Remote Monitoring of Instrumented Structures Using the INTERNET Information Superhighway

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ABSTRACT

The requirements of sensor monitoring associated with instrumented civil structures poses potential logistical constraints on manpower, training and costs. The need for frequent or even continuous data monitoring places potentially severe constraints on overall system performance given real-world factors such as available manpower, geographic separation of the instrumented structures, and data archiving as well as the training and cost issues. While the pool of available low wage, moderate skill workers available to the authors is sizable (undergraduate engineering students), the level of performance of such workers is quite variable leading to data acquisition integrity and continuity issues - matters that are not acceptable in the practical field implementation of such developed systems. In the case of acquiring data from the numerous sensors within the civil structures which the authors have instrumented (e.g., a multistory building, roadway/railway bridges, and a hydroelectric dam), we have found that many of these concerns may be alleviated through the use of an automated data acquistion system which archives the acquired information in an electronic location remotely accessible through the Internet global computer network. It is therefore possible for the data monitoring to be performed at a remote location with the only requirements for data acquistion being Internet accessibility. A description of the developed scheme is presented as well as guiding philosophies.

1. Introduction

The recent advent of advanced materials with internal sensory and reaction capabilities, i.e. 'intelligence,' has opened the door for many useful applications in civil structures, e.g. bridges, buildings, dams, in contrast with aerospace structures. Structures built with intelligent materials will be able to sense external loads, assess the internal stresses and damage caused by the loads, and, if necessary, respond appropriately. Although relatively few structures are presently built with such materials, the potential market for the application of these materials can be quite large[1]. The most probable candidates for the initial application of these materials will be high-performance structures such as skyscrapers, including intelligent buildings, bridges, and those facilities where failure presents large safety concerns, such as nuclear waste containment vessels, bridge decks, dams, and structures under construction.

Large scale structures that have actually had fiber optic sensors embedded into them are still relatively few. Holst and Lessing[2] have installed fiber optic displacement gages in dams to measure shifting between segments. Fuhr et al.[3] report the installation of fiber optic sensors into the Stafford Building at the University of Vermont. Similar installations have been completed at the Winooski One dam in Winooski, VT[4], in the newly constructed physics building on the campus of the Dublin City University in Ireland[5], and in a railway overpass bridge in Middlebury, VT[6]. Researchers at the University of Toronto, in conjunction with City of Calgary (Alberta, Canada) officials, have embedded fiber optic strain gauges into the prestressed concrete support girders on a highway overpass[7].

A major challenge to building and using a comprehensive sensor system is that a variety of physical parameters must be measured using sensors that are often spatially distributed across the span of a large structure. The sensing and data processing requirements are complicated by most of the measurands exhibiting dynamic behaviors with time scales that vary over several orders of magnitude. An additional concern is that modern data acquisition hardware collects enormous amounts of data, only a small fraction of which may be useful.

In the case of an instrumented civil structure questions regarding the data acquistion and frequency of monitoring of the embedded sensors arise. In parallel, labor concerns ranging from training of sensor "inspectors" to who actually performs the processing and analyzing of the acquired data are legitimate matters in the practical field implementation of such developed systems.

2. Data Acquistion from Instrumented Structures

We have been concerned with the acquistion of data from embedded and surface attached sensors which are placed throughout a potentially large instrumented civil structure. Two issues predominate our activities: (1) collection of the sensors' data at a single central location within (or near) the instrumented structure; and (2) development of a method for remote monitoring of this sensor information. With respect to issue 1, we have proceeded to use radio telemetry for data acquistion and concentration at a single central location[8]. Issue 2's requirements are currently being met through the use of system software resources associated with the Internet global computer network. The Internet is actually a collection of approximately 30,000 computer networks. There is a vast array of network software utilities that manage and control network node-to-node communications. We have found that for simple data archiving and subsequent remote locale retrieval, the use of an "anonymous" File Transfer Protocol (FTP) site is optimal. This allows raw, time history data from each embedded sensor to be archived on an Internet networked computer in a file (or folder) that may be accessed using FTP. Information security may be obtained by requiring a password to access this data, or, complete world-wide Internet access may occur if the sensor data is archived in an anonymous FTP accessible file/folder. Power frequency data acquired from fiber optic vibration sensor #16, located within turbogenerator #3's support mount is displayed as Figure 1. This data was accessed remotely using a modem equipped Macintosh LCII microcomputer from the "WinOneDam@emba.uvm.edu" anonymous FTP data site located on a Sun Microsystems computer at the University of Vermont. A portion of the raw data is shown in this Figure as well as the associated frequency power spectra.

In conjunction with the monitoring of the status of the embedded sensors is the need to concurrently monitor the electric power generation status as well as the water level and flow rates. Two methods are used for this data acquistion: (1) traditional analog-to-digital (A/D) conversion of the electrical values associated with each turbogenerator's water flow rate, turbine rotation rate (RPM), generation efficiency and generator output electrical power; and (2) simple TV camera video capture of the operator's consoles associated with each turbogenerator. In the first case, the acquired individual voltage levels are interfaced to a unique channel on a microcomputer's A/D board, sampled, scaled, time-tagged and stored in memory for transmission to the Internet host computer. This information is then formatted on the Internet-host and placed in an anonymous FTP account for worldwide Internet access. In the second case, the acquired video frames, (1 for each console display plus the outside camera) are transmitted to the Internet-host computer's "WinOne-video" Mosaic file for worldwide Internet access and viewing using Mosaic or a comparable video display program.

