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Hybrid weighted mean for CBR adaptation in mechanical design by exploring effective, correlative and adaptative values

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ABSTRACT

The implementation of case based reasoning (CBR) adaptation in parametric mechanical design can generate the design solution to unknown design problem by adapting similar solutions from other problems already solved. Classical weighted mean (WM) method is a common statistic adaptation method because of its domain independent and easily to be implemented, but with lower adaptation accuracy. A new hybrid WM (HWM) method for CBR adaptation in mechanical design is proposed in this paper, and its contribution is taking advantage of various implicit knowledge hidden in similar case data to improve the performance of WM. To achieve this goal, multiple similarity analysis (MSA), grey relation analysis (GRA) and inductive adaptability analysis (IAA) are firstly used to systematically explore the effective value (EV) of similar case for new design problem, the correlative value (CV) between problem and solution features, and the adaptative value (AV) of similar case's solution element for new adaptation situation, respectively. Then CV, EV and AV compose the integrated weight value of each solution element of similar case in HWM, and the optimal proportion of EV, CV and AV on the integrated weight is also discussed. Based on the parametric transformer design cases, the comparisons of adaptation performances between HWM and other statistical and intelligent methods were carried out, and the empirical results show that HWM has the better adaptation performance than other comparative methods by comparing the adaptation accuracy.

1. Introduction

Computer-aided parametric design is a useful tool to assure the rapid development of engineering mechanical with minimal expense to strengthen the enterprise's ability of responding to market [1]. However, there is no underlying theory to determine the parametric values of new mechanical product, thus the relative research has been a searching process for more accurate methods. In the beginning, the human preference-oriented method was used on the foundation of experiential knowledge of human beings. Then, the automated parametric design (APD) methodology was proposed, for example, De Silva and Behbahani [2] presented an approach based on the existing mechatronic design knowledge for parametric design of a mechatronic system. Lin et al. [3] took the advantage of pre-built design rules to output the designs of the main and standard parts of a progressive die. Lin and Hsu [4] also utilized the design rules to design the main components of a drawing die. Wu et al. [5] developed a parametric gating design system for die-casting die with pre-defined design rules. However, in many domains, especially those poor in theory but strong in practice, the design knowledge and experience of APD are so much complexity that it is hard for them to be represented as the simple rules or models successfully.

With the development of intelligent technique and soft computing, the computational techniques have been introduced into APD. Among them, case based reasoning (CBR) is regarded as a potential method, since it is similar to human beings' reasoning process, which can learn over time, and reason with concepts that have not been fully defined or modeled. Finally, CBR can provide an explanation of how the solution is produced. These advantages of CBR make it a chief inference tool in APD [6,7]. In CBR-based APD, the existing design case is represented as two sets of feature-value pairs that denote the design problem and corresponding solution, and designer can determine the parameter values of new product through analogical reasoning on these similar retained cases [8]. For instance, Liu and Xi [9] developed a case-based parametric design system for test turntable. Cobb and Agogino [10] present a case-based synthesis method for micro-electromechanical systems, and the case study indicated that the utilization of CBR can result in a 25% reduction in design area. Saridakis and Dentsoras [11] developed a case-based design module in the application area

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of parametric design of oscillating conveyors. However, in most situations, due to the market competition and the increasing diversity of customer needs, the solution of old case is not always appropriate for the encountered new problem, so the case adaptation has a significant effect on the success of CBR in APD. How to perform the adaptation procedure by taking advantage of solution values from K similar cases without having to excessively rely on designer's subjective judgement still remains challenging obstacles to the CBR, because the adaptation operation generally needs to be guided by some organised form of domain knowledge, and the adaptation knowledge is not always accessible and available [12,13].

As an effort to deal with this challenging issue, we concentrate on CBR-based APD in this research and devote to the investigation of adaptation approach of CBR in APD by exploring and utilizing the various adaptation knowledge derived from K similar case data such as effective, correlative, and adaptive values, and the empirical comparisons of the adaptation performances between the proposed method and other adaptation methods are carried out to validate its superiority. The breakdown of the paper is organized as follows. The next section gives a description on literature review. Section 3 makes specification on proposed method. Section 4 describes the empirical design. Section 5 presents the empirical results and relevant discussions. The last section provides the conclusions and suggestions for further research.

