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Conceptual Design of Tires using Multi-Objective Design Exploration

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The importance of the rule of simulation at a conceptual design stage is pointed out recently. The methodology using multi-objective design optimization and data mining [1, 2], which is called MODE (Multi-Objective Design Exploration) [3], is helpful to find out design knowledge. In this study, we show that MODE is fruitful to determine the direction of the design at a conceptual design stage of real world example i.e. contour design of a fuel efficient tire.

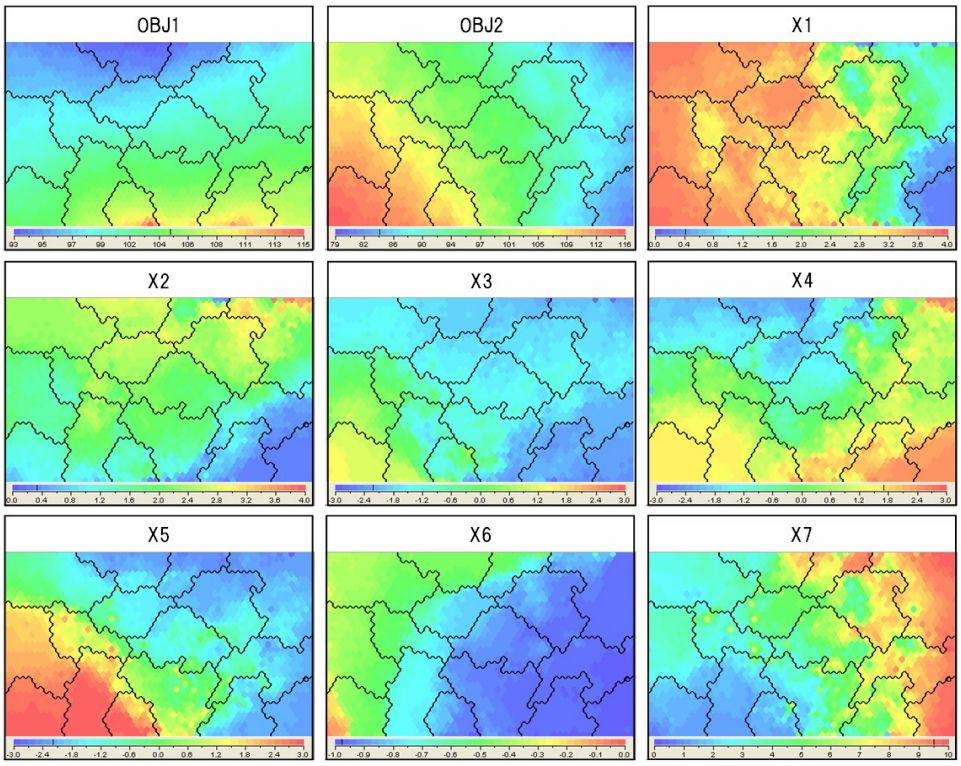

Figure1: Self-organizing map using MLS filter. The map shows relationship between objective functions (OBJ1 and OBJ2) and design variables (X1-X7).

Seven design variables (X1-X7) to specify tire contour and four objective functions (OBJ1-OBJ4) of tire performance including rolling resistance are chosen in this study. Our procedure of MODE consists of nonlinear finite element analysis to predict tire performance, evolutional computation to get desirable solutions including Pareto solution, and data mining to find out design knowledge. SOM (Self-Organizing Map) [3] and decision tree [4] are used to obtain diverse design knowledge between tire performance and tire contour. Here, SOM with MLS (Moving Least Square) filter is used to obtain the structured smooth data of design variables in an objective function space (see figure 1). We can overlook the whole causation with the objective functions and the design variables using this map. On the other hand, a decision tree gives a rule to get the aimed performance balance as shown in figure 2. We were able to acquire some knowledge to be usable at a conceptual design stage by SOM and decision tree. In order to demonstrate the validity of the knowledge, we produced prototype tires. The experimental results of them guaranteed the validity and the effectiveness of the knowledge and MODE. Furthermore, the latest fuel efficient tire, which was designed based on the knowledge, was released in July 2013. MODE is fruitful to determine the direction of the design at a conceptual design stage.

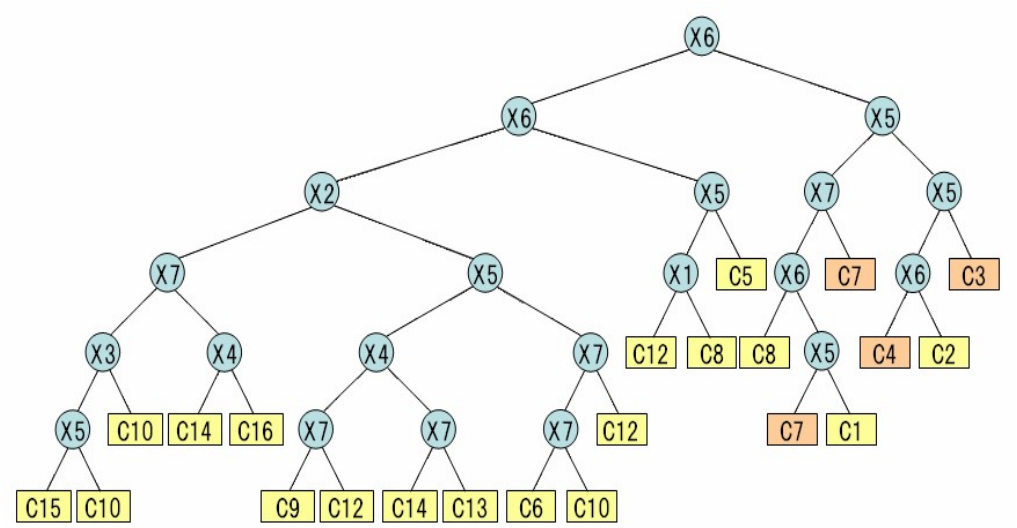

Figure 2: Decision tree for clusters (C1-C16) of objective functions and design variables (X1-X7). Each cluster shows the specific performance balance of a tire and is obtained by SOM shown in figure 1. C3, C4 and C7 are the clusters which have aimed performance balance.

REFERENCES

[1] S. Obayashi and D. Sasaki, Self-Organizing Map of Pareto Solutions Obtained from Multi-Objective Supersonic Wing Design, *AIAA Paper* 2002-0991, 2002.

[2] M. Koishi and Z. Shida, Multi-Objective Design Problem of Tire Wear and Visualization of Its Pareto Solutions, *Tire Science and Technology*, Vol.**34**, No.3, pp.170-194 2006.

[3] S. Obayashi, S. Jeong and K. Chiba, Multi-Objective Design Exploration for Aerodynamic Configurations, *AIAA Paper* 2005-4666, 2007.

[4] *Viscovery SOMine Version 4.0 Users Manual*, Viscovery Software GmbH, 2001.

[5] I. H. Witten and E. Frank, *DATA MINIG Practical Machine Learning Tools and Techniques*, 2nd Edition, Morgan Kaufmann Publishers, 2005.