Dynamic Schedule Management Architecture Based on Parts and Packets Unified Product System

Eiji Arai[1], Akira Tsumaya[1], Hirokazu Watanabe[1], Hidefumi Wakamatsu[1], and Keiichi Shirase[2]

1) Department of Manufacturing Science, Graduate School of Engineering, Osaka University, Yamadaoka 2-1, Suita, Osaka 565-0871, Japan.
{arai, tsumaya, hirokazu, wakamatu}@mapse.eng.osaka-u.ac.jp.
2) Department of Mechanical Engineering, Kobe University, Rokkodai 1-1, Nada-ku, Kobe 657-8501, Japan.
shirase@mech.kobe-u.ac.jp

ABSTRACT: In a construction project, although the completion day of the project is clearly decided, construction schedule is often changed by the weather or the actual progress situation of the project. Therefore, when a difference arises between present state and the master schedule, it is necessary to adjust the construction schedule and to execute immediately. Besides, since a construction project is usually carried out as a cooperative work by many companies, how to transmit information smoothly and how to share them together are an important issue. In this paper, the dynamic scheduling management system architecture that is based on the parts and information packets unified technology is proposed.

We assumed that each part or unit has a data career, which handle such as identification number, position of the part, state of the part. Some of them re used to define the part's identity. They are given as the initial data, and are unchangeable and static for each part. Another kind of information is changeable and dynamic.

Using these data, progress of the project process is compared with the master schedule. If the difference arises between them, scheduling system derived the present workability of each section/machine/people and dynamically re-schedule to optimize the processes.

A pilot system that realized our proposal is developed and applied to a case study. As a result, the system can derive the changing state of section/machine/people and make the dynamic re-schedule by using the data originating in the part or unit.

KEYWORDS: Distributed System, Dynamic Scheduling, Parts and Packets Unified System Architecture, Production Process.

1. INTRODUCTION

A complicated production system is needed to satisfy by various requirements to production in recent years. The concept of an autonomous distributed production system is proposed as what can adopt to such circumstances. Numerous researches were done to construct intelligent and autonomous production system so far. Many of them focused on product facilities, and constructed intelligent system using network structure. By connecting with a network and communicating each other, each production facility can understand production status and can respond to the status. These methods are available when production facilities and products exist in the limited space like an automation factory. [Ueda, Ranky, Wiendahl, Fujii, Sugimura, Shirase]

On the other hand, the production system which production facilities and products are widely distributed like a construction production project causes problems by combining and communicating production facilities mutually. For example, status grasp cannot be performed on real time when the distance between the facilities is too long, or processing performed during the transfer between facilities cannot be grasped. In the case of the cooperative work by several different companies, it is difficult to combine facilities in a network.

Construction production differs from general machine production in that parts and units are supplied from different wide-spread fields and the component factories are also distributed

geographically. It is difficult that an integrative system treats or utilizes each facilities' information in such a production style.
In recent years, IC tags which can store various data to parts are utilized, and can be used from a viewpoint of cost, size, and a function of communication. Therefore, the information about various production activities are given / read / written by using IC tags which stuck on parts, and the production system which manages the dynamic scheduling based on IC tags can be proposed.

2. CONCEPT OF PARTS & PACKETS UNIFIED SYSTEM

The concept of a dynamic production scheduling system using parts and packets unified architecture is shown in Figure 1. The IC tag is attached in the materials, parts, and units composed with some parts, and ID number and the present status are written in it. Status is rewritten according to becoming a unit from materials. The IC tag attached on a unit transmits ID number, current position, and status through network system whenever it passes through the gate provided in the inside of the factory, the construction site, in the transfer route between them, and the entrance of a warehouse, etc.
On the other hand, as for the production planning side, progress management of the production project is performed by the scheduling system after a master schedule is drawn up. The scheduling system can show the position and status in which each part / unit should exist. By comparing with real-time information on each part / unit transmitted through network system to the information on the master schedule, a gap between the master schedule and an actual state is detectable. According to the quantity of a gap, re-scheduling is performed when the system judges it is needed.

