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INTERACTIVE TRADEOFF ANALYSIS AND PREFERENCE MODELLING FOR PRELIMINARY MULTIOBJECTIVE SHIP DESIGN SYNTHESIS

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This paper presents the application of a new interactive multiple objective decision making (MODM) procedure to a preliminary ship design synthesis problem. This procedure is composed of an interactive step trade-off method (ISTM) and the estimation and optimization of a set of utility functions. The ISTM method is used as a preference learning process to assist a designer (decision maker or DM) in generating a representative sub-set of efficient designs (solutions). In this learning process, the DM is expected to compare the generated solutions as well as objectives in a pairwise manner to express his preferences. A set of additive piecewise linear utility functions are then estimated, and they are used to help the DM search for his best compromise design. The preliminary ship design model used is a strongly nonlinear multiobjective optimization problem and curve fitting techniques are used for modelling discrete data. This model is fully investigated using the new MODM procedure. This study is aimed at demonstrating the ability and potential of the procedure to deal with design synthesis problems of large made-to-order engineering products through preference modelling and utility optimization.

Keywords: Multiobjective optimization; preference modelling; interactive methods; utility functions; preliminary ship design

1. INTRODUCTION

Many activities in engineering design consist of procedures which essentially involve dealing with decision problems with multiple, potentially conflicting requirements reflecting technical and economical

performance of a design. Design synthesis problem form one class of design decision problems where designs have to be evolved based on multiple performance objectives as well as technical and economical constraints. The aim of design synthesis is to develop a compromise design which attains these objectives as closely as possible and satisfies the constraints strictly.

The preliminary design of a ship may be generally constructed as a nonlinear multiobjective optimization problem with the design space often being non-convex. A range of interactive MODM methods may then be applied to deal with such problems, such as the surrogate worth trade-off (e-constraint) method [2], the minimax solution approach [12], the STEM method [5,13] and the ISTM method [15,16]. Multiple objective engineering design synthesis favours the use of interactive MODM methods as such techniques allow the solution to progress towards a preferred solution through an evolving or an adaptive approach and this mirrors the adaptive nature of the design process for large, complex, made-to-order engineering products.

However, most interactive methods suffer from the inability to search for and justify the best compromise design without extensive guesswork on the part of the DM as *a priori* preference information is rarely available. A new interactive MODM procedure has recently been developed which combines a preference learning process based on the ISTM method and a search process for the best compromise solution through the estimation and optimization of a set of additive piecewise linear utility functions based on simple ordinal or cardinal pairwise comparisons of the generated solutions and objectives [18,19].

This new technique can assist the DM to check and eliminate any inconsistent preference information. The DM can, whenever necessary, re-evaluate and modify the preferences he has already provided by re-estimating or revising the utility functions. This enables the DM to carry out sensitivity analysis in an explicit manner in order to examine the robustness of the obtained best compromise solution. Such an analysis may enhance the DM's confidence in the chosen solution. Furthermore, the explicit representation of the preferences for individual designers could provide a basis for conflict resolution in team design. The technique also allows the DM to define and modify his acceptable achievement levels for all objective functions so that

any unacceptable solution can never be identified as the best compromise solution in the search process.

The detailed design of a large made-to-order engineering product such as a large ship is a complex process requiring complex models. In the early design stages, however, a simplified model may be sufficient for preliminary design analysis. Such a preliminary design model will often be a mathematical one, facilitating useful investigations of the relations between design variables and performance measures.

This paper is intended to demonstrate the application of the above new MODM procedure to the multiobjective ship design synthesis problem. The basic interactive decision making process of ISTM and the techniques for estimating and optimizing utility functions are described first. The modelling process of discrete data and the construction of the preliminary ship design model are then discussed. This model is then comprehensively investigated using the new MODM procedure. The obtained results are analysed and illustrated to help understand the design problem in question as well as the implementation process of the MODM procedure. The main purpose of this study is to demonstrate the ability and potential of the MODM procedure to deal with large, complex innovative engineering design synthesis problems through preference modelling and utility optimization.

2. TRADEOFF ANALYSIS AND PREFERENCE MODELLING

2.1. ISTM-Based Interactive Tradeoff Analysis

A preliminary multiobjective ship design problem may generally be constructed as the following multiobjective optimization problem (MOP)