'94 KACC (1994. 10. 17 ~ 20)

Composition of Real-Time Robot Workcell using Token-Bus

Dong-Jun Kim° Kab-Il Kim
Dept. Electrical Eng. Myong Ji University

Abstract

Integration of intelligent robot workcell is now a hot issue in CIM and robotics area. This paper dealt with relatively low-level essential topics, i.e., multi-robot coordination and real-time communication for the integration of intelligent robot workcell. For the coordination of multi-robot system, the tightly-coupled coordination is proposed using the various sensors. In order to handle the numerous communication data, time-critical communication network (Field-bus) is introduced and investigated. Finally, intelligent robot workcell is suggested using the Mini-MAP and Field-bus.

I. Introduction

Production automation system or CIM system are composed of workcells, which can execute the collection of works a category. These workcells cab be realized as various types of composition, i.e. simple workcell has a robot, and complex workcell has robots, sensors, CNC, PLC, etc.. In order to increase the dependability of machine at process, workcell becomes more complex and intelligent. Ultimately collections of these intelligent workcells make the production automation system or CIM system, namely workcell will be the basis of these intelligent manufacturing system. Complex automation system can not be composed unless the workcell becomes intelligent and systematic management.

Though many problem have to be solved for the implementation of intelligent workcell, relatively low level essential topics(multi-robot coordination and real-time communication for the integration of intelligent robot workcell) is studied in this paper. When many devices operate in a category, it is necessary or efficient to cooperate two or more devices. In this case, in order to coordinate the devices (especially, robots), sensors have to be used. For example, to grasp the moving object on the conveyer, the vision sensor is needed. Also, cooperation work of two robots will not be executive by simply using the command of conventional industrial robot, but by using the force/torque sensor for the force control. Namely, to revise the operation of robot by sensor data, kinematics and inverse kinematics of robot should be calculated in real time to control the trajectory. Another advantage of this sensor-added-operation is to correct the errors of equipment (robot) itself. Even though the initial calibration and high precision, the equipment(robot) has its own error bound and accumulation of errors by repeated use. These errors can also be corrected by the assistance of sensors. These error correction problem can also be achieved by the improvement of equipment precision and structural design. But it is more reasonable to use the sensors instead of improvement of precision and structure with respect to the present technology and economical point of view.

Another topic of our interest is the systematic design of workcell using network concept. As the workcell becomes more and more complex the number of equipments and data are both increased. Conventional point-to-point serial/parallel connection is too complex to communicate and realize the workcell. Therefore, the network concept is introduced among the workcells. First network concept introduced to the manufacturing system is MAP(Manufacturing Automation Protocol), which is the well-known network protocol widely used. This network concept which has OSI 7 layers is basically used among the workcell. Recently the mini-MAP which has OSI 3 layers(1,2,7 layers) is used for the real-time communication within or among the workcell. But further inspection of equipments and sensors within workcell, most equipments have input and output data and relatively small amount of data. Instead, sensors and actuators have output data and relatively large amount of data. So, according to the features of sensors and actuators, the need of high speed one-directional communication network increased[1]. In this paper, Field-bus is selected as such a need.

Though many papers are published concerning about the coordination of robots and the operations of manufacturing system, few dealt with the coordination and systematic operation concurrently within the workcell using communication network. [2] implemented the coordinated robot system. In this paper, two robots was driven concurrently by using one computer, but those did not use the sensors. This is the realization of kind of trajectory-wise coordination. Advanced trajectory-wise coordination which use force/torque sensor was implemented in[3](tightly-coupled). But these two papers dealt with only the real-time coordination problem using a control computer, and did not have the flexibility of addition of equipments or sensors, because of lack of communication concept.

