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E-catalogue library of machines for constructing virtual printed-circuit assembly lines

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Abstract

To easily and smoothly construct a virtual production line for a simulation of environmental performance, productivity and manufacturability, the use of a manufacturing machine e-catalogue library is proposed in this paper. A machine vender such as a machine tool maker and equipment provider registers an e-catalogue of his product to the library using a corresponding template. The designer of a production system constructs a virtual production line by selecting an adequate manufacturing machine's e-catalogue from the library. In this paper, this e-catalogue library concept is applied to the electric-power consumption simulation of a PCA (Printed Circuit Assembly) line. A PCA line consists of a solder paste printing machine, two or three electronic part mounters, reflow furnace and testing machine. Each machine's e-catalogue consists of descriptions not only for specifications but also for computational expressions according to the behavior of the machine. Using experimentally implemented e-catalogues, virtual PCA lines are configured for simulation of electric power consumptions. These virtual lines are configured as a multi agent system of machine agents which are generated based on a selected machine's e-catalogue.

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1. Introduction

At the production planning stage, traditionally, simulation systems have been used to forecast productivity, manufacturability and so on [1-4]. There are various types of simulation systems available commercially [e.g. 5,6]. Furthermore, recently, cyber-physical manufacturing systems such as Industry 4.0 and Industrial Internet are the big trends [7,8]. In both cases, it is required to construct a virtual production field in the virtual factory on the computer as a simulation field. A virtual production line is constructed by connecting virtual machines. A virtual machine is constructed based on a machine model.

A virtual machine is usually implemented as software such as a software agent which is a model of a machine. This machine model contains static properties and dynamic behaviors. There are several useful standardization efforts [9-12]. Unfortunately, in these efforts, the provided machine model is not enough for the construction of a virtual production line. This is because they are only for modeling static properties of manufacturing machines and connecting relationships among components parts of machines. In addition to this modeling, behaviors such as state transition and operation results which are produced as a combination of machine activities should be modeled.

For a simulation of environmental performance in addition to productivity and manufacturability, the digital eco-factory has been proposed by the authors [13-15]. The digital eco-factory is constructed on the virtual production line modelling an actual production line which is constructed by virtual machines. An environmental performance simulation strongly requires to model dynamic behavior of machines. A multi-agent based construction of the digital eco-factory was applied and a trial digital eco-factory had been implemented for a PCA (Printed Circuit Assembly) line [16]. This trial showed that dynamic behavior accurately can be modeled as a software agent.

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However, it is difficult for the user of a production simulation system such as a production system designer and operator to write a software program of agents. Then, it is proposed that a user constructs a virtual production line by selecting an adequate machine model from the repository. A machine model can be called an e-catalogue of a machine and the repository of machine models can be called an e-catalogue library. In this paper, it is shown how to model the machine behavior and how to make e-catalogues through a PCA example. A trial system is examined for electric power consumptions in a PCA line.

2. Virtual production line for the simulation of energy consumption

2.1. Requirements to a machine model by the digital eco-factory

Three use cases of a digital eco-factory are considered [15,16]. The first case is the determination of the configuration of the production line and the examination of performances of newly introduced machine/equipment by virtual manufacturing execution according to the testing production scenario from the energy efficiency view and productivity view. The second use case is applied after process planning which is supported by the product design tool such as a CAD/CAM system. This case is the evaluation of the production plan for the product by virtual manufacturing at a digital eco-factory. The third use case is monitoring the actual production line by comparing with reference data from the digital eco-factory. In any use cases, simulation on the virtual production line is required. Watching the state changes of virtual machines on the virtual production line in a time series is important. Because if only total results are watched, it is difficult to find points for improvements.

Energy efficiency such as electric power consumption is changed according to the status of a machine, such as operational or on standby. Furthermore, the power consumption in the operation status is changed depending on the produced product. It means that a machine model should include a behavior model in addition to property descriptions.

2.2. Construction of the digital eco-factory using the e-catalogue library

When using the digital eco-factory at first, the user constructs his/her own virtual production line on the computer. This constructing procedure starts the step of selecting machine e-catalogues from the library and describing the connecting relationship between machines, control policy and etc. A machine e-catalogue includes the following machine behavior descriptions in addition to the specification and properties:

- states of machine (e.g. stand-by, in operation)
- state transition and transition trigger (e.g. material input, power on, operation finish)
- relations among activities (e.g. operation sequence)
- required product data, schedule data and operation data
- calculating formula and required parameters (e.g. energy consumption, operation time)

The conceptual structure of a digital eco-factory constructing system is shown in Fig. 1. After selecting e-catalogues, the system generates a description for machine agents and the configuration of the virtual production lines to construct a virtual factory. The virtual factory on which simulation is done is constructed as a multi agent system. When using the digital eco-factory, input of a production scenario such as product data, schedule and operation data are required. These data affect to machine behaviour

2.3. The e-catalogue library of machines

A machine vendor such as a machine tool maker and manufacturing equipment provider develops a machine e-catalogue of his machine using a corresponding standardized template, or a machine vendor prepares a machine e-catalogue by following standardized methods and rules. A machine vendor registers the e-catalogue to a common repository or their own open repository for distribution. This common repository is called the e-catalogue library of machines. In Fig. 2, the e-catalogue registration system is shown.

A template is prepared by machine type. Normally, one machine type has one template. Machines of the same

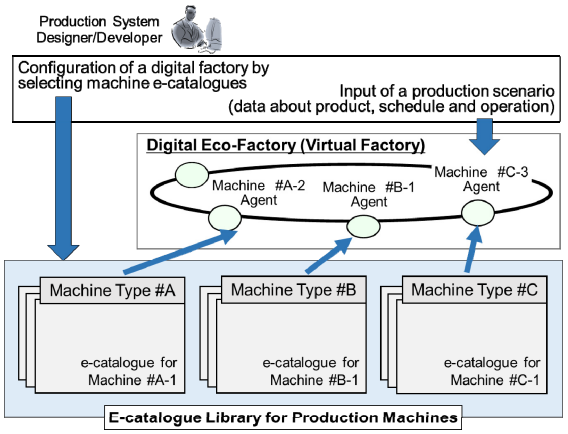

Fig. 1. Construction of the digital eco-factory using the e-catalogue library.

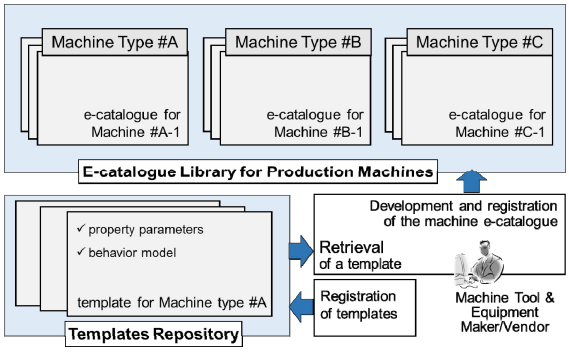

Fig. 2. Construction of a machine e-catalogue library.