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Automatic Simulation Model Generation Based on PLC Codes and MES Stored Data

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Abstract

One of the most widespread techniques to evaluate various aspects of an existing manufacturing system is discrete-event simulation (DES). However, building a simulation model of a manufacturing system needs great resource expenditures. Automated data collection and model buildup can drastically reduce the time of the design phase as well as support model reusability. Since most of the manufacturing systems are controlled by low level controllers they store structure and control logic of the system to be modeled by a DES system. The paper introduces an ongoing research of PLC code processing method for automatic simulation model generation of a conveyor system of a leading automotive factory.

Keywords: Programmable Logic Controllers; Manufacturing; Computer Simulation

1. Introduction

During the last few decades planning and control of production systems developed in parallel with computer sciences. As it is well known, one of the most important factors for a production firm is to secure the widest product variability and the minimum lead time. These requirements lead to complex production systems that run in a rapidly changing environment. Planning, monitoring and control of a manufacturing system can be significantly supported by creating the digital map of the real factory and processes.

To make responsible production planning and control decisions of a production system based on the information of the digital factory is always a nerve-racking task because there might be differences between the digital and the real factories. So it is essential to keep digital representation valid by following the changes occurred in the real factory. The conventional way to achieve this is to refresh the digital representation manually after any (some) changes in the real factory that is a time and resource consuming task.

Discrete event simulation (DES) is one of the most widely spread techniques to evaluate various aspects of a manufacturing system [2], [6] and [7]. However, on the one hand, the design phase of a simulation project needs great resource expenditures. On the other hand, simulation is usually applied to long-term planning, design and analysis of manufacturing systems. These models are termed “throw away” or “stand-alone” models because they are seldom used after the initial plans or designs have been finalized. As opposed to the “traditional” use of simulation, Son et al. proposed that once the system design has been finalized, the simulation model that was used for evaluation also could be used as the basis for system control [11]. In their concept simulation was created by using neutral system components, i.e., they made efforts to build simulation models for Shop Floor Control System (SFC), generated automatically.

Data needed to build simulation models of manufacturing systems are available in production databases or

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can be collected. Nowadays majority of the enterprises apply PLCs for low level control of processes. Subsequently, the topology and the control logic of the manufacturing system needed for a simulation model are inherently kept in these PLCs. In our understanding topology is a directed graph in which nodes represent the elements (e.g. robots, tool machines) of the manufacturing system. The edges are the connections between the elements. They exist if there is possible material flow between the elements. The direction of the edges represents the direction of the material flow. Accordingly, building material flow simulation models of a production system can be supported by data and control logic extracted from PLC programs.

The paper introduces an ongoing research of PLC program and historical data processing method that generates a structured dataset that can be used by manufacturing simulation software to automatically create and parameterize a model.

2. Automated simulation model building

As stated by Ryan and Heavey in [13] a simulation project can be characterized by the so called "40-20-40 rule" regarding the required time ratio. The rule states that time spent developing a simulation project can be divided as follows:

- 40% to requirements gathering,
- 20% to model translation,
- 40% to experimentation.

Several previous studies aimed at reducing the time needed by the development phase of a simulation project of an existing manufacturing system that highlights the importance of this topic. The time-consuming requirements gathering phase contains data collection and preparation. Significant planning time reduction can be achieved by automating data gathering and preparation of an existing manufacturing system [12].

Several approaches have been used automatic simulation model buildup by automatic input data gathering and processing. Park et al. in [8] suggested a naming rule in PLC codes to automatically identify objects and control logic in code giving a basic data set to build simulation model. This approach needs a renaming process on PLC codes if naming rule suggested is not applied.

Bagchi et al. describe a discrete event simulator developed for daily prediction of WIP position in an operational wafer fabrication factory to support tactical decision-making in [1]. Model parameters are automatically updated using statistical analysis performed on historical event logs generated by the factory, while "snapshot" (specified later) of current status of production is generated by using the manufacturing execution system (i.e., aggregated info of PLCs).

The most widely spread applications of using PLC codes for generating simulation models aims at verifying PLC codes themselves. Han et al. propose a prototyping to improve limitations of existing control logic verification methods and ladder programming in [5]. The technique proposed by them supports functionality verification of PLC code on low control level.

A certain research was carried out to develop a method to reduce the time required for building simulation models. Wya et al. proposed a generic simulation modeling framework to reduce the simulation model building time in [3]. The proposed framework is composed of several software that contain information of layout and control logic of the modeled objects. According to this approach layout and control logic of manufacturing systems must be designed by the appropriate software.

As it was highlighted several developed method apply PLC code processing for supporting automatic simulation model building and some of them is for evaluating PLC codes themselves. Contrarily PLC code process method proposed by the authors of this paper is for evaluating the effects of changing PLC codes on the overall system.

3. Novel solution for reducing simulation model building time

3.1. Data needed to build a simulation model

Regarding the conventional simulation model building method the data of system topology can be gathered from the shop floor layout that provides information on the physical structure. Basically the layout identifies elements of the system, their dimensions and internal distances.

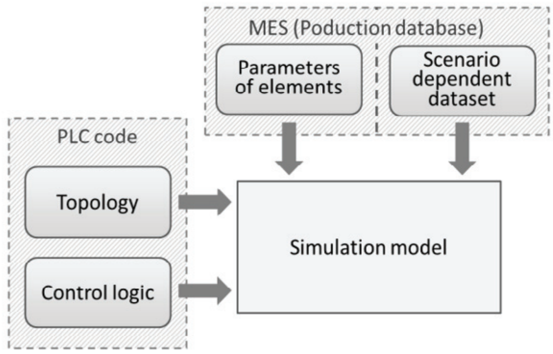

Fig. 1. Data gathering for simulation model

Our approach relies on data which are or can be made available in MES and PLC code (see Figure 1.).

Elements controlled by PLC have unique identification, so a list of elements can be retrieved from PLC program. Relations of elements also can be extracted from PLC programs, because there are references in the code between elements that are connected. Hence topology of controlled system is incorporated in the PLC program.