Point	fiber_freq.y	freqs.y
0	6.1583e-05	0
1	3.3713e-08	12
2	8.6179e-08	24
3	3.6841e-08	36
4	1.6613e-07	48
5	3.1326e-08	60

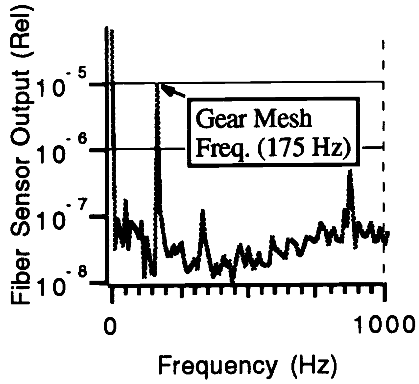
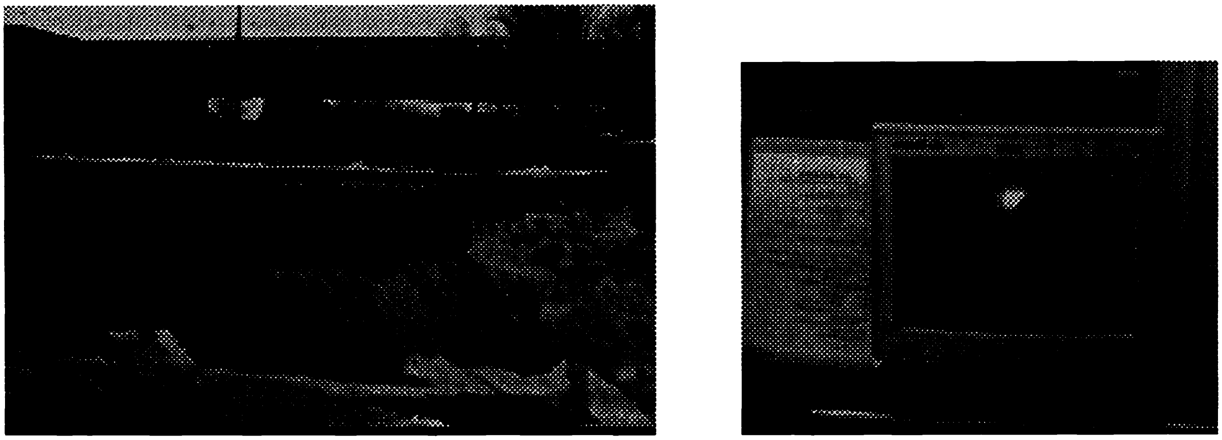


Figure 1. FTP accessed embedded sensor data obtained from the Winooski One dam.

In a manner somewhat similar to the FTP site, the use of the Internet network utility program "Mosaic" has been chosen for the visual display of video frames acquired from video cameras positioned at the Winooski One dam. Mosaic is an Internet-based global hypermedia browser that allows the user to discover, retrieve, and display documents and data from all over the Internet. It is part of the World Wide Web project, a distributed hypermedia environment originated at CERN and collaborated upon by a large, informal, and international design and development team. Mosaic, which can be copied for free from many Internet software archives, organizes information into a so-called "home page", which serves as a table of contents about a particular topic or group of topics.

In the context of instrumented civil structures information, we have configured a multimedia (video/audio) equipped microcomputer for acquiring and preprocessing of the video images obtained from the cameras located at the instrumented structure, in this case, the Winooski One hydroelectric dam. Near realtime video images are placed into the appropriate Mosaic source location home page. All video images are not archived, due to limited physical disk space, but rather have the last 30 frames temporarily stored. Viewing of the video frames is achieved using Mosaic on an Ethernet configured Internet accessible (IP - Internet Protocol addressed) microcomputer.

The images shown as Figure 2 represent the Mosaic video viewing of the Winooski One dam on April 6, 1994 at 2:20 PM EST. Specifically, Figure 2.a shows the outside video view of the water flowing over the dam at this time. Figure 2.b shows the associated video frame of the camera's view of the control monitor for turbogenerator number 2. From this frame the operational values and river level and flow rate data of this generator are readily apparent (please note that the full screen sized video frames have been reduced for this publication).



(a) (b)

Figure 2. Internet accessed, Mosaic displayed realtime "snapshots" of: (a) from an outside deck video camera showing the current water flow level at the Winooski One hydroelectric dam; (b) powerhouse control console associated with turbogenerator #2. The actual display has been reduced from its full screen size for this publication.

3. Summary

The requirements of sensor monitoring associated with instrumented civil structures poses potential logistical constraints on manpower, training and costs. The need for frequent or even continuous data monitoring places severe constraints on the monitoring performance given real-world factors such as available manpower, geographic separation of the instrumented structures, and data archiving as well as the training and cost issues. We have found that many of these concerns may be alleviated through the use of an automated data acquistion system which archives the acquired information in an electronic location accessible through the Internet. It is therefore possible for the data monitoring to be performed at a remote location with the only requirements being Internet accessibility.

4. References

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