A Knowledge-Based System for Sharing and Reusing Tacit Knowledge in Robotic Manufacturing

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ABSTRACT

A critical problem in robotic manufacturing is that the task of teaching robotics is rather time-consuming. This has become a serious problem in the present age of cost reduction. Collaboration with a company in the field has revealed that the root cause of this problem is that there is not a common knowledge base in this domain, which can serve as shared and reused knowledge. In robotic manufacturing, the skills and experiences of skilled workers are a form of tacit knowledge that is difficult to be acquired and transferred to other workers and robots. This paper proposes a knowledge-based system for sharing and reusing tacit knowledge in the robotic assembly domain. In this system, a modified EBL (Explanation-based Learning) method is proposed to generalize tacit knowledge from specific robotic programs made by skilled workers. A newly operational criterion is proposed for the generalized tacit knowledge, which demands that it should be expressed understandably by human workers and be reusable by robots to generate programs automatically.

Keywords: Knowledge Acquisition, Knowledge-Based Systems, Knowledge Reuse, Knowledge Sharing, Robotic Manufacturing, Tacit Knowledge

INTRODUCTION

Robots are being deployed in more and more industrial sectors. However, a critical problem in robotic manufacturing is that the task of teaching robots is too time-consuming (Brogårdh, 2007; Blomdell et al., 2005; Haegele et al., 2005). This has become a bottleneck to improving the flexibility of robotic manufacturing systems, which keeps small and medium size enterprises (SMEs) away from robotic automation. This problem is especially severe in the robotic assembly domain.

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Therefore, various methods have been proposed to facilitate the task of teaching robots (Argall et al., 2009). Many researchers have applied virtual reality technologies (Aleotti, 2004; Li, 2000; Chong, 2009), while others have used intuitive teaching methods such as leading robots directly by human hands (Maeda, 2008) or instructing robots by voice (Pires, 2006). Although these methods indeed simplify the task of teaching robots, they overlooked the essential fact the task of teaching robots is to transfer knowledge from human workers to robots.

By teaching robots a series of assembly tasks, it can be seen that the repetitive teaching of similar tasks and the repetitive revising of a new task are the main causes of the slowness of the task. To solve this problem, it is important to be able to share and reuse the skills and experiences of skilled workers. Thus, this paper proposes a knowledge based system (KBS) for sharing and reusing knowledge in robotic manufacturing. The fundamental issue in this approach is how to acquire and accumulate the knowledge of skilled workers into a knowledge base, i.e., a knowledge infrastructure.

Generally, the skills and experiences of skilled workers are a kind of tacit knowledge that is difficult to clearly articulate and transfer to others. Nevertheless, skilled workers can do implement such tacit knowledge in their demonstrations of teaching robots. As a result, the robotic programs of skilled workers are products of the skills they used, and contain their tacit knowledge. The problem herein is how to identify such an essential part that is implementing their skills and reusable to other similar cases. In this paper, a method based on explanation-based learning (EBL) is used to selectively acquire the knowledge of skilled workers by analyzing their robotic programs.

EBL is a deductive learning method for acquiring generalized knowledge from a single specific observation (DeJong & Mooney, 1986; DeJong, 2006). In contrast to other learning methods, such as artificial neural networks (ANN) that require many training examples, EBL can learn new knowledge from a single example, with the aid of a knowledge intensive analysis using a domain theory (i.e., a pre-encoded knowledge base) (Mitchell et al., 1986; Wang et al., 2008). Because it enables learning without repetitive human tutoring, EBL is an appropriate method for learning the tacit knowledge of skilled workers. Sawaragi et al. (2006) have applied EBL in container loading problems to capture the tacit knowledge of experts. Levine and DeJong (2006) have used EBL to generalize operation skills in the flight domain. In this paper, a modified EBL is proposed to design the knowledge based system.

In the following of this paper, we introduce the background of robotic assembly and the EBL method, and the related works. We present the proposed KBS and its knowledge acquisition mechanism and present experiments on reusing the acquired knowledge along with analyzed results. Next, we compare the proposed method with other methods and discuss the importance of tacit knowledge sharing. Finally, a conclusion is presented.

**BACKGROUND DESCRIPTION**

**Problem in Robotic Assembly**

As shown in Figure 1, robotic assembly refers to using two or more robots in a work cell to complete the assembly of a wide variety of products that are made of various workpieces.

Robot teaching is the most important and difficult work in robotic assembly. Workers teach a robot in the following steps: 1. making a program for the task of assembling a work-piece; 2. Setting the robot in teaching mode, and teaching the robot the coordinates of points in the program with a teaching pendant; 3. checking the effectiveness of the teaching by letting the robot execute the commands one by one; 4. setting the robot in playback mode to check the automatic execution of the robotic program.

Robot teaching is awfully time-consuming for the following two main reasons. First, workers have to teach robots repeatedly even for similar assembly tasks, because there is no
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