Artificial Neural Network in Mechatronic System Control via Internet

Tibor VINCE

Dept. of Theoretical Electrical Engineering and Electrical Measurement, FEI TU of Košice, Slovak Republic
tibor.vince@tuke.sk

Abstract—The article presents regulation possibilities of mechatronic system via Internet and possible improvements of such control using Artificial Neural Network. Due to the development of Internet technique and speed increase of transmission, the inexpensive convenient communication approach is provided for the remote control system The paper also handles the advantages and disadvantages of Internet as a control and communication bus at different levels of the information hierarchy.

Keywords—Remote control, Internet, Artificial Neural Network, Mechatronic system, Information architecture

I. INTRODUCTION

There is huge effort to integrate different cooperating systems in one complex system. The basic problem is communication between these different modules of the system, especially when the modules are located in different locations. According to communication requirements, appropriate communication way has to be chosen.

Continual evolution of the Internet enables higher and higher communication requirements to be fulfilled. The Internet begins to play a very important role in industrial processes manipulation, not only in information retrieving. With the progress of the Internet it is possible to control and regulate remote system from anywhere around the world at any time. Distance remote via Internet, or in other words, Internet-based control has attracted much attention in recent years.

Such type of control bus allows remote monitoring or regulation of whole plants or single devices over the Internet. The design process for the Internet-based control systems includes requirement specification, architecture design, control algorithm, interface design and possibly safety analysis. Due to the low price and robustness resulting from its wide acceptance and deployment, Ethernet has become an attractive candidate for real-time control networks.

It is necessary to regulate mechatronic system in such remote regulation in some cases. The goal of the article is to explore existing possibilities for Internet based real-time regulation, eventual trends, review of advantages and disadvantages of distance remote via Internet at different levels of information hierarchy and possible solutions. The article presents regulation of mechatronic system as an example of such a real-time regulation and discusses possibilities of utilization Artificial Neural Network (as part of Artificial Intelligence).

II. ARTIFICIAL NEURAL NETWORK

An artificial neural network (ANN), often just called a "neural network" (NN), is a mathematical model or computational model based on biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on internal or external information that flows through the network during the learning phase.

Since the early 1990’s, there has been a growing interest in using artificial neural networks for control of nonlinear systems. Numerous applications have demonstrated that neural networks are indeed powerful tools for the design of controllers for complex nonlinear systems. Among different kinds of neural networks, the most widely used ones are multilayer neural networks and recurrent networks. In case of Internet-based Control is very important some kind of auto-adaptation.

By solving tasks in field of electric drives we meet following basic problems: system simulations, identification of system parameters, system state quantities monitoring, drive regulations and malfunction diagnostic. There is possible successful utilization of neural network in all these fields of problem. The most important neural network attributes in this field are: various nonlinear functions approximation, parameters settings based on experimental or learning data, data processing and robustness.

Two different models are used in identification models creation: mathematics and physics analysis and experimental identification. In case of complex subjects both methods are required. Neural network can be used as direct neural model connected parallelly or serial-parallelly in learning state. Neural network can be used also as inverse identification model in dynamic system. Today’s computer science performance allows to replace classical methods of parameters estimation by automatic identification. Main advantages include complex test signals generation possibilities, sophisticated identification algorithms, on-line identification possibilities etc.

The condition of the Internet is a very varying parameter and the control system controlling via Internet has to compensate the variation. One of the solutions is to employ
the neural network. It is possible to teach neural network behaviour for different conditions of networks. The advantage of this solution is that neural network is a more universal tool and condition of the Internet can be used as one of the many parameters that relate with controlling and regulation.

### III. INFORMATION ARCHITECTURE

As mentioned before, there is effort to integrate different subsystems in one complex system. Integration of information and control across the entire plant site becomes more and more significant. In the manufacturing industries this is often referred to as “Computer Integrated Manufacturing” (CIM). There is increasing use of microprocessor-based plant level devices such as programmable controllers, distributed digital control systems, smart analyzers etc. Most of these devices have "RS232" connectors, which enable connection to computers. If we began to hook all these RS232 ports together, there would soon be an unmanageable mess of wiring, custom software and little or no communication. This problem solution results in integration these devices into a meaningful "Information Architecture". This Information Architecture can be separated into 4 levels with the sensor/actuator level as shown in Fig. 1, which are distinguished from each other by“4Rs” principle criteria: [1]

**Response time**: as one moves higher in the information architecture, the time delay, which can be tolerated in receiving the data, increases. Conversely, information used at the management & scheduling level can be several days old without impacting its usefulness.

**Resolution**: an Abstraction level for data varies among all the levels in the architecture. The higher the level is, the more abstract the data is.

**Reliability**: Just as communication response time must decrease as one descends through the levels of the information architecture, the required level of reliability increases. For instance, host computers at the management & scheduling level can safely be shut down for hours or even days, with relatively minor consequences. If the network, which connects controllers at the supervisory control level and/or the regulatory control level, fails for a few minutes, a plant shutdown may be necessary.

