VIRTUAL REAL-TIME INSPECTION OF NUCLEAR MATERIAL VIA VRML AND SECURE WEB PAGES

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ABSTRACT

Sandia National Laboratories' Straight-Line project is working to provide the right sensor information to the right user to enhance the safety, security, and international accountability of nuclear material. One of Straight-Line's efforts is to create a system to securely disseminate this data on the Internet's World-Wide-Web. To make the user interface more intuitive, Sandia has generated a three dimensional VRML (virtual reality modeling language) interface for a secure web page. This paper will discuss the implementation of the Straight-Line secure 3-D web page. A discussion of the "pros & cons" of a 3-D web page is also presented.

The public VRML demonstration described in this paper can be found on the Internet at the following address. (A Netscape browser, version 3 is strongly recommended)

`http://www.ca.sandia.gov/NMM/`

INTRODUCTION

Very few things in this world are as valuable and dangerous as fissile material. In response, President Clinton has demanded that the United States ensure that its "fissile material meet the highest standards of safety, security, and international accountability."[1]

In the past, providing this protection was very human intensive. Unfortunately, human interaction with the material has numerous drawbacks. Not only are people exposed to radiation, but opening the vaults and inspecting the material could provide additional opportunities for accidents, diversion, and sabotage. Minimizing human interaction with the material can also have financial benefits[5].

It is hoped that technology can help reduce these risks while still maintaining the highest standards of safety, security, and international accountability. One solution would be for authorized users to make "virtual" inspections instead of manual ones via remote monitoring technologies such as Straight-Line[2,3,4].

An optimum solution for a "virtual inspection" could include the following:

- Relevant real-time and historical sensor information would be securely available to authorized users.
- The user could conduct these inspections from his/her desktop computer.
- The software would be extremely simple to use and intuitive. Specifically, the interface would simulate a real visit as closely as possible.

The Internet's World-Wide-Web provides a tool to implement a potential solution.

- Secure web pages can disseminate information securely to user's desktops using widely available, widely used software
- Virtual Reality Modeling Language can provide a 3-D interface for the web site.

This paper will describe the VRML interface, provide an overview of its implementation, and list the "pros & cons" of a 3-D web page.

THE INTERFACE

Accessing the Straight-Line secure VRML demonstration web page is quite similar to that of accessing any other web page on the internet. One simply points a Netscape browser to `http://www.ca.sandia.gov/NMM` and follows the directions. After entering an user-ID and password (public ones are posted on the page), the user can access the VRML web page (see figure 1).

Navigating in the VRML model can be done in several ways. Detailed descriptions of these techniques can be found in the "Help" documentation of the browser. The simplest way is to use the "view points" (available by clicking the right mouse button while in the VRML frame). These viewpoints are at predefined, convenient spots. The VRML interface can be a bit disorienting at first – and these viewpoints are useful if one gets "lost".

DISCLAIMER

The sensor data for the magazine is displayed in the bottom frame of the page. Initially, the magazine door switch and magazine motion sensor status are displayed. Scrolling down this lower frame also reveals the last 5 magazine "events". (i.e. a motion sensor detecting motion, the opening or closing of a door, etc.)

As one nears the front door of the magazine, they will see to the right a "notice sheet". Clicking on this item will allow the user to download an authenticated and encrypted "human email" messages. It is recognized that sensors alone may not provide the complete story. A message from an onsite inspector may provide key insight to off-site users. The messages for the Straight-Line demonstration used AT&T's "Secret Agent" software for authentication and encryption. Other third party software packages could also be used depending on user requirements. The author found it convenient to configure Secret Agent as a helper application. Thus Netscape will automatically call the program when a Secret Agent file (i.e. a file with an .sa file extension) is downloaded.

Going into the magazine, one can view the nuclear material containers (see figure 2). Two of the barrels have "sensor packs" on them. Clicking on these barrels will bring up the sensor data for these barrels in the bottom frame. This data includes the container temperature, total radiation dose, etc.. Clicking on the camera inside the magazine will provide the latest video snapshot from the camera.