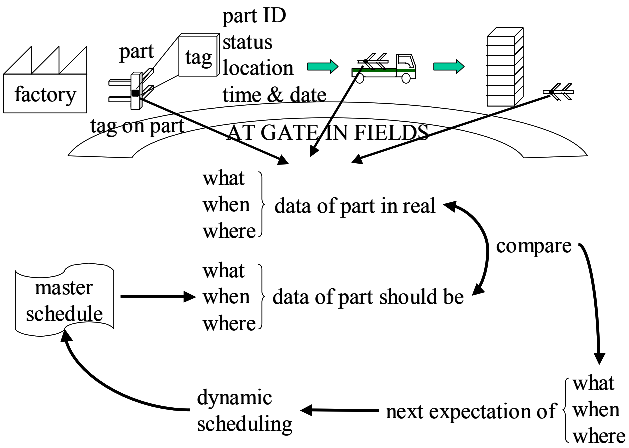


Figure 1. The concept of dynamic production scheduling system using parts and packets unified architecture.

3. SYSTEM ARCHITECTURE

The architecture of parts and packets unified manufacturing system is explained on this section. Figure 2 shows the system architecture in the case of parts processing and assembly processing in a factory. The network system built by the conventional intelligent manufacturing system has combined production facilities, such as production cells and stations. Meanwhile, in the proposed system, the information that each part have in IC tag can be exchanged with network system through the gate provided in each production facilities. For example, at the gate provided in the outlet of a processing facility, the status of parts is rewritten according to the contents of processing.
If the memory capacity of IC tag will become large in the future, it is also possible to compose a network system only with IC tags attached to the parts by storing processing processes and work information in IC tag, and exchanging information about them with production facilities. However, since the present IC tag has not satisfactory memory capacity, the proposed system hybridized the network system which combines production facilities, and parts and packets unified system. Process and work information are transmitted to production facilities from the scheduling and CAM systems through the network. The part ID in the ID tag is checked and after processing process, the status of the part is rewritten and also is sent to

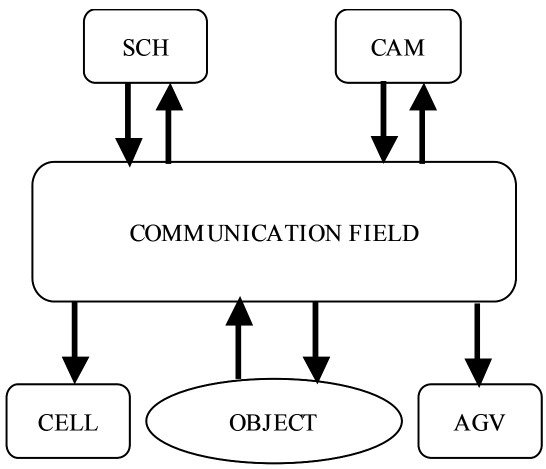


Figure 2. The concept of parts and packets unified manufacturing system architecture in a factory.

CAM system.

Then, the link with IC tag and the network system is described. Two methods can be considered for linking with IC tags and the network system in the field activities; those are shipped and conveyed from a factory, stored in a warehouse, stored in a construction site, performed assembly, and installed as a final position in a building. One is the method of using hand scanner type IC tag reader / writer. By this device, the position, time, and status information of each part can be read / written. The other method is providing gates, which can operate information on IC tags, in required places in the field. By this method, since the data on a IC tag can be automatically read / written when passing through the gate, it is especially useful in a warehouse and a construction site.

Here, the realization of the component driven type construction system by linking IC tags with the network system is discussed. For example, the component assembly process by a robot as shown in Figure 3 is considered. The robot acquires information of a component from a operation server using ID number attached to the component, then operates the component, and sends ID number and the work result of the component it operate to the server. On the other hand, the operation server performs operation and management of components information, and sends the information about a component to a robot according to requested component ID number. [Umetani]

This method using parts and packets unified system can grasp the position of each component on real time. Therefore, parts and packets unified production system can be carried out using data in real time not only for production planning or scheduling but also for work planning such as

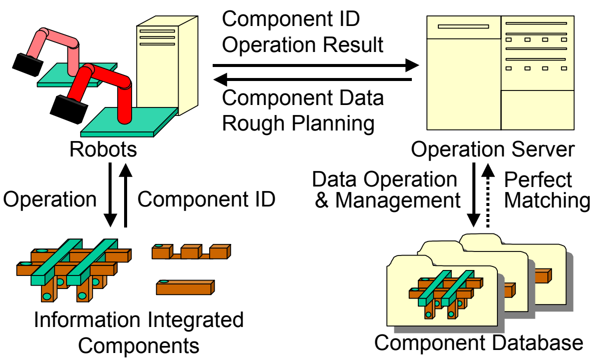


Figure 3. The component driven type construction system by link with IC tag and network system.

planning conveyance route from materials place to assembly position including the sequence of the crane operation. This system can also cope with the case of producing by comparing with actual material management to master schedule.

