

복잡한 제조 및 물류 시스템에서의 시물레이션을 위한 자동 모델 생성 프로세스

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Automating Model Building Processes for Simulation of Complex Manufacturing and Logistics Systems

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ABSTRACT

Simulations have been used to evaluate the efficiency of logistics or manufacturing systems and predict the outcomes of the systems. New simulation models are needed to evaluate new alternative plants and layouts during the resource design process. Although it is easy to handle minor changes in parameters by modifying a simulation model, it takes considerable time and effort for simulation modelers to alter the layout, which involves changes in many simulation sub-models. Therefore, this study proposes a method to transfer information in AutoCAD layout to the simulation model automatically. This study also defines a standard document as an Excel Form, and suggests a method to transfer information on the basic layouts, processes, resources, and workers to a simulation model automatically. A simulation tool, called Tecnomatix Plant Simulation 9.0, was used for this study. The proposed approach in this study was applied to a semiconductor wafer factory for a case study.

Key words : Simulation, Layout, Automatic Modeling, Semiconductor, AutoCAD

요약

시물레이션은 물류 또는 제조 시스템의 효율성을 평가하고 시스템의 결과를 예측하는 데 사용되었다. 새로운 시물레이션 모델은 시설 설계 프로세스 중에 새로운 대체 설비 및 배치를 평가하는 데 필요로 한다. 시물레이션 모델을 수정하여 매개 변수와 같은 사소한 변경을 처리하기는 쉽지만 시물레이션 모델러가 많은 시물레이션 서브 모델의 변경을 포함하여 레이아웃을 변경하는 데는 많은 시간과 노력이 필요로 한다. 따라서 본 연구에서는 AutoCAD layout의 정보를 시물레이션 모델에 자동으로 변환하는 방법을 제안한다. 또한 표준 문서를 Excel 양식으로 정의하고 기본 레이아웃, 프로세스, 시설 및 작업자에 대한 정보를 시물레이션 모델에 자동으로 변환하는 방법도 제안한다. Tecnomatix Plant Simulation 9.0이라는 시물레이션 전용 Tool이 사용되었다. 본 논문에서 제시한 접근한 방법은 반도체 웨이퍼 공장을 대상으로 사례 연구되었다.

주요어 : 시물레이션, 레이아웃, 모델 자동화, 반도체, AutoCAD

1. Introduction

Simulations are popular tools for providing standard,

objective, and reliable data about a system to predict the performance and design a system in a range of fields. The following benefits of performing a simulation project were estimated by the VDI-directive 3633 (VDI, 2009): (1) 20% of the total investment cost is influenced by the simulation; (2) the investment is reduced by 2-4% at 0.5-1% cost of the total investment for the simulation. Despite the usefulness of the simulation, whenever a project is conducted, a human expert is needed for modeling, and it takes excessive time to

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construct models of various alternatives. In a real situation, the simulation study cannot be done for various alternatives because of the manual remodeling required, which consumes considerable time with many detailed changes in the basic model required to obtain a good layout.

In general, the simulation procedure consists of the abstraction, simulation modeling, experiments with the interpretation of results, and the modifications of the simulation model, which is illustrated in Figure 1. This procedure from the simulation modeling to the modifications of the simulation model is repeated as many times as necessary before it is put into practice. After obtaining information on the performance of the system, the layout or input parameters of the simulation model need to be modified, which has previously been done manually in traditional approaches.

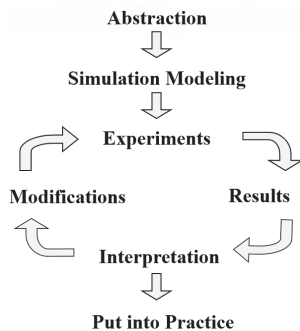


Fig. 1. The procedure of simulation

Modifications of the AutoCAD layout and input data are the most time consuming work when revising the simulation model. A simulation modeling method in a plant simulation provides a function of saving a CAD layout figure file, which is a type of bitmap (png, jpg, bmp etc), and then imports the figure file to use as a background image. Next, the modeler determines the scaling factor by considering the size of the background image of the simulation model. He/she can then collocate resources, paths of the transport equipment and those for people moving onto the image of the simulation. This type of the manual work during simulation modeling is popular in the modeling process by using the simulation tool in this paper as well as by most of existing plant

simulation tools.

Simulation modeling can be done manually when the number of resources and the size of the layout are small. On the other hand, in situations where the number of resources is too large and the simulation model is too complicated, it takes a large amount of time for modeling and the modifications, and, in addition, there is a high likelihood of error during the modification, such as missing resources, incorrect input of the data into the model, and incorrect connections among guide paths. It is extremely time consuming to modify the model whenever there is a change in the CAD layout. As a result, only a small number of alternatives can be evaluated through the simulation study.

