Health Monitoring System via Ethernet and JAVA with Distributed Sensors and CCD Cameras

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ABSTRACT

Smart structures for health monitoring is a noticeable technology for advanced composite structures and civil structures. For the health monitoring, embedded optical fiber sensors are getting popular. For the practical objectives of health monitoring, however, not one but several kinds of sensors are required, and unfortunately these sensors are not limited to optical fiber sensors. A new technology for making conventional sensors distributed sensors is required. The present study proposes Ethernet LAN technologies for the sensor integration technology. The present paper addresses Ethernet LAN technology for the health monitoring, and advantages of adoption of Ethernet LAN. JAVA technology makes it possible to do health monitoring on the intranet web sides.

INTRODUCTION

Health monitoring system have many sensors mounted on, and the structural integrity is monitored through the measured data. For the health monitoring system, optical fiber strain and thermal sensors are generally adopted as distributed sensors. However, many kinds of sensors like speed counters , leakage sensors, gas sensors and CCD cameras are required for practical health monitoring systems. In some cases, actuators may be necessary for closing safety valves. These sensors and actuators require thick bundles of analog lead wires, and this cause cumbersome handling of thick bundles of lead wires. The bundles of lead wire may cause significant increase of weight. In some cases, the bundles of lead wires make replacement of structural components impractical.

The present study proposes a new idea using Ethernet LAN for transfer of digital data of sensors and actuators. Using Ethernet LAN for transfer the data, thick bundles of lead wire are not required or at least minimized, and the replacements of structural components become quite easy because just plug-in socket is required for changing sensors and actuators. Since Ethernet LAN uses digital data transfer protocol, Ethernet LAN is robust against electro-magnetic noise compared with the analog lead wires.

Ethernet LAN is generally used to transfer digital data packets such as e-mail, multimedia information or WEB data. To transfer analog data of sensors via Ethernet has already attempted in several cases. Tate et. al. have applied

Ethernet LAN for fire research data transfer of ex-USS SHADWELL [1]. They placed 10-base-2 Ethernet LAN in the ex-USS SHADWELL to prevent placement of many thick bundles of analog leading wires and noise. They used PCs for each data collection. Ballard and Chen have adopted PC network using Kermit protocol for measurements of wind load of a luminaire tower [2]. They uses desktop PCs and A/D converters, and the collected data is transferred to a central workstation via telephone line using Kermit protocol. For factory automation, Daniel [3] and Winker et. al. [4] have proposed adoption of Ethernet LAN technology for transfer of data of machine tools and image of machining using CCD camera. However, no research has proposed a health monitoring system using Ethernet.

The present study proposes another new idea of health monitoring using Ethernet LAN. The idea is a Plug & Monitor system. The Plug & Monitor system does not require structural analysis or experiments to detect damages of structures. The system just requires Plug-in of sensors to Ethernet. Computer software automatically constructs relations of distributed sensors of structures, and judges deviation from normal relations. The system is demonstrated using a beam specimen.

All of these monitored conditions are sent and processed using JAVA packages developed in the present study. Using the JAVA packages, we can easily install health monitoring web sites and reuse the packages for another systems.

ETHERNET LAN TECHNOLOGY

Ethernet/802.3 standard is a normal LAN specification for digital communications of computer net works, and the transfer rate is 10 M bps. Ethernet is the standard of the lower two layers of computer network packet communication system divided into 7 layers. The two layers are a physical layer and a data-link layer that are hardware standard for the computer network packet communication system. Maximum spacing between two computer stations of Ethernet is 2.8 km, and the maximum number of stations in a network is 1024. Using a sub-network technology with routers, the total length and number of stations can be extended.

All data are packed into data-link-frame packets in the data-link layer. In the data-link-frame, header 12 byte is the destination address, the next 12 byte is the sender address, the next 4 byte is the protocol type, the next 92-3000 byte is the user data and the last 8 byte is the frame check sequence. If the size of the user data exceed the limit of 3000 byte, the data is divided into multiple packets.

Ethernet adopts half duplex communication system. While a station is sending data, the entire network is fully dominated by the station. However, the transfer rate is 10M bps, and this rate is high enough. Therefore, all of stations can have equal chance of communication in the scale of seconds. If a station tries to send data when another station is sending data, a network collision occurs, and the both of the data is destroyed. The network collision is automatically detected using the frame check sequence, and the both data are sent automatically after the random interval. Therefore, the most important problem for the data transfer using Ethernet is “REAL TIME” sending. Since the all of the stations have equal chance to send data, a station can not reserve priority for sending data. This is significance reason why Ethernet is not widely applied to factory automation field.

