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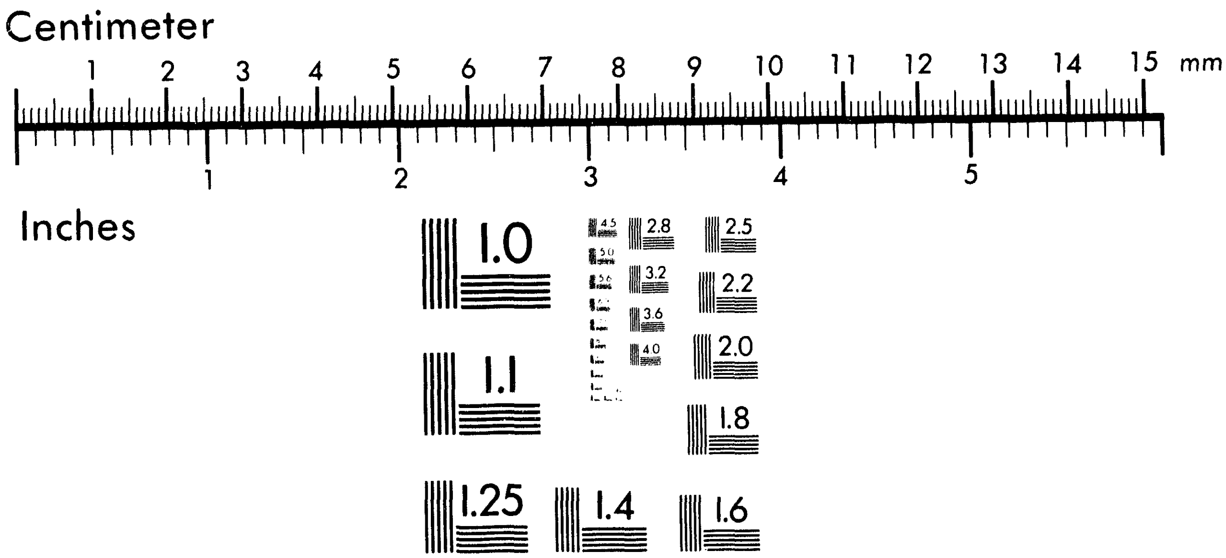

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TITLE: UNATTENDED DIGITAL VIDEO SURVEILLANCE: A SYSTEM PROTOTYPE FOR EURATOM SAFEGUARDS

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UNATTENDED DIGITAL VIDEO SURVEILLANCE: A SYSTEM PROTOTYPE FOR EURATOM SAFEGUARDS

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ABSTRACT

Ever increasing capabilities in video and computer technology have changed the face of video surveillance. From yesterday's film and analog video tape-based systems, we now emerge into the digital era with surveillance systems capable of digital image processing, image analysis, decision control logic, and random data access features—all of which provide greater versatility with the potential for increased effectiveness in video surveillance. Digital systems also offer other advantages such as the ability to "compress" data, providing increased storage capacities and the potential for allowing longer surveillance periods. Remote surveillance and system to system communications are also a benefit that can be derived from digital surveillance systems. All of these features are extremely important in today's climate of increasing safeguards activity and decreasing budgets. Los Alamos National Laboratory's Safeguards Systems Group and the EURATOM Safeguards Directorate have teamed to design and implement a prototype surveillance system that will take advantage of the versatility of digital video for facility surveillance and data review. In this paper we will familiarize you with system components and features and report on progress in developmental areas such as image compression and region of interest processing.