4. APPLICATION TO DYNAMIC SCHEDULING

In the manufacturing system in a factory, the information of what part and when exists is important. On the other hand, in a construction production, the information of where a part exists is indispensable. For example, efforts for looking for parts in production site, or efforts for arranging parts when they are on the place where they must not exist, are often seen. Although the former function can be supported directly by the proposed system, the method of describing existence position of component corresponding to production schedule is needed in order to realize the latter function. Realization of this function is a future work.

Here, an application system of production process within a factory is explained as an example of the parts and packet unified production system. The components of the system are shown in Figure 4. This example has the following preconditions.

- This factory has following facilities; those are five machining cells, two AGVs (Automated Guided Vehicle), and a storage.
- Previously, the initial value of machining ability on each machining cell is set up as shown in Table 1. If the ability of machining cell changes during the production, proposed scheduling system calculates new value using the started and finished processing time data obtained from parts.
- The manufacturing process in this system is limited to machining operation processes.
- Part processing which consists of several jobs

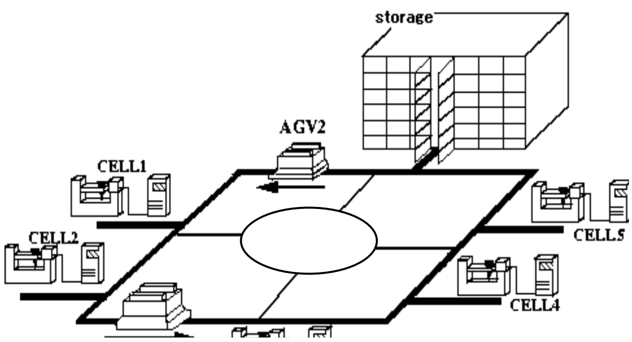


Figure 4. The component of manufacturing system in a factory.

is prepared as a candidate for production example.

- The order of processing jobs is determined beforehand, and cannot be changed.
- Each part has processing geometrical form and volume as data, and machining time is calculated based on these information.
- Scheduling is performed according to the SPT (Shortest Processing Time First) rule which makes the shortest average processing time in the job shop.
- It is assumed that the conveyance capability of two AGV are equal, and it moves in the orbit with one way. Therefore, the distance between each cell is given to a meaning as shown in Table 2.
- Table 3 shows an example of the work data. According to this work data, each job is given with processing order. Moreover, the processible cell is beforehand decided according to the processing type.

Table 1. Machining ability of machining cell.

Processing form	1	2	3	4	5	6	7	8
Cell 1	20	30	12	30	30	20	28	6
Cell 2	25	24	16	24	15	24	30	22
Cell 3	20	30	16	32	30	30	30	9
Cell 4	30	30	16	30	10	30	21	9
Cell 5	12	30	24	16	12	30	30	12

Table 2. The distance between machining cell.

	storage	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
storage	0	5	10	15	20	25
Cell 1	25	0	5	10	15	20
Cell 2	20	25	0	5	10	15
Cell3	15	20	25	0	5	10
Cell 4	10	15	20	25	0	5
Cell 5	5	10	15	20	25	0

Using those data, the simulation model which performed machining process was constructed. The total image of a factory model is shown in Figure 5. In this model, each part has position and time data on IC tag. By receiving these data on real time, the system check the number of waiting part for machining process, and calculates the machining ability of each machining cell at any time. Then, when an actual state differs from a master schedule, re-scheduling is performed dynamically.

Table 3. Work data of proposed system.

Parts ID	Job ID	Group ID	order	Processing form	Volume	Processible Cell	Status
1	1	1	1	1	200	1, 3, 5	0
1	2	1	2	2	200	1, 2, 4, 5	0
1	3	1	3	3	200	1, 2, 3, 4	0
1	4	1	4	2	200	2, 3, 4, 5	0
1	5	1	5	1	200	1, 3, 4, 5	0
2	6	1	1	2	200	1, 3, 4, 5	0
2	7	1	2	5	200	2, 3, 4, 5	0
2	8	1	3	2	200	2, 5	0
2	9	1	4	7	200	1, 2, 3, 4, 5	0
3	10	1	1	7	200	1, 2, 3, 5	0
3	11	1	2	8	200	1, 2, 3, 5	0
4	12	1	1	4	200	2, 3, 5	0
4	13	1	2	2	200	1, 2, 4, 5	0
4	14	1	3	4	200	1, 3, 4, 5	0
4	15	1	4	5	200	1, 2, 4, 5	0