When a set of input data is transferred to the simulation model, in most cases, the data is input into the model through Dialog screens and the variables are input manually one by one. Some parts of the input data may be entered into the simulation model using various types of Text files, Excel files, Xml files, or database forms. In simulation models, manual input of the data of various types can cause errors in the input data, whose accuracy is critical to the success of a simulation study.

To overcome the disadvantages of the manual input of the data to simulation models, this study proposes a method to change the modeling work from the manual operation to an automatic operation. This method is expected to enable a person, who is not a simulation modeling expert, to construct a simulation model and perform a simulation experiment using the input data extracted from the AutoCAD layout and Excel file.

2. Literature reviews

Many simulation studies have been done in manufacturing and logistics areas. Qiao et al.(2003) proposed an approach to a data-driven manufacturing design and simulation system. Using a shop data information model that contains information on the orders, manufacturing, negotiation, facilities and management, a scenario manager combines and reconfigures the function groups, each of which represents a typical

manufacturing capability. Tyan et al.(2004) propose an integrated modeling framework for analyzing the combined effects of machine dispatching rules and material handling vehicle dispatching rules in a fully automated semiconductor fab. The framework consists of the input data and parameters, the simulation model, and the presentation mechanism. Benjamin et al.(2006) described the role of ontologies in facilitating simulation modeling. They outlined the technical challenges in distributed simulation modeling and described how ontology-based methods can be used to address these challenges. Mavel et al.(2011) described a case study of integrating a simulation system with the production planning and scheduling process in a tier two automotive supplier. Kamrani et al.(2010) proposed a structured methodology for analyzing manufacturing complexity due to increased product variety. A series of cost models were developed to capture the impact of the increase in product variants on inventory and storage costs of subassemblies. The paper presented a set of simulation-based methodologies for measuring complexity.

Some researches have discussed the simulation model building to reduce the time and costs for its development. Kim et al.(2009) proposed a generic simulation modeling framework to reduce the time needed to construct a simulation model. They discussed how to develop an integrated simulation model in a short period of time for production processes and material handling processes using the AutoMod simulation tool (Applied Materials, Inc.). Park et al.(2010) suggested a naming rule in PLC codes to automatically identify objects and control logic in program code giving a basic data set to build a simulation model. Wy et al.(2011) also proposed a simulation modeling framework which is composed of several software that contain information on layout and control logics of the objects. They used AutoMod as a simulation platform. Song et al.(2011) suggested a framework for integrating a production simulation and material handling simulation for a TFT-LCD fabrication plant, in which the integrated simulator could be subdivided into a control system and an application system using the software layer. Choi (2012) suggested a framework to automatically generate the simulation

model of production and material handling system by using the AutoMod simulation tool and the Excel file. However, the additional Excel work is required to draw a simulation layout from the AutoCAD layout. Ra and Choi (2014) also studied the automated generation of simulation model. The conceptual model design for building the simulation model is manually developed by using the Excel and Visio files. Then, based on that conceptual design, the Arena simulation tool (Rockwell Automation, Inc.) generates simulation model automatically.

Table 1. Comparison with previous works in accordance with automated model building processes

	Choi(2012)	Ra and Choi (2014)	This paper
Converting simulation layout	Manual by drawing in Excel	Manual by drawing in Visio and Excel	Automatic by extracting from AutoCAD
Creating simulation model	Automatic	Automatic	Automatic
Creating product and process data	Not described	Not described	Manual input to Excel file
Simulation tool	AutoMod	Arena	Plant simulation

Although several literatures discussed similar topics with this paper, as shown in Table 1, this paper is different from the two previous studies, which are mostly related to the contents in this paper, in the following aspects: (1) this work suggests automated methods for extracting layout information from AutoCAD files to create the simulation layout automatically; (2) this paper firstly standardizes the documents in Excel form for dealing with various products and processes, which makes it possible to generate a new simulation model only by changing data values in the Excel file; (3) this is the first paper proposing an automatic model building method for a simulation using Tecnomatix Plant Simulation 9.0 (Siemens PML Software, Inc.), which is a simulation platform different from those used in the previous studies; (4) this study developed each operational rule as an independent module (method), which made the modification of the rules much easier.

