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Surveillance Tools for Safer Schools

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General Report

By Herbert L. Blitzer

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Surveillance Tools for Safer Schools

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Final Report

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Section 1 Executive Summary

This work started with a quick survey of technology needs and perceptions so as to confine further studies on the more useful technology options. There were tests of individual devices, systems concepts and mathematical routines for image processing. It found that there is new digital video technology that can be useful in helping school administrators maintain a safer environment. These need to be well thought through prior to purchase and installed with proper understanding of how the overall system will take advantage of the various cameras and other detectors in the overall system.

Section 2 Table of Contents

The overall project was divided up into six sections and selected scientists worked on the various sub projects. Each team submitted a report of its investigations and those are reproduced in this comprehensive report along with some additional commentary in each area as needed. General conclusions are summarized at the end.

- Section 3 Introduction 3
- Section 4 Measuring the Use of Safety Technology in American Schools 5
- Section 5 Camera Testing for School Safety 6
- Section 6 Integrated Systems for School Surveillance 12
- Section 7 Audio Surveillance Discriminator 28
- Section 8 Automatic Behavior Detection 29
- Section 9 Image Quality Improvement 39
- Section 10 General Findings and Conclusions 41
- Section 11 Appendices 44

Section 3 Introduction

The purpose for video surveillance in schools is to help the administrators maintain a safe environment. Specifically, they want help in deciding what actions to take under certain circumstances. A pair of decision trees can summarize this situation. The first tree has to do with monitoring the current situation. The second deals with analysis and investigation of an event after the fact. We will refer to these as the "***current tree***" and the "***investigation tree***". There is a third reason for mounting cameras in a school -- some argue that simply mounting cameras has a deterrent effect on inappropriate behavior. We have deemed that this is not a technology issue and, therefore, not within the purview of this study.

Current Tree

The ***current tree*** deals with monitoring current activities and is used to help administrators take actions in real time to nip inappropriate behavior in the bud. The idea being to rapidly intervene in an event before it can escalate into a major problem.

- The first node on this tree is: "Is anything unusual happening?" There are basically two answers that are possible: "Yes" or "Probably", and "No". If the answer is No, there is no need to respond. But if the other answer is obtained, then this leads to the next node.
- The second node on the tree is: "What is the nature of the event in progress? Is it potentially serious or not?" Again, there are two possible answers. If the answer is no, there is no need to do anything further. But if the yes answer is obtained, then this leads to the next node.
- The third node on the tree is: "Should some particular action be taken?" In the negative situation, no further action is required. But here there are several potential affirmative answers. Some examples, it might be that:
    - There is a fire, turn in an alarm.
    - There is an unidentified person in a supposedly secure area, send an investigator, or query the person on the intercom, and/or lock certain doors, etc.
    - There is a fight in the band room, send a faculty member or administrator to quench the situation.
    - There is gunfire, quarantine key areas, call the police, and engage on the intercom.

Investigation Tree

Clearly the details of this node will be developed for each individual building, and they are only listed here as indicators of what might be established.

The Investigation Tree deals with obtaining details after an event has occurred to help determine disciplinary action and to help refine the school's safety program so as to reduce the potential for such an event in the future. The nodes on this tree are:

- The first node is: "What is the nature of the activity and its indicators?" There is an open-ended range of responses that can range from accident to malevolence.
- The second node is: "Who is involved?" Here an attempt is made to identify the people and key objects that are fundamental to the event. Again the responses are open-ended.
- The third node is: "Who did what?" Clearly the attempt here is to assess blame if appropriate. The responses are open-ended.
- Finally, there is the issue: "Should disciplinary action be taken?" In some cases the response will be: "No, but the school's plan should be amended in a particular way." Or the response could be to seek either internally applied discipline or an indictment.

The objective of the video system relative to the ***current tree*** is to help minimize the escalation of damage with a relatively high degree of accuracy and a minimal expenditure. It is important to remember that overwhelmingly, in today's schools, *nothing* bad occurs *most* of the time. In respect to the ***investigation tree***, the objective is to understand what occurred, how it got started, and assist with prosecution of offenders if indicated. It is noteworthy that with respect to the ***current tree***, support for making decision is real time is the key, and image quality is of secondary importance. The reverse is true regarding the ***investigation tree***.