Some virtual simulation was performed using the system. Here, the making re-scheduling corresponding to the ability fall of a machining cell is introduced as an example case. This system checks number of waiting parts work in machining process of each machining cell derived from position data of the part, and If the number of waiting part is rather than a setting number, this system performs re-scheduling. On re-scheduling

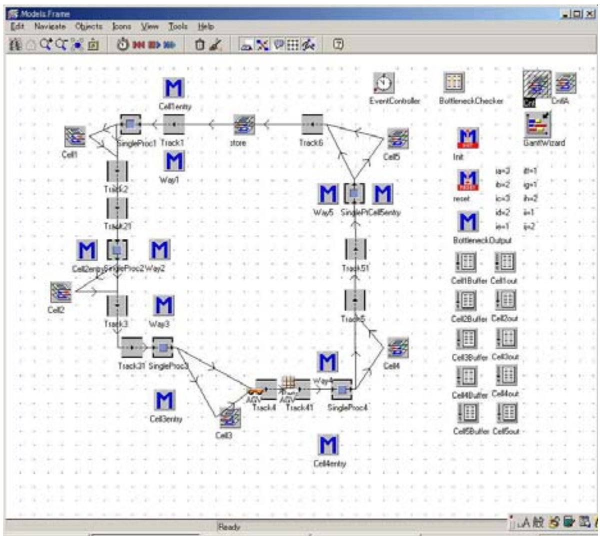
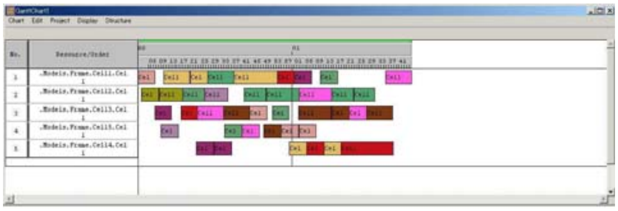
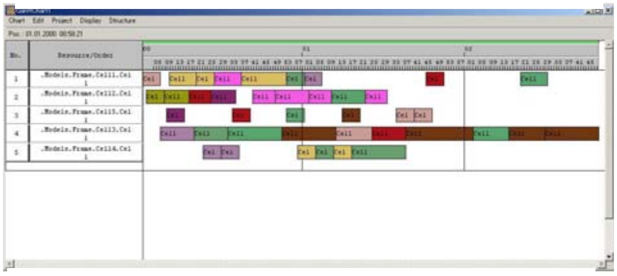


Figure 5. The simulation model of the factory.

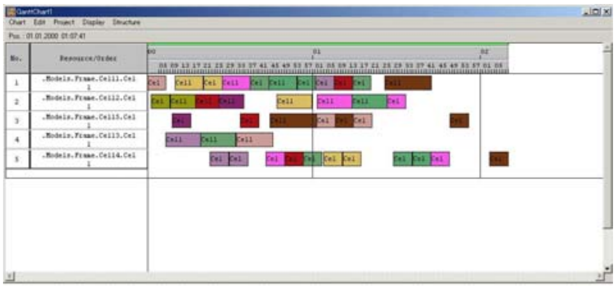
process, the ability of the cell is re-calculated by using information on the processing start time and finish time from latest processed part.
The Gantt chart of the simulation is shown in Figure 6, and temporal change of the number of waiting parts work in process is shown in Figure 7. In each figure, (a) the master schedule, (b) the result when not dealing with the ability fall of a machining cell., and (c) the result of after dynamic scheduling are shown. As these results, the system worked effectively against changing state of production facility. This shows that the parts and packet unified production system has feasibility of dynamic re-scheduling according to environment.



(a). The master schedule.



(b). The result when not deal with the ability fall.



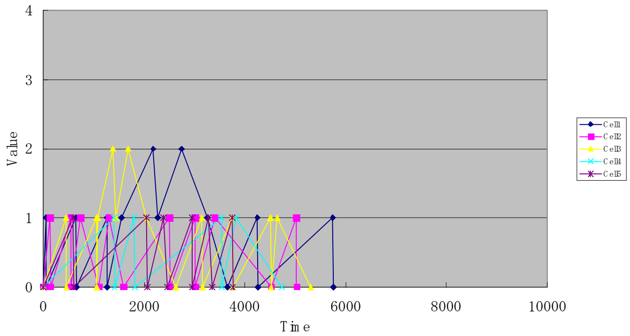
(c). The result of after dynamic scheduling.