[4] dealt with multi-robot system using real-time communication network. This paper proposed the distributed module architecture with emphasis on the integration of robot system using port directed communication concept[7], but did not mention about the composition and operation of workcell. [5] suggests the real-time communication problem in workcell. This paper propose the new bus access

mechanism called 'polled bus' which reduces the information loosing rate compared to the 'token bus'. But, in considering the addition time using the poll number, communication time is increased compare to the token bus. And [6] uses the existing token bus LAN (Local Area Network) for the real-time coordination robots system, and only analyze the performance for the low-bound time limit of token bus mechanisms.

Under these circumstance, we propose the workcell using coordination of equipment and communication network. This paper is composed of like this: in next section, the structure of robot workcell is addressed, and in section Ⅲ, the access mechanism used for workcell is mentioned. And in section Ⅳ, the robot coordination is explicitly explained and the implementation of robot workcell is followed in section Ⅴ. Finally, in section Ⅵ, conclusions are followed.

Ⅱ. Structure of Robot Workcell

In this section, components and protocols of workcell is considered. As mentioned earlier, in manufacturing process can be divided into small processes called workcell. This partition of manufacturing process has many benefit in the aspect of efficiency and flexibility. From now on, we consider only the workcell for the discussion and analysis of manufacturing system.

1. Components of Workcell

Generally, workcell includes controller, robots, sensors, CNC, PLC, and conveyer, etc.. Also for the coordination of two or more robots, force/torque sensor, tactile sensor, or vision sensor are essentially needed. In our Lab, a simple workcell is constructed using robot, controller, force/torque sensor, and vision sensor. This simple workcell will be used for the rest of this paper.

2. Protocol used in Workcell

For the communication of whole production automation system, MAP which uses 7 layers OSI reference model is proposed by GM. The main purposes of MAP are to offer temporal communication ordering composition as well as to eliminate incompatibility between equipments. However, MAP is too slow to handle the real-time communication, relatively high-speed communication protocol called mini-MAP is proposed. Mini-MAP just uses 3 layers of OSI reference model(1,2,7 layers) instead of 7 layers, so this protocol is now widely used for the real-time communication within or among the workcell.

But, as the intelligence of workcell is improved the workcell uses more and more sensors and actuators, which has the characteristics of one directional communication and many data. So, new protocol called Field-bus which is simple in structure and chief in price compared to the mini-MAP is gradually adapted for communication of sensors and actuators. The benefits of using Field-bus are low cost, easy installation and maintenance, and flexibility. The standard or widely used specifications of communication protocols of MAP, mini-MAP, and Field-bus are summarized in table 1. Up to now, usually two types of Field-bus is proposed for the integration of sensors and actuators.(Fig 1, and 2) The former(Fig. 1) employs mini-MAP and Field-bus for the construction of workcell. The sensors and actuators are located only in Field-bus. The later(Fig. 2) employs Field-bus only for the construction of workcell, so workcell is directly located to the mini-MAP. In both method, MAP is used for the management and administration of overall network, but the former(Fig. 1) has the more load than the later(Fig. 2), because in the former workcell is located directly to the MAP.

In this paper, the concept of former(Fig. 1) is adapted for the construction of overall network, because this one is more widely used than the later and has more flexibility and consistency. So, the workcell is considered to be located in MAP and consisted of mini-MAP and Field-bus. In this next subsection, the architecture of field-bus is studied.

TABLE 1. Communication Protocol

(PA: Process Automation CB: CarrierBand BB: BroadBand)

Protocol	Field bus	Mini-MAP	MAP
transmission rate	31.25kbps (PA) 1, 1.25Mbps	5Mbps(CB coaxial, fiber optics) 10Mbps(BB coaxial, fiber optics)	5Mbps(CB coaxial, fiber optics) 10Mbps(BB coaxial, fiber optics)
medium	twist pair cable	750Ω coaxial cable 50/125μm fiber optics 62.5/125μm fiber optics 100/140μm fiber optics	750Ω coaxial cable 50/125μm fiber optics 62.5/125μm fiber optics 100/140μm fiber optics
topology	star, bus	bus (CB, BB) star (fiber optics)	bus (CB, BB) star(fiber optics)
maximum transmission length	1900m(PA) 750m(1Mbps) 500m(1.25Mbps)	a hundred m (CB coaxial) a hundred m - a km (BB coaxial, no repeater) note: changable by conditions	a hundred m(CB coaxial) a hundred m - a km (BB coaxial, no repeater) note: changable by conditions
number of station	32	32 (CB)	32 (CB)
protocol architecture	3 layer (physical, data link, application layer)	3 layer (physical, data link, application layer)	7 layer
access method	token passing	token passing	token passing
standization level	on the consideration of internation standard	international standard	International standard

