PLC CODE PROCESSING FOR AUTOMATIC SIMULATION MODEL GENERATION

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ABSTRACT
One of the most widespread techniques to evaluate various aspects of a manufacturing system is discrete-event simulation (DES) (Banks 1998, Law and Kelton 2000, O'Rielly and Lilegdon 1999). However, building a simulation model of a manufacturing system is a difficult task and 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 (e.g., PLCs, CNCs) 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. Results of the validation process and simulation experiments are also described through a case study.

Keywords: PLC code, manufacturing, simulation, generic simulation model

1. INTRODUCTION

As majority of manufacturing simulation projects constrained on financing issues or on close deadlines, it is necessary to reduce the most time-consuming and expensive tasks of a simulation project. The design phase of a simulation project constituted by input data preparation and model building can be significantly reduced by using automatic data gathering and processing.

On the other hand, simulation is 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. (2001) proposed that once the system design has been finalized, the simulation that was used for evaluation could be used as the basis for system control. 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 model of a manufacturing system are available in production database or can be collected. Nowadays majority of the enterprises are installing automated manufacturing system (AMS) consisting of programmable logic controllers (PLCs). Subsequently, the topology and the control logic of the manufacturing system needed for a simulation model are inherently kept in these PLCs. Consequently, building of simulation models can be supported by data and control logic extracted from PLC codes.

The paper introduces an ongoing research of PLC code 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 (2006) the most commonly used rule of a simulation project is the so called "40-20-40 rule". 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.

Time-consuming requirements gathering phase contains input data collection and preparation. Significant planning time reduction can be achieved by automating data gathering and preparation.

Several approaches have been used for automating simulation model buildup by automatic input data gathering and processing. Park et al. (2010) suggest 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. (2008) describe a discrete event simulator developed for daily prediction of WIP position in an operational wafer fabrication factory to support tactical decision-making. 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 PLC).

The most widely spread applications of using PLC codes for generating simulation models aims of verifying PLC codes themselves. Han et al. (2010) propose a prototyping to improve limitations of existing control logic verification methods and ladder programming. The technique proposed by them supports functionality verification of PLC code on low control level. Contrarily PLC code process method proposed by the authors is for evaluating the effects of changing PLC codes on the overall system.

Several previous studies aimed of reducing the time needed by the development phase of a simulation project of a manufacturing system that highlights the importance of this topic.

Research is carried out to develop a method to reduce the time required for building simulation models. Wya et al. (2011) proposed a generic simulation modeling framework to reduce the simulation model building time. The proposed framework composed several software that contained information of layout and control logic of the modeled objects. According to this approach layout and control logic of the manufacturing system must be designed by the appropriate software.

3. NOVEL SOLUTION FOR REDUCING SIMULATION MODEL BUILDING TIME

3.1. Data needed to build a simulation model

Simulation models related to manufacturing systems require several types of data.

Shop floor layout provides information on the physical structure. Basically the layout identifies elements of the system, their dimensions and internal distances. Elements controlled by PLC also have unique identification, so a list of elements can be retrieved from PLC code. Relations of elements also can be extracted from PLC codes, because there are references in the code between elements that are connected. Even it is not easy to reverse engineer them the topology of controlled system is incorporated in the PLC code.

Second indispensable information of manufacturing systems is the control logic of their elements. Control logic describes the response to be given on PLC’s output depending on the input. The control logic consists of structured methods so variables and object’s relationship can be transformed to the language of the simulation software.

It is also necessary to parameterize elements of the simulation model. Most of PLC codes do not operate with these kinds of parameters of controlled element however, AMSs usually apply Manufacturing Execution System (MES) that stores status changes of controlled elements and timestamp of state change events. Possible states and parameters of elements can be retrieved by statistical evaluation accomplished on these data as shown on Figure 1.

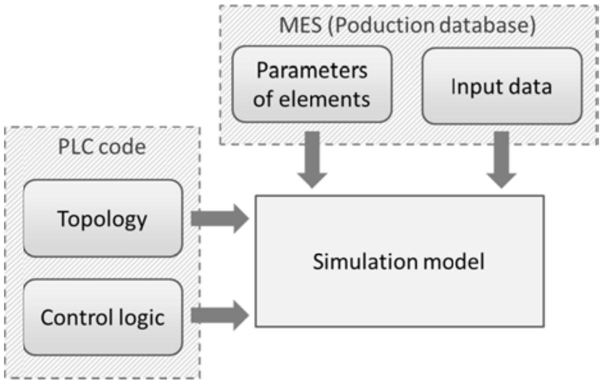

Figure 1: Data gathering for simulation model

3.2. Data needed to run a simulation model

After building and parameterizing a simulation model it is ready to evaluate system performance in several production scenarios. Evaluations of the response given to cut-off scenarios are commonly used technique of testing maximum performance of a system. They are also called stress tests. Performance limits of a system can be determined by stored historical data of factory. Input parameters of cases when system run on maximum performance can be automatically detected by defining parameters that shows performance of the system and parallel recording the set of input parameters as well.