Ethernet has 4 kinds of cables, 10-base-5, 10-base-2, 10-base-T and 10-base-F. The 10-base-5 and 10-base-2 adopt coaxial cables, and very tough against noise. These two cables are usually used for connections of bus topology. Using the 10-base-5, maximum segment length is 500m, and can be extended to 1500m using repeaters. Connecting stations to the 10-base-5, transceivers are required. The minimum spacing of the transceivers is 2.5 m. The 10-base-2 cable uses BNC cables, and the maximum segment length is 185m. T type connectors are required to connect stations in the 10-base-2. The 10-base-2 is cost-effective and easy-to-handle, however, a trouble at just one point causes a trouble of all of entire network.10-base-T is a twisted pair shield-less cable, and very easy-to-handle. Usually star topology is adopted for the 10-base-T, and the 10-base-T requires network hubs. The 10-base-T is very easy for handling, however, is not tough enough against noise. 10-base-F uses optical fibers as data sending cables. The optical fiber is for multi-mode of 850nm wave length. The maximum segment length is 2000m. Since the 10-base-F is very tough against noise, the 10-base-F is suitable for outdoor usage. However, The 10-base-F requires expensive hubs.

The most popular data transfer protocol is TCP/IP protocol. The TCP/IP protocol is for the network layer and transport layer, and this is adopted as standard for internet. All hosts of stations on the network have IP address, and the data packets have the destination IP address and IP address of sender’s in the data-link-frame. The TCP/IP protocol recognizes hosts using 32 bits IP address just like 127.0.0.1 (This is an address for local host). A sender station sends the data directly when the destination host locates on the same sub-network, and the sender sends the data to the network router when the destination host is not on the same sub-network. The network router references routing tables and send the data to an appropriate host. In the case that the router adopt a dynamic routing table, the router can send the data appropriately by searching another route even when there is network trouble in a route. UDP/IP protocol is quite similar to the TCP/IP protocol, and often used in intranet. The UDP/IP protocol does not check the connection and data collision, but can send data quickly. This protocol is used for requirement of real time information such as checking time.

HEALTH MONITORING SYSTEM

Smart terminals for health monitoring

For conventional applications that adopted Ethernet for data transfer, PCs ,A/D converters and Ethernet card were required. This requirement made the health monitoring via Ethernet cumbersome. Recently new products that have CPU, memory, ROM, Ethernet IC and A/D converter in one small case have been produced and are commercially available. One of the intelligent terminal is “SmartLink” produced by Keithley. The size is 169 mm long, 35mm width and 28mm height. The SmartLink have 3 channel s of strain gages or 8 channels of voltage measurements of 12 bit, and can storage 15000 data on memory. The maximum reading frequency is 33kHz. Since the SmartLink adopts UDP/IP protocol, users must pay attention for data collision.

Another smart terminal is NetLink developed by a Japanese company DESCO Inc.. The new device have 4 A/D converter channels and 2 D/A channels in a very small package just like PC cards. Since this new smart terminal has D/A converter, users can react on the base of the sensor information using this smart terminals. For example, when fracture of a gas pipe-line is detected, the pipe-line valves can be closed remotely.

Most of the health monitoring users want to obtain additional information except for the sensors. The answer is using web cameras. Using web cameras, users can confirm what is happening practically by seeing images. A small web camera has already been commercially available. One of the camera is NetEye that has CCD cameras ,CPU, memory, ROM and Ethernet port produced by AXIS Inc. Since this NetEye is very small (length 150mm, height 40mm, width 100mm), this cameras can be installed in the small space like inside of the body to see the condition of the inside.

Schema of new health monitoring system

Using the intelligent terminals described above, it is possible to construct health monitoring system via Ethernet. The health monitoring system proposed in the present study is shown in Figure 1. The example shown here is a health monitoring system for Japanese new bullet trains. Multiple kinds of sensors such as optical sensors, thermometers, vibration sensors and speed counters are mounted on the each structural components. In order to check by human eyes, web cameras are mounted under the railroad carriages. Sub-network is constructed in each equipment, and the main backbone Ethernet placed through each equipment. Each sub-network has a CPU to control sensor and actuator to avoid data collision that may cause long delay of data transfer. This can improve the problem of the real time measurements through Ethernet. The CPU judges damages of each part. Once the damage is judged, the information is sent to the main CPU just in front of the driver. Each sub-network CPU has web server to supply information of the condition of the each equipment. The driver can also check each equipment through the web. The total information is sent to a central information center using wireless LAN.

Using Ethernet for health monitoring gives quite a lot of advantages as follows.

(1) Since the Ethernet is digital technology, this is very tough against noise. When the 10-base-F is adopted, electro magnetic noise can be neglected.
(2) Multiple sensors that is not distributed sensors can be connected in a cable.
(3) Replacements of sensors and actuators in service are very easy.

(4) Multiple kinds of sensors and actuators can be connected in a cable.
(5) Troubles of sensors and actuators do not affect network system.
(6) Changing network topology due to change of train carriages is possible by just changing plugs.
(7) Using dynamic routing and multiple network cables, trouble of a network can be automatically avoided.
(8) Multimedia information using CCD cameras can be available to confirm practical condition.
(9) Not just measuring but reaction is possible using an Ethernet cable.
(10) Ethernet technology has already been an established stable technology.

