Equipment Engineering System
—Domain Specific Modeling Environment for Factory Automation*

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1. Introduction

Domain Specific Modeling provides a modern solution to demands for higher productivity by narrowing the gap between problem and solution modeling. In the past, productivity gains have been sought through new programming languages. Today, domain-specific modeling languages provide a viable solution to the ongoing need to raise the level of abstraction beyond coding, making development faster and easier [1,2].

Within the Factory Automation field, especially with large-scale FA equipment such as semiconductor / liquid crystal / solar array panel manufacturing equipment or automobile assembly lines, many FA controllers, such as Programming Logic Controllers (PLCs), Motion Controllers, Robots, Graphical Operation Terminals (GOTs) etc, are being used. The programming of these FA controllers depends on the type of FA controller and the engineering task for the tool involved (Fig. 1).

As equipment became larger and more complicated, the scale of control software also grew, and the relation between control software for various tools became more complicated. As a result, the behavior of the equipment as a whole became difficult to understand in its entirety, and development took a long time.

In order to solve these problems, we researched and developed Equipment Engineering Systems that model the behavior of the whole equipment as a flow of processes [3].

Fig. 1 An example of FA line equipment

2. Features of Equipment Engineering System

Our Equipment Engineering System models equipment behavior as PLC control flow of a process, because PLCs are at the core of control flow. The flow of processes is described with a visual domain specific language called “Process Flow Description Language”. Fig. 2 is an example of the “Process Flow Description Language”. “Process Flow Description Language” has elements as shown below.

1) The “Hierarchical Process Element” is an abstract unit of process flow.
2) The “Ladder Process Element” is assigned to a ladder program of PLC. It has input and output variables for receiving data from other Ladder Process Elements, and has external variables for sharing data between PLC, Motion Controllers, GOTs and mechanical devices.
3) The “Guard Element”, the “Branch Element” and “Join Element” control data flow between Process Elements.

4) The “Input Element”, the “Output Element” and the “Tag Element” are assigned to external resources such as input and output signals of the mechanical devices. Data flow is shown by lines connecting each element.

A process flow program describes control of the data flow between sub equipments which together constitute the total equipment.

On the other hand, since control of the mechanical equipment is by sequence control, the ladder program can describe control of the mechanical equipment easier and simpler, rather than using “Process Flow Description Language”. Therefore, in our Equipment Engineering System, a user performs hand coding of a mechanism’s control programs using a PLC engineering tool. And ladder programs are assigned to “Ladder Process Elements”.

Fig. 2 An example of “Process Flow Description Language”

These ladder programs can refer to the value of input-and-output variables and external variables of the “Ladder Process Element”, and cooperate with “Process Flow Description Language” through these variables.

The main functions of our Equipment Engineering System (EES) are as follows (Fig. 3).

1) EES describes the whole processing flow for large-scale equipment consisting of many FA controllers, by using the visual domain specific language called “Process Flow Description Language”.

2) EES cooperates with FA controller engineering tools (“Ladder Process Elements” are assigned to ladder programs which control machines).

3) EES automatically generates the “Flow Control Program”, executed on PLC and controls the data passing between “Ladder Process Elements”.

4) EES can debug efficiently by monitoring equipment states on the process flow editor.

Although the data transfer programs between Process Elements are in stereotyped expression, they become complicated because of the huge quantity of codes. EES automatically generates a Flow Control Program which performs this processing. The user can thus concentrate on coding of the mechanical control programs. As a result, it leads to potential increase in utility of the equipment.

3. Evaluation

As shown in Fig. 4, we developed “Imitation FA Line” for evaluating the Equipment Engineering System. “Imitation FA Line” consists of two PLCs, two motion controllers, and one GOT. This Line imitates semiconductor manufacturing equipment. Fig. 5 shows the mechanicals of the “Imitation FA Line”. It is constructed with the “Line Type Imitation Equipment” and the “Cluster Type Imitation Equipment”,

Fig. 4 System construction of Imitation FA Line
Fig. 5  Mechanicals of Imitation FA Line

Table 1  Scale of “Imitation FA Line” program

<table>
<thead>
<tr>
<th>STEPS</th>
<th>RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatically generated program (Flow Control Program)</td>
<td>22333</td>
</tr>
<tr>
<td>Manually programmed ladder program</td>
<td>21239</td>
</tr>
</tbody>
</table>

with each piece of equipment having some sub equipments.

We developed the control program of “Imitation FA Line” combining our Equipment Engineering System and engineering tools for each FA controller. The number of steps and rate of programs generated automatically (Flow Control Program) and the ladder program, which is programmed manually (Mechanical Control Program), are shown in Table 1.

Table 1 shows that the development period of control programs may be reduced by half, by using our “Equipment Engineering System”.

4. Conclusion

In this paper, we described the function of the Equipment Engineering System which models the control software of FA equipment as a flow of processes. Moreover, the result of development of the control software of the “Imitation FA Line” using our system is shown. This result shows that our Equipment Engineering System could automatically generate about half of the control program.

Future work is described below,
- Examination of the description pattern of a process flow program according to equipment classification.
- Extension of “Process Flow Description Language” which describes cooperation between FA apparatus other than PLCs, such as Motion Controllers, Robot Controllers, Graphical Operation Terminals, and etc.

References