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Shape Optimization in Product Design Using Interactive Genetic Algorithm Integrated with Multi-objective Optimization

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Abstract

This paper proposes an interactive genetic algorithm (IGA) integrated with multi-objective genetic algorithm (MOGA) in development of a generative design system. IGA is used in initializing and handling single dimensionally qualitative objectives. MOGA is used in optimizing two quantitative objectives. Qualitative factors are considered as design objectives to be optimized together with quantitative criteria. The multi-objective optimization is regarded to concurrent handling of two quantitative criteria. Shape of product is modeled by parametric modeling with Rhinoceros and Grasshopper. IGA is processed using Galapagos in Grasshopper. Shape optimization of the product is processed by using MOGA in MATLAB and linked to Grasshopper. Pareto-optimal front is generated to show the optimal solutions, which is able to support designers in decision making. The perfume bottle design is used as an illustration of the proposed framework, but the framework is applicable to other design problems.

Keywords

Generative design Interactive genetic algorithm Multi-objective genetic algorithm Qualitative Multi-objective optimization Pareto-optimal front Bottle design

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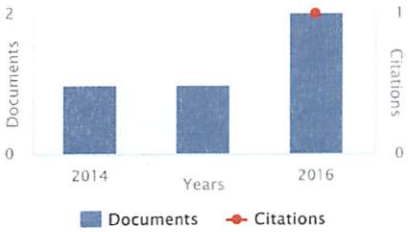

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Top of page

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Shape Optimization in Product Design Using Interactive Genetic Algorithm Integrated with Multi-objective Optimization

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Abstract. This paper proposes an interactive genetic algorithm (IGA) integrated with multi-objective genetic algorithm (MOGA) in development of a generative design system. IGA is used in initializing and handling single dimensionally qualitative objectives. MOGA is used in optimizing two quantitative objectives. Qualitative factors are considered as design objectives to be optimized together with quantitative criteria. The multi-objective optimization is regarded to concurrent handling of two quantitative criteria. Shape of product is modeled by parametric modeling with Rhinoceros and Grasshopper. IGA is processed using Galapagos in Grasshopper. Shape optimization of the product is processed by using MOGA in MATLAB and linked to Grasshopper. Pareto-optimal front is generated to show the optimal solutions, which is able to support designers in decision making. The perfume bottle design is used as an illustration of the proposed framework, but the framework is applicable to other design problems.

Keywords: Generative design · Interactive genetic algorithm · Multi-objective genetic algorithm · Qualitative · Multi-objective optimization · Pareto-optimal front · Bottle design

1 Introduction

At present, computer-aided art and design tools play important role in the entire design and development process. These tools are able to support artists and designers from initial conceptual ideas, through optimization of design parameters and aesthetic considerations [1–3]. Conceptual design is considered as a process in which designers generate broad and various alternatives [4], consequently, in this stage, designers usually deal with the activities such as generating and recording ideas, and deciding to continue to generate more ideas or desire to explore the possibilities of the existing ones [5]. Product design problems then cove with both qualitative and quantitative criteria, which can be considered as multi-objective optimization.

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Interactive Evolutionary Computation (IEC) becomes more important in design process that is directly related with human factors such as emotion, preference, feeling, etc. [6].

Designers desire the tools that can effectively support their activities, decision making, and allow them to easily collaborate with the tools since the conceptual design phase. Therefore, it is highly motivating and constructive to develop an interactive generative design system with optimization of multiple objectives for supporting designers during generating their ideas in the beginning of design process. The mentioned system is supposed to support designers who are not familiar with CAD systems. This paper aims to develop an interactive genetic algorithm working with multi-objective optimization, which considers qualitative and quantitative design constraints.

The paper is organized in five main sections. The related works such as interactive evolutionary computation and multi-objective optimization with genetic algorithms are described in Sect. 2. Section 3 introduces the proposed interactive genetic algorithm with multiple objectives. Section 4 provides the illustration of the case study of perfume bottle design, experimental results and discussion. Lastly, Sect. 5 provides the conclusions of the research and the future works.

2 Related Works

2.1 Interactive Evolutionary Computation

Interactive Evolutionary Computation (IEC) is an optimization technique that based on Evolutionary Computation (EC) in which fitness function replaced with human subjective evaluation [6]. Therefore, IEC system optimizes the target system to achieve the desired outputs based on the user's evaluation. Takagi [6] said that the IEC is considered as an approach that embeds human emotion, preference, intuition or named kansei into the target system. IEC is applied in various applications such as artistic image creations, product design, and engineering. In this paper, we focus on the applications of product design and industrial design.

Brintrup *et al.* [7] developed an interactive genetic algorithm (IGA) for designing ergonomic chairs with qualitative and quantitative fitness. They compared different IGA types in several criteria. Hu *et al.* [8] developed an interactive co-evolutionary CAD system used for garment pattern design. The system core is based on inspired co-evolutionary algorithm for working with human experts. Sun *et al.* [9] developed an interactive genetic algorithm for designing sunglass lens. The algorithm is able to work with large population using semi-supervised learning. Lu *et al.* [10] proposed an interactive evolutionary design to create marble-like textile patterns. Dou *et al.* [11] proposed a multi-stage interactive genetic algorithm (MS-IGA). It divides the large population of the traditional interactive genetic algorithm into many stages in relation to different functional requirements. They applied the MS-IGA to the car console conceptual design system. It is aimed to capture the knowledge of users' personalized requirements and to achieve the product design.