R&D Theme

Development of Actuator Location Optimization Algorithm and Its Application to Modeling and Weather Problems

Progress until FY2022

1. Outline of the project

Since a weather field has a large number of degrees of freedom, weather simulations take quite a long time. Therefore, it is not practical to use an algorithm that performs a huge number of weather simulations for actuator selection. We will develop actuator-position-selection algorithms that can be applied to such large systems based on a mathematically formulated problem in this theme. To efficiently evaluate the performance of the algorithm, simulation models of relatively small systems are also developed in parallel with the development of the actuator-selection algorithm. For these test models, the developed algorithm shows that the actuation at the selected location can significantly modify the field with a probability of over 99% better than that at a randomly selected location (Figure 1). We finally show the effectiveness of the developed algorithm for a weather model.

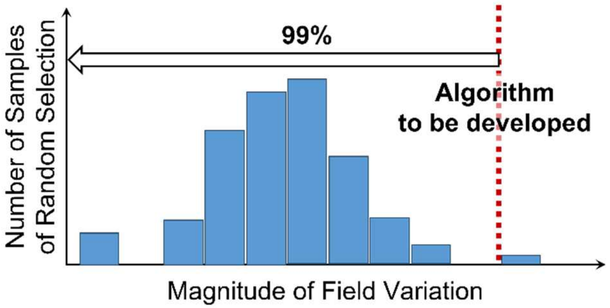

Figure 1: Objective of actuator-selection algorithm

2. Outcome so far

To take advantage of our prior knowledge, we organized and evaluated algorithms for sensor-position optimization problems, which are dual problems of the large-scale actuator-position optimization problems. First, we applied the currently available sensor selection algorithms to several sensor selection metrics for linear models and compared their performance. As a result, we found that the greedy method has high performance and low computational cost for sensor selection for systems with a large number of candidate sensor positions. We concluded that it is reasonable to proceed with algorithm development based on the greedy method. Hence, we proposed new greedy methods such as the random-selection elite group greedy method (Figure 2) to improve the performance of the greedy method. Furthermore, we theoretically guaranteed the performance of these new greedy methods. We found that the sensors selected by the greedy method for a performance metric based on a linear inverse problem can enhance other metrics for linear models. This suggests that sensor selection for the linear inverse problem, which is computationally inexpensive, may be able to replace sensor selection for other metrics.

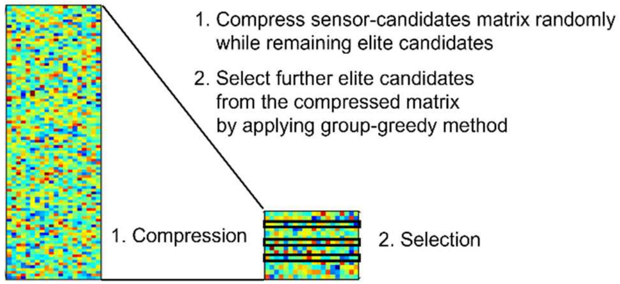

Figure 2: Random-selection elite group greedy method

To evaluate the performance of the actuator-selection algorithm, simulation models such as the linearized Ginsburg-Landau equation (Figure 3 (left)) and the Lorenz 96 model (Figure 3 (right)) were developed.

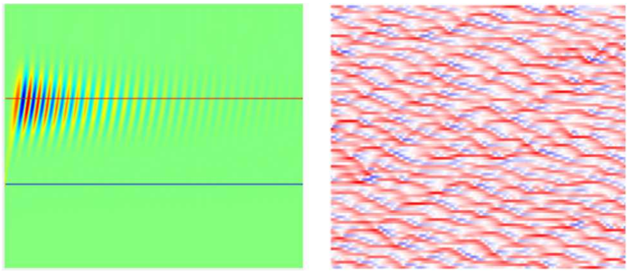

Figure 3: Simulation results of test models

3. Future plans

In collaboration with the themes "Mathematical problem formulation for actuator location optimization" and "Development of an evaluation method for optimized actuator location based on weather simulation" in this project, we will develop actuator-location optimization algorithms that can be applied to weather fields. First, based on the results in the previous works on sensor-position optimization algorithms, we will develop actuator-position optimization algorithms for linear models using the duality. Then, based on the knowledge gained from the development of the algorithms for linear models, we will develop actuator-position optimization algorithms that can be applied to nonlinear models, including weather models, and demonstrate the effectiveness of these algorithms.