Section 4 Measuring the Use of Safety Technology in American Schools

In order to assure that technology explorations were focused on solving the correct problem, a small survey of district school safety administrators was conducted. Dr. Crystal Garcia reports on the project in her report. In summary, it was found that many schools are using video surveillance, mostly in its most basic form of closed circuit TV going directly to a few monitors and VCR's. While most thought this was a useful approach, some did not and some thought it was expensive to install and operate.

A few school districts are working with other technologies, such as entry control devices, metal detectors, and the like. These are being used as stand-alone devices and not generally seen as effective. There are indications that there is need for more cross communication among school administrators in different districts relative to technology. Some schools are interested in installing certain technologies, not knowing that some of their peers in other schools have made such installations and are finding it to be ineffective.

One of the problems that was cited frequently was "false alarms". We believe that this is because these currently require an in-person response. At the same time, there is apparently very little use of, or even familiarity with computer-integrated, intelligent systems. Since it seems reasonable to believe that these systems could take the initial alarm signals and facilitate a video-based follow up, work with this type of system was given priority.

Appendix A contains a reproduction of the report prepared by Crystal Garcia, Ph.D.

Section 5 Camera Testing for School Safety

Michael Bone of the Naval Surface Warfare Center, Crane Davison, (NAVSEA) prepared a report of the camera testing done by he and his colleagues. That report is included. Their testing covered three performance aspects: dynamic range, resolution, and color reproduction.

Relative to dynamic range, the findings are encouraging. They show that the *monochrome* cameras had ranges of about 10,000 to one. This compares favorably with photographic films. Negative films typically have a dynamic rage of about 20,000 to one or so. And for purposes of reference, the human eye has an operational range of about 1million to one. The *color* video cameras were not as good. They tended to have a dynamic range of a few hundred to one. It was also found that the response curves were not particularly straight, meaning that point-by-point slope correction would be useful in getting better prints from the captured images. While it is not mentioned in the report, the video images tend to be rather grainy in the darker, but not yet black portions of the images.

In live action photography, discussed later in the section written by Suzali Suyut, it was clear that the compression routines used tended to quantize the gray scale. Thus there are not always smooth transitions from one shade of gray to another. This can easily be seen on images of flat surfaces that are not evenly illuminated. Please note that the same effect, occurring on a smaller scale can confound images of finer detail, reducing the effective resolution of the cameras when used in a system with significant compression. The result is lower resolution that would be achieved using high contrast resolution test targets.

The NAVSEA report also discusses measurements of resolution. The data in their Table 5 gives the results in terms of line pairs per millimeter at the image plane (the effective value on the CCD chip inside of the camera). The Air Force test target that was used was designed for use with traditional photographic film, and gives the resolving power of the film as used in the given camera. This is done this way so that photographers can choose which film to use for each assignment. However, in most electronic sensor cameras, there is no equivalent for “changing the film”, and so it is more useful to report the equivalent number of line pairs that one might capture across the width of a frame. The reciprocal of this number, adjusted for the size of the frame actually captured gives an indication of the smallest feature that the photographer might be able to see in the images. In practice it is far too tedious to measure resolution across the full frame, so measurements reported in this study were made near the center of the frame and the results are extrapolated to the full frame. Typically, resolution will decrease towards the edges of the frame, but the readings were considered to be sufficient indicators for the purposes of this project. In addition, it is traditional to somewhat align the test target so that the bar patterns are vertical and horizontal. With traditional photographic film, this is not normally an issue of consequence since the silver grains are randomly aligned in the focal plane. With electronic cameras, however, this *is* an issue since the actual sensing surface is comprised on small tiles that are normally square and arranged in a pattern that is vertical and horizontal (parallel to the edges of the image frame). For the purposes of this report both the edge degradation and the diagonal image effects were not evaluated, hence the data give a best case, practical result.

