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3D Visualization System of Manufacturing Big Data and Simulation Results of Production for an Automotive Parts Supplier

Dahye Hwang¹[0000-0002-0990-1484] and Sang Do Noh^{1*}

¹ Sungkyunkwan University, Suwon, South Korea
sdnoh@skku.edu

Abstract. Recently, many manufacturers have recalled their products owing to quality issues. It is increasingly difficult to determine the cause of quality issues because of the complexity of the supply chain. Thus, it is essential to share manufacturing information throughout the product life cycle. However, small and medium-sized enterprises (SMEs) often lack the necessary infrastructure and information systems.

This research proposes an open-source system allowing the 3D visualization of production history and simulation results. The production history includes products' time stamps and inspection results, defect information, and a status of each facility. This information is then used to construct a product workflow and simulation model. Further, it is possible to compare simulation results for up to three alternative scenarios. The system is developed using open-source libraries for easy diffusion and application to SMEs in the automobile industry. A method for the implementation of this system to Korean auto parts companies is introduced.

Keywords: 3D Visualization, Lot Tracking, Manufacturing Information.

1 Introduction

As the companies involved in the production cycle of products are diverse, identifying the cause of quality issues is often extremely challenging and time-consuming [1][2]. A more thorough record and analysis of production cycle information could mediate this challenge [3]. However, many small and medium-sized manufacturing companies have difficulty systematically organizing information generated during parts manufacturing due to a lack of appropriate information infrastructure [4][5]. Additionally, as the fourth industrial revolution develops, the number of research efforts to digitize factories increases. However, most of this research surrounds real-time data exchange for virtual reality factory implementation or Cyber Physical System realization [6][7][8].

This study proposes an open-source 3D visualization system to cope with quality problems after shipment. If a quality problem occurs within the quality assurance period after its sale to customer, it is difficult to find the cause by simply checking production

history of product. The purpose of this study is to provide users with an intuitive view of quality problem by visualizing production history data. The system presents process status and material flow of the product claimed after its delivery. It also allows users to simulate a production model with their inputs by using production history as the base information and returning simulation results in 3D.

2 3D Visualization of Production History and Simulation Results

The architecture of a 3D visualization system of production history and simulation results is shown in Fig 1. It consists of a user application, a production history tracking system, a 3D visualization system with a simulation engine, and four databases.

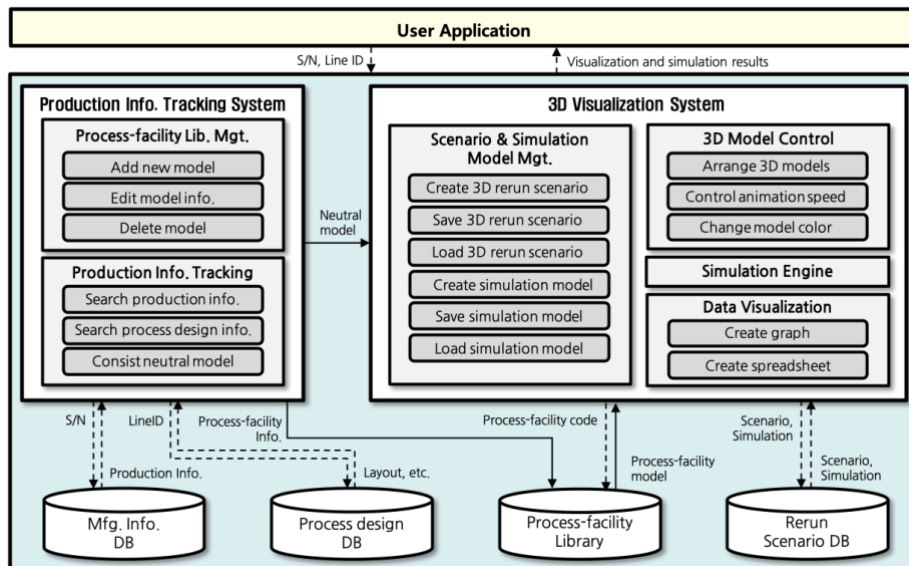


Fig. 1. An Architecture of 3D visualization system

The user application manages the input and output of the system. A serial number with the “Product/Lot” information is used to track an item’s production history. Production line code is used to load a layout and location data of facilities. Simulation settings include the total simulation time, warm-up time, process cycle time, loading/unloading time, buffer capacity, and defect rate. Finally, the user application outputs a 3D visualization of past production flow and simulation results.

A production history tracking system consists of two management modules: one for the process-facility library and one for the production history. While the process-facility library management module handles adding, editing, and deleting 3D models and the basic information for processes and facilities, the production history management

module searches past production information of ‘Product/Lot’ using its serial number and configures a neutral file to represent the scenario.

A 3D visualization system is composed of a simulation engine and three management modules for (1) rerun scenario/simulation, (2) 3D model control, and (3) data visualization. The rerun scenario/simulation model management module creates, saves, and cuts rerun scenarios or simulation models. Each scenario includes up to three simulation models and is created based on a neutral file generated from the production history tracking system. Rerun scenario contains real production history and visualization data, such as capacity, defect rate, process sequence, process-facility codes, and layout, to represent line status when the selected product was being produced. On the other hand, simulation model contains process time and buffer capacity in addition to the rerun scenario’s visualization data. The 3D model control module accelerates or decelerates the speed of 3D objects in the presented animation. The data visualization module refines raw simulation data and shows the result in graphs and tables.