This study proposes a method for transferring useful

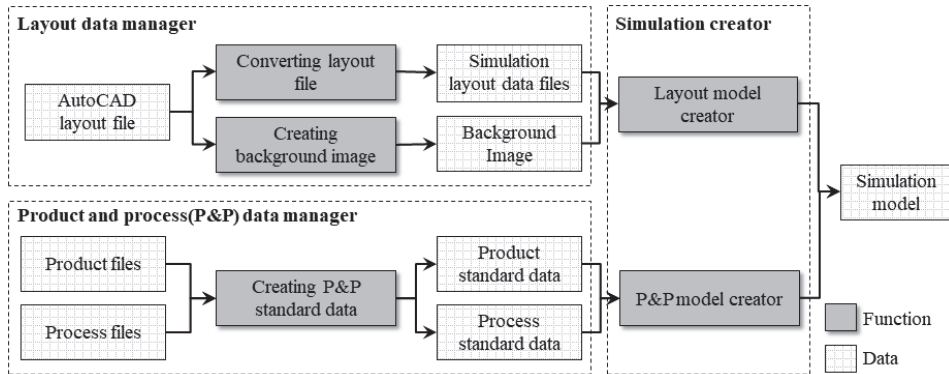


Fig. 2. Framework for automatic building of the simulation models

data from the AutoCAD layout to Excel data when performing a simulation project and a method for generating a simulation model using the Excel data. A procedure for constructing simulation models efficiently is introduced through a case study of applying these methods.

Section 3 proposes a framework of automated model building. Section 4 introduces a case study and concluding remarks are provided in the final section.

3. Framework for Automatic Building of Simulation Models

While the building of a simulation model is normally a manual operation in traditional approaches, it can be done in an automated way through the proposed framework which is divided into three parts (see Figure 2). The first part is ‘Layout data manager’, which is to extract the simulation layout data including the locations of resources and to create background image from AutoCAD layout file. The second part is ‘Products and processes (P&P) data manager’, which creates the input data on the products and processes for the simulation. The third part is ‘Simulation creator’, which develops the simulation model by using the converted layout data file and the P&P data.

3.1 Layout data manager

To support the automated simulation layout modeling, simulation layout data file and background image are

prepared by the functions of ‘Converting layout file’ and ‘Creating background image’, as shown in Figure 1.

3.1.1 AutoCAD layout file

AutoCAD layout data consists of resources and paths of workers or transporters. The AutoCAD data for resources is assigned to a layer code. An example of layer code is the ‘PJ1_01_02_03_01_Milling Machine.’ A layer code consists of the project name, area, process, maker, model, and resource name. Different layer codes may be assigned, even to the same type of equipment. The path for workers to move is one of the most important factors for describing a factory. This is important in the workload analysis because workers might need to carry products manually if automated transporters are not used. Therefore, the path should be described in AutoCAD in detail.

3.1.2 Converting layout file

The function of ‘Converting layout file’, programmed by Visual Basic programming tool, has been developed to convert AutoCAD layout file into simulation layout data file in the Excel form. In other words, this function transforms the AutoCAD layout containing all the information, which is necessary to create a simulation layout automatically, to the excel data. The excel file can include the coordinates of the resources, the names and the codes of the resources, as well as the paths of the workers or transporters. This program has been developed for removing manual works for automatic

layout drawing and defining resources in the simulation model building.

Currently, any drawing by AutoCAD is used as the background of simulation models. On the background of the simulation model, the resources, equipment, and work-path, etc. are modelled manually. However, this study proposes a new way of modeling to avoid these time-consuming works by automatically extracting the data from the AutoCAD and using it automatically in simulation model.

In AutoCAD, any information cannot be stored into the objects. However, to distinguish all the resources and paths in AutoCAD, we utilize the function of ‘Layer’(layer) in AutoCAD. Thus, a resource can be defined as a layer which is classified by project (factory), area, process, maker (manufacturing company), model, and resource name. Each layer for the resources and paths has its own code information. The procedure of ‘Converting layout file’ can be described in more detail as follows:

Step 1: (Manual) Define the layer information for each resource and path on the AutoCAD layout

Step 2: (Automatic) Extract the layer information with code and the coordinate (F_x , F_y) from the AutoCAD layout for each resource and path, where

F_x = x-coordinate of AutoCAD layout

F_y = y-coordinate of AutoCAD layout

3.1.3 Creating the background image

The AutoCAD layout can be directly saved as an image file, which can be used as the background image of the simulation model. In the case of the manual simulation building, the layout image is firstly inserted into the background of simulation. Then, we are easily able to recognize the location of resources and paths from the inserted background image. Next, the resources and paths can be created on their location of background image one by one.

The background image can be transformed as follow: at first, run AutoCAD program; click the Menu → File

→ Plot menu; select the menu in Print/Plotter of ‘PublishToWeb JPG’ or ‘PublishToWeb PNG’. Finally; match the simulation scaling factor with the scale of AutoCAD.

3.1.4 Simulation layout data file

By the function of ‘Converting layout file’, AutoCAD layout data of resources and paths, such as equipment, buffers, worktables and PC desktops, are transferred to a resource table and a path table for the simulation layout data, as illustrated in Table 2. The resource table includes the resource code, the its AutoCAD coordinates of resources, and the layer code data consisting of the project code, area code, process code, maker code, model code, and resource name. The path table includes the coordinates of the worker paths.