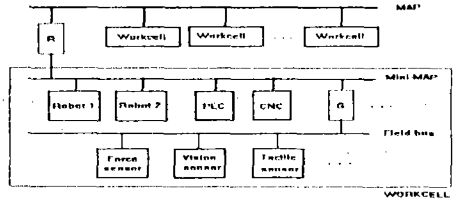

Figure 1. System Construction: case 1

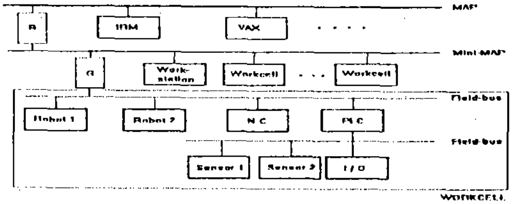

Figure 2. System Construction: case 2

3. Architecture of Field-bus

Architecture of Field-bus consist of 1,2,7 layers of OSI reference model. In the 1st layer(Physical layer), a bus topology supporting 32 stations per segment is generally adapted and shielded twisted pair or coaxial cable is usually used for the communication media. Link layer(2nd layer) is consisted of MAC(Medium Access Control) and LLC(Logical Link Control).

In MAC, which is the low level structure of link layer, two access mechanisms called master/slave and token passing method are usually adapted for the control of communication. This will be addressed explicitly later section. And LLC, which is the upper structure of link layer, provides services such as SDN, SDA or RDR, etc..

Finally, application layer(7th layer) includes the basic services and functions which is needed for the operations of system, i.e., the functions which can alter parameter values of equipments and, input/output the variables periodically etc.. Thus, in the functions of MMS(Manufacturing Message Specification) of MAP, remote variable access and event management functions are adapted as the application layer function in Field-bus. These functions are selected suitable for the execution ability of the each Field-bus.

In next section, the token passing access mechanism is applied to the proposed network. And through the performance analysis, the feasibility of application of proposed access mechanism which can realize the robot workcell is addressed.

III. Access Mechanism for Workcell

Standard specification of access mechanism of MAP and mini-MAP is token bus mechanism. Token bus mechanism is also selected as the Field-bus access mechanism. We compare the token bus mechanism with the other mechanisms and analyze the token bus mechanism for the application to our workcell.

1. Comparison of Access Mechanism

Access mechanism of communication network is largely classified by their topology; namely, star, ring and bus topology. Firstly, in the star topology, a main station is used to connect all the substations in the network. Communication for one substation to another is directed to the main station. The advantages of this topology are simple control, easy trouble diagnosis and retrieval, and little affection of damages of a substation and line. And the disadvantages are nondistributional control and failure of all system by the damages of main station. These two features are fatal disadvantage for the construction of network.

Secondly, in the ring topology, all the stations are attached to a closed loop and all the data transmission and acknowledgement is performed using this loop. There is no main or substations in this topology. This uses the distributional control concept. But after the arrangement of stations to a ring, change of the order and addition of the stations is difficult.

Thirdly, in the bus topology, stations are simply connected to the bus, which is the bidirectional communication media. The main features of this topology are that all stations can transmit the data concurrently and there is no need for the assignment of massage direction and path. In this topology, distributed control mechanism is used in case of the data collision on the bus, so all the station has the function of processing ability by the distributed processed structure. Therefore, these is no function of control processing structure of assignment of communication paths. By this feature, bus access mechanism is widely used for the communication of modern network.

