less available outputs would give better performance than the single-rate controllers.

In this thesis, robust control design for multi-rate systems with uncertainties is considered by guaranteed cost control approach. The controller is based on a state-space model and the state variable is estimated by a minimal order multi-rate observer. The design problem is expressed by matrix inequalities and solved by an iterative algorithm of a linear matrix inequality technique.