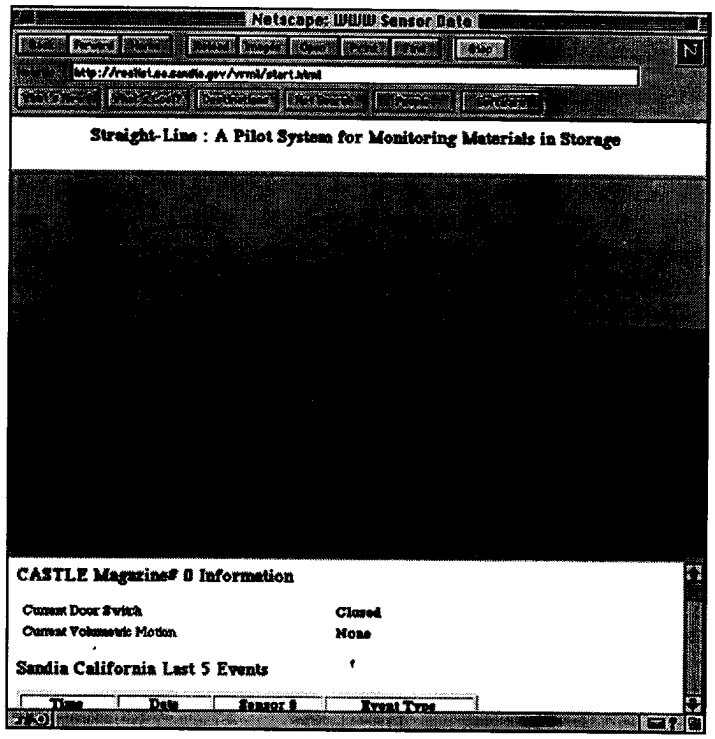

Figure 1, View of the Storage Magazine

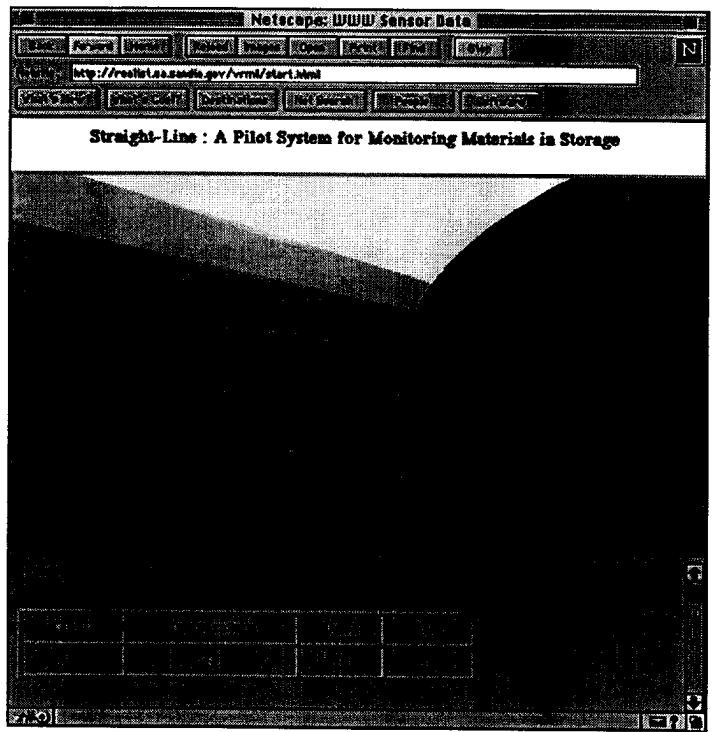

Figure 2, Inside the Storage Magazine

IMPLEMENTATION

Gathering the sensor data

The sensor data displayed on the publicly available 3-D web page is sensor data generated by a software simulator. However, the simulated data is in the same format as the real sensor data from the Sandia/California Straight-Line exhibit. These sensors were installed during Straight-Line's Fast-Track effort (see reference 2). During the summer of 1996, the Fast-Track hardware is being upgraded. Upon the completion of this task, real sensor data could be easily displayed in the Straight-Line 3-D web page.

The sensors used by Straight-Line include temperature, radiation total dose, fiber optic seal, container motion, door switch, room motion, and a video snap shot camera. The video camera will take a snap shot whenever an "event" occurs, on regularly scheduled intervals, and upon user request. A more detailed discussion of the Straight-Line architecture can be found in references 2,3, & 4. (Not all of these features are included in Straight-Line's VRML page)

The sensor data is transmitted via RF to the Straight-Line Magazine Data Unit (MDU). The MDU stores the data, controls the video camera, and relays the information to a central Site Data Unit (SDU)

via a local area network at the facility.

The SDU provides the main database for all sensor and image data for the site. The database also contains configuration and location data for the sensors. This configuration data could then used by the web page to create realistic layouts of sensors in the storage facility.

A National Data Unit (NDU) is then used to monitor the various SDUs and provide information to the web servers. Currently, the Straight-Line system is installed at three different locations -- Sandia / California, Sandia / New Mexico, and at the DOE Pantex Plant in Texas. The NDU and SDUs are connected via a virtual private network overlaid on the Internet. (Note: at present, the VRML interface is an exploratory effort and is operational only with Sandia California sensor data - or its simulator).