Among the bus access mechanism, CSMA/CD(Carrier Sense Multiple Access with Collision Detection), Polled bus[5], and token bus mechanism is considered as the manufacturing network. CSMA/CD is widely used for the communication mechanism of the LAN(Local Area Network), but it is impossible to use at a real-time communication because of unbounded communication delay. Also Polled bus has the advantage of low data missing rate, but the communication time is larger than the token bus mechanism because of the design of poll number. By these reasons, the token bus mechanism is selected for the communication of multiple robot workcell.

2. Token Bus Mechanism

Token bus mechanism receives/transmits token which has s specific bit pattern and controls media access among stations. Only the station which possess the token is granted to control the media for a specific time. And the logical ring which possess the token is decided before hand and this can be altered when needed. After the transmission of message, token moves to next ordering station. Token bus is used for the communication access mechanism of MAP and mini-MAP and is also used for existing many field-bus. Therefore token bus is selected for the network access mechanism which will be composed to our Lab., and its performance analysis is performed with emphasis on average cycle times and delay time for the feasibility study to our network.

An expression for the average transfer delay of a token ring can be derived as a special case of hub polling. The following parameters are specified:

- X_t → The control token frame length in bits;
- $\overline{X}$ → The average length of a data frame, including overhead (with second moment $\overline{X^2}$);
- R → The channel bit rate in bits/second;
- M → The number of active stations on the bus;
- τ → The end-to-end propagation delay in seconds;

and

- Nm → The average number of packet transmitted in order to empty the buffer.

For the performance analysis the average cycle time and delay time must be determined which assumed the exhaustive service.

The following conditions are assumed in determining the desired quantities:

- The arrival processes are statistically equivalent Poisson processes with equal average arrival rates, λ [packet/sec];
- The walk time, w, between stations is constant and is the same for every consecutive station pair;
- The channel propagation times between stations are equal and are included in the walk time;
- The packet length distributions, for random length packets, are the same for packets arriving at each station.
- The number of stations is M, channel bit rate is R [bits/second].

(1) Average Cycle Time

Let N_m be the average number of packets with average length $\overline{X}$ bits stored at a typical station when the go-ahead poll arrives at this station. The common channel with capacity R is then available to the station to transmit data, and $N_m\overline{X}/R$ seconds are required to empty the station buffer. To be more precise, N_m, in the expression for time to empty the station buffer, should include not only the packets stored at the time service begins, but also those that arrive during the time the station is receiving service. After the station buffer is emptied at one station, access to the channel is transferred to another station in a time equal to the walk time, w. The length of an average cycle can thus be expressed as

$$T_c = M[\ N_m\overline{X}/R + w] \tag{1}$$

since the average time to empty a station buffer and transfer to the next station is the same for each of M stations.

The average number, N_m, of packets that must be transmitted to empty a station buffer in the steady state is determined by the average arrival rate, λ packets/second, and the average cycle time T_c as $N_m = \lambda T_c$. Then (1) can be combined and simplified to yield an expression for T_c as

$$T_c = \frac{Mw}{1 - M\lambda \overline{X}/R} \tag{2}$$

The quantity $M\lambda\overline{X}/R$, which is the ratio of the total average arrival rate to the network to the total capacity of the network, was defined earlier as throughput, S. Thus

$$S = M\lambda\overline{X}/R \tag{3}$$

and a final expression for average cycle time is

$$T_c = \frac{Mw}{1-S} \tag{4}$$

(2) Delay Analysis

As stated previously, a basic performance measure for polling networks is the average time, W, an arriving packet at a typical station must wait before reaching the head of the queue in the station buffer. This average waiting delay can be divided into two component delays;

- The waiting delay, W_1, in the station buffer while other stations are being served; and
- The waiting delay, W_2, in the station buffer while that particular station is being served.