Camera	Image Resolution LP/mm*		Frame Resolution Lp/Fram		Smallest Resolvable Feature (mm)		
					Head Shot	Waist Shot	Full Figure
	Width	Height	Width	Height	10" high	40" high	80" high
Philips LTC 0450/21 A	42.5	42.5	242	185	1.4	5.5	11.0
Philips LTC 0350/21 A	33.7	30.1	192	131	1.9	7.8	15.5
Philips LTC 0330/21	26.8	26.8	153	116	2.2	8.8	17.5
Philips LTC 0430/61 A	42.5	42.5	242	185	1.4	5.5	11.0
Philips LTC 0350/21 A	37.9	37.9	216	165	1.5	6.2	12.3
Philips LTC 0500/20	33.7	42.5	260	250	1.0	4.1	8.1
Panasonic WV-CP460	47.7	42.5	272	185	1.4	5.5	11.0

* from NAVSEA report, Table 5.

In the above table, the data from the NAVSEA table 5 are interpolated out to indicate the equivalent line pairs per frame width and height. Then the three columns on the right show the size of the smallest feature that one would expect to be resolved in the images. For example, the typical fixed ballpoint pen is about 7 mm in diameter. So a ballpoint pen would be almost indistinguishable in a waist to head shot with the Philips cameras that have smallest features larger than 7 mm. The typical button on a man's shirt is about 10 mm in diameter. As a result, only the Philips LTC 0500/20 would resolve these in a full figure shot. Some other common items are: the iris of an adult's eye is about 8 mm in diameter. The wire on the typical computer mouse is 4 mm, and the nose bridge on the typical pair of wire-frame eyeglasses is about 1.5 mm.

From this analysis, it is clear that one should not expect to identify people on the basis of video that captures the full figure of an adult person or any space greater than that. In fact, a waist to head shot is even borderline. A far better approach is to aim for head and shoulders shots if one wants to make identifications using normal surveillance video cameras. Wide-angle video can show the general activity in a broad area, but it is not likely to be useful for identification of individuals and or hand-held items in that area.

To visualize the effects, consider the photos on two pages entitled "Resolution Effects". In the first, the images represent the same set up, using the Philips LTC 0430/61, which is a color video camera with a typical wide angle lens (2.8 mm). Notice that the camera is able to show almost the entire 30' by 18' room. It is also able to show that there is a person in the room. But as the person moves away from the camera, he quickly becomes unidentifiable. The photos represent distances increasing as per the following scale:

Photo A	25 inches
Photo B	51 inches
Photo C	76 inches
Photo D	102 inches
Photo E	204 inches
Photo F	306 inches

Except for the placement of the face in the frame, Photo A would be comparable to a waist shot and Photo B would be comparable to a full figure image. On the second page of photos, the face has been cropped from the original images and enlarged as needed to give roughly the same size head on the print. Note that the frame of the eyeglasses is visible in Photo A, but gone in Photo B. The dark areas on the front of the shirt are due to the depression associated with the buttonholes, but a close examination with a magnifier will show that there is no evidence of a button – just a dark area. By Photo D the eyes are virtually gone, and the head in Photo F looks more like that of a dog instead of a person. The distance markers that are on the floor are three and a half inch white squares with a two and a half inch circle. Notice that the squares beyond that being used in Photo D, the circle is just about gone. The distance to the marker in Photo D is 111 inches. This distance related resolution problem is exacerbated by the saturation effect in the sensors (mentioned in the NAVSEA report) to completely obliterate the circles beyond this point.

From the NAVSEA report it is clear that color fidelity is not reliable. One will get color images, but one should not plan on using color information in any detailed identification. That is one can say there is interest in the individual with the blue slacks and the red shirt, but one should not plan on saying that a particular shirt is a match for one in the image.

Appendix B contains a reproduction of the report prepared by Michael Bone.

