Control System Design and Analysis with CEMTool for Control Education

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1. Introduction

For the analysis and design of control systems, many CACSD (Computer-Aided Control System Design) softwares are developed and have emerged as indispensable tools. They are widely used at universities and research centers [1]-[3].

Current CACSD is performed in a single PC. That is, plant and controller are simulated in one PC. However, in real control systems, the controller is located apart from the plant. Therefore, it is necessary to construct a two-part simulation system, in which the controller and the plant are located apart from each other and simulated independently, in order to reflect real situation. In this case, plant and control simulation behaves like a real system. This is good for control education and also helps to understand the role of the controller. CACSD packages to handle this kind of functions are very rare.

Two-part real-time simulation system consists of two independent PCs, which are connected by some interfaces. The interface methods should meet the following requirements: handling many I/O points, fast data transmission for fast sampling time, low cost, and reliability. The interface methods should be compared in terms of these requirements.

In real systems, plant and controller exchange analog signals for continuous variables. In order to reflect this real situation, AD/DA interface is a logical choice. The advantage of AD/DA interface is that data transmission is very fast. However, in order to deal with a number of I/O points, many AD/DA interface boards are necessary. This leads to a high cost. In addition, noise is a serious problem in using AD/DA boards, which means degradation of reliability.

In view of the above, it can be noted that other methods are necessary to meet above requirements. This paper suggests communication interfaces for two-part real-time simulation. In particular, we compare RS-232 and Ethernet interface, which are widely used in connecting PCs. These two methods are also investigated and compared in terms of above requirements. It is noted that Ethernet is a suitable interface method for two-part real-time simulation system.

In this paper, the test bed is implemented with existing CACSD packages CEMTool and SIMTool [4][5], which were developed in Seoul National University. Two PCs representing plant and controller are connected by three interface methods such as AD/DA, RS-232, and Ethernet. Communication blocks are implemented in CACSD packages for the user to handle the communication interface. This paper is organized as follows. In Section 2, communication characteristics are introduced and analyzed. In Section 3, two-part real-time simulation system is implemented with communication blocks. In Section 4, Simulation result through AD/DA interface method is shown. Finally, our conclusions follow in Section 5.

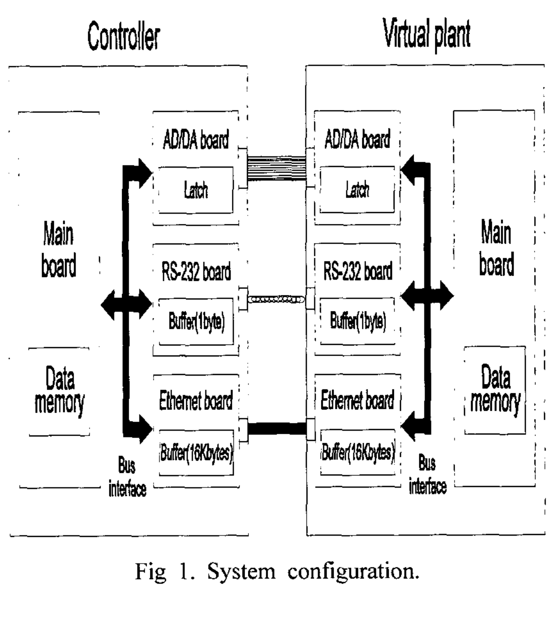

Fig 1. System configuration.

2. Communication characteristics for Real-time simulation

The system configuration is in Fig. 1. The above communication methods have different characteristics and thus, different performances. Therefore, it is worth analyzing and comparing the characteristics and performance of each method.

Time delay [6][7] in communication is the main issue in measuring the performances of the interface methods since it affects the whole performance of the simulation system. The communication delay between the plant and the controller is in Fig. 2.