1.0 INTRODUCTION

Los Alamos National Laboratory's Safeguards Systems Group and the EURATOM Safeguards Directorate have begun a collaboration to develop a multi-camera video surveillance prototype based on the Los Alamos Experimental Inventory Verification System (EIVSystem). This system will function as a remote, unattended, data-gathering system with intelligent features designed to reduce the amount of recorded video data. The basis for this collaboration are features of the EIVSystem that have been demonstrated in US domestic safeguards and show potential for use in the automated, unattended surveillance systems required by EURATOM Safeguards. The purpose of this developmental effort, currently called "EURATOM Alpha," is to develop leading-edge software and technologies into surveillance systems that will meet the future needs of nuclear safeguards inspection and regulatory bodies. Because computer and video hardware are changing so rapidly, our goal is to focus on the development of surveillance strategy and state-of-the-art software while remaining flexible enough to incorporate rapidly changing video technology. By developing *strategy* we mean to improve the way surveillance systems are used through integration with radiation monitoring equipment, process data available from other computer systems, and advanced communications systems. *Software* development allows the use of new methods for analysis and decision making that will reduce recorded data to that of safeguards significance.

2.0 BACKGROUND

The EIVSystem is a video-based surveillance system designed to help reduce the frequency of physical inventories in domestic nuclear materials vaults and long-term stores.[1] It uses digital video motion detection to detect events and records video and change data for safeguards review. This surveillance system is computer-based and has one or more charge coupled device (CCD) camera(s), a disk data store, and a tape archival system. The EIVSystem uses Sun Microsystems or any compatible SPARC architecture.

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The EIVSystem is part of an overall defense-in-depth protection strategy that relies on multiple layers of security to provide complementary nuclear safeguards measures.

Unique features of the EIVSystem include wavelet transform motion detection, region of interest processing, and wavelet transform image coding (compression). Wavelet transform difference coding of video images performs motion detection based on the discrete wavelet transform (DWT) sub-band coding and adaptive uniform scalar quantization. This frequency domain process provides the EIVSystem with real-time motion detection and image compression ratios greater than 60:1 with excellent reconstructed image quality. Region of interest features allow multiple "zones" to be defined as surveillance areas, each having its own user-defined properties and action list.

The Los Alamos EIVSystem is a prototype developed to test the use of intelligent, automated surveillance in domestic safeguards. This system is installed at two DOE facilities and is currently undergoing final software modifications. It is scheduled to be fielded in the summer of 1994 as the MONITOR Surveillance System.

3.0 EURATOM ALPHA: REQUIREMENTS

The basic system requirements for Alpha have been developed through EURATOM experience with surveillance systems and Los Alamos experience in the development and fielding of the EIVSystem. Of course, the standard hardware components of any video surveillance system exist, for example, cameras, computer, and storage media; experience dictates that these components should be "off the shelf" hardware, easily swapped and easily maintained with commercially available parts. Alpha will consist of a field unit—the data acquisition system—and a data review unit designed for "office area" use.

Alpha is to be a "front-end" video system, using the system's motion detection ability to trigger event recording, but the importance of a time-lapse mode was recognized by all for "back-up" and verification of correct operation of the front-end mode. And, as with the hardware, many standard software requirements are recognized such as an easy-to-use window-based user interface, data authentication and compression, and computer security features. In the following sections, we will present a brief overview of those features that are standard to all video surveillance systems and more detail on special features that are unique to the Alpha prototype design.

4.0 ALPHA HARDWARE

Like the Los Alamos EIVSystem, the Alpha system will use SPARC architecture; the variety of computers available in this architecture will allow system hardware to be scaled specifically to the application. For example, a four-camera system can be implemented using a small, single cpu computer; where extra speed is required or for larger systems, a multi-cpu system can be used with no other changes to software or other hardware components. Portable units are available for 1-2 camera, or temporary, installations and are also useful as transportable data viewing systems. Our goal is to provide the most flexibility in hardware choices while using commercially available, standardized components.

System data storage can be either on-board or external using 1 to 5 gigabytes of disk storage. Disk packaging and capacities are changing quickly in today's rapidly expanding computing environment, so we will design this system to be compatible with "currently available" SCSI technology rather than designing to a specific disk or capacity. Current technologies allow us to easily store digital data on 1.05, 2.1, or 2.9 gigabyte disks that can be housed in cages of up to 48 disks each. For the Alpha prototype, we will target a digital disk storage capacity of 1.05 to 5.25 gigabytes; 1.05 gigabytes will be sufficient for most 3-month surveillance period applications, and more can be added where necessary. Digital tape drives holding 5 gigabytes are used to store back-up data, store time-lapse-mode data, and to off-load data for viewing at other locations.