In order to evaluate behavior of systems in situations that have never happened before input parameters must be set manually. This type of experiments is so called “what-if-scenario” experiments.

Ramp up phase distorts results of the simulation run so it is necessary to ignore or avoid it. In order to achieve this goal simulation run must start from a steady state. A so called snapshot of real system is created and initial states and parameters of model are set according to states and parameters of snapshot. To analyze the behavior of a system in real time, snapshots are created periodically. This adaption of simulation model needs real time connection with production database hence it is an on-line application of the model.

3.3. Proposed methods

As mentioned above, several types of data are needed to build up a simulation model. Each type of data is generated by different methods and processes.

3.3.1. Variable and value identification of the PLC code

The base of data gathered from PLC code is in AWL format according to text-based IEC 61131-3 standard. A grammar definition language (ProGrammar, www.programmar.com) is applied to identify variables, values and methods of PLC codes by defining rules and the nature of them. As PLC code is a strictly defined language this process can be applied on different codes as well.

The test PLC code as all the PLC codes consists of blocks. One block describes the behavior of one actuator (e.g. electric engine actuating the conveyor). Every block consists of two main parts (see Figure 2):

- In the first part the inputs of the PLC are stored in the appropriate memory field.
- The second part of the block is for function call. The arguments of function call are defined in this part, as well as the name of the function.

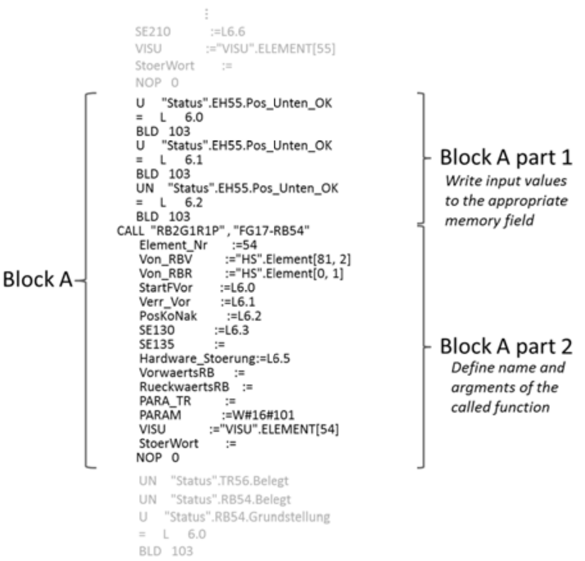

Figure 2: PLC code part

The well-defined syntactics of the code allows the identification of all inputs and parameters. As ProGrammar is a grammar definition language it is possible to create a language to identify the variables and parameters of the code by parsing the code with the defined language. Data stored in the code such as the connection of the objects can be gathered by this process, as all the blocks have references to the id of the connected objects. According to the direction of the material flow two type of reference exist:

- Reference to the next object (successor object)
- Reference to the previous object (predecessor object)

Possessing the information of the connections of the object it is possible to generate the system topology.

3.3.2. Topology graph generation

A technical computing software (Mathematica, www.wolfram.com/mathematica) is applied to visualize the results of the above process (see Figure 3). Results support the automatic buildup of simulation models.

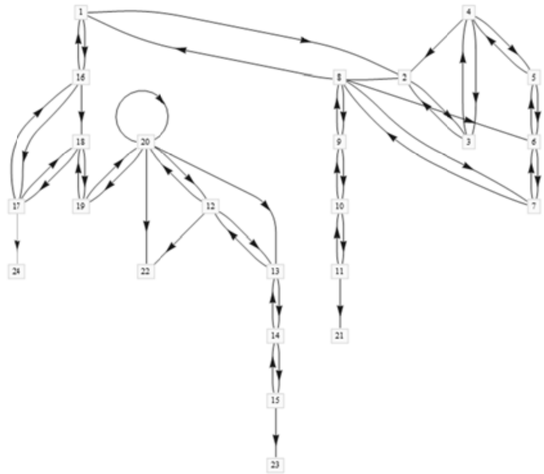

Figure 3: Part of topology of a conveyor system

As Mathematica is suited to call the parsing method of ProGrammar using a predefined command, it can be fed with data of connection among the parts of the conveyor system. After a conversion of data, the topology of the examined system can be generated by a graph creating command. The data received from ProGrammar can also be converted to a connection table form. Special simulation software (Tecnomatix Plant Simulation ver10) and its internal connection tables and methods are applied to generate the simulation object instances and run the simulation. (see Figure 4).

