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Comparative Study of Data Mining Methods for Aerodynamic Multiobjective Optimizations

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ABSTRACT

Practical aerodynamic design problems are typically multiobjective design optimization problems that have multiple contradicting objectives and many design parameters. Goal of multiobjective design optimization is to find Pareto-optimal solutions to reveal trade-off information between the objectives and effect of each design parameters. Recently, idea of “multi-objective design exploration (MODE)” [1] was proposed by Obayashi et al. as an approach to find such design information. They proposed to use multiobjective evolutionary algorithm to find Pareto-optimal solutions and to use data mining methods such as self-organizing map (SOM) to extract design information from the Pareto-optimal solutions. However, it has not been discussed yet which data mining method is suitable for analysis of Pareto-optimal solutions among many data mining methods. Therefore, the objective of the present study is to apply data mining methods such as SOM, clustering, and decision tree to an aerodynamic design optimization problem and to find the best data mining approach for aerodynamic multiobjective optimizations.

Here, Pareto-optimal solutions of the multiobjective aerodynamic design optimization problem of flapping airfoil motion [2] are considered. Objectives are maximization of the time averaged lift ($C_{L,ave}$), maximization of the time averaged thrust ($C_{T,ave}$), and minimization of the time-averaged required power ($C_{PR,ave}$) at the given cruising condition. The flapping motion of the airfoil is parameterized by frequency (k), plunge amplitude (h), pitch amplitude (α_1) and offset (α_0), and phase shift between plunging and pitching (ϕ). The objective values are evaluated using a two-dimensional imcompressible Navier-Stokes solver and a multiobjective evolutionary algorithm code is used to obtain Pareto-optimal solutions. As the result, 561 Pareto-optimal solutions is obtained. In this abstract, SOM, scatter plot matrix, and clustering are compared.

Figure 1 presents Pareto-optimal solutions mapped onto two-dimensional space using SOM and colored according to the ojbective function value or the design parameter

value. These maps show that the present three objectives are contradicting and therefore there is no solution that optimize all three objectives. These maps also give some other information such as; 1) Phase shift between plunging and pitch angle must be near ninety degrees, 2) Pitch angle offset of most Pareto-optimal flapping is almost zero except for the flapping motions for high lift, and 3) Reduced frequency is a tradeoff parameter between minimization of required power and maximization of lift or thrust.

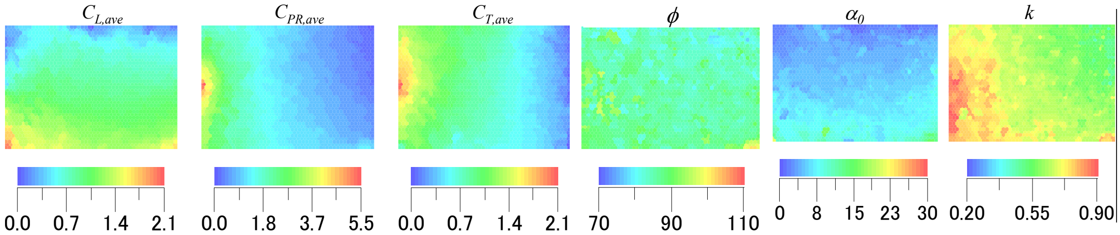

Fig. 1 Analysis using self-organizing map

Figure 2 is scatter plot matrix of the Pareto-optimal solutions. The scatter plot matrix contains all the pairwise scatter plots of the the design parameters and objectives in a matrix format. In Fig. 2, strong correlations are observed between lift and pitch angle offset, between required power and frequency, and between thrust and frequency.

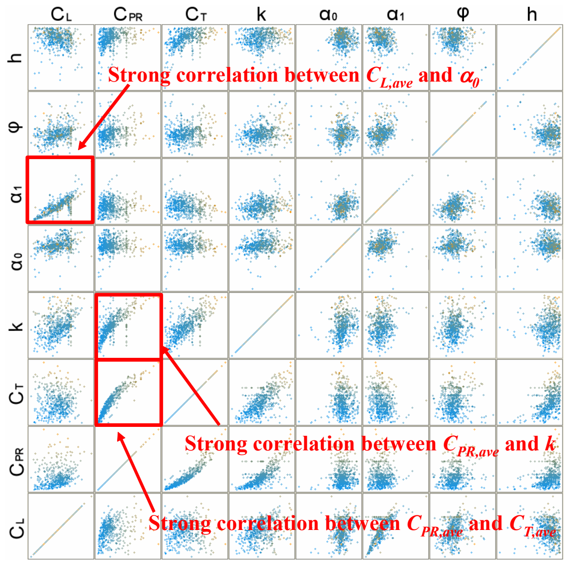

Fig. 2 Analysis using scatter plot matrix

Figure 3 shows result of clustering using expectation maximization method according to objective function values. The high $C_{T,ave}$ group are shown by red points. This analysis also presents usefull information such as 1) frequency must be high to maximize thrust, 2) phase shift must be almost 90 degrees to be one of the Pareto-optimal solusions.

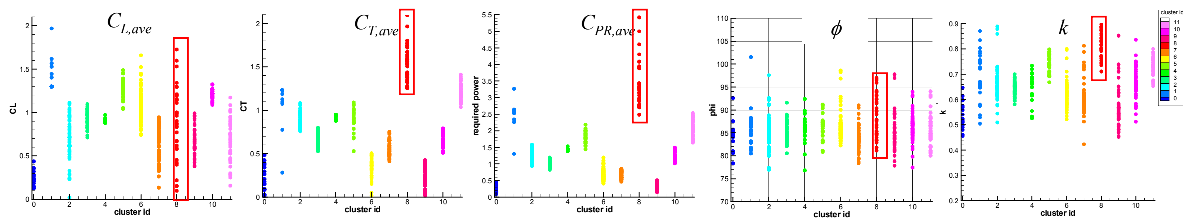

Fig. 3 Analysis using clustering

REFERENCES

[1] S. Obayashi, S. Jeong, and K. Chiba, "Multi-Objective Design Exploration for Aerodynamic Configurations", AIAA Paper 2005-4666, (2005).

[2] A. Oyama and K. Fujii, "A study on Flapping Motion for MAV Design Using Design Exploration," AIAA Paper 2007-2878, (2007).