The four databases used in this system are (1) the process-facility library, (2) the manufacturing information database, (3) the process design database and (4) the rerun scenario database. Of these, the manufacturing information database and process design database are part of a legacy system, for example, MES. The process-facility library is a 3D model library consisting of a standard process-facility and a customized process-facility. A standard process-facility library provides a basic pre-modelled 3D model commonly used in the target industry, and a customized process-facility library containing user applied process-facility 3D models.

3 Implementation

In this study, a standard process-facility library was developed by selecting commonly used facilities found by visiting all the production lines of the target company. As a result, 23 types of facilities frequently used in the electric component manufacturing line were selected and modeled in 3D using Trimble's SketchUp Pro 2018.

To evaluate the performance of the developed 3D visualization system, authors requested software testing from the Korea Testing Laboratory. The evaluation measures the time required to run a single 3D process facility model and then divides the time by the size of the model file to calculate the speed (sec/MB). Table 1 summarizes the system environment for the performance evaluation.

Table 1. Tools/Software used in system development

Item	Tool/Software
OS	Windows 10 Pro 64 bit
CPU	Intel Core i7-7700 CPU 3.60 GHz
RAM	16 GB
HDD	500 GB
Programming Languages	C#
Open-source Library	MonoGame

Seventeen models were selected at random from the process-facility library to measure the speed. Sizes of the model files used for the evaluation are between 1.00 MB and 1.6 MB. The loading speed of the model had a maximum of 0.768 sec/MB, a minimum of 0.692 sec/MB, and an average of 0.735 sec/MB. Additionally, the difference between the fastest loading time and the slowest loading time was very small, 0.076 sec, which suggests that the model loading speed is more affected by the loading preprocessing than by the model file size.

Visualization of a large amount of production history information with 3D animation makes it easier to identify the problematic process and the results of the inspection process than when viewing such information in the existing text-based documents. In particular, when confirming the production history information of each lot, it became easy to specify information on various layers such as time, process, and product as shown in Fig. 2. Facility which has defect history or is selected by user highlight in red or blue.

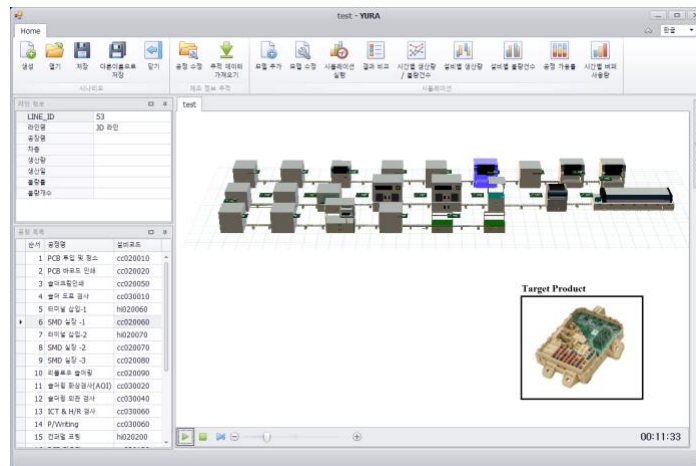


Fig. 2. Example of production history visualization

As a result of the simulation, the number of defects per hour, the number of defects per facility per hour, the utilization of each process, and the buffer utilization over time can be efficiently viewed and considered as seen in Fig. 3. Simulation results are available to show in 3D animation as production history visualization.

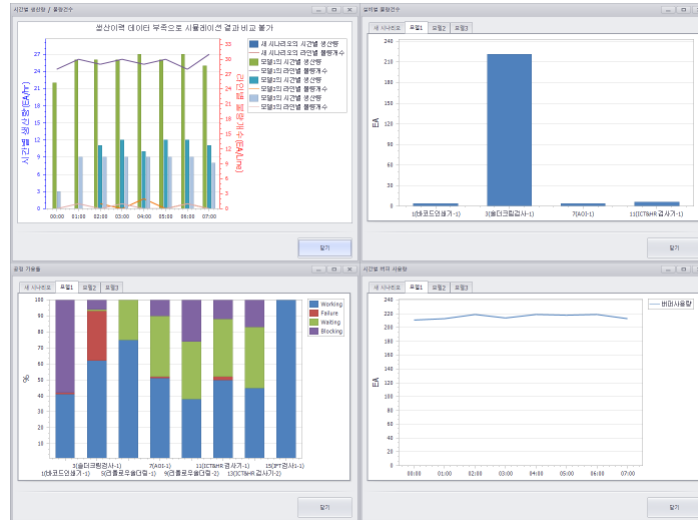


Fig. 3. Examples of simulation results

4 Conclusion

This research has developed an open-source based 3D visualization system of production history and simulation results for SMEs. Through this system, the production environment of specified product or lot can be represented in 3D. In this manner, users can better visualize supply chain occurrences and errors through analyzed data rather than through extensive text and document-based data. For example, users who want to check a production line or process status at a specific production point can view the necessary information on a single screen without a separate query search or document comparison. To evaluate current production live productivity, a comparison of present production lines and hypothetical alternatives is possible through simulations that utilize adjustable settings.

Applications to the other production lines and improvement of the simulation engine's performance are required as a future works of the research.

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