Road To Cyber Physical Factory
(Application Examples of Intelligent Factory and its Technology)

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Abstract

The future factory by using Autonomous System, we call Autonomous Decentralized Flexible Manufacturing Systems, is presented. The virtual factory and several kinds of simulations for production systems and scheduling problems is presented. The simulations application examples for automobile production lines are presented. IoT production and Cyber Physical Factory which is the near future manufacturing model are presented. Its application example for automobile parts production is also presented.

Keywords: intelligent manufacturing, cyber physical factory, GA, scheduling, process planning, robot assembly .

1. Introduction

Since 1980, Computerized machine tools and robots have been developed. This paper describes the history of the Intelligent manufacturing systems and their technology including Artificial Intelligence and GA [1][2]. The technology are as follows. The future factory by using Autonomous System, we call Autonomous Decentralized Flexible Manufacturing Systems, is presented. The virtual factory and several kinds of simulations for production systems and scheduling problems is presented. The simulations application examples for automobile production lines are presented. IoT production and Cyber Physical Factory which is the near future manufacturing model are presented. Its application example for automobile parts production is also presented.

2. Manufacturing history

Figure1 shows the history of Manufacturing automation or intelligent technology.

The first step of Manufacturing Automation is Mass Production. The mass production has a kind of conveyer and each operator does his or her jobs of the processes flowed from the conveyer. The first mass production started in the world was Ford motor company.

The second step of Manufacturing Automation is the development of Numerical control machine tools (NC Machine). By the NC machine, variety of parts can be manufactured without setup changes.

The third step of Manufacturing Automation is the development of Transfer production line. The line is based on the mass production and some kinds of variety parts can be manufactured because of computer control and NC machine.

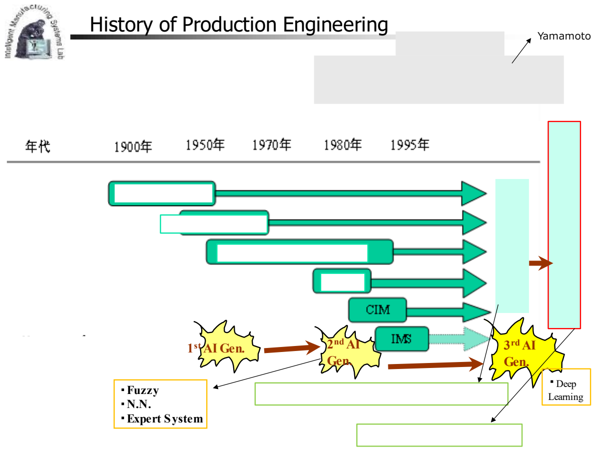


Figure1. Factory automation history

The fourth step of Manufacturing Automation is the development of Flexible Manufacturing Systems (FMS). FMS does not include the conveyer but include Automated Guided Vehicles (AGV), Machining Centers that can operate some processes and Automated warehouse.

The fifth step of Manufacturing Automation is the development of Computer Integrated Manufacturing (CIM). CIM is the computerized technology of not in factory but in all departments of industrial company such as departments of sales, product development, experiment department and product plan department.

The sixth step of Manufacturing Automation is Intelligent Manufacturing Systems (IMS). IMS is called as the 21st century technology.

3. Autonomous Decentralized Factory

One of the IMS technology is an autonomous decentralized factory (ADF) [3][4]. ADF does not need a computer host. ADF has some elements (agents) that represents NC machine tools, Machining Centers, AGVs and warehouse like Figure 2. Without orders of a computer host, each agent includes each knowledge and each agent exchanges other agents' knowledge. Thanks to the knowledge exchanges, ADF can efficiently operate productions. The functions by the knowledge exchanges are negotiations and cooperation. The functions order each agent which AGV takes and sends it to which machine tool. In this way, ADF can give each agent efficient orders and a total factory output efficiency can keep high without production scheduling system. ADF needs a real-time decision making. To carry out the real-time decision making corresponding real-time scheduling, Reasoning to Anticipate Future that the author proposed is necessary.

