Identification and distributed control of large scale systems

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1 Introduction

The control of spatially distributed interconnected systems is of great interest in practical applications such as flexible structures, wind farms, biochemical reactions, etc.. The biggest challenge in distributed control of spatially interconnected systems is the complexity of the control algorithms. The system matrix that describes the input-state-output behavior of N interconnected subsystems, with subsystems of order n, will be of size $nN \times nN$ matrix. Therefore conventional solution algorithms will require $O(n^3N^3)$ floating point operations (flops), which makes traditional controller synthesis expensive for fine discretization or large number of distributed subsystems. To surmount this obstacle, a lot of research has been done during the past decade. Sequentially Semi-Separable(SSS) matrix provide an effective approach and this structured space matrix allows for decoupling of distributed controllers, thus distributed controllers can be designed separately. In [1], some efficient algorithms have been developed to do controller synthesis of 1-D system in $O(n^3N)$ flops, which is a linear computational complexity. To extend this to multi-dimensional systems, our research focuses on designing a fast solver for multi-level SSS matrices of linear computational complexity for 2-D systems, which is a big challenge for controller synthesis that requires advanced concepts form numerical linear algebra. This fast solver for multi-level SSS matrices can be applied for identification and distributed control of wind farm.

2 Distributed Control of Large-Scale Systems

In [1], some efficient algorithms for SSS matrix operation of linear computational complexity are designed for distributed control of 1-D systems as shown in Figure 1. To extend his research, we consider the 2-D spatially distributed interconnected subsystems, which are shown in Figure 2. By utilizing methods described in [1], we can first assemble the 1-D string system $\overline{\Sigma_s}$ to a state-space model. The matrices of $\overline{\Sigma_s}$ all have an SSS matrix structure. Then the 2-D distributed system is equivalent to another 1-D distributed system, with subsystems $\overline{\Sigma_s}$. Therefore, the matrices of the state-space model all have a multi-level SSS matrix structure, that is, generators of this type of matrix have an SSS matrix structure. These matrices are of size $nMN \times nMN$, where M and N are the number of subsystems along the vertical and horizon direction, respectively. The structured matrix approach of distributed control has the property that the distributed controller is decoupled and can therefore be designed separately, which leads to a flexible controller configuration.

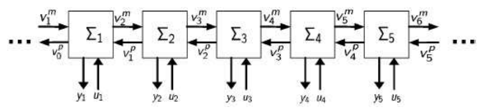

Figure 1: 1-D spatially distributed interconnected system structure

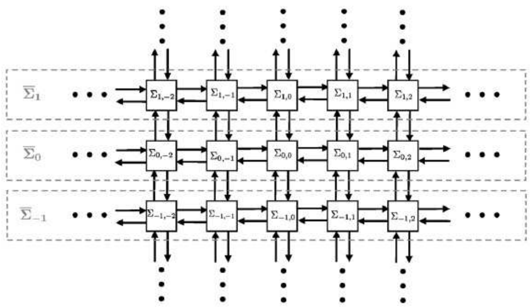

Figure 2: 2-D spatially distributed interconnected system structure

3 Expectation

Ordinary matrix operations have computational complexity of $O\big((nMN)^3\big)$, which is prohibitive for controller synthesis. The goal of this research is to develop a fast solver for multi-level SSS matrices that has linear computational complexity, and to apply this fast solver to the distributed control of wind farms with the same structure as the 2-D system shown in Figure 2.

References

[1] J. K. Rice. *Efficient Algorithms for Distributed Control: A Structured Matrix Approach*. PhD thesis, Delft University of Technology, 2010.