Development of a plastic injection molding training system using Petri nets and virtual reality

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Received May 20, 2005; revision accepted Sept. 1, 2005

Abstract: In this study, Virtual Reality (VR)-based plastic injection molding training system (VPIMTS), which can be modeled as an integrated system with a task planning module, an intelligent instruction module, a simulation module, and virtual environment (VE) module, was developed. Presented in this paper are an architecture of VPIMTS, a practical knowledge modelling approach for modelling the training scenarios of the system by using Petri nets formalism and key techniques (FEM, injection molding procedure modelling) which have been developed independently. The utilization of the Petri net model realized the environment where the trainee can behave freely, and also made it possible to equip the system with the function of showing the next action of the trainee whenever he wants. The overall system is a powerful approach for highly improving the trainee’s comprehension and injection molding study-efficiency by building digital, intelligent, knowledgeable, and visual aids.

Key words: Virtual reality, Petri nets, Plastic injection molding, Virtual training, Finite element methods

INTRODUCTION

At present, plastic as a substitute for metals in products is the most important mainstay in industrial raw materials. Furthermore, plastic injection molding is one of the most common and versatile methods for mass production of complex plastic parts with excellent dimensional tolerance. Since the technology of injection molding has been widely applied in manufacturing, training on injection molding is of great importance. The traditional approach is to consult some technical books on injection molding and an operating manual and follow their instructions. It is not only time-consuming but sometimes, important information is not retained. A trainee may also look for advice from experienced workers. But lengthy explanations to trainees are mostly ineffective. Training in injection molding can possibly be done in a real factory where the trainee practices operating a real injection machine, but it is expensive and dangerous because mishandling during the process of training may damage the expensive injection machine.

In view of the above findings, the development of an intelligent, knowledgeable and digital training platform for the training in injection molding is critically important. The learning platform for virtual injection molding developed by Zhang (2002) uses C-Mould software to calculate analytical data by using finite element methods, and integrated with the animation of Flash, simulates the injection molding machine motions, helps the trainee to realize the operating condition of the injection molding machine and is a good tool for the training of novices in injection molding. But, the main shortcoming of this platform is that it is unattractive because of the use of 2D images, which makes this platform lack the “feeling” of reality, more importantly, the human-computer interaction.

Virtual Reality (VR) technology is applied as a solution to the training system for injection molding. VR technology makes it possible for anyone to experience various kinds of operations in a virtual environment just like in the real world. VR-based training is considered to be one of the fields to which
VR technology can be applied effectively (van Dam et al., 2002; Vora et al., 2002; Wang et al., 2004). But, although the availability of VR in the field of training has been recognized, one remaining problem of a training system in a virtual environment (VE) is that the behavior of the trainee is very limited and the workload of the instructors is heavy.

The aim of this study is to develop a new type of injection molding training system in VE in which the trainee can behave freely and can get advice on what to do next whenever he wants in order to reduce the workload of the instructors. In this study, the formalism of Petri nets is applied for representing the operating and injection molding procedures.

Petri nets constitute a general tool for describing the behavior of concurrent discrete events (Sorensen and Janssens, 2004; Kiritsis et al., 1999). The use of a Petri net model realizes the environment in which the trainee can behave freely, and is also the function that shows the next action to implement in a virtual environment to the trainee. Furthermore, in this study, an immersive and interactive VPIMTS is created on an Onyx2 workstation, a toolkit WTK and OpenGL interface by using VR technology and finite element methods (FEMs). A practical knowledge modelling approach is applied to model the training scenarios of the system by using Petri nets formalism. The overall system is a powerful approach to improve the trainee’s comprehension and study-efficiency on injection molding by developing digital, intelligent, knowledgeable, and visual aids.

FRAMEWORK OF THE VPIMTS

In this approach, a VPIMTS is composed of four interactive modules: a task planning module, a simulation module, an intelligent instruction module, and VPIMTS environment. Fig.1 illustrates the modules and the message flow among them. Briefly, the functionality of the modules is as follows:

The responsibility of the task planning module is to adaptively generate appropriate training task plans based on a Petri net according to training goals. It is composed of a knowledge base, a goal decomposition, an action analysis and Petri net modelling. The final training goal of the VPIMTS can be formulated as “make the trainee familiar with the manual operation of an injection machine and know the procedure of injection molding”. Based on the knowledge of injection molding, first, decompose the final complex training goal into simple sub-goals and then analyze plausible actions of the trainee. Then construct goal-task decision tables from which to extract the corresponding training task according to the training goal inputted by trainee. Finally create the training plan using Petri net.

![Fig.1 Program architecture](image)

The simulation module receives the training plan from the task planning module, and initializes the model including CAD modelling, FEM and injection molding procedure modelling. The shape and structure of an injection mould and a machine are different (for example a double-plate or three-plate injection mould and a horizontal or vertical injection machine). Also 3D geometric modelling of manufacturing equipments including injection mould and machine is fussy and complicated work by using CAD software. Because of these reasons, with integration of OpenGL interface, a geometric model of an injection mould and an injection machine based on the boundary representation is created by using Delaunay triangulation technique (Escobar and Montenegro, 1996). In this system, the database of geometrical model of injection mould and injection machine is created.

The intelligent instruction module continuously receives messages from the task planning module and provides timely instruction and recommendations to the trainees according to their performance.

Finally, the VPIMTS environment sends training goals inputted by a trainee to the task planning module, receives the instructions from the intelligent in-