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Applying case-based reasoning to cold forging process planning

Yonggang Lei^{*}, Yinghong Peng, Xueyu Ruan

Department of Plasticity Engineering, Shanghai Jiaotong University, Shanghai 200030, PR China

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Abstract

On the basis of the practical situation of cold forging process planning, the disadvantages of a rule-based solution are discussed, and a case-based reasoning-based cold forging process planning (CFPP) system model is proposed. Several key problems involved are analyzed, among which a feature-based part representation scheme and a two-level retrieval mechanism are introduced to solve the problems of case representation and case retrieval. It is established in this paper that case-based reasoning-based CFPP is a promising technology for both long-term research and the promotion of efficiency for current cold process planning systems. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Case-based reasoning; Cold forging; Computer-aided process planning

1. Introduction

Cold forging is a metal forming process which shapes a workpiece between dies at room temperature. It has advantages over machining such as little material waste, higher productivity, good dimensional and form error tolerance, and improved properties of the workpiece. Usually, cold forging needs several “preforming” operations to make the required formable part from an initial round slug without product- and die-defects. Determining the feasible or optimum serial preforming operations for making a part has been called process planning. This task is usually considered as an “art” to be undertaken by highly experienced die designers who use both empirical judgement and established (but mostly not well documented) design or technology rules which were obtained through many years of experimentation.

By process planning, usually people mean machining process planning since much research has been conducted in this area. However, according to recent developments in cold forging technology and computer technology, the application of computers in cold forging process planning (CFPP) has been growing rapidly, the initial development being led by Noack [1]. After the expert system approach was introduced to engineering applications, several knowledge-based systems [2–6] were developed for CFPP. Since

the nature of the heuristic knowledge and experience is fragile, and not well structured, it is not acquired easily and represented well in an expert system. In addition, to build an expert system, a knowledge engineer has to interview molding personnel and try to elicit appropriate knowledge in the form of rules. This knowledge is difficult to uncover and the knowledge acquisition becomes a bottleneck in the construction of the expert system. In this paper, a new approach, case-based reasoning (CBR), is adopted to solve the problem. CBR can mean old solutions to meet new demands, using old cases to explain new situations, and using old cases to critique new solutions. There are several benefits of applying CBR technology in computer-aided CFPP. It allows the reasoner to propose solutions quickly, hence reducing the time needed to work them out. In addition, remembering previous experience helps to avoid the repetition of past mistakes. The learning process available with a CBR system enables it to become more efficient by increasing its memory of old solutions and adapting them.

2. Case-based reasoning

The concept of CBR was first described as Dynamic Memory [6]. Since then CBR technology has been applied in a wide range of application areas, including catering, recipe making, dispute mediation, criminal sentencing, mechanical design, etc. [7,8]. At the highest level of generality, a CBR cycle may be described by the following processes (see Fig. 1):

^{*} Corresponding author. Tel.: +0086-021-62934523.

E-mail address: lyg70745@mail1.sjtu.edu.cn (Y. Lei).

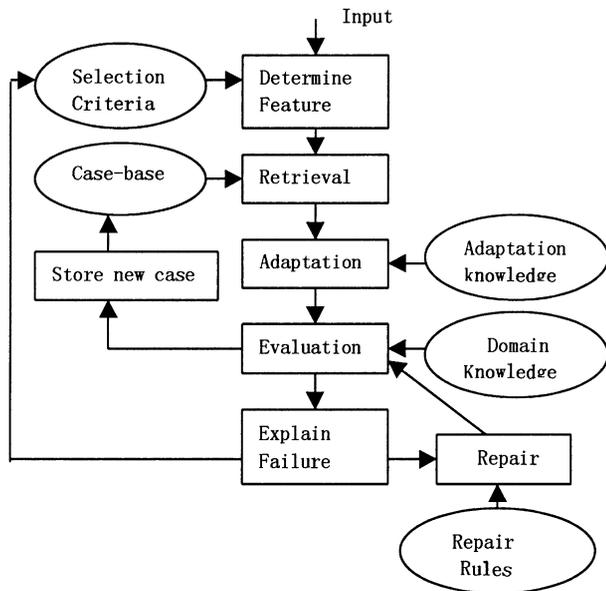


Fig. 1. The diagram for case-based reasoning.

3. Overview of CFPP

In this paper, the authors introduce a prototype of a case-based CFPP system. The CFPP system uses the concept of CBR combined with a feature-based approach in order to produce process plans. It uses feature attributes to index and code the parts, unlike conventional variant systems which are based on the concept of group technology for part coding and classification. The CFPP uses a case-base which stores previously produced successful process plans. The most similar cases from the case-base are retrieved and adapted in order to fit the requirements of the newly designed part. If the new part is unique and the process plan is found to be working well, it is indexed and stored in the case-base as a new case, thus enabling learning from past experience.

Fig. 2 shows the general structure of the CFPP. It uses a simplified version of a blackboard architecture. The system consists of a controller, a part index module, a specified case-base, a normal case-base, a retrieval manager, a modification and adaptation module, a testing and storage module and a default process plan generating module. The controller determines the order in which the various knowledge sources will be executed.

The CFPP performs the following tasks:

1. *Determine feature.* Find features which can describe new problems completely and correctly.
2. *Retrieval.* Retrieve one or several similar cases from the case-base.
3. *Adaptation.* Recognize the differences between the selected design case (cases) and the new design problem, and adapt the selected design case (cases) to solve the new design problem.
4. *Evaluation.* Evaluate the proposed solution to decide whether it is acceptable in new problem solving. If failure occurs explain the reason and try to repair it with repair rules. If this is successful, store the new solution case in the case-base in order for it to be used afterwards.

From the above processes it can be conducted that CBR is different to rule-based reasoning and model-based reasoning, being analogous to the way humans naturally solve problems, so it is appropriate to be used in computer-aided CFPP.

1. There are two case-bases (special and general case-base) in the CFPP system. A special case-base is proposed for some special requirements from relevantly experienced clients of a cold forging enterprise, and to their special requirements CFPP uses usercode and other conditions to retrieve a suitable process plan. However, the special case-base is too rigid to be used in a new environment, and in the following pages if not stated explicitly, ‘case-base’ means ‘general case-base’.
2. Representing cases: All the cases are represented using a feature-based scheme, and a frame structure is adopted as the methodology to describe the features of the cases. A frame consists of several geometrical entities and the relations between those geometrical entities, as described in Section 3.

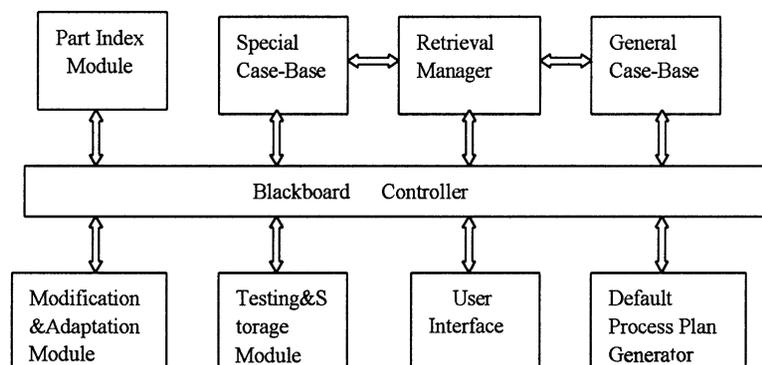


Fig. 2. Structure of the CFPP system.

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