System cameras can be any PAL or NTSC camera, with *automatic* video format determination performed at system start-up. Our current video applications use CCD cameras with analog outputs, but the newly available true digital cameras will also be compatible. Camera cabling can be either fiber-optic or coaxial, and signals will be coded at the camera and authenticated at the host computer.

5.0 ALPHA SOFTWARE

Basic software requirements for Alpha include an easy to use window-based user interface for system configuration, operation, and data review; computer security features; external system communications; data authentication; user selectable "regions of interest"; and data compression. The window-based user interface is an important but standard component of any computer application so we will not describe its elements in detail. The design goal for the Alpha user interface is ease of use; operation of the program should be intuitive and the user should be able to use the system with little formal training.

Computer security features will be implemented in the form of mandatory and discretionary access controls. Mandatory access controls for the Alpha system consist of user passwords for system entry on both the surveillance data acquisition unit and the data viewing unit; discretionary access controls include file and feature access permissions that limit the user to only those files and features allowed by the system administrator. In general, there will be three access levels: inspector, technician, and system administrator; however, complete flexibility will allow custom configuration of access controls by the system administrator.

Alpha's external communications capabilities will include modem, serial, and ethernet. Modem communication will be used to transmit daily "state of health" messages back to the inspection authority's headquarters and can be used to retrieve system data where remote data transmission is appropriate. Serial communication capabilities allow Alpha to be integrated with new or existing radiation measurement devices or a variety of other sensors. No current plans exist to use the ethernet capability, but future implementations of this system will likely use ethernet communications for all on-site, inter-system communications. All external communications will be encrypted or authenticated to ensure the integrity of Alpha system data.

5.1 Region of Interest Operations

One drawback of simple video event detection is that it does not distinguish between important and unimportant events; it reacts to every change and movement—which is not always necessary. In any room, there are areas that do not require tight security; even high-security areas may include regions of low-security significance, like walkways and doorways, where personnel movements are normal and expected. What is needed, then, is "graded protection": differing amounts of protection for sensitive and non-sensitive areas. A video motion detector should be intelligent enough to provide this.

5.2 User Interface

Alpha will address the need for graded protection by providing *Region of Interest processing*. Region of Interest processing allows the user to selectively protect regions of a room. On a computer with a graphical user interface, inspection personnel will show Alpha which objects in the room require surveillance and how much (see Fig. 1). In effect, every region in the room can be given its own separate alarm. Alpha takes this region information and uses it in everyday processing.

The Region of Interest interface was developed at Los Alamos and at the University of New Mexico for use with the Alpha on X Windows graphical workstations. Using an electronic mouse, the user can define regions quickly and efficiently by drawing borderlines around and between objects in a black-and-white video image (Fig. 1). The Region of Interest tool represents the best use of point-and-click windowing technology; it is much easier to draw regions using a mouse instead of a computer keyboard.

5.3 Color Code and Levels of Security

Region borders can be either geometric or curved and can be color-coded red, yellow, or green. The border color denotes the security level of the enclosed region: red represents the tightest security, yellow medium security, and green the most casual security. These color-coded region maps tell Alpha how to respond to changing conditions and detected events. For example, detection of motion in a "red zone" will trigger video recording for the duration of that event; detection of motion in a less sensitive "yellow zone" may only trigger the recording of a single image; and motion detected in a "green zone," where authorized human motion is expected, may simply cause a line of text to be recorded in an event log.

5.4 Access Control

Regions of interest are defined by inspection personnel during configuration of Alpha. After deciding which objects require more protection and which require less, an authorized user logs in to the Region of Interest interface and draws borders around those objects.