Table 2. Illustration of simulation layout data files

(a) Resources

Project	Layer					Code	Coordinate	
	Area	Process	Maker	Model	Resource Name		X(F_x)	Y(F_y)
PR1	_A01	_10	_41	_11	_PC Desk		14743	3950
PR1	_A01	_10	_05	_01	_Table		36480	24627
PR1	_A01	_01	_BP	_03	_Ready Buffer		36500	41195
PR1	_A01	_01	_BF	_05	_Finished Buffer		33770	16634
PR1	_A01	_03	_01	_01	_Milling Machine	MIL01	33817	35702
PR1	_A01	_03	_02	_01	_Milling Machine	MIL05	25230	23836

(b) Path

Layer	Path							
	1st coordinate		2nd coordinate		3rd coordinate		4th coordinate	
Path Code	X(F_x)	Y(F_y)	X(F_x)	Y(F_y)	X(F_x)	Y(F_y)	X(F_x)	Y(F_y)
FP_000001	7433	45271	7433	43895				
FP_000002	32300	30945	32300	30045	32736	30045	32736	28710
FP_000003	28703	28180	29560	28160	29560	27591		
FP_000004	28051	44784	28051	44708	28703	44078		

Through the function of ‘Converting layout file’, the data of AutoCAD are transformed to simulation layout data in the form of Excel file. This can be used to create a simulation model automatically by matching the Layer Code data, the location data of resources and paths, which is saved in excel data with a class model

(equipment, buffer, worktable, worker path etc.).

3.2 Product and process data manager

According to a company that requires a simulation project, the product and process are different and have their own management method. In other words, for each project, the data of product and process are differently defined and entered, which is the time-consuming work. Therefore, we propose the standard document to manage the product and process data for logistics and manufacturing industries. Although the data file for products and processes might be different from one project to another, it is very useful if a standard document for products and processes is created. The created document can be used for the next project with minor modifications to the model or to test other alternatives in the subsequent studies.

The product and process data can include shift schedule, information on products, routes of products, product specification, operation ID, production schedule, and WIP (Work In Process). This data is used for the next function of ‘P&P Model Creator’ to create the attributes and the simulation data of the process objects, equipment objects, etc. in the simulation model.

3.2.1 Creating P&P standard data

As mentioned above, product and process (P&P) standard data should be created from the P&P file of a corporation as input for simulation modeling. P&P standard data has a table format which consists of the information including jobs for production of products, processes, and etc. Table 3 is an example of a job information data table. Table 4 is an example of equipment information data table.

3.3 Simulation creator

Important steps in the simulation modeling are the creation of the simulation model automatically using simulation layout data file, which was converted from the AutoCAD layout and data of product and process by ‘Creating P&P standard data’, which are described as follows:

Table 3. An illustrative table of job information

Field Name		Description
Level 1	Job Name	Job name of the first level
	Job Name	Job name of the second level
Level 2	Job Name	Job name of the second level
	Job Time	Job processing time of the second level
Working Place		Working places or types
Equipment Break Down		Model code of machine
Period of Run (%)	Dist. Type	The types of distributions
	Para. 1	First parameter of distribution
	Para. 2	Second parameter of distribution
	Min	Min value of distribution
	Max	Max value of distribution
	Unit	A periodic unit of running jobs

Table 4. An illustrative table for process information

Field Name		Description
Project		Project code or factory code
Area		Area code of factory
Process		Process code
Maker		Maker code of machine
Model		Model code of machine
Equip. Code		Machine code
Processing Time (Run/Min)	Type 1	Processing time by material type
	Type 2	
	Type 3	
	Type 4	
Quantity/Run		Number of materials processed by a machine in one run
Run Unit		Unit of materials processed by a machine in one run
Input Quantity		Number of material input in a machine
Input Unit		Unit of material input in a machine
Yield Rate (%)	Dist. Type	Type of distributions
	Para. 1	First parameter of distribution
	Para. 2	Second parameter of distribution
	Min	Min value of distribution
	Max	Max value of distribution
Rework Rate (%)		Rework rate uses the same format as yield rate field
MTBF(hour)		MTBF uses the same format as yield rate field
MTTF(min)		MTTF uses the same format as yield rate field
Buffer	Size	Max quantity of buffer
	Unit	Unit of material flow stored in buffer
	Waiting Time	Minimum waiting time of the material
	Mix	Possibility to mix different materials in the same lot

3.3.1 Layout Model Creator

This module creates a simulation layout model using the simulation layout data file including information on the equipment, worktables, the buffers, and paths. For example, it recognizes the resource code and classifies the classes in the simulation model. The location of a resource is decided based on the scaling factor of the simulation model and the coordinates of AutoCAD. The center of a resource in the AutoCAD layout is converted automatically to the center of the corresponding resource in the simulation model.