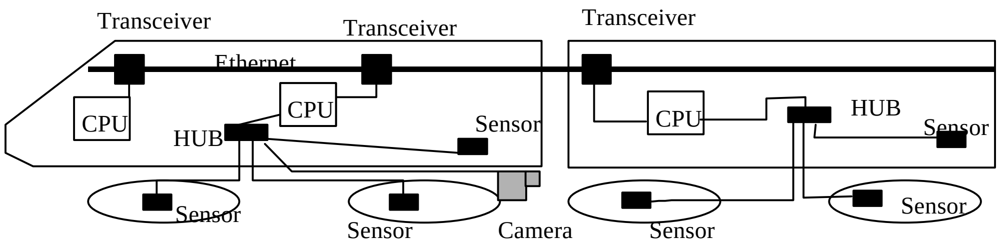

Fig.1 Schema of health monitoring system via Ethernet LAN

The health monitoring system is constructed by using Java computer language. Java is one of the object oriented language without platform dependency. The computer platform independence brings high reusability of programming packages. This is illustrated in Figure 2.

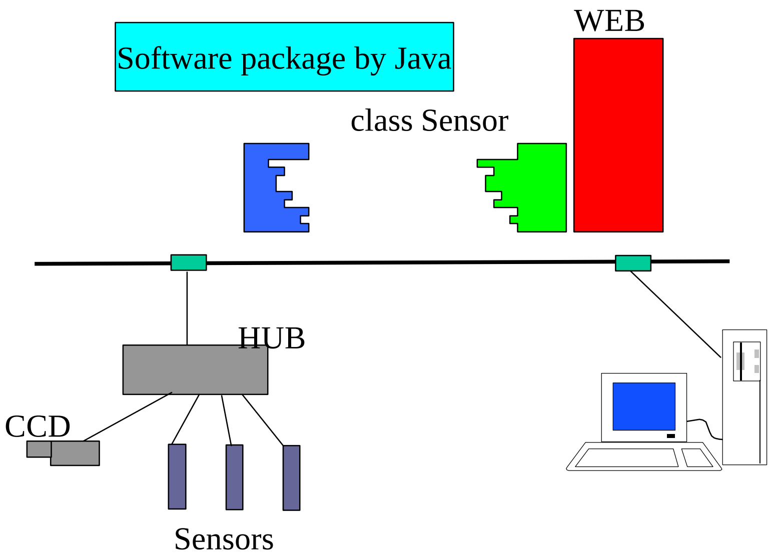

FIGURE 2 Sshema of Java packages for health monitoring

Moreover, Java applets is quite easy application of Web programming. In our future work, the health monitoring web sites will be constructed. The web monitoring system is illustrated in Figure 3.

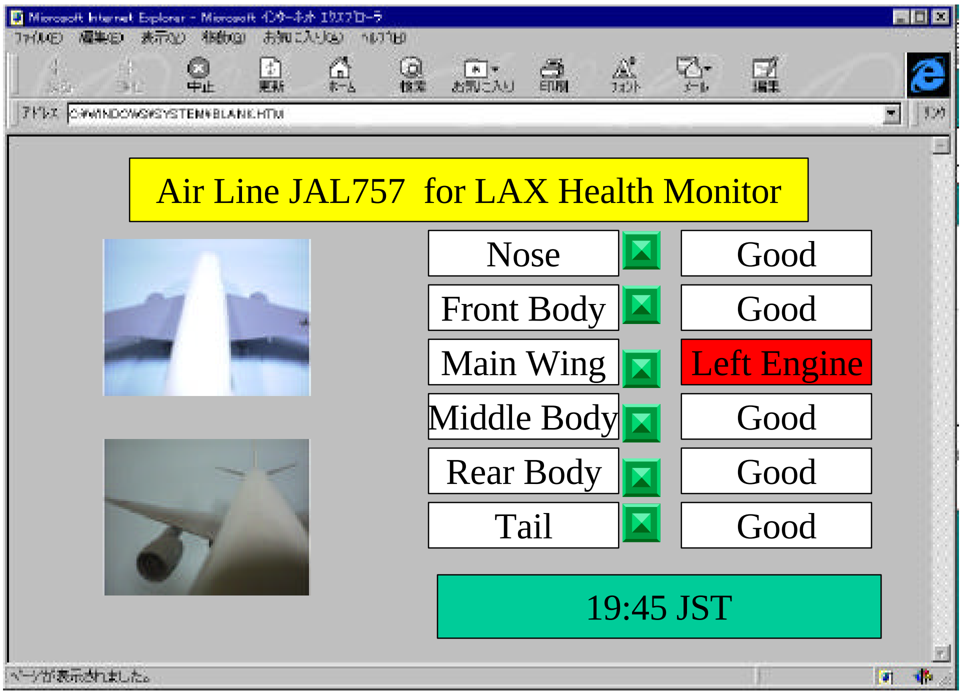

FIGURE 3 Illustration of user interface of health monitoring system

CONCLUDING REMARKS

The present paper describes the advantage of using Ethernet LAN for health monitoring of structures. Ethernet LAN is attractive technology for health monitoring using multiple kinds of sensors or non-distributed sensors. The implementation of the sensors or actuators in Ethernet LAN requires a new smart terminal that has CPU, A/D converter, memory and Ethernet in a small package. Since the smart terminal s have been commercially available, the health monitoring system is quite reasonable now.

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