Each time the user draws a region, the Region of Interest tool will ask him or her to briefly describe the new region (see Fig. 2).

Alpha will then use this description of the region any time an event occurs there. At the same time, the short description can be recorded in Alpha's event log for later use in generating informative event reports.

5.5 Advanced Features

Region of Interest processing is the basis for advanced capabilities like *direction-sensitive alarms*. Direction-sensitive alarms are alarms that only go off when motion in certain prohibited directions is detected. This capability would be useful for detecting wrong-way motion of items under surveillance.

The Alpha user will create a direction-sensitive alarm by drawing a series of regions. Notice, for exam-

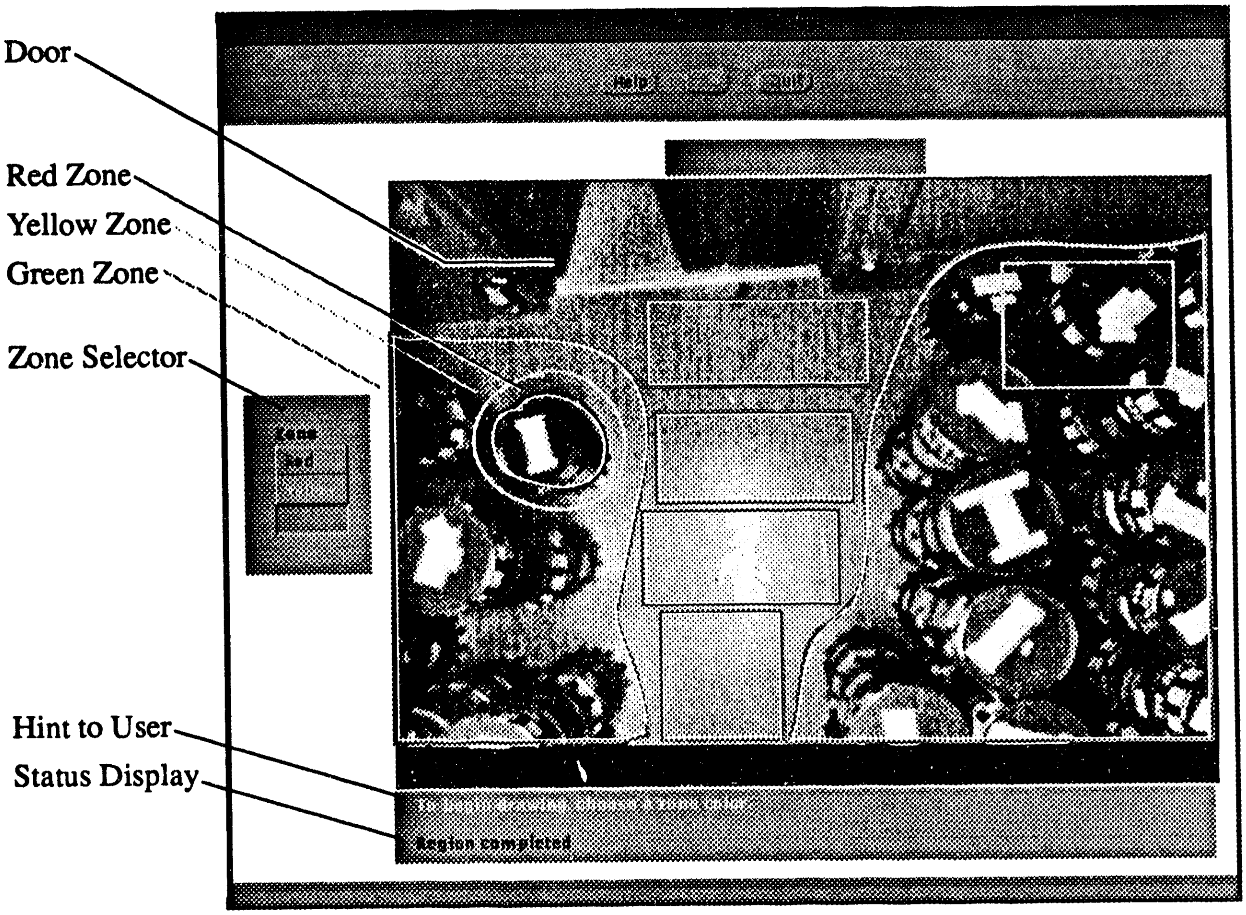

Figure 1.
A video image of a storage vault. The user has divided the image into regions of interest (colored zones).