The layout modeling process is divided into three parts: background image setting, automatic creation of resources, and automatic creation of paths.

The background image setting uses the background image from the AutoCAD layout which is created in the previous phase. This step is not related to the real simulation operation, but is a necessary step for confirming the simulation layout of resources and paths, which are created automatically by ‘Layout Model Creator’.

In the step of automatic creation of resources, the location of resource objects is determined by using the simulation layout data file with the location information of them. Note that the location of resources in the simulation model (px, py) is converted from the simulation layout data (Fx, Fy) by adjusting the reference point (dx, dy) , which is formulated in equation (2). The equation (1) explains that the adjustment of the reference point (dx, dy) which is derived by the difference of the reference location between AutoCAD layout (Ax, Ay) and simulation layout (Sx, Sy) . Figure 3 illustrates the formula for ‘Layout Model Creator’.

Likewise, the paths of workers or transporters are created by using the equation (2) in the step of the automatic creation of paths. The location information of paths is imported from the simulation layout data file, then it is adjusted by the amount of (dx, dy) . Next, the adjacent paths are automatically connected to each other.

$$dx = Sx - \frac{Ax}{1000 \times SSF}, dy = Sy - \frac{Ay}{1000 \times SSF} \quad (1)$$

$$px = dx - \frac{Fx}{1000 \times SSF}, py = dy - \frac{Fy}{1000 \times SSF} \quad (2)$$

where

- SSF : Simulation scaling factor
- Ax : x-coordinate of a reference point in the AutoCAD layout
- Ay : y-coordinate of a reference point in the AutoCAD layout
- Sx : x-coordinate of a reference point in simulation background image matching with Ax
- Sy : y-coordinate of a reference point in simulation background image matching with Ay
- dx : adjustment when Ax is converted to the coordinate of the simulation model
- dy : adjustment when Ay is converted to the coordinate of the simulation model
- px : x-coordinate converted to the location in simulation model from the Fx - coordinate
- py : y-coordinate converted to the location in simulation model from the Fy - coordinate.

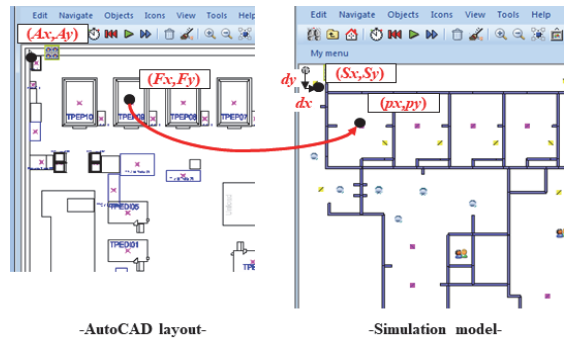
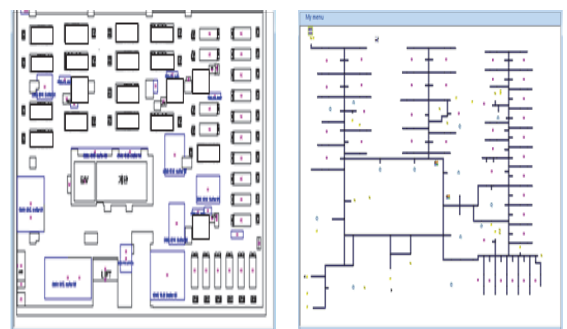


Fig. 3. Illustration of the formula for Layout Model Creator



(a) Background image (b) Created simulation model

Fig. 4. Illustration of a background image and its created simulation model

Figures 4(a) and 4(b) show an example of the background image and the created resources and paths, respectively. The paths and resources can be generated automatically but the connections among the paths and resources should be made manually. This is because the connections are not known in advance. However, it is possible to make some connections automatically by using several rules.

3.3.2 P&P Model Creator

‘P&P Model Creator’ converts P&P standard data to a data table of the simulation model. It consists of 9 modules, as shown in Figure 5.

