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著者(和文)	定本知徳
Author(English)	Tomonori Sadamoto
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論 文 要 旨

THESIS SUMMARY

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学生氏名： Student's Name	定本 知徳	指導教員（主）： Academic Advisor(main)	井村 順一
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This thesis provides a line of work for development of control theory for large-scale network systems such as distributed parameter systems and electric power networks. An observer and a controller for such a large-scale network system are necessarily required to be low-dimensional compared with systems of interest and to guarantee an a priori performance of the whole network system. In Chapter 2, we propose a design method of low-dimensional linear functional observers to estimate a given set of states via observer reduction approach where a low-dimensional observer approximates a given original observer for systems of interest. We first clarify that we have to take into account not only an initial state estimation error but also external input signals. Furthermore, analyzing the approximation error arising from the above two error factors by means of model reduction techniques, we clarify the relation between the approximation error and the L2-performance of the estimation error. Moreover, we devise a systematic low-dimensional observer construction algorithm satisfying a prescribed L2-performance of the estimation error. This type of observer is useful for estimation of a limited number of states such as load power in a particular area of electric power network systems. However, for example in electric power network systems involving a number of consumers and various power plants, we are required to estimate the load power of overall power network systems (not in a particular area) with small computational costs. In view of this, in Chapter 3, we propose a novel type of low-dimensional observers called average state observer. The observer estimates averaged states, which represents average behavior of systems from a macroscopic point of view, instead of estimating all of system states. However, it is nontrivial to find a set of states capturing average behavior in general. To overcome this difficulty, we utilize the concept of clustered model reduction. Furthermore, deriving a tractable representation of the error system, we provide a design procedure for average state observers with systematic determination of a set of states capturing average behavior of systems. Moreover, we show a theoretical estimation error bound in terms of the L2-norm. In Chapter 4, we propose hierarchical distributed control where the control system consists of several layers in which subsystems and hierarchically clustered subsystems are controlled by distributed controllers. The proposed method has advantages that distributed controllers can be designed individually without taking into account other controllers and the overall network system, and moreover, an L2-performance of the closed-loop system improves as improving a performance of distributed controllers that stabilize disjoint subsystems individually. Towards systematic design, we utilize state-space expansion that enables us to deal with the state variables associated with disjoint subsystems and those associated with interference among hierarchically clustered subsystems in a tractable manner. Moreover, by the integration of a hierarchical distributed observer having good compatibility with the structured controller, we build a framework to implement an observer-based hierarchical distributed control. The designed hierarchical distributed (observer-based) controller in each layer necessarily has the same dimension as that of the system to be controlled. Thus, the designed hierarchical distributed controller does not fully comply with practical application for large-scale systems from a viewpoint of computational costs for implementation. In Chapter 5, we propose a design method of low-dimensional hierarchical distributed controllers for large-scale network systems via a controller reduction approach. Supposing that a hierarchical distributed controller is given by the method in the previous chapter, we find a low-dimensional hierarchical distributed controller approximating the original one for any sets of locally stabilizing controllers. Since the existing controller reduction techniques cannot explicitly take into account the interconnection structure among controllers, this controller reduction problem cannot be solved by the straightforward use of those techniques. Thus, we explicitly utilize the hierarchical distributed structure of the closed-loop system. More specifically, taking into account the inherent hierarchy of information transmission which can be represented as the block-triangular structure of a coordinate transformed closed-loop system, we show that the approximation error of compositional units in upper layers does not affect those in lower layers. Furthermore, we clarify the relation between the approximation error and the performance degradation of the closed-loop system. In Chapter 6, as a first step towards low-dimensional observers/controllers design for nonlinear large-scale network systems, we show the importance and necessity of nonlinear low-dimensional modelling through an example of a real industrial application. More specifically, we first construct a nonlinear thermal-diffusion network model of the plasticization cylinder, which is an important component in plasticization process, while taking into account the temperature-dependent properties of heaters (which makes the model nonlinear). Next, we reduce the dimension of nonlinear network systems by explicit use of the particular structure of the nonlinear network system arising from radiation to the air of heaters. Finally, in Chapter 7, we provide concluding remarks and discuss on future works of this thesis.