Figure 3 shows the physical relationship between the different waiting periods, and they are related mathematically by

$$W = W_1 + W_2 \tag{5}$$

The pattern of activities for a polling network in a cycle with average parameters is shown in Fig. 4. From the point of view of a station i, the cycle consists of the time station i is being served and the remaining time, during which it is idle. The following calculation shows the relative size of the average values of these times, W_1 , and W_2. The average number of packets that must be transmitted over the channel by a particular station while it is being served is expressed $N_m = \lambda T_c$. The corresponding average service time for the station is N_m times the channel service rate in packets/second or $\lambda T_c \overline{X}/R$. Defining the parameter, ρ, as

$$\rho = \lambda \overline{X}/R \tag{6}$$

the average service time per station can be expressed as ρT_c, as shown in Fig. 4. The remaining part of the "average" cycle during which the station is idle is then, of course, $T_c(1-\rho)$. Now consider packets arriving at random during the time, $(1-\rho)T_c$, which is the average length of time that station i is waiting to be served. The packets arrive from a Poisson process, and for such "random" arrivals it is intuitive, when the number of packets is large, that the average time, W_1, that these packets must wait for service is given by

$$W_1 = \frac{(1-\rho)T_c}{2} \tag{7}$$

It can be shown that the arrival times are distributed independently and uniformly on the interval $[\ 0,\ (1-\rho)T_c]$ so that (7) is an exact result for ρ and T_c constant, as is the case for an average cycle. By using equation (2)and (7)

$$W_1 = \frac{Mw(1-\rho)}{2(1-M\rho)} \ . \tag{8}$$

The second component, W_2, of the total average delay experienced by arriving packets is the average time packets must wait to reach the head of the queue in the station buffer after the station begins receiving service. The average service time is $\frac{\overline{X}}{R}$. Thus if X is a random variable that represents packet length in bits, then its first and second moments are denoted $\overline{X}$, $\overline{X^2}$. It follows that

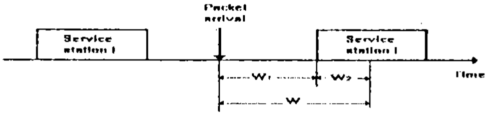

Figure 3. Division of waiting times for a typical packet

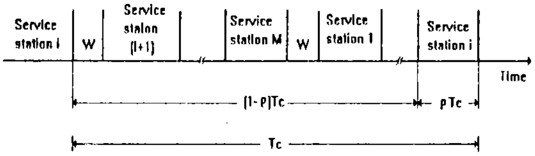

Figure 4. Cycle time

service time for a packet is X/R, and hence its variance is $(\ \overline{X^2}/R^2 - (\overline{X}/R)^2\ )$. Finally substitution in the delay time of M/G/1 queue yields

$$W_2 = \frac{(M\lambda)\overline{X^2}/R^2}{2(1-\rho)} \tag{9}$$

Throughput for the distributed queue, or for the network in the present application, is given by $S = M\lambda(\overline{X}/R)$ in conformity with (3) and (7), and thus

$$W_2 = \frac{S\overline{X^2}}{2\overline{X}R(1-S)} \ . \tag{10}$$

This expression for W_2 from the zero walk time network is added to the expression for W_1 to find the total delay W. Thus, using equ.(8) and (10), W can be expressed as

$$W = W_1 + W_2 = \frac{Mw(1-S/M)}{2(1-S)} + \frac{S\overline{X^2}}{2\overline{X}R(1-S)} \tag{11}$$

Equ.(11) can be used to give the average waiting time for packets at a station or average access time. The walk time, w, depends on the average propagation delay between stations. This delay is determined with the assumption that transfer between any two stations on the bus is equal. The solution to this problem in probability is well known. Also the number of stations is large, and gives approximately one-third the length of the bus as the average spacing between randomly chosen stations, or an average time delay of $\frac{\tau}{3}$ seconds. Using this average delay of $\frac{\tau}{3}$ seconds, the walk time can be expressed as

$$w = \frac{X_t}{R} + \frac{\tau}{3} \ . \tag{12}$$

The average transfer delay, T, can be obtained with equ.(11) by adding average propagation and packet transfer times to yield

$$T = \frac{\overline{X}}{R} + \frac{\tau}{3} + \frac{Mw(1-S/M)}{2(1-S)} + \frac{S\overline{X^2}}{2\overline{X}R(1-S)} \tag{13}$$