Resolution Effects – Full Frames

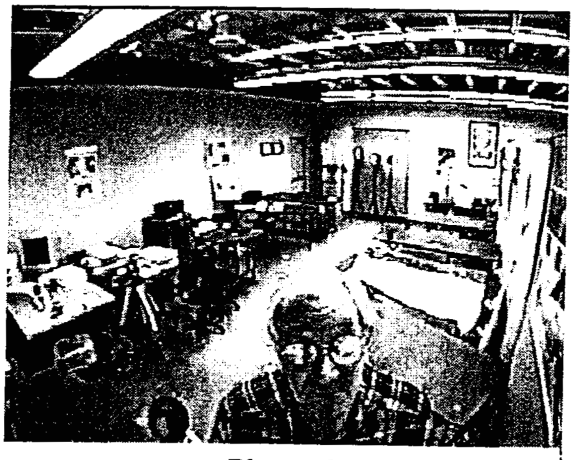


Photo A

Photo B

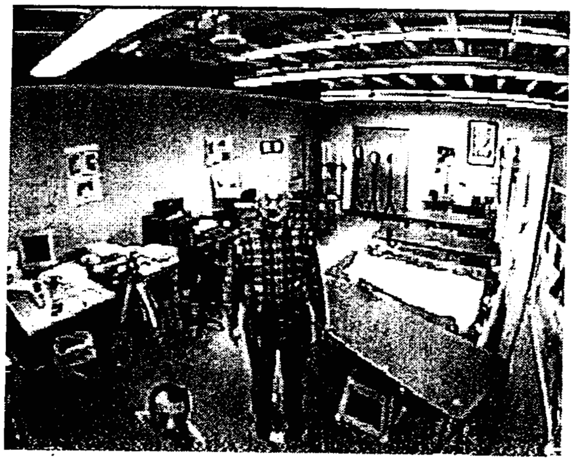


Photo C

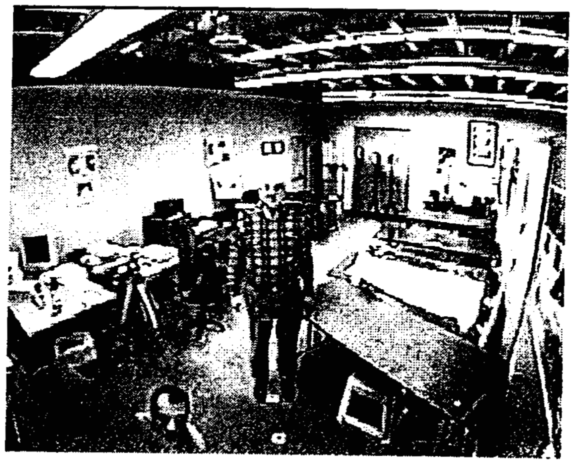


Photo D

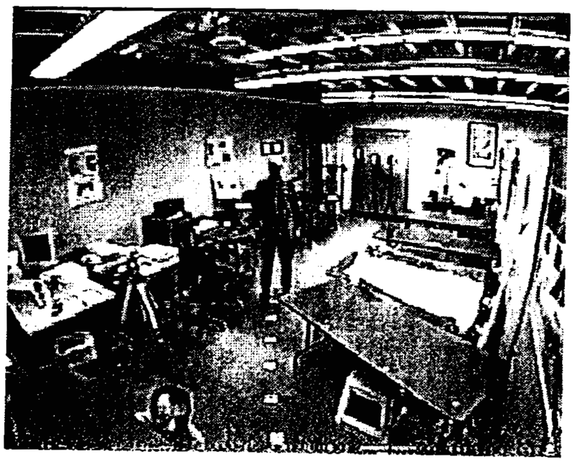


Photo E

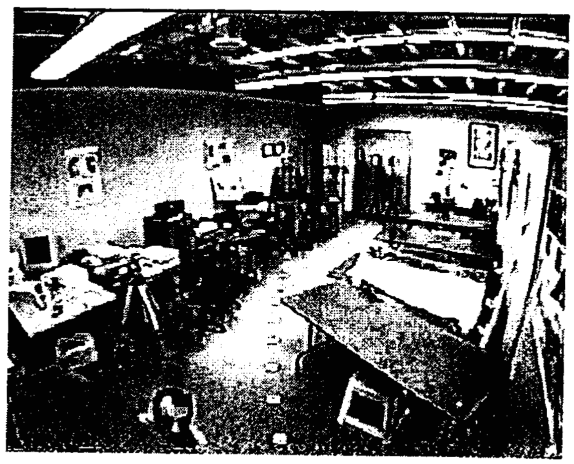


Photo F

Resolution Effects – Cropped and Enlarged

Photo A

Photo B

Photo C

Photo D

Photo E

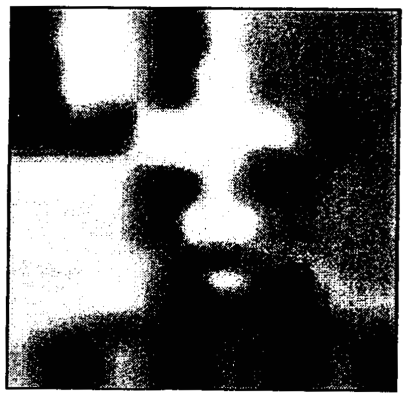


Photo F

Section 6 Integrated Systems for School Surveillance

The following section is a reproduction of the report prepared by Suzali Suyut, in which his team assembled and operated a number of systems to evaluate ease of use and their ability to perform per expectations.

Integrated Systems for Surveillance

Suzali Suyut
Research Scientist, Institute for Forensic Imaging

Analysis of the Objectives of a Surveillance System

The basic idea of a surveillance system is to acquire information about what is happening, or what has happened in a specified area. The interest may be in: (1) monitoring current events or it may be to (2) investigate specifics after a particular event has occurred.

In the case of real-time monitoring, the implied premise is that action will be taken as soon as certain events are detected. So while this, to some degree, amounts to "recognition" in the investigative sense, it also has a patrol responsibility as well. A further implication is that the event of interest is expected to be a rare occurrence. Otherwise, one might post a person in the area to directly observe the situation (basically a guard doing in-person surveillance), or take greater precautions in the design of the area itself.

In a practical sense, it is often the case that the sort of event of interest is not a hard one to observe when it occurs, but could happen in any of several areas. Furthermore, there might often be several indications. For example a fight among students would be visually easy to notice and it will probably also involve certain unusual audio signals as well. Video-based surveillance systems will often be designed to cover a wide area, even if image quality is sacrificed. It also implies that there is either someone watching the surveillance system at all times, or there is sufficient intelligence in the system to alert an operator to focus attention on a particular portion of the area under watch. Basically, the "guard" is able to watch a much larger area than if present in person. Experience has shown that guards