Disseminating the data

The web servers sit between the NDU and the Internet and provide the primary user interface. Special firewalls are also installed between the NDU and web server, and between the web server and the Internet. These firewalls are used to help prevent unauthorized access or tampering with the Straight-Line system.

What is a secure web server?

A secure web server is simply a web server that is limited to authorized users only. The two key features are:

- User Authentication: Only authorized users are allowed to log in and access information.

- Link Encryption: Information is encrypted as it flows from the server to the user. This prevents "eavesdroppers" from acquiring the data.

The Straight-Line 3-D web page demonstration uses a Netscape Commerce Server to provide encryption from the web server to the user's desktop computer. A variety of encryption algorithms are supported, including RC2, RC4, and DES. It is also possible to limit encryption solely to the DES algorithm to comply with Federal Information Processing Standard 46-2.

User authentication is currently handled by standard user-IDs and passwords. The use of client certificates is being investigated for future user authentication. (The soon to be released Netscape browser version 3 will support these certificates.)

How secure is secure enough?

The question of how secure is secure enough is tough. The difficulty lies in that every situation is different.

Project Straight-Line is prototyping and evaluating several different methods for protecting information. The goal of Straight-Line has been to develop a site independent system that could be used with a variety of sensors and situations.

To determine which system is appropriate, numerous questions must be asked. These include "What is the street value of this information" and "What is the cost to stakeholders if this information is released".

Once the issues are understood, one can begin to make the right choices regarding security. Fortunately, web page technology allows the use of a wide range of networks and media. Some potential choices that Straight-Line has worked on include:

- **Internet**: A regular Internet connection may be appropriate for some types of unclassified information. Commercially available firewalls and web servers provide standard, industrial strength security. Just as a deadbolt can keep many physical threats out, these commercial products can keep many of the electronic threats out. Moreover, users need only Internet access and an up-to-date web browser such as Netscape Navigator to access the data. This maximizes usability while maintaining "best industry practice" security. If the result of unauthorized disclosure of the information is relatively low (i.e. the cost of losing a piece of information is less than several thousand dollars) this option may be appropriate – especially if the users are geographically and organizationally diverse. (The Straight-Line VRML web page uses such a system).

- **Regular Internet Plus "Pre-Encryption":** An Internet connection with additional "pre-encryption" may be appropriate for protecting information that requires a greater level of security. Adding pre-encryption can allow one to avoid some of the vulnerabilities inherent in http (hypertext transfer protocol) and web servers. Unfortunately, pre-encryption means that the files are encrypted with the user's public key before they are sent through the firewall to the web server. The user also needs special software (i.e. a custom "plug-in" or "helper-application") to decrypt the files after they arrive. This type of configuration allows the web server to be "dumb" -- the web server itself never sees plain-text data. Thus even if a hacker totally compromises the

web server, they are still prevented from seeing the plain-text sensor data.

There are some disadvantages to this system. Managing the pre-encryption keys becomes increasingly difficult as the number of users increase. Moreover, real time updates to "dynamic" web pages are more difficult to implement. Using Java and other "glamorous" technologies is also difficult. However, despite the additional burdens placed on the user and system administrator, this system offers very good security and utilizes the Internet's connectivity for geographically and organizationally diverse users.

Straight-Line is developing a prototype of this system. However, the interface uses standard HTML (Hypertext Markup Language), not VRML. Fortunately, a VRML interface could be constructed if needed.

- **Intranet**: A simple way to avoid the perils of the Internet is to simply not use it. Setting up an isolated private network (real or virtual) is a simple, brute force method to keep out unwanted visitors. If the intranet uses TCP/IP, then the web servers and browsers will work quite well. For classified information, a secure intranet is often a good choice. The security of this option is quite high, but the drawback is that every user must have access to the private network. However, for users demanding the highest security, an intranet may provide the optimum mix of security and usability.

  The web pages (both HTML and VRML) developed for the "Regular Internet" method would work equally as well on an Intranet.

Need-to-Know Issues

So far in this paper, we have assumed a single type of user. However, for many applications, there would likely be several types of users. Moreover, some of the sensor information may be classified.

It is not the intention of this paper to provide a detailed description of the techniques used to implement our need-to-know policies. The VRML demo is for a single type of user, and contains no classified information. However, for completeness, a brief description of Straight-Line's need-to-know techniques are provided below.

Collecting classified sensor information: If a sensor produces classified data, it will be immediately encrypted at the sensor with US government approved encryptors. This encrypted data (plus other unclassified information needed by classified user) is then sent up through the system and then securely transferred to a secret network. Once on the secret network, it is decrypted and made available to authorized users via a web page on that network.