2. Research background

When CBR methodology is applied into APD domain, the similar design solutions can rarely be directly used as the suitable solutions for the new design contexts, which require a set of adaptations. Many CBR-based APD systems utilize the most similar case as the only candidate for the adaptation process, and the hand coded adaptation rules are pre-defined in these systems [14–16]. The study of adaptation by referring to more than one cases ($K > 1$) is a more complicated issue, and the statistical adaptation methods have been employed since 1990s, such as the closet analogy [17], the mean [18], the median [19], weighted mean (WM) [20], and multivariate regression analysis (MRA) [21]. Among them, the WM is most widely used statistical method, which allows the more similar cases to have the more influence than less similar cases in adaptation process [7,22]. Because of their domain independent and easily to be implemented, the statistical adaptation is regarded as the baseline mode nowadays. Later, the intelligent adaptation based on machine learning algorithms have been introduced, which use inductive learning to acquire the differences between old cases and their corresponding solutions and apply the acquired differences to implement automatic case adaptation [23]. Various intelligent methods including neural networks [24–27], genetic algorithm [11,28–30], support vector machine [31–33], and decision tree [34] have been employed for case adaptation in abundant researches. Although the intelligent methods are time-consuming, they can produce more accurate adaptation results than statistical methods on the whole. The drawback of intelligent methods lies on the sufficient case data needed in the process of case adaptation. However, the majority of researches in the area of

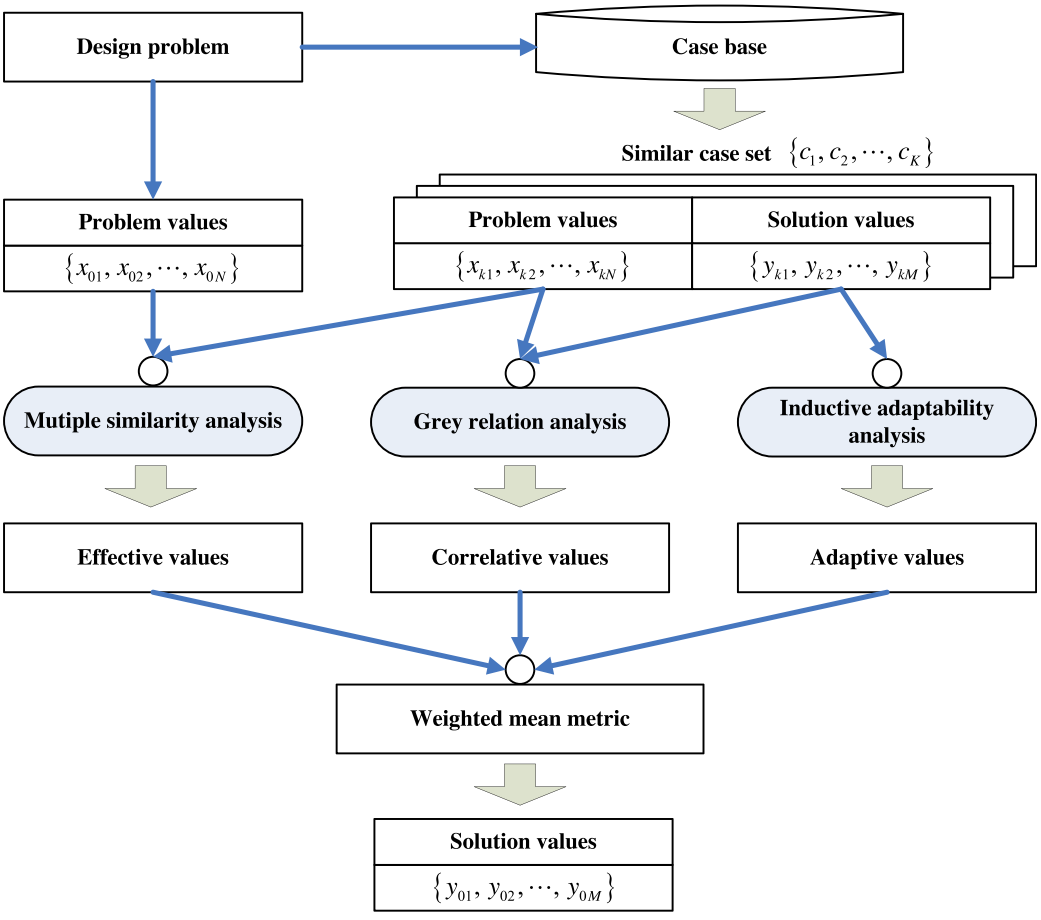

Fig. 1. The framework of hybrid weighted mean for adaptation generation.