Figure 6. The Gantt chart of the simulation.

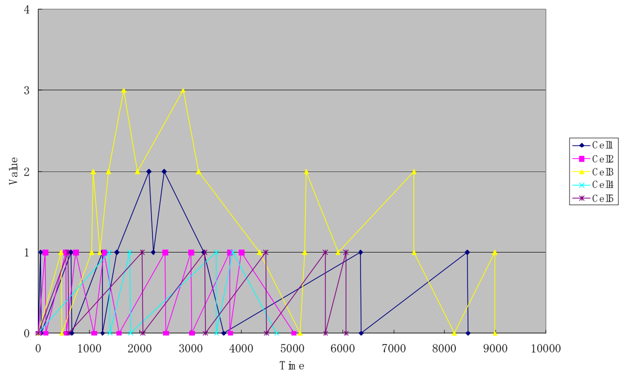
5. CONCLUSIONS

The following conclusions can be drawn.

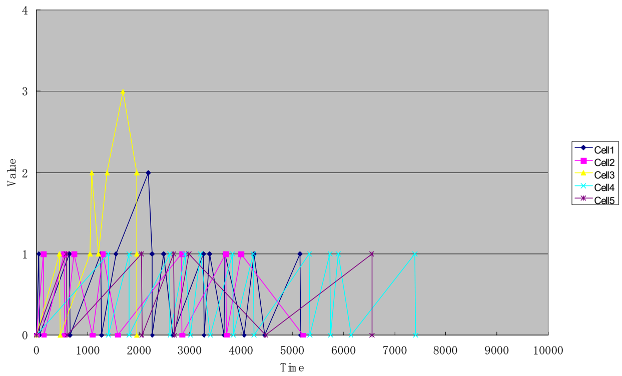
- It is thought that parts and packets unified system is available in construction production.
- The concept and the architecture of parts and packets unified system were proposed.
- A case study about the scheduling system in a factory was shown and the feasibility of parts and packets unified system was discussed.



(a). The master schedule.



(b). The result when not deal with the ability fall.



(c). The result of after dynamic scheduling.

Figure 7. The temporal change of the number of waiting parts work in process.

- The issues for using parts and packets unified system more effectively to construction production was considered.

From these conclusions, it is possible enough to apply this architecture to the field of construction production. By combining these different fields by the same management architecture, it is believed that distributed decision making between enterprise, which treats wide range domain, is also realizable.

6. ACKNOWLEDGEMENT

This research is supported in part by "Innovative and Intelligent Parts-Oriented Construction (IF-7 II) " Project (IMS 96009).

7. REFERENCES

[Ueda] Ueda, K., 1992, *An Approach to Bionic Manufacturing Systems Based on DNA-Type Information*, Proc. International Conference on Object-Oriented Manufacturing Systems, pp. 305-308.

[Ranky] Ranky, P.G., 1992, *Intelligent Planning and Dynamic Scheduling of Flexible Manufacturing Cell and Systems*, Proc. 1992 Japan-U.S.A. Symposium on Flexible Automation, pp. 415-422.

[Wiendahl] Wiendahl, H.P., Garlichs, R., 1994, *Decentral Production Scheduling of Assembly Systems with Genetic Algorithm*, Annals of the CIRP, Vol. 43, No. 1, pp. 389-396.

[Fujii] Fujii, S., Kaihara, T., Morita, H., Tanaka, M., 1999, *A Distributed Virtual Factory in Agile Manufacturing Environment*, Proc. 15th Conference of the International Foundation for Production Research, II, pp.1551-1554.

[Sugimura] Sugimura, N., Tanimizu, Y., Yoshioka, T., 1999, *A Study on Object Oriented Modeling of Holonic Manufacturing System*, Manufacturing System, Vol. 27, No. 3, pp. 253-258.

[Shirase] Shirase, K., Honjou, S., Wakamatsu, H., Tsumaya, A., Arai, E., 2002, *Co-operative Scheduling Based on HLA*, Proc. 5th International Conference on Design Information Infrastructure Systems for Manufacturing 2002, pp. 25-33.

[Umetani] Umetani, T., Arai, T., Mae, Y., Inoue, K., Maeda, J., 2002, *Parts and Packets Unification for Construction Automation and Robots*, Proc. 19th International Symposium on Automation and Robotics in Construction, pp. 311-316.