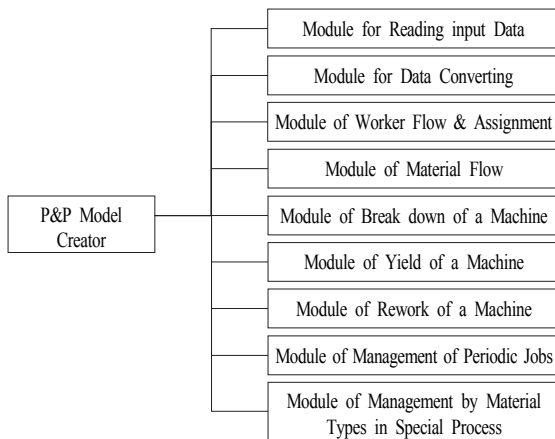


Fig. 5. Major modules of the P&P model creator

Module for Reading Input Data reads data tables from P&P standard data and keep them temporally before being transformed into the data type for the simulation. Module for Data Converting covertes these data into variables, table form, and attributes of objects. Module of Worker Flow and Assignment generates workers with specified flows and assigns works to workers based on their priorities. All works are assigned to workers based on work-priorities. The function of the fourth module is to control material flows starting from arrivals of products and going through transferring, waiting, processing, and up to their shipping (see Figure 6). The fifth to seventh modules represent control break down, yields, and reworks of machines. The eighth module manages jobs which has a periodic occurrence.

The last module manages special products, jobs, and machines.

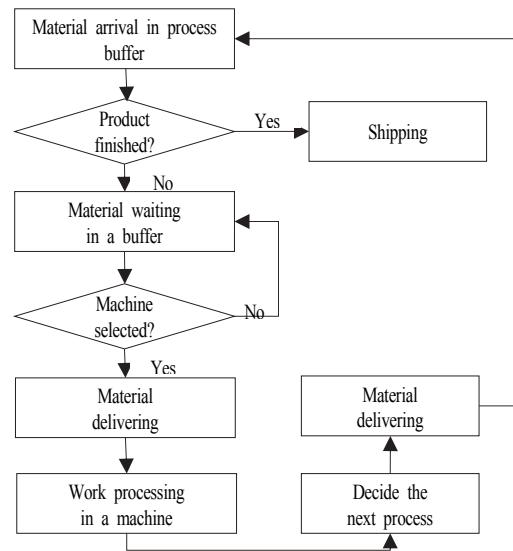


Fig. 6. Overall logical material flow of the P&P Model Creator

4. An Industrial Application

The method described in the previous section was applied to a project to generate simulation models in a semiconductor wafer factory. This company has 8 areas, 37 different processes, 300 pieces of equipment, 560 different resources including worktables, PC desks, and 164 buffers. The entire process for producing semiconductors was included in this case study.

Real data, which are used as the input data, are the monthly production amount by product during one year, the production amount by product during the first month, real WIP data at the beginning of the simulation time, which was used for reducing the warming up time, real data on operation route for each product, and relations between real operation code and layer code in the simulation.

4.1 Model and main elements

The model of this case study was made by the classes in folders of ‘Setting’, ‘Lib’, ‘AutoCreate’, ‘ProcJob’ and ‘AOL’ (see Figure 7).

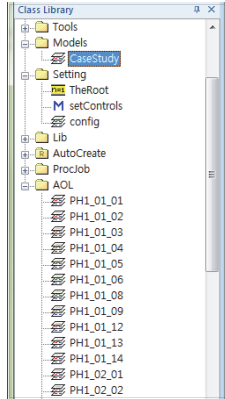


Fig. 7. Classes and model for the case study

The ‘Setting’ folder consists of the global variables of file path, excel sheet name, part size, etc., which are used in the entire model. The ‘Lib’ folder consists of the basic classes required to construct a simulation model. Here, the main basic classes are constructed as follows. The ‘Equip’ class is a representative object describing the equipment of the real system’s process. This class consists of ‘WorkerJob’ object, which describes the job of a worker, and ‘MachineRun’ object, which describes the operation of a piece of equipment (see Figure 8).

In this case, more than 200 machines among 300 machines process at least each 200 ~ 600 jobs. If 200 machines have 200 jobs, at least 40,000 objects is needed in the simulation model. However, this study developed the simulation model with only 22 objects and made it possible to execute the simulation even for the case with a large number of jobs. As a result, the number of objects was reduced to 10%, and the simulation model generation time is reduced to 20% compare with the general model. In addition, the simulation running time could be maintained at a reasonable level even for large sized models by the approach in this study. For example, it took under 12 hours to run a simulation model covering a month in a real situation, while it took a very long time or the simulation is stopped for the same case when the traditional approach was used.

A ‘MachineRun’ object may express the rework of a product, a failure, a pause, and a yield of a machine as well as the normal operation of a piece of equipment.