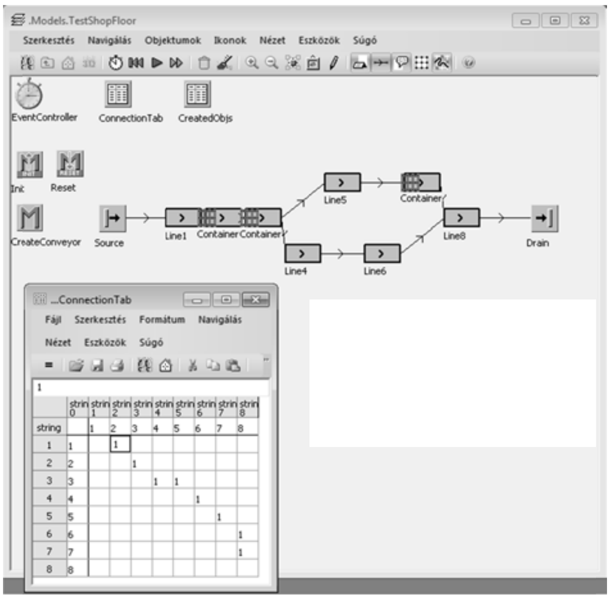

Figure 4: Screenshot of test run executed on simulation model

A production database is used by providing parameters of the elements and input data for the simulation model (see Figure 1). Directly and indirectly usable data are gathered from MES database, and transformed as well as processed to the format that simulation software is able to apply (Kádár et al. 2010, Pfeiffer et al. 2009., Pfeiffer 2007.).

4. PRELIMINARY SIMULATION RESULTS

The proposed solution introduced in the previous section is tested on real data of complex conveyor system in a large-scale manufacturing factory by using a part of the real PLC code of the running system. Main drawbacks of currently applied simulation methods enlisted by decision makers for testing changes of either physical system or control system are as follows:

- specific building blocks, models of processes are redundantly implemented in separated systems, which results in more development time and costs;
- there is no integrated design and analysis environment or system where the overall system and processes can be analyzed;
- there is no factory-standard, uniform user interface;
- results of current simulations cannot be automatically adapted in real system;
- real-time daily use is not possible (manual changes required).

On the base of the above assumptions, the target of the research is to build a new simulation system in which the simulation model is an inherent part of the control system hence, input comes automatically from real execution system and support is provided to evaluation of simulation results.

This means the collection of data from PLC level, enabling reliable, automatically generated DES models, furthermore, manual intervention regarding simulation (data collection, modeling, parameterizing) can be reduced to a definitely low level.

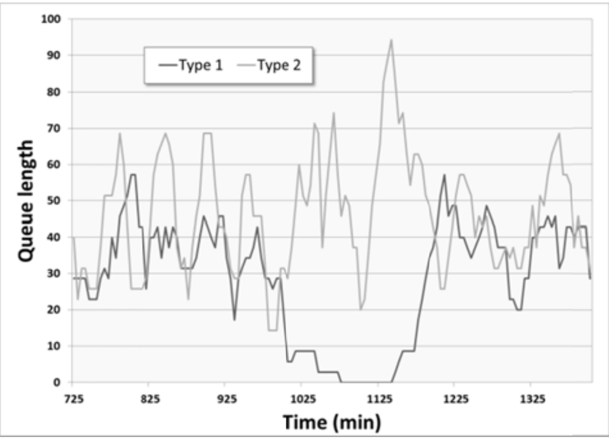

Figure 5: Number of waiting pallets on a critical section of conveyor system

Two main areas of use are distinguished when creating simulation from PLC level codes automatically:

- Off-line, i.e., planning level: Simulation is used for analyzing effects of changes in system, and fed with historical input data and relevant production data for parameterization.
- On-line, i.e., execution level: Simulation is applied for short-term “what-if” analysis. In case of certain deviation or disturbance has occurred decision maker is able to test several predefined methods, scenarios for resolving problem.

Figure 5 shows results of a preliminary test run of number of waiting pallets on a critical section of conveyor system. Two types of pallets (Type1, Type2) were examined in this test.

Consequently, these results of simulation experiments can be easily adapted in real factory, thus enabling fast, flexible and smooth changes in factory, e.g., analyzing possible effects of changes in some part of PLC code of control system.

5. CONCLUSIONS

This paper revealed a discrete-event simulation approach applied for decision support of control related production applications. Design phase is a significant part of a simulation project; hence reducing time of it heavily affects the effectiveness of the whole project. Automated data gathering supporting the buildup of simulation models is a possible solution to achieve this goal and is also a solution to create reusable models. Several approaches were studied in the topic and revealed that PLC codes store information needed to build up a simulation model. A new process for extracting topology and control logic data of system from PLC codes has been introduced. Data stored in production database were used to parameterize objects of the model and generating input for simulation experiments.

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