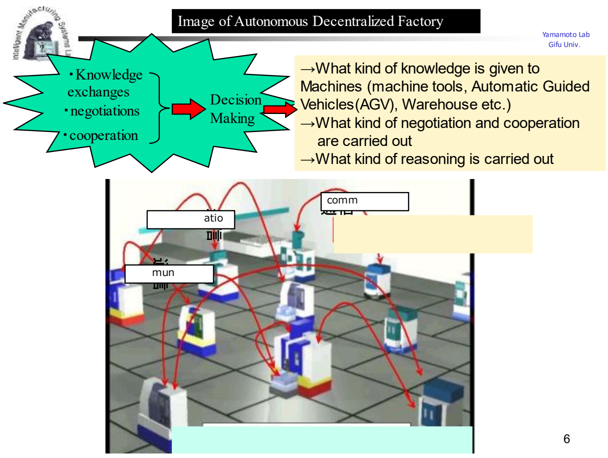


Figure 2. Autonomous decentralized factory

4. AGV and its Mind

When ADF carries out, unexpected problems happen. One of the problems is AGVs collisions or AGV interference.

In order to avoid the problems, the AGV moving control needs some kinds of if-then rules. Although, the number of AGVs are small, the rules take an effect to avoid AGVs interference. When the number of the AGVS moving in the factory, unexpected situations happen and the rules cannot be beforehand expressed.

Human beings can avoid the unexpected happening not always using rules but using a mind. I proposed the AGV mind and applied it into the ADF.

The AGV mind has two kinds of mind, one is the modest mind and the other is the arrogant mind [5][6]. The AGV that has the modest mind gives a way to other AGVs. The AGV that has the arrogant mind forcibly moves (See Figure 3). AGVs sometimes exchange the two minds just like humans do.

By using the AGVs with a mind and AGVs that do not have a mind, many virtual production simulations were carried out.

The results show that the collision (interference) number of AGVs with a mind are 0. The production outputs of using AGVs with a mind are bigger than those of using AGVs that have no mind (See Figure 4).

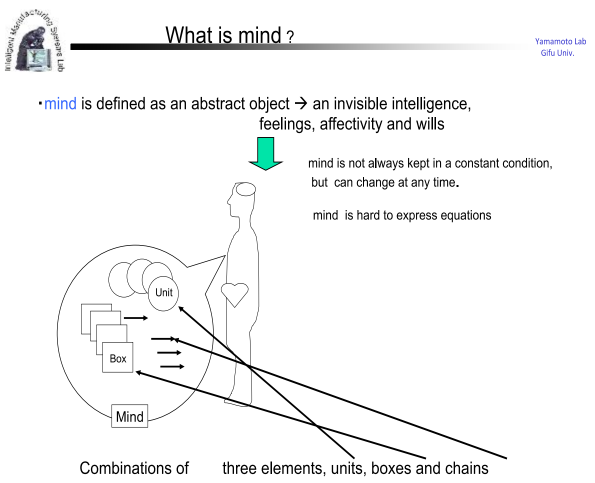


Figure 3. AGV mind

Results

Conditions	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3
MC average efficiency (%)	35.3 21.2	22.9 41.7	25.8 46.8	11.7 19.3	11.4 25.7	16.1 30.7	9.3 16.7	11.6 22.0	13.6 26.9
Collisions avoidance number	161 0	396 0	423 0	105 0	276 0	465 0	123 0	234 0	477 0
Outputs	93 264	86 311	141 349	48 170	45 225	56 272	36 146	48 195	61 235

Without mind / With mind

Figure4. Simulation results for AGV mind

5. Parts layout Decision system by GA

In an assembly line, we need parts supply for an assembly line. To quick parts supply, we need to decide the efficient parts stock area. The efficient means how efficient the operator can pick up the parts from the parts shelves. Because of it, we need to decide which part is put on which shelf like Figure 5 and 6.