watching for very rare events tend to become bored and inattentive. So if the probability of an event occurring per venue is low, there will be a greater chance of an event occurring in total if the same person watches several venues at the same time. Accordingly many video surveillance systems have a large number of cameras and their signals are displayed on many screens, with each screen carrying views from four or more cameras. Unfortunately, if the rate of occurrence is very low, the number of venues that would need to be watched is so large that the system and the concept become impractical.

In the case where one is investigating particulars after an event is known to have happened, there is a different set of priorities. It is important that there be a reliable recording of the event as it occurred, or that there be recordings that facilitate gaining an understanding of the details. These steps are intended to facilitate identification, and, if possible, individualization. Accordingly, image quality is quite important. Since video cameras have very limited native image quality, it is almost impossible to get both a view of a wide area and at the same time the means to see details well enough to make identifications and individualizations. There are some cameras that have pan, tilt and zoom (PTZ) capability, but these are expensive. Also, either someone must control its settings in real time, or there must be sufficient intelligence in the system for it to automatically do this. Both of these have their problems with today's technology. In the case of a live operator imposing controls, we have to deal with the numbing effect of watching nothing happen on a large number of screens for a long period of time. In the other case, the intelligence currently available is quite limiting. For example there are systems that will track a person walking across an otherwise static field, or a car driving through an otherwise quiescent parking lot. But these are not all that interesting. In school surveillance, one is often searching for a particular type of behavior, for example, a fight in the midst of a lot of behavior that is not a fight. This is a much harder task. Another problem with PTZ cameras is that when they are in telephoto mode on one portion of the scene, there is no record of what is happening anywhere else in the area. So, if the camera zooms in on one car entering a parking lot, it is probably ignoring a second car that came in afterwards.