For fixed length packets, $\overline{X^2} = (\overline{X})^2$ and thus equ.(13), after substitution of equ.(12), becomes

$$T = \frac{\overline{X}}{R} + \frac{\tau}{3} + \frac{MX_t(1-S/M)}{2R(1-S)} + \frac{\tau(M-S)}{6(1-S)} + \frac{S\overline{X}}{2R(1-S)} \quad \text{----}(14)$$

$$T = \frac{\overline{X}}{R}\,\frac{2-S}{2(1-S)} + \frac{MX_t(1-S/M)}{2R(1-S)} + \frac{(M+2-3S)\tau}{6(1-S)} \quad \text{----}(15)$$

For exponentially distributed packet lengths, $\overline{X^2}=2(\overline{X})^2$, and the corresponding average transfer delay is given by

$$T=\frac{\overline{X}}{R(1-S)}+\frac{MX_t(1-S/M)}{2R(1-S)}+\frac{(M+2-3S)\tau}{6(1-S)} \quad (16)$$

Curves that show T versus S can be plotted from either equ.(14) and (16). Specific results, however, depend on the choice of the parameters M, Xt, τ, $\overline{X}$, and R. In the following section, we will consider the methods of robot coordination.

Ⅳ. Robot Coordination

In this section, we consider the coordination problem among the equipments within the workcell, especially coordination among the robots. Also the coordination between robot and other equipment (i.e. conveyor etc.) is corresponded to robot coordination. Robot coordination is classified to point-wise and trajectory-wise coordination. In point-wise coordination, robot is operated according to the point-to-point movement. And in trajectory-wise coordination, robot is operated according to the calculated trajectory values.

1. Point-wise Coordination

This coordination can be realized by the command of conventional industrial robots. That is, robots move independently to the given target point by separated controller. But robots move in a same working space, there is a possibility of collision during movement or waiting for a ordering of works. So, the coordination of robot is needed to solve this kind of problems. Of course, strictly speaking, this is not a coordination. But in a wide sense, this can be considered as kind of coordination because of the avoidance of collision and ordering among robots. This coordination can be classified to the coordination due to the independent motion and serialized motion.

1) Independent Motion Coordination

Independent motion is the case that the robots are in the same working space and operate the separate works. Operational errors of one robot do not affect to the operations of the other robots. Coordination is realized as the collision avoidance problem.

2) Serialized Motion Coordination

When robots assemble several or more parts, ordering of the operation of robots is needed. Also the error of one operation affects to the operations of the other robot. So, it is convenient to treat this coordination as a separate one with a independent motion coordination. This coordination problem is considered recently, but it has little relation with the subject of this paper. So it is not discussed further.

2. Trajectory-wise Coordination

It is impossible for two or more robots to move one object using point-wise coordination. Each robot have to be synchronized to move one object concurrently; namely trajectory synchronization. The trajectory synchronization can not be realized using commands of traditional robot languages, but be realized by the calculated trajectories. In order to do this synchronization, each robot have to be controlled by one main controller; namely, servo drivers of each robot are received the desired analog velocity signal from one main controller. In this case the complex computations like inverse kinematics must be performed within the one sampling time of robot controller. For example, the sampling time of FARA robot is 32msec. Recently, a few robots release their contents of controller and driver, so extra hardware or software is not needed for the communication and synchronization. By this synchronized control, intelligent robot system can be realized by the feedback of sensor data. Intelligent robot system handles many data by the addition of sensors, so there may be problems of communication burden. This problem will be treated in other section, and the only coordination problem is handled in this section.

