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Editorial: The need for design space exploration and design optimisation methods

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Biographical notes: Dr. G. Gary Wang is currently an Associate Professor at Simon Fraser University (SFU). Before joining SFU, he has been an Assistant/Associate Professor at the University of Manitoba (UM) for about nine years. He is active in research on design optimisation, design for manufacturing and advanced manufacturing. Through the years, he has gained international recognition, especially for his work on design optimisation. He is the recipient of the 2005 National I.W. Smith award for creative engineering from the Canadian Society for Mechanical Engineering (CSME), as well as the 2007 Rh Award from UM for outstanding research contributions in the Applied Science category. He is currently serving as an Editorial Board Member for *CSME Transactions* and the *International Journal of Advanced Mechatronics and Robotics*.

Bernard Yannou is a Professor of Industrial and Mechanical Engineering at the Laboratoire Génie Industriel (LGI) of Ecole Centrale Paris (ECP), France. He currently supervises the design management research group. He received an MSc (1988) in Mechanical Engineering from Ecole Normale Supérieure of Cachan, and an MSc (1989) in Computer Science from Paris-6 University. He received a PhD (1994) in Industrial Engineering from Ecole Normale Supérieure of Cachan. His research interests are centred on the preliminary stages of product design: defining the design requirements, synthesising the product concepts, the rapid evaluation of product performances under uncertainty, the preference aggregation of the product and the project performances for the supervision of the design process and the subjective and perceptual evaluation of products.

This special issue arises from the observation that modern product development often involves complex analyses from multiple disciplines, consideration from product life cycle aspects, making difficult tradeoff decisions and in the meantime, achieving optimal product design at the lowest costs and in the shortest time. To systematically integrate various design perspectives to achieve the optimal design is a very challenging task. Such an integration and optimisation capability is in great demand and potentially of a significant benefit to all manufacturing industries. Design space exploration and optimisation is an important and often necessary step in product development. Research in this area has yielded many promising approaches and strategies. This special issue of *IJPD* was intended to present the state of the art in this area and promote further research in order to provide engineers with practical tools that support integration and optimisation.

Between November 2006 and August 2007, we received 23 submissions to the special issue from all over the world. All of the papers went through rigorous reviews from which only 11 have been selected. The 23 submissions revealed that design exploration and optimisation have been understood in a large scope. Our choice has been to promote certain diversity without going too far – creativity methods, for instance, were excluded from design exploration considerations. Finally, these 11 papers fall into four categories.

The first category is Design Visualisation for aiding designers to make decisions on dimensioning in an intuitive and comprehensive manner. Chiu *et al.* proposed a Hyper-Radial Visualisation Method that considers weight preference and uncertainties for multiple objective problems. Mattson *et al.* provided rather complex case studies for concept exploration/selection using s-Pareto frontiers. Design visualisation is not, however, limited to multi-objective optimisation; the visualisation of the design space, problem space, interaction between variables and functions, feasible/infeasible regions, abstract decision making charts, and so on, may also be explored and developed.

The second category may be referred as Space Exploration, in which we have four selected papers. Each of these papers deals with the space exploration from different perspectives and thus provides a diverse and yet complementary view of the approaches. Gomes *et al.* proposed a knowledge-based strategy to support design optimisation with an application example. Knowledge is represented as rules in guiding the design space exploration. Li reviewed the matrix-based decomposition methods which are useful for featuring the relationships between components and/or functions of a design solution. As a result the product as well as the design project can be modularised. A unified model of decomposition algorithms is also proposed. Tiwari *et al.* developed an approach that can assist a designer to quickly obtain a set of promising solutions based on morphological chart and genetic algorithm. Though having limitations, this method provides a quantitative way to generate promising concepts at the early design stage. Yannou *et al.* argued that design exploration techniques, robust design, and design for reliability should be used in that order of increasing complexity to reveal as early as possible the inconsistencies with performance specifications.

The third category focuses on Optimisation Algorithms. Younis *et al.* developed a region elimination method for Metamodel-based Design Optimisation (MBDO). Issacs *et al.* applied surrogates of regions to assist an evolutionary algorithm for multi-objective optimisation. Shao and Krishnamurty took advantage of potential local optima as well as areas of maximum approximation error as new sample points for the next iteration of metamodeling. Wang *et al.* developed an adaptive space mapping method and successfully applied the method to sheet metal forming. All these methods, as one can see, employ metamodeling in one way or the other. The dynamics between sampling, metamodeling, and optimisation are of interests to the authors.

The last but not the least is the application section. Scaravetti and Sebastian documented in detail the design of aircraft air conditioners and the use of different tools in space exploration and optimisation. Readers can also see application cases in other papers in this issue.

The topic of design space exploration and optimisation is a broad area. The readers of this issue should be aware of the fact that no single issue can cover all the important directions and researches for this broad topic. Finally, we'd like to thank all the authors who contributed to this issue and we certainly look forward to new advancement in the area of space exploration and design optimisation!