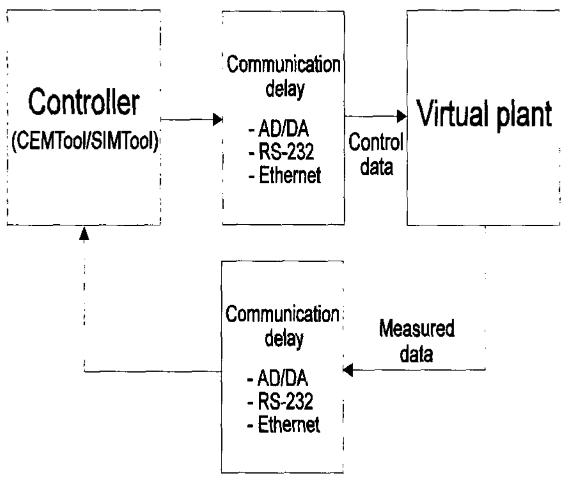

Fig 2. Time delay in the network.

Using AD/DA converter board is important for control education since it makes the users feel close to real situations. The AD/DA converter board communicates with main board using latches. In general, only a small number of bytes can be accomodated at one time. Thus, if the real-time simulation system has a number of I/O points, many AD/DA boards are necessary to cover all the I/O points. This leads to a high cost. However, in terms of data transmission speed, AD/DA interface method is good since all the AD/DA boards transmit data at the same time. The transmission time is represented as

$$t_{ii} = t_{pb} + 2 * t_{ad} + t_{ac}$$

where t_{ii}: time delay between interface boards, t_{pb} : propagation delay of one bit in the case of AD/DA interface, t_{ad}: Analog(digital) to digital(analog) conversion time, t_{ac}: Channel acquisition time in case that n AD/DA boards, which can transmit one byte at one time, are used.

RS-232C is one of the basic ways to connect the individual PCs. It is simple and requires low cost relative to the other methods. Also, it can cover multiple channels depending on how to program. However, since it communicates with the main board using its buffer accomodating a small number of bytes, the performance of the real-time simulation system can be degraded as in the case of using AD/DA board. One way to improve the performance is constructing a RS-232C communication board with a dedicated CPU and considerable size of memory. In this case, since the main board can transfer a large quantity of data at one time to the RS-232C communication board, the performance of the simulation system can be enhanced. However, since the RS-232C communication is originally not an efficient method, it can be a deadlock. Also, the cost rises up very much. The communication delay between the main board and the RS-232 board is represented as

$$t_{mi} = (\frac{n}{2}) * t_{miR}$$

where t_{mi}: transfer time from main board to interface board, t_{miR}: transfer time of one byte in the case of RS-232 when the PC interface bus is 16-bit bus. The transmission time between RS-232 boards is represented as

$$t_{ii} = n * t_{pbR}$$

where t_{pbR}: propagation delay of one byte in the case of RS-232 interface.

TCP (Transmission Control Protocol) /IP (Internet Protocol) and Ethernet compose a set of communication protocols that are widely used nowadays [8][9]. TCP/IP controls user data transmissions and supports reliable communications between users. The Ethernet protocol, which is a kind of medium access control (MAC) protocol [10], is a topology based on the random access of the physical medium. Therefore, it may introduce excessive transmission delays if the number of nodes is large and the communication is ramdom. However, in this two-part real-time simulation system, Ethernet without TCP/IP is very good since the communication is deterministic and the collisions don't occur in the network.

In general, since Ethernet interface board has considerable size of buffers such as 16K bytes, many I/O points can be covered easily. This means that Ethernet doesn't have the disadvantage of performance degradation of the simulation system. In the case of using Ethernet, the communication delay between the main board and the Ethernet board is represented as

$$t_{mi} \ = \ (n/2) \ * \ t_{miE}$$

where t_{mi}: transfer time from main board to interface board, t_{miE} : transfer time of one byte in the case of Ethernet in case the PC interface bus is 16-bit bus. The transmission time between Ethernet boards is represented as

$$t_{ii} \ = \ n \ * \ t_{pbE}$$

where t_{pbE}: propagation delay of one byte in the case of Ethernet interface.

