Identification and distributed control of large scale systems : an application to wind farm

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ABSTRACT

With the increasing capacity of wind farms, distributed control and optimization is of great importance for their cost-efficient operation. However, interconnections between wind turbines caused by aerodynamics are very complex and pose big challenges to wind farm operation and optimization. Therefore, efficient algorithms for identifying aerodynamic interconnections between wind turbines are required. The main difficulty in distributed control and identification 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 $nN \times nN$. Therefore most conventional solution algorithms will require $O(n^3N^3)$ floating point operations (flops), which makes traditional controller synthesis expensive if the number of distributed subsystems is large.

OBJECTIVES

The wind farm shown in figure 1 can be described by the 2 dimensional interconnected system shown in figure 2. Our research focuses on developing fast algorithms that have linear computational complexity for 2-D system, and this can be applied for identification of aerodynamics and distributed control of wind farms.

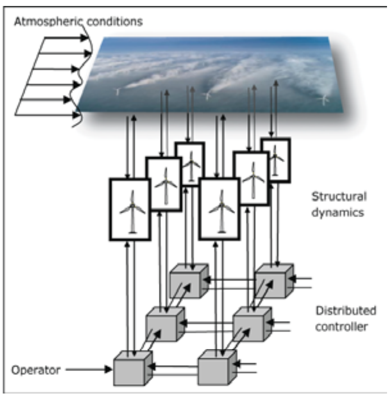

Figure 1: Offshore wind farm

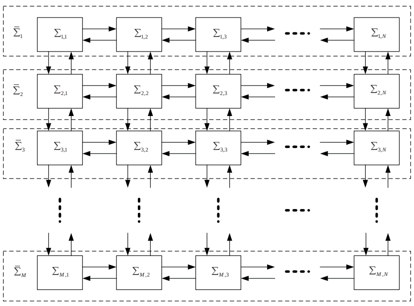

Figure 2: 2-D interconnected system

METHODS

The concept of Sequentially Semi-Separable (SSS) matrices [1][2][3], yielding algorithms of linear computational complexity, provides an effective approach to distributed control and identification of large scale system. An example of a one-dimensional spatially interconnected system that can be described by an SSS matrix structure is shown in figure 3. Computational time of Extended Kalman Filter (EKF) for identification of this 1-D system is shown in figure 4, which shows the nice property of linear computational complexity of SSS matrices.

Multi-level SSS (MSSS) matrices that orients from SSS matrices, also keep the nice property of SSS matrices, which is very attractive for controller synthesis and identification of 2-D system. By exploiting properties of MSSS matrices, fast algorithms can be implemented to accelerate the computational speed efficiently.

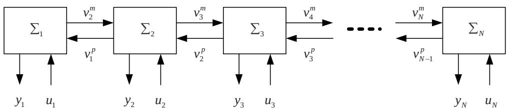

Figure 3: 1-D interconnected system

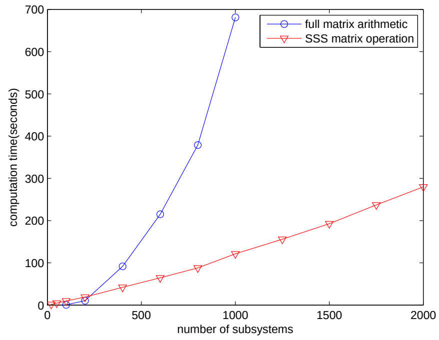

Figure 4: Computational time of EKF for identification of 1-D system

RESULTS

Computational time of Extended Kalman Filter (EKF) for identification of 2-D system described by heat equation based on SSS matrix structure is shown in figure 5. We can see from the figure that the computational time is proportional to the number of interconnected subsystems, which shows linear computational complexity.

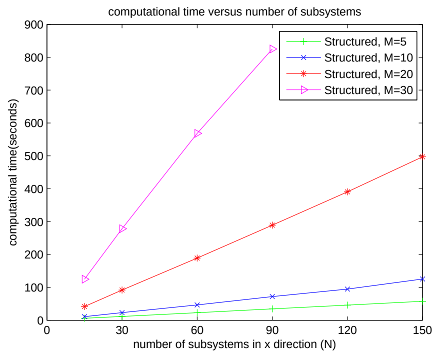

Figure 5: Computational time of EKF for identification of 2-D system

CONCLUSIONS

According to figure 5, it can be seen that identification algorithms based on SSS matrix structure has shown linear computational complexity. By exploiting properties of MSSS matrices, such as structure preserving model order reduction, much faster algorithms can be achieved for identification of aerodynamic interconnections of wind farm shown in figure 1, which is vital for controller synthesis and optimization of wind farm.

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