Interactive Hybrid Evolutionary Computation for MEMS Design Synthesis

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Abstract. An interactive hybrid evolutionary computation (IHC) process for MEMS design synthesis is described, which uses both human expertise and local performance improvement to augment the performance of an evolutionary process. The human expertise identifies good design patterns, and local optimization fine-tunes these designs so that they reach their potential at early stages of the evolutionary process. At the same time, the feedback on local optimal designs confirms and refines the human assessment. The advantages of the IHC process are demonstrated with micromachined resonator test cases.

Keywords: interactive hybrid computation, MEMS synthesis, evolutionary computation, optimal design.

1 Introduction

Evolutionary computation based on a multi-objective genetic algorithm (MOGA) has been used for microelectromechanical system (MEMS) design synthesis [1, 2]. Incorporating gradient-based local optimization at the end of the evolutionary process, referred to herein as the “standard hybrid GA process”, has been shown to improve the performance of the evolutionary MEMS design synthesis process [3]. This paper explores the integration of local optimization into intermediate generations of the evolutionary process in order to allow the refinement of promising designs at an early stage of the evolutionary process and guide search towards more promising design regions earlier. This method applies local optimization either to the whole population [4] or to individuals with the best performances [5] in intermediate generations. Applying local improvement to the whole population may be computationally prohibitive on large complex problems like MEMS design synthesis. On the other hand, limiting local optimization to the best individuals based on the quantitative fitness function does not guarantee local improvement of all designs with good patterns as these patterns have not yet reached their potential. Some of these designs
could evolve to much better design solutions if fine-tuned or if given enough time to evolve in the evolutionary process.

Interactive evolutionary computation (IEC) is a model of using the symbiosis of human expertise with evolutionary algorithms for a user-directed search, which has been used to evaluate objectives of MEMS designs that are difficult to model [6]. During the IEC process, human experts assess all individuals subjectively and assign fitness values based on their judgment of the potential for performance or a recognition of innovative design patterns. The reliance on human judgment to guide the evolutionary process has both potential strengths and weaknesses. On one hand, human expertise can be effectively exploited for guidance of a naive evolutionary process. On the other hand, including a human in the evolutionary loop introduces the need for rapid convergence to prevent human fatigue, and human assessment tends to have a component of subjectivity and non-linearity of focus over time [7]. To solve the human fatigue problem, Kamalian, et al., suggested a method with the human in a supervisory role, providing evaluation only every \( n^{\text{th}} \)-generation during the IEC process [6].

To reduce the influence of the subjectivity and non-consistency of human assessment on the evolutionary process, we present an interactive hybrid computation (IHC) algorithm that uses local optimization to fine-tune all selected designs by a designer so that these designs reach their potential at early stages of the synthesis process. The performances of these locally-optimized designs can also be beneficial in confirming and refining the human’s subjective assessment of these designs over time. The advantages of the IHC process are demonstrated on the synthesis of surface-micromachined resonators.

2 Interactive Hybrid Computation (IHC) Process

IHC exploits human expertise in identifying potentially good design patterns, using the results of local optimization to refine fitness values of strong designs and reduce the influence of subjectivity and non-consistency of the human evaluation.

During the IHC process, a human designer evaluates all the designs or a subset of them, such as those in the Pareto optimal set for multi-objective fitness functions, before applying local improvements. To reduce human fatigue, human input is only applied at certain predefined generations during the hybrid evolutionary processes. In our MEMS resonator test cases, IHC provides the designer with multiple design concepts within a graphical user interface (Fig. 1.) at predefined generations to evaluate all the designs or a subset of them in the current generation. If the designer identifies a promising design pattern, he/she can click the ‘local_Opt’ button, to enable the MEMS synthesis process to apply gradient-based local optimization to the design. After gradient-based local optimization has been performed, the geometrical parameters and performances of the optimized designs are fed back into the genotype and the phenotype domains of the GA process to replace the original designs.