One strategy that is now starting to find application in banks is the use of multiple cameras set in different ways. A few cover wide areas and can be used to recognize that certain events may be taking place. Other cameras are strategically located and set up to render smaller areas, and, therefore, be more useful in making identifications. For example in the fight scene just mentioned, a wide area camera might indicate that a fight is occurring in a certain location and it will probably be possible to determine the color and basic type of the clothes of the combatants. In an after the fact investigation, the cameras that had been placed at doorways to capture closer photos of individuals entering and leaving the room in question can be searched to find out who came in wearing the indicated clothes.

The objectives for a surveillance system go beyond the basics of simply viewing, or even recording a lot of video. In order to do effective and cost efficient surveillance, one must be careful in designing the system and much care is required in installation.

Systems Architectures:

There are innumerable systems that can be envisioned, but for the purposes of this report we will deal with two main categorizations: Conventional and Digital. And, under the heading of Digital, we will discuss three levels of complexity.

The basic architecture of a video surveillance system consists of three components: input device, controller and storage medium. A comparison of conventional and digital surveillance system are shown in figure 1. The source of the signals is the camera, or set of cameras. The analog signals are processed through a multiplexer if there are several cameras. The multiplexer combines signals from a number of cameras. The output of the multiplexer is sent to video recorder (usually a VCR) and TV monitor (not shown) in a conventional system and to a digital video management system in the digital systems. In the conventional system, the final information is preserved in analog format on videotape, while in the digital system, digital data are stored on whatever medium is selected (hard drive, DVD, CD, etc.) The monitor is the viewing device associated with the digital video management system, usually a computer monitor.

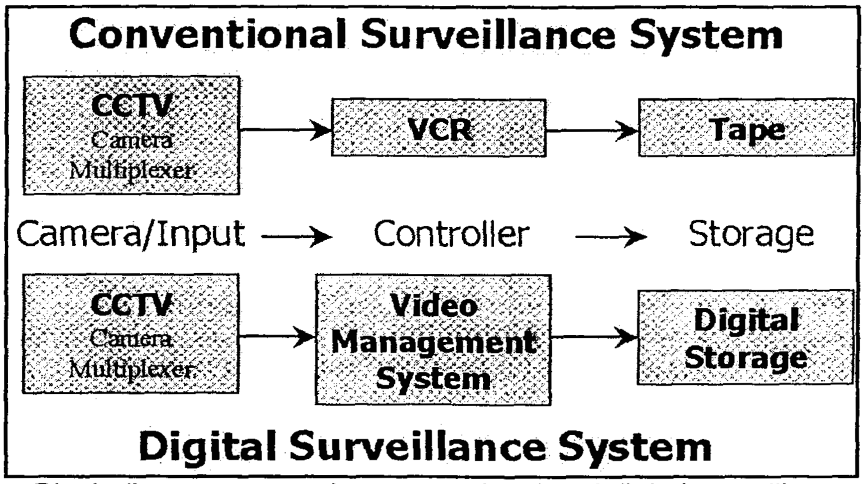


Figure 1: Block diagram comparing conventional and digital surveillance system

1. Conventional Video Surveillance System

The conventional video surveillance system consists of cameras, multiplexer, video recording (VCR) and tape. In the typical setting of a conventional surveillance system one is doing continuous recording of multiple cameras on videotape using a VCR. Some systems record four or sixteen cameras simultaneously, and showing all of the camera outputs on a single TV screen. Other systems record images from a set of cameras sequentially, showing and recording the outputs from the various cameras for a few seconds each. One of the major set backs of the conventional system is image quality when multi-image or alternate recording is used. In either case, with this approach there is no real-time monitoring capability if there is no operator watching the screen(s) and generally there are only a limited number of cameras and they all usually have wide-angle lenses. Thus, there is limited investigation capability as well. To make the situation worse, when multiple images are displayed on a single screen, they are recorded that way as well. This means that the actual resolution of the recorded information is quite a bit lower than the native resolution of the camera. If, for example, four cameras are displayed on a single screen, the camera resolution will be cut by half, taking a bad situation and making it worse. In the case of sequential recording the task of tracking or looking for events afterwards is quite challenging and it may well be the case that if a key event took place very quickly, and there are, lets say four cameras to be sequenced, the odds of missing the event altogether increase significantly.