Trajectory-wise coordination is classified to loosely coupled case in which robots are synchronized without the help of sensors and tightly coupled case in which robots are not only synchronized but also controlled by the sensor data.

1) Loosely-coupled Coordination

Loose-coupled coordination is synchronized by the calculated trajectories of robots without sensors, but can not be considered the position errors during the synchronized motion. Namely there is no force information to be caused by the position errors, which makes the distortion of object or overload of robots. So, loosely-coupled coordination is not considered as a perfect coordination because it does not correct the position errors and synchronization errors during the coordination.

2) Tightly-coupled Coordination

Tightly-coupled coordination considers the sensor information for the correction of errors as well as the synchronization of motion between/among robots. One example of this tightly-coupled coordination is that one robot called leader is responsible for the position of the object and the other robots called follower just follow the leader using the force sensor data. By this tightly-coupled coordination, true coordination can be realized with reduced errors and the intelligent robot system can be performed.

Until now the possible coordinations of robots are considered. Using these coordinations, several command level operations are executed in the respect of Manufacturing Message Specification(MMS). Next will be the performed example of network realization using existing equipments and communication protocols.

Ⅴ. Implementation of Robot Workcell

This section introduce the workcell that we want to construct using the manufacturing communication network.

1. Communication Network

The workcell that we want to construct need robots, gateway for the interfacing between Field-bus and Mini-MAP, and some sensors. Medium access method in the communication is token bus. These are shown in the Fig. 5.

Position data sampling time of the robot is 32ms, and position computation is executed in the time.

In the Fig. 6:
case 1: Medium : 5Mbps fiber optics
Maximum number of stations : 32
Transmission delay : 32 → 0.9ms
10 → 0.5ms

16ms is used to process and computation in the LLC, MAC, and physical layer. Then these values are usable.

In addition, fig. 7 and 8,
Case 2 : Medium : 1, 1.25 Mbps twist pair cable
Transmission delay : 32 → 4.5ms(1Mbps),
3.62ms(1.25Mbps)
10 → 2.35ms(1Mbps),
1.89ms(1.25Mbps)

Because these value are less than 16ms, also these values are also acceptable. Consequently workcell operation is not affected by using the Field-bus protocol with respect to the communication delay time.

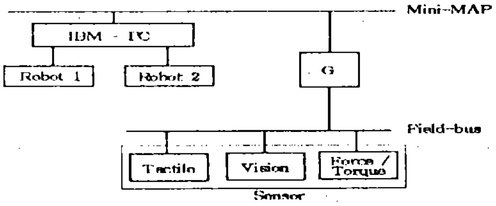

Figure 5. A example of the system construction

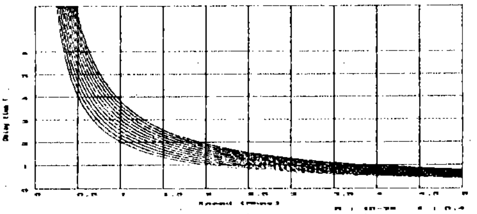

Figure 6. The relationships between transmission rate and delay time

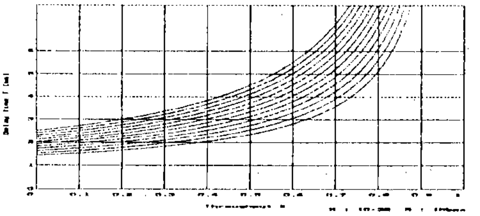

Figure 7. The relationship between throughput and delay time(transmission rate: 1Mbps)

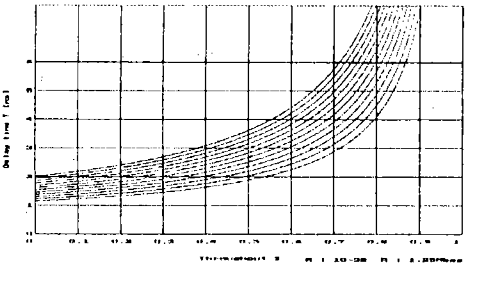

Figure 8. The relationship between throughput and delay time(transmission rate: 1.25Mbps)

2. Robot Coordination

In section IV, trajectory-wise coordination is considered for the intelligent robot workcell, which can not be realized by the industrial robot itself but can be realized by one main controller which is interfaced to two robots. In this subsection, the experiment of robot interface is discussed.