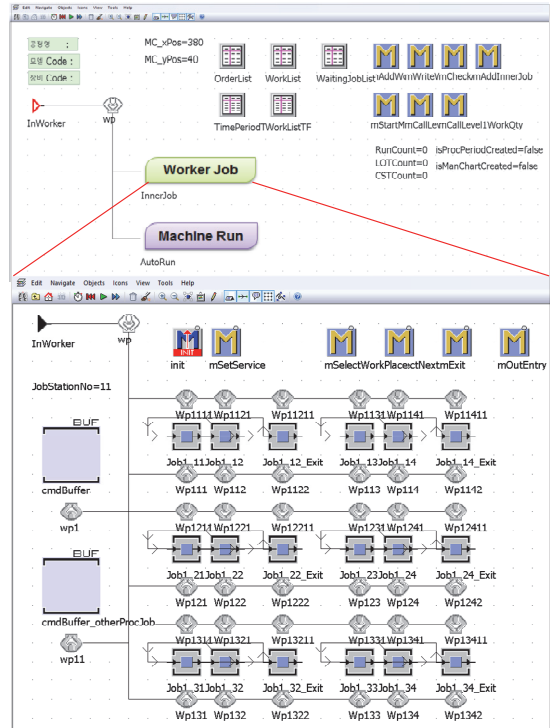


Fig. 8. ‘Equip’ Class

This class also has a function to assign jobs to the equipment, control jobs, and provides the operation priority to each job. The ‘Other’ class is a representative object for describing the resources except machines for the operation. The ‘ProcessBuf’ class is an object for describing the buffers between processes (see Figure 9). This class is for storing products, combining products to a lot, and separating cassettes for feeding them to pieces of equipment.

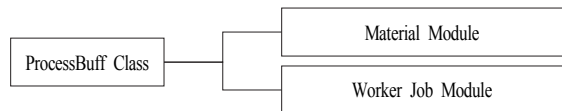


Fig. 9. ‘ProcessBuff’ Class

The ‘Proc’ class is a representative object for describing various processes. This class consists of methods for controlling jobs in a process and data objects, which are converted from standard documents. In addition, this class includes a ‘Workers’ object for assigning workers to the various jobs of a process and equipment.

The ‘AutoCreate’ folder consists of a ‘LayoutCreator’ class for constructing a simulation model automatically and a ‘DocumentsCreator’ class for converting the P&P data files to data tables of the simulation model (see Figure 10). The ‘LayoutCreator’ class is an object for building a simulation model automatically. This class consists of an ‘AllObjects’ object to create pieces of equipment, buffers, processes, and other resources and the ‘WorkerPath’ object for creating the path of workers automatically. The ‘LayoutCreator’ class is an object for converting the P&P data files to data tables of the simulation model (see Figure 11). The ‘ProcJob’ folder consists of process objects created by ‘Proc’ class. The ‘AOL’ folder consists of equipment objects created by ‘Equip’ class. These are created in the simulation model automatically.

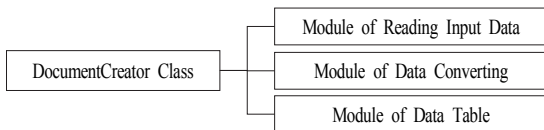


Fig. 10. ‘DocumentCreator’ Class

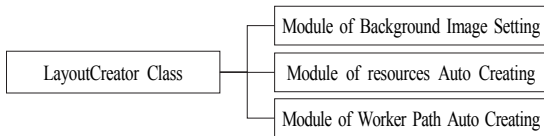


Fig. 11. ‘LayoutCreator’ Class

4.2 Simulation Reports

In this case study, reports on the simulation results provide information on the average down time of pieces of equipment, average lead time in various equipment and processes, average WIP in the buffers and pieces of equipment, and the average working time of workers.

The report on the processing and non-processing time of machines shows the statistical data on the failures, pauses, product shortages, and the processing time of machines (see Table 5 and Figure 12). The report on the lead time shows the statistics on lead time of various pieces of machines and processes as well as on the processing quantities by various machines and

processes. Statistics on WIP shows the changes in the WIP quantities in the buffers and equipment.

As an example of the statistic reports of the simulation, Figure 12 shows a report on the processing and non-processing time of the machine whose table information is described in detail at Table 5.

string	Process Name	Process Code	Layout Layer Code	Machine Code	Down Code
1	LMR	6850	PH1_08_03_01_01	TCLMR03	AutoRun
2	Bulk Inspection	7020	PH1_08_08_01_01	TCBK101	AutoRun
3	PACKING	7350	PH1_08_12_01_01	Pack04	Material
4	DB SIDE POLIS	6100	PH1_06_01_03_02	TPDP563	Material
5	SLIGHT Etching	3900	PH1_04_03_01_02	TEET02	AutoRun
6	PSE-I(SWE)	3305	PH1_01_04_01_01	TSAFP03	AutoRun
7	Lapping	3670	PH1_01_09_01_01	TSLAP06	AutoRun
8	PWE-II	6950	PH1_08_05_02_01	TCWF506	AutoRun
9	DB SIDE POLIS	6100	PH1_06_01_03_02	TPDP562	Material
10	Lapping	3670	PH1_01_09_01_01	TSLAP06	Material
11	Lapping	3670	PH1_01_09_01_01	TSLAP04	Prepare