ple, the line of red zones leading from the door in Fig. 1; the user might configure these zones to set off an alarm if motion occurred first in the bottom region, then in the region above it, then in the region above that, and so on; such a sequence of events would imply motion toward the door.

Combinational alarms are possible too, i.e., alarms that go off when motion occurs simultaneously in one region *and* in another, or when motion occurs in one region *and not* in some other region. This alarm capability can be useful when detection of large object motion is desired but detection of human motion is not.

6.0 IMAGE COMPRESSION AND THE WAVELET TRANSFORM

Data storage capability is of primary importance to the viability of any computerized data acquisition system. This is especially true for international safeguards, where unattended surveillance periods are currently up to 3 months and could increase with increasing inspection activities and decreasing budgets. To achieve the required compression ratios and maintain minimal loss of quality in the reconstructed images, we determined that commercially available solutions like the ISO "JPEG" image compression standard were not adequate. Instead, we adopted a wavelet transform compression algorithm based on predictive image coding strategies, currently being developed at Los Alamos.

Using the wavelet transform, a prediction of each frame is made based on the previous frame, and the error residual (the difference between the actual and predicted frames) is coded for storage or transmission or both. The change detection algorithm plays an important role in the compression process in that it is used to adjust the quality level in the frame-difference coder based on the activity in the scene. By using relatively low quality coding on frames with little activity, compression ratios greater than 60:1 with excellent reconstructed image quality can be realized.