At normal recording rates, typical tapes can record up to two hours of video at rated quality. It is possible to increase the recording hours per tape, but there is an image quality loss when that is done. Taking an example, if a system records four cameras per VCR/Screen, and it is set to record four hours of video on each tape, one could expect rather poor image quality (relative to investigative needs). At the same time, if the total system had a total of 20 cameras – five screens, and was normally used during a 12-hour day, the system would generate 15 tapes per day. If the tapes were held for two five-day weeks before being reused, the system would have some 150 tapes on hand at any one time. Clearly the bigger the total system, the bigger the data storage problem.

Also note that finding selected passages on a serial storage medium such as videotape makes it difficult to find the right passages when one has to go back to retrieve information.

With conventional systems, all signal connections carry analog signals and are made with coaxial cable. This means that the wire is expensive per linear foot and if the connections cover long distances, the signal to noise ratio will suffer.

It is possible to utilize auxiliary sensors in these systems so as to record only when there is a need to do so, and this is shown in the diagram in Figure 2.

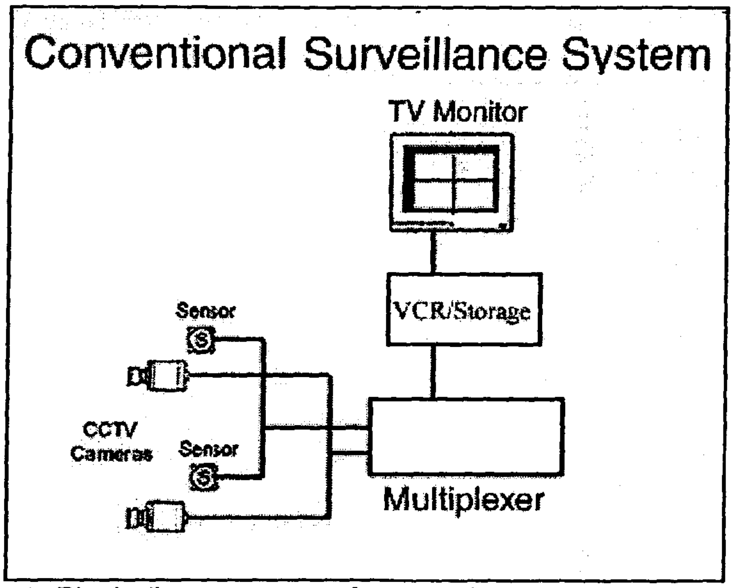


Figure 2: Block diagram setup of conventional surveillance system

2. Conventional and Computer Monitoring and Controlling Surveillance System

One step up from conventional video surveillance system is a system that adds a digital (computer based) capability for performing digital monitoring and utilizing computer directed control. This technology places an emphasis on software development that interfaces to the input and output devices via a host computer. For example, one can display a floor plan of a full school building and show where each camera is located relative to other features in the rooms and outdoor venues. The operator can then choose which cameras to view and can, by use of any centrally located outbound controls, affect the area being viewed. If the computer is connected to a network, then it can be possible for others to log onto the network and view the situation as well. While this system has some nice additional features, it is still basically an analog system and retains many of the limitations as the conventional system. This system is shown in Figure 3.

The components in the purely video portion of the system are linked with coaxial cable and carry analog signals. Hence, there can be cost and signal quality problems. Once the signals are converted to digital signals, the transmission requirements are reduced.