Since the network speed of Ethernet is much faster than RS-232, the transmission time is much shorter.

It is not always necessary to use TCP/IP on Ethernet. Here it can be noted that using Ethernet without TCP/IP is a good way to get a good performance in the two-part real-time simulation system.

3. Simulation Tool with Communication blocks

In order to implement two-part real-time simulation, communication part should be programmed in controller and plant each other to transfer data between controller and plant. The implementation should consider the following conditions : all of three communication methods, convenience of use, and flexibility of papameter modifying.

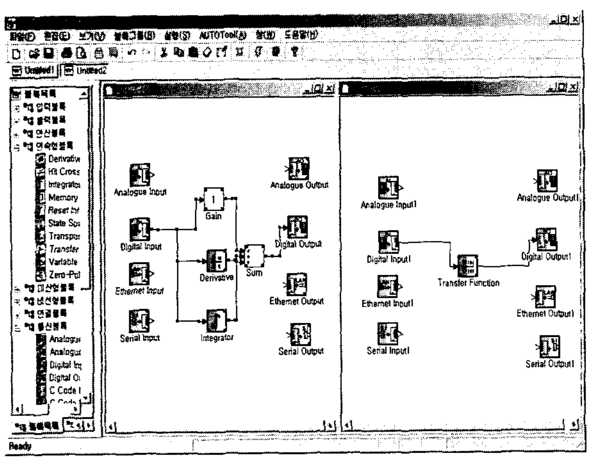

Fig 3. Controller and Plant.

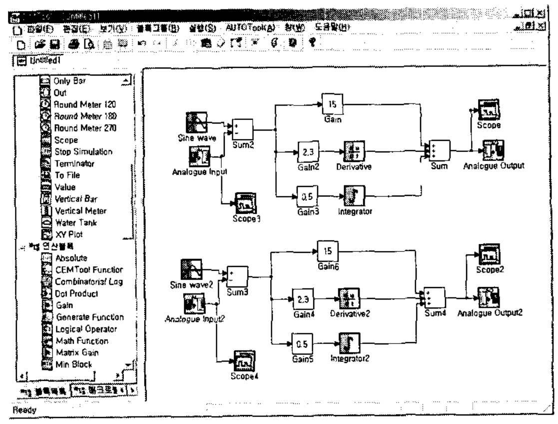

Fig 4. Controller modelling.

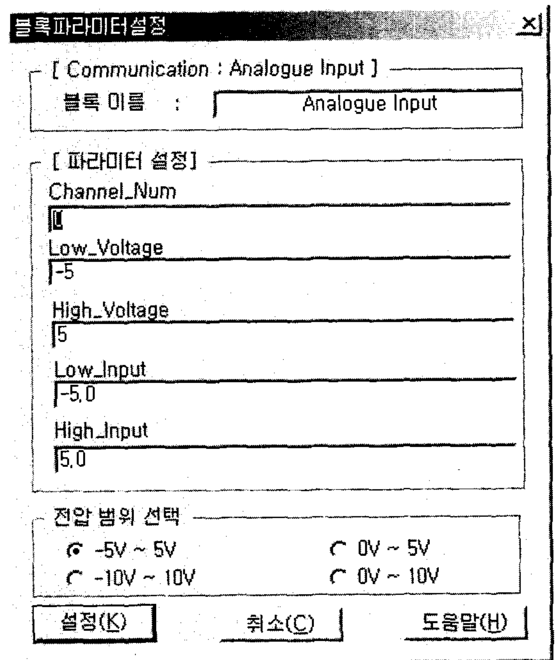

Fig 5. AI (analog input) parameter.