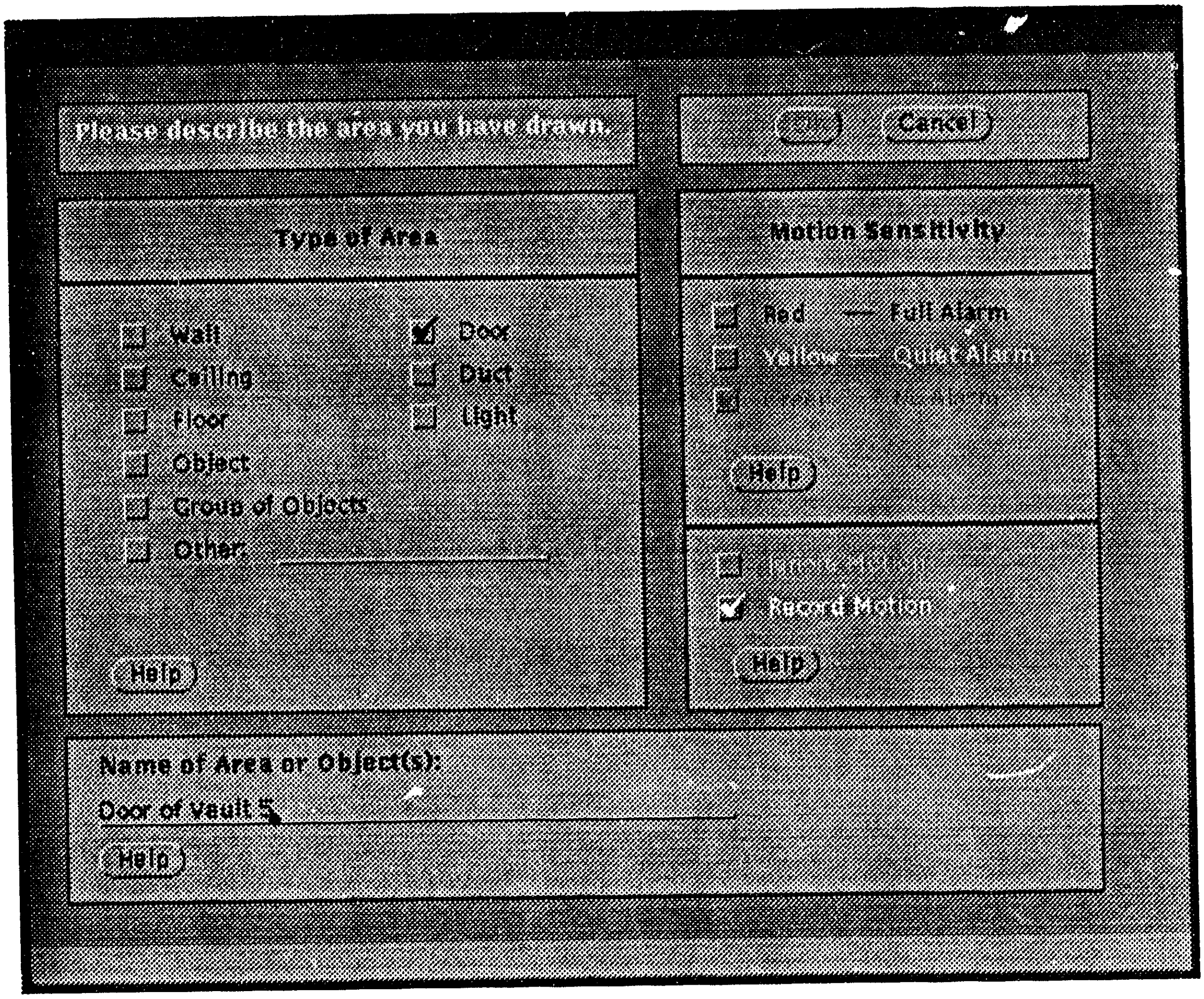

Fig. 2.
Sample fill-in form. The user is asked to check boxes and fill in blanks to describe a new region.

Compression of image frames is based on discrete sub-band coding of the wavelet transform and adaptive uniform scalar quantization. The sub-band coder is a two-channel perfect-reconstruction multi-rate filter bank with linear-phase FIR filters corresponding to a family of regular, bi-orthogonal wavelets; this same multi-rate filter bank is used in the FBI's wavelet/scalar quantization standard for coding digital fingerprint images.[3,4] The filters are applied to row and column vectors of an image using symmetric extrapolation at the image boundaries; this "symmetric wavelet transform" technique is detailed in Ref. 5. The resulting two-dimensional transform is then cascaded down five levels to produce the 16-band octave-scaled decomposition.

While the scene is inactive, the frame-to-frame differences are extremely small and can be coded at a very low bit rate with little perceptible distortion, allowing a continuous record to be archived at a low storage cost. Of course, as soon as an event occurs and the state becomes active, a much higher bit rate is needed to record the event accurately. A major advantage of adaptive scalar quantization is that the user-imposed overall bit rate can be changed on the fly. In most image-sequence coding scenarios, it is very difficult to maintain constant perceptual image quality by automatically measuring scene content and adaptively modifying the quantizer bit rates. However, in the specialized, remote-surveillance scenario under consideration, image coding conditions divide naturally into active/inactive states, and there is a straightforward criterion for deciding when and by how much quantizer bit rates should be changed.

The transformed difference image, coupled with input from other sensors (e.g., motion or radiation sensors), can be fed to an event detector that automatically triggers a higher bit rate (and possibly an increased frame rate) in response to an event detection. Bit rates for the inactive state can be preset to minimize the amount of data required to verify that the scene remained unchanged when sensors detected no activity, and bit/frame rates for active states can be set high enough to provide necessary resolution for monitoring activities. This allows us to provide uninterrupted coverage of the scene at very low storage cost during inactive states while still producing high-resolution coverage of active states.

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