**Reparability**: The reparability considers the ease with which control and computing devices can be maintained.

Local computer on supervisory control level is able communicate with higher levels of information architecture via Internet, but there is also possibility to use the Internet also in lower levels of the Information Architecture. The Internet can be linked with the local computer system at any level in the information architecture, or even at the sensor/actuator level. These links result in a range of 4Rs (response time, resolution, reliability, and reparability). For example, if a fast response time is required a link to the control loop level should be made. If only abstracted information is needed the Internet should be linked with a higher level in the information architecture such as the management level or the optimization level.

### IV. NETWORK PERFORMANCE

There are more parameters in mutual relationship, which refer to network condition or network performance. One of performance parameters is Latency. Latency means a time required to transfer an empty message between relevant computers. Another parameter is Data transfer rate. Data transfer rate is the speed at which data can be transferred between sender and receiver in a network. The unit of this parameter is Bits/sec. For message transfer time calculating is equation 1. A third parameter of network performance is Bandwidth. Bandwidth is a total volume of traffic that can be transferred across the network. Maximal data rate formula is shown in equation 2. This maximum is only theoretical, not reachable in practice [5]

\[
\text{Message transfer time} = \text{latency} + \frac{\text{length of message}}{\text{Data transfer rate}}
\]  

\[
\text{Max. data rate (bps)} = \text{carrier Bandwidth} \cdot \log_2 (1 + \frac{\text{signal/noise}}{\text{carrier Bandwidth}})
\]

The all parameters are pointing on the main disadvantage of controlling via the Internet – packets delivery delay. When packets are concurrently transported over an ordinary Ethernet, packets may experience a large delay due to contention with other packets in the local node where they originate and collision with other packets from the other nodes. By data transmission, four sources of delay spring up at each hop: nodal processing, queuing, transmission delay and propagation delay. The most significant part of total delay belongs to queuing. By queuing is considered the following equation 3:

\[
\text{TI} = \frac{L}{A} \cdot \frac{A}{W}
\]

where TI is traffic intensity, L is packet length (bits), A is average packet arrival rate, and W is link bandwidth (bps).

If ratio L*A/W will be very small almost 0, average queuing delay is small. If ratio L*A/W rise up to 1, delays become large (exponentially) and if ratio L*A/W is bigger than 1 average delay is infinite, more “work” arriving than can be serviced.

### V. SOLUTION APPROACH

Adequate control software, appropriate computers on client

Fig 1. Information Architecture
and server site and Internet with satisfactory connection speed are necessary for successful mechatronic system control controlling. Definition of “adequate” control software, computer and connection speed depends on concrete mechatronic system. In generally, regulation of mechatronic system may be considered as real-time regulation problem and time intervals in tens of milliseconds. The time intervals may vary significantly from every regulation system. For regulation system via Internet is very important if the regulation loop time interval must be under one millisecond, in milliseconds or may be over hundreds of milliseconds and more. In the architecture design, a remote regulation of mechatronic system via Internet generally includes three major parts: client, server and regulated mechatronic system. The general remote regulation system architecture is shown in Figure 2. The client part is the interface for the operations.

It includes computers, control software with user interface for operators or superior system. Client computer receives state information of mechatronic system, connection state and other information related to the system regulation via Internet. Received information will be processed and evaluated in remote computer.

The server part contains a server computer, which is connected to the converter. Server contains all required drivers and devices for communication with the converter.

Communication of server with converter could be based on several ways (RS232, Profibus, CAN, USB, etc.). Sophisticated converters may be Ethernet enabled and may be connected directly to the Internet. But if the client computer is located in outside network – not in LAN network, where the converter is located, the server computer is recommended. The third part of system architecture is the mechatronic system with the controller itself. Common way for distance regulation is, when remote client computer has limited functions – only start/stop of mechatronic system. The regulator itself (for instance PI regulator) is located on server site, or is implemented in converter.

But Internet speed progress open possibility for real-time control from client site, so there is possibility that Internet could be part of the regulation loop. Between client computer and server could be thousands of kilometers, or they could be in the same room. The difference is in the communication delay, but generally the system is the same. The communication service (the bus) can be achieved by wired connection, mostly Ethernet, or wireless – very popular WiFi.

If regulated system is sufficiently slow, also GSM devices may be used for Internet communication.

VI. CONCLUSION

It is become to be a standard, that many control elements have been embedded with Internet-enabled functions, for example, PLC with TCP/IP stack, smart control valves with a built-in wireless communication based on TCP/IP protocol. There is possibility that some mechatronic system could be connected directly to the Internet. On the basis of done analysis it is evident that the existence of server as a gate to the Internet for mechatronic system is still highly recommended (because of capriciousness of Internet, computer crime and many other reasons). By utilizing of UDP Internet protocol it is possible to regulate real-time systems with tenths milliseconds of feedback. When compare Ethernet as a bus with other standard types of industrial bus, there are more advantages and disadvantages. The most powerful advantage is nearly unlimited size of bus, possible huge distance, open system of the internet protocols and accessibility of the Internet.

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REFERENCES