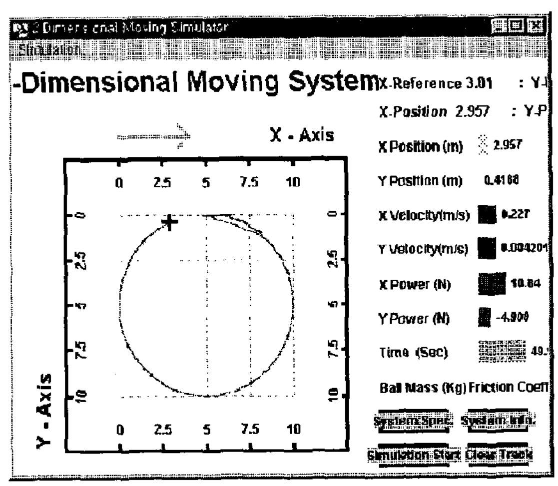

Fig 6. Two degree of freedom position control.

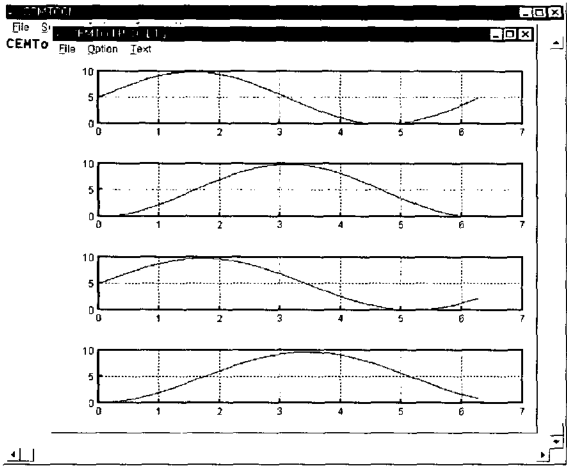

Fig 7. Plot window.

To satisfy above conditions for simulation, we implemented three types of six communication blocks (Fig. 3) in SIMTool. Since all blocks which include communication blocks are depicted as bitmaps in SIMTool, it is readible. and since these blocks have parameters needed to specify communication port and dada type, users have only to modify parameter values of these blocks in order to decide port and data. Besides, we can plot the results through Scope block of SIMTool.

SIMTool (Fig. 4) always works together with CEMTool and is an object-oriented [11][12] block diagram graphic editor. The model which was edited with SIMTool is calculated on CEMTool. CEMTool performs matrix calculation and has structure to enable users to develop and extend algorithms easily (ex:toolboxs of MATLAB; Carabelli, 1995). Fig. 3 shows controller and plant which are implemented in SIMTool. In order to construct two part real time simulation system, we have only to implement the controller and the plant each other in two PCs with SIMTool.

4. Simulation with AD/DA board communication

In this section, a control system for a virtual plant (Two degree of freedom position control system) is constructed using CACSD (Computer Aided Control System Design) packages SIMTool and CEMTool.

The dynamics of this plant is represented as

$$\begin{aligned} M\dot{V}_x + B\dot{x} &= F_x \\ M\dot{V}_y + B\dot{y} &= F_y \end{aligned}$$

where M : Mass of rolling ball (kg), B : Coefficient of friction, V_x, V_y : Velocity of x, y (m/sec), F_x, F_y : Pushing power toward x, y (N).

Default coefficients are that $M = 1kg$ and $B = 0.01$. This plant has two I/O channels (reference and output), so we can see that the output signal tracks the reference signal in two dimensional plane (X and Y axis) visually.

Fig. 4 shows modeling with SIMTool; Fig. 5 papameters of AI (analog input) block in SIMTool; Fig. 6 and Fig. 7 simulation results in virtual plant and CEMTool each other.

5. Conclusion

In this paper, two-part real-time simulation was investigated in terms of cost, transmission time, I/O point, scale, reliability, cable length, etc. In order to support three kinds of communication method such as AD/DA, RS-232C, and Ethernet, three types of communication blocks were implemented in SIMTool. In addition, simulation of two degree of freedom position control system was simulated through AD/DA board with SIMTool and CEMTool.

Two part real time simulation of this paper has the following advantages. First, it will be good for rapid prototyping of digital control system. Second, since it makes us feel close to real plant control, it may be very useful for control education. Third, it has little time constraint, is inexpensive, and is easy to test, compared to real plant control.

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