Fig. 12. An example of simulation reports on the processing and non-processing time of the machine

Table 5. Description of the report table on the processing and non-processing time of the machine

	Description
Process Name	Process Name of Real System
Process Code	Process Code of Real System
Layout Layer Code	Code generated by ‘Layout Model Creator ‘
Machine Code	Machine Code of Real System
Down Code	Event types occurred at a machine
Start Time	Start time of an event
End Time	End time of an event

4.3 Validation and Analysis

In the simulation project for a semiconductor factory, it is usually that 10 ~ 20 days are necessary for converting a simulation layout to the corresponding simulation model manually. Wy et al. (2011) reported that the traditional approach required about 2 weeks to build a simulation model. According to a previous experience by an author at the same company, 10 years ago, it took about 20 days to build a simulation model for the problem of 20% size of the case study in this study and it took 6 months for re-build alternative models which were changed about 20 times. On the other hand,

after developing the program in the paper for generating simulation models automatically, it took less than 1 hour to generate a simulation model automatically. The connection between paths and resources was the only part that was done manually, which took 1~2 hours. Therefore, for all the tasks from the generation of a simulation model to performing a simulation experiment, it took approximately 3 hours in total. Therefore, more than 90% of the time was saved using the model generation modules developed in this study. Table 6 Summarizes the comparison between the traditional approach and that in this study.

Table 6. Comparison between the traditional approach and that in this study

	Traditional approach	Approach in this paper
Layout model creation	10 ~ 20 days	1~2 hours
P&P model creation		1 hour
Layout change	1 ~ 7 days	10 minutes ~ 2 hours
Data change	A few hours	Less than 10 minutes

Through a validation process, it was found that the production capacity of the simulation model was consistent with that of a real system with a gap smaller than 5%. Table 7 illustrates a part of the comparison result on the productivity between the simulation (SIM) and the real system (MES) where the gap for each process between SIM and MES was smaller than 5%. The utilizations of resources of the simulation model were close to those of the real system, and the average difference was smaller than 10% in the result of case study. For the verification and validation, the report on raw data in Figure 12 was used. The reported raw data were the processing time, the down time by the machine type, the flow time of each product by machine. All the raw data during one day were collected and event times of each machine are compared between real data and simulation data to the unit of 0.0001 seconds. In addition, the total time of all elapsed times between events was evaluated to check whether it becomes 24 hours.

Table 7. A result on production capacity between the simulation(SIM) and the real system(MES)

Process	Production capacity				Gap ((C-D))
	SIM (A)	MES (B)	SIM (C=A/B)	MES (D)	
Ingot mount	378,965	379,604	99.8	100	0.2
Wire saw	361,025	379,914	95.0	100	5.0
ASC	360,977	372,083	97.0	100	3.0
PSE-1	360,048	370,541	97.2	100	2.8
Slice complie	390,484	371,082	105.2	100	5.2
Edge grinding	374,625	364,322	102.8	100	2.8
Lapping	350,737	351,240	99.9	100	0.1
LWE	355,294	351,166	101.2	100	1.2
Caustic etching	358,230	344,687	103.9	100	3.9
EWE	358,230	344,696	103.9	100	3.9
Edge grinding2	355,366	333,319	106.6	100	6.6
DB side grinding	356,776	342,878	104.1	100	4.1
PSE2	355,585	342,868	103.7	100	3.7
H/L Mark	173,962	173,380	100.3	100	0.3
HLM Micro	173,767	173,312	100.3	100	0.3
Slight etching	357,111	345,720	103.3	100	3.3
Average					2.9

5. Conclusions

This paper proposed a method for constructing simulation models automatically, and introduced a case study of using this method. Various modules for building simulation models automatically were developed and introduced. The modules for implementing the method include ‘Layout data manager,’ ‘Product and process data manager,’ and ‘Simulation creator’. The ‘Layout data manager’ inputs AutoCAD layout to the automated simulation modeling system. The ‘Product and process data manager’ prepares a standard document for most of the product and process-related data. The ‘Simulation creator’ creates the simulation model automatically using the simulation layout data file, which was converted from the AutoCAD layout data and inputs ‘Product and process standard data’ into the simulation model automatically.

By automating the time consuming processes during

the simulation modeling, it was found that the errors and modeling time could be reduced by more than 80%. These methods can be a powerful method for constructing many alternative simulation models and applying the changed input data to a simulation model. In a case study of a semiconductor factory, using these functions, it was found that many simulation models could be tested to obtain the best alternative in a short time.

As a future study, this model can be used to automate the connection process between the resources and workers. The method in this study can be applied to other areas, such as product systems and logistics systems. In addition, generic modules for generating simulation models, which can be applied to a range of industries, can be developed.

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