Project Straight-Line is currently prototyping this system. For the prototypes, no actual classified information is used. Truly classified data will be processed in the future only after all necessary government approvals have been obtained.

Data Compartmentalization: Fortunately, most of the data collected by Straight-Line is unclassified. However, because of need-to-know concerns, different types of users will only be given the information that they require.

Because there are only a few types of users, the primary method Straight-Line uses to disseminate data to different types of users is to use multiple web servers. Each web server is tailored to the needs of the particular user type. Moreover, the NDU and its access control lists will provide only the allowed types of data to that particular web server. Thus, if a particular type of user is not allowed to see radiation data, then the NDU will not send radiation data to that web server. In addition, the web server will not be set up to ask for, receive, or properly display the radiation data.

Impelementing VRML

VRML is rather new, thus presenting several challenges to 3-D web authoring. In fact, VRML did not exist until Mark Pesce and Tony Parisi unveiled VRML at the First International Conference on the World Wide Web in May 1994. The first draft of the VRML 1.0 specification was presented at the Fall WWW conference with the completed specification posted on the web by May 1995.

One of the deficiencies in the VRML 1.0 specification have allowed incompatibilities between VRML authoring tools and browsers; models that work in one browser may cause another to crash. The Straight-Line demonstration has been optimized for Netscape, version 3.

In the future, Straight-Line hopes to implement VRML 2.0. This standard under development and seeks to extend the VRML specification by adding behaviors. This will allow objects to move, change color, and interact with the user and each other. VRML 2.0 is currently in final draft and will be presented at the SIGGRAPH conference in August 1996.

VRML 2.0 enhancements will allow user interaction including the opening and closing of the gate or door along with the changing of a barrel's or sensor packs color based upon derived information. Further, the user

interface can be extended to use more intuitive navigational devices (i.e., spaceball, head mounted devices, and gloves).

The Straight-Line VRML Demonstration Model

Due to the lack of authoring tools available, an existing modeling package with a VRML translator was used. All objects were created from scratch using Strata Studio Pro Blitz 1.75 on a Power Macintosh 7100/66 and 8500/120.

Studio Pro allows the assignment of minimal material attributes (i.e., color, transparency, shine), lighting, and WWW Anchor nodes. Refinement of the model was done using a text editor (BBEdit Lite); this included camera locations along with the additional anchor information which allowed for the targeting of the HTML frames.

PROS & CONS

Benefits of a 3-D web page include the following:

- 3-D interaction is more intuitive. Simply put, humans find 3 dimensions more natural than 2 dimensions.
- A 3-D virtual inspection comes closer to simulating a physical inspection than 2 dimensions could provide. This may have benefits in increasing "transparency" between parties with regards to the status of the nuclear material
- An accurate rendering gives a user a much better understanding of how the material is stored and how the sensors are placed.
- The New web browsers (i.e. Netscape Navigator version 3) contain built in VRML viewers. Since most Internet users browse the Internet with Netscape, most users will not have to load any special software to view a VRML document.
- Displaying additional sensor hardware in the storage magazines is easily done via VRML. For example, if a new camera is added, then the web author just adds another camera icon in the right place of the VRML document and makes the necessary hyperlinks. The next time a user logs on to the web site, they will notice a new camera. Clicking on the new camera can then provide the snap shots from this device.

Disadvantages of 3-D web pages include:

- 3-D web technology is very new. The standards are changing quickly. A VRML page developed now is in danger of becoming "out of date" rather quickly.
- Though many government and corporate users have high speed access to the Internet, it is likely that some users will still be limited by 28.8kbs or slower modems. Thus the time to download highly detailed images may be excessive.
- An experienced user may find the VRML interface to be a little slow. With standard, 2-D interfaces, an advanced user can memorize key combinations and quickly retrieve the desired information.
- The VRML 1.0 standard has numerous problems. These will not be resolved until Version 2.0 is adopted by the key industry players and implemented in their VRML authoring and viewing tools.

SUMMARY

There are numerous reasons for replacing manual inspections of nuclear material with virtual inspections. Minimizing costs, radiation exposure, and opportunities for accidents, diversions, and sabotage are compelling reasons to install remote monitoring technologies.

Secure 3-D web pages can contribute to providing realistic virtual inspections. From a usability viewpoint, a Netscape browser is very widely known and used by most Internet users at their desktop. From a security viewpoint, a variety of implementations can be used to satisfy a significant range of requirements. From a intuition standpoint, a 3-D interface is much more realistic than 2-D.

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