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Petri Net-based workflow management systems for in-process control in a plastic processing plant

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Abstract

To manage a complex system, an operation model is proposed for evaluating the effectiveness and efficiency of each possible plan. During the planning process, an easy-to-use modeling system for operation modeling could be very useful for assisting the shop floor manager to understand and predict the performance of operation plans. In this paper, the Petri Net is used as a tool to realize the proposed modeling concept. Derived from the basic Colored Petri Net (CPN) language, a Modular Colored Petri Net (MCPN), composed of a number of CPN Modules (CPNMs), is proposed for this adaptive modeling approach. The CPN in each CPNM represents the discrete event logic of the corresponding operation. Despatching rules of the material and activities are modeled by the components and functions of the CPNs in these CPNMs, and the dynamics of the system can be modeled by the transition firing and connections amongst them. In this way, the time and cost for the development and maintenance of the shop floor operation model can be reduced. The application of the system in in-process control in a plastic processing plant is illustrated in the paper.

Keywords: Workflow modeling; Colored Petri Net

1. Introduction

1.1. Workflow management

A workflow management system (WMS) is defined as a system that completely defines, manages, and executes workflow through a software application where the order of execution is driven by a computer representation of the workflow logic [1]. The basic functions of a WMS, including the definition of tasks and procedures, are discussed in [2]. Management of workflow covers the manipulation of information involved in controlling, monitoring, optimizing and supporting a business process. Since workflow management develops a systematic foundation to specify and manipulate information, it can be adopted to solve many communication problems in production management. With an effective WMS in the system, business policies and practices can be automatically deployed, implemented, monitored, measured and, if necessary, improved. Moreover, with an in-depth understanding and a well-defined formal definition of the business processes in an organization in the development and operation of a WMS, the flow of business processes can be continuously improved through systematic analyses. Adoption of an effective WMS can also foster better tracking of business processes and enhance the reliability of the operation system.

A typical plastic processing routing involves a large number of steps in complex sequences in various stages of the operation, such as planning, preparation, forming, finishing, decoration and recycling. Examples of some common steps are given in Table 1.

These complex sequences of tasks involve various types of resources such as machines, operators and their skills, etc. It is found that since each step requires only its specific resource, other resources are usually in an idle state. In order to optimize the productivity of the resources, the allocation of work to them must be carefully planned and managed. A workflow system for a material processing environment to speed up its work by eliminating non-value work both within and between operations and to balances the overall work load to improving the overall efficiency is required. It is used as a tool to assist different levels of executives, engineers and clerical staff to improve their productivity.

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Table 1
Examples of the steps in a typical plastic product production using the injection molding method

Categories	Sub-categories	Examples	Required/labor resource
Planning		Mold design	Engineer
		Machine selection	Engineer
		Material selection	Engineer
Preparation	Material preparation	Drying	Drying chamber/labor
		De-airing	Vacuum chamber/labor
	Mold preparation	De-rust	Mold/labor
		Cleanup	Mold/labor
		Mold setup	Mold/special labor
	Machine preparation	Container cleanup	Injection machine/labor
		Hooper filling	Injection machine/labor
		Barrel filling	Injection machine/labor
		Test injection	Mold, injection machine/special labor
Forming		Injection molding	Injection machine/special labor
Finishing		Parting	Labor
		De-solventing	Labor
		Deblurring	Files/labor
Decoration		Printing	Print machine/labor
		Hot stamping	Hot plating machine/labor
		Pad plating	Pad plating machine/labor
		Spraying	Spraying machine/labor
Recycling		Internal recycling	Granulating machine/labor
		External recycling	Labor

For effective planning of a complex system, an operation model has to be constructed for evaluating the effectiveness and efficiency of each proposed plan during the planning process. However, owing to the complexity of such a model, the development process using traditional methods is usually time-consuming and error-prone. To overcome these problems, which are mainly due to the ill-organized and partitioned structure of the specification of operation and its components, a more systematic and structural methodology is required.

Objects and events to be handled in a workflow system in a plastic process plant cover a wide range of tasks at different levels of aggregation. However, a number of basic types of primitive elements of a workflow model were categorized in [4] as shown in Table 2.

1.2. An example: an injection molding workshop

This example describes an injection molding workshop with three injection machines, Machine_1001 to 1003.

Table 2
Elements of a workflow system

Elements	Definition and features	Examples in plastics processing
Business process (sub-process)	It is a set of one or more linked procedures or activities which collectively realize a business objective or policy goal, normally within the context of an organizational structure defining functional roles and relationships	Produce 300 Product_A (including Machine, Mold and Material preparation, Machine Setup, etc.)
Task	It is the smallest meaningful unit of work	Fill material into hopper
Resource	It is the tool or other substance that is required for the execution of some work items	Operator_1
Work item	It is a task which needs to be executed for a specific case. Some work items are executed by a resource	Fill material for Product_A into hopper of Machine_1
Activity	It is a work item which is being executed by a specific resource	Fill material for Product_A into hopper of Machine_1 by Operator_1