In order to solve the problem, the system to find the efficient parts layout system by using GA. We call the system Virtual Assembly Cell-production system (VACS) (See Figure 7)

Figure 5. Parts shelf

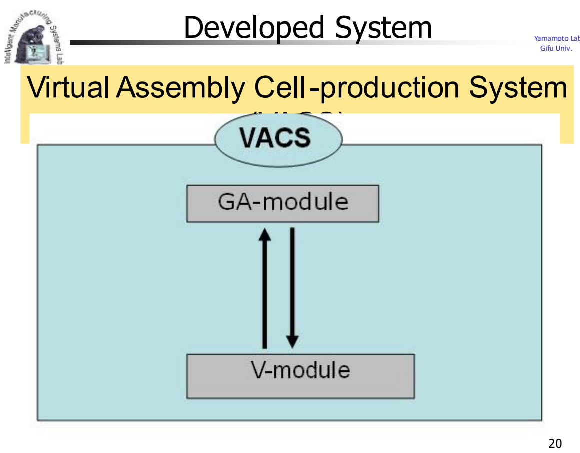
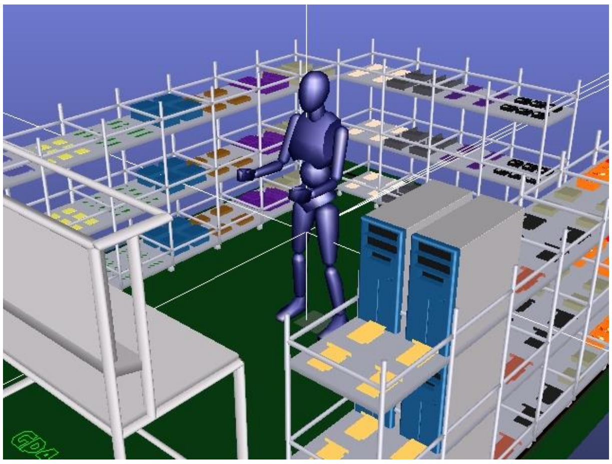


Figure 6. Parts layout and cell production



Fugure7. Outline of VACS

6. Cyber physical factory

Recently, IoT production has been developed. However, The characteristic of the IoT production is to gather information from the production line and machine tools, to analyze the gathered information and to return the analyzed information results. The period between the time og gathering information and the time of returning the results need a few days. That means the IoT production does not carry out the real-time scheduling.

To carry out the real-time scheduling, we need to develop the cyber physical factory.

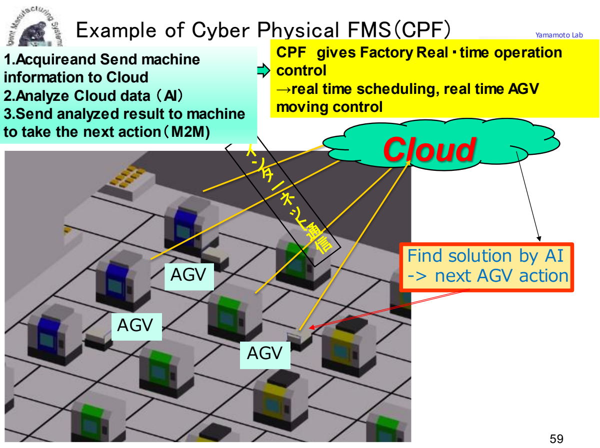


Figure 8. Outline of cyber physical factory

To carry out the real-time scheduling, it is important to use RAF mentioned above. The gathered information is uploaded into the cloud, RAF in the cloud finds the next AGV action and to send it to the agent. The process is carried out immediately.

7. Conclusions

This paper describes the history of the automation manufacturing from the 1900 to the near future. The next important of the industrial companies need Intelligent technology and the cyber physical factory.

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Authors Introduction

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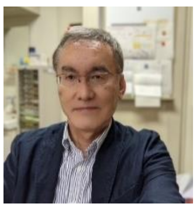

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