For the implementation of trajectory-wise coordination, the robot is interfaced to one computer. Velocity command is applied per 2msec and position data is revised per 32msec. As mentioned earlier, the robot motion is not affected by the delay of communication network.

When two robot move without force sensor, the torques of each joints can be increase by the position errors. So, force sensor is used to one robot, resulting that the torques of each joints do not increase and follow the given trajectories without any distortion of object and overload of robot joints.

VI. Conclusion

This paper proposed the robot coordination and the applicability of Field-bus. Robot coordination is classified to a point-wise and trajectory-wise. Also the later is divided the loosely-coupled and tightly-coupled coordination. For the IRS tightly-coupled coordination is generally used for the coordination of equipments and robots. In the workcell level, the Mini-MAP and Field-bus is used to connect the devices and sensors and for the systemic management. And we select the token-bus that we will use in the network and discussed the performance analysis of token-bus. In the selection of access mechanism, polled bus reduced the massage missing rate compared with the token bus. But token bus has a less transmission time than polled bus.

The next subject is physical implementation of proposed system. Also before the implementation, the simulation and reduction of transmission delay in the Field-bus should be preceeded.

Reference

[1] P. Pleinevaux and J. D. Decotignie, " Time Critical Communication Networks : Field Buses," IEEE Network. Vol.2, No.3 , May ,1988, pp.55-63.

[2] Y.F.Zheng, J.Y.S.Luh, and P.F.Jia, "Integrating two industrial robots into a coordinated system," Computers in Industry, Vol.12, 1989, pp.78-97.

[3] Kab I. Kim and Y.F.Zheng, " Two strategies of position and force control for two industrial robots handling a single object," Robotics and Autonomous Systems, Vol.5,1989, pp.395-403.

[4] Kang G. Shin and Mark E. Epstein, " Intertask communications in integrated multirobot system," IEEE Journal of Robotics and Automation, Vol.RA-3, No.2, April, 1987, pp. 90-99.

[5] Kang G. Shin , " Real-time communications in a computer-controlled workcell," IEEE Trans. on robotics and Automation, Vol. 7, No.1, February, 1991, pp.105-113.

[6] Qichao Yin and Y.F.Zheng, " Performance analysis of token bus LAN in coordinating multiple robots," Preceedings of the 1992 IEEE international conference on robotics and automation, Nice, France, May, 1992, pp. 455-460.

[7] A.Silberschatz, " Port directed Communication," Comput. J., vol. 24, pp. 78-82, 1981.

[8] ---, Newsletter of The Korean Association of Standard Automation Systems, Vol. 1, 2, 3. 1992. 11, 1993. 2, 1993. 6.

[9] ISA/SP-50, 1991-1992, Draft Standard, Instrument Society of America.

[10] On-Ching Yue, Charles A.Brooks,"Performance of the Timed Token Scheme in MAP," IEEE Transactions on communications, vol. 38 , No. 7, JULY , 1990.

[11] G.G.Wood," Field bus, a developing low level Industrial LAN Standard," presented at EFOC/LAN 86, Amsterdam Netherlands , June. pp.23-27, 1986.

[12] Kim DJ, Kim KI, Jang HS, Lee BD," A Study on Integration of Intelligent Robot Workcell using Real-time Communication," 1993 Proceeding of KIEE Summer Conference, Vol. A, pp.406-409. July, 1993.

[13] Son YS, Kim DJ, Won JH, Kim KI, Kim DW,"A Study on the Driving of SCARA Type Robot using PC," 1994 Proceeding of KIEE Summer Conference, Vol. B, pp. 1058-1060, July, 1994.