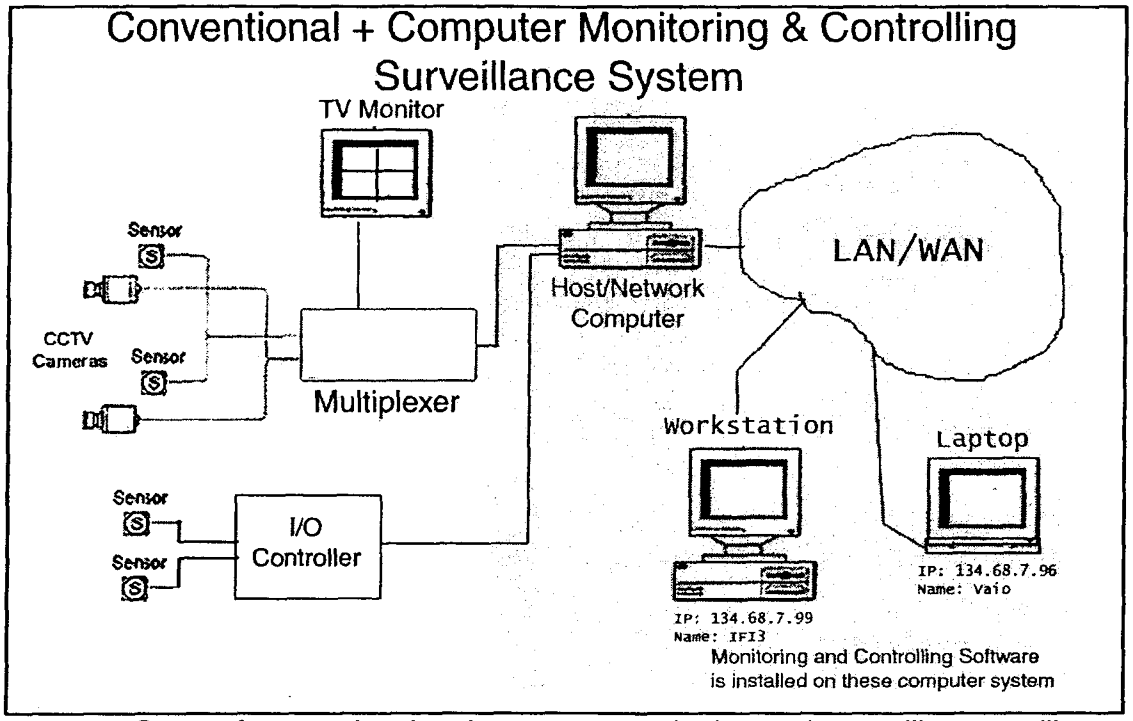


Figure 3: Setup of conventional and computer monitoring and controlling surveillance system

3. Standalone Network Based Surveillance System

In this type of system, the cameras are connected to an analog-to-digital converter that can be located close to a cluster of cameras. The system is diagramed in figure 4 and the analog to digital converter is labeled the wavelet recorder. This device converts the camera signals to digital format, compresses the signals using wavelet compression and records the information, at least temporarily. Typically these devices can handle 8, 16, or 32 cameras. The inputs from the cameras are coaxial and carry analog information. The output is typical LAN or WAN cabling and these carry digital signals.

The storage capacity of the wavelet recorder can be sized to accommodate various lengths of time from a few days to a week or more. Capacity depends upon the size of the included hard drive system, the level of compression, the number of cameras connected and the effective frame rates of the cameras. Each camera can be independently controlled. As is the case with the conventional plus computer monitoring system described above, this system's signals can be accessed via a LAN or WAN. In addition, the wavelet recorder can be actuated via the network and reprogrammed. Clearly precautions must be made to assure that only authorized users have access to the system.

Systems of this type offer a large degree of flexibility. One can select the camera(s) to view, search the recorded data with a true random-access database manager, and schedule viewing times for each camera. The system can be programmed to record by exception only. For example some or all of the cameras on a wavelet recorder can be programmed to detect motion, or motion in certain parts of a frame, and so on.

Information that has been stored on the wavelet recorder can be downloaded to another digital storage device relatively easily. And, one can be very selective about which information is downloaded taking only what is needed for a particular investigation.

Since all of the signals beyond the wavelet recorder are digital and in standard LAN or WAN format, all of the analog, noise prone data are carried by coaxial cable only as far as the nearest wavelet recorder. A virtually unlimited number of wavelet recorders can be included in a single system. And, if the network is a WAN, all of the schools in a whole school district can be monitored easily from a single location. In addition, since there is a LAN already involved in the system, it is possible to log into that LAN from a distant location. Thus police or fire fighters approaching a school could, under the right circumstances, access live images from the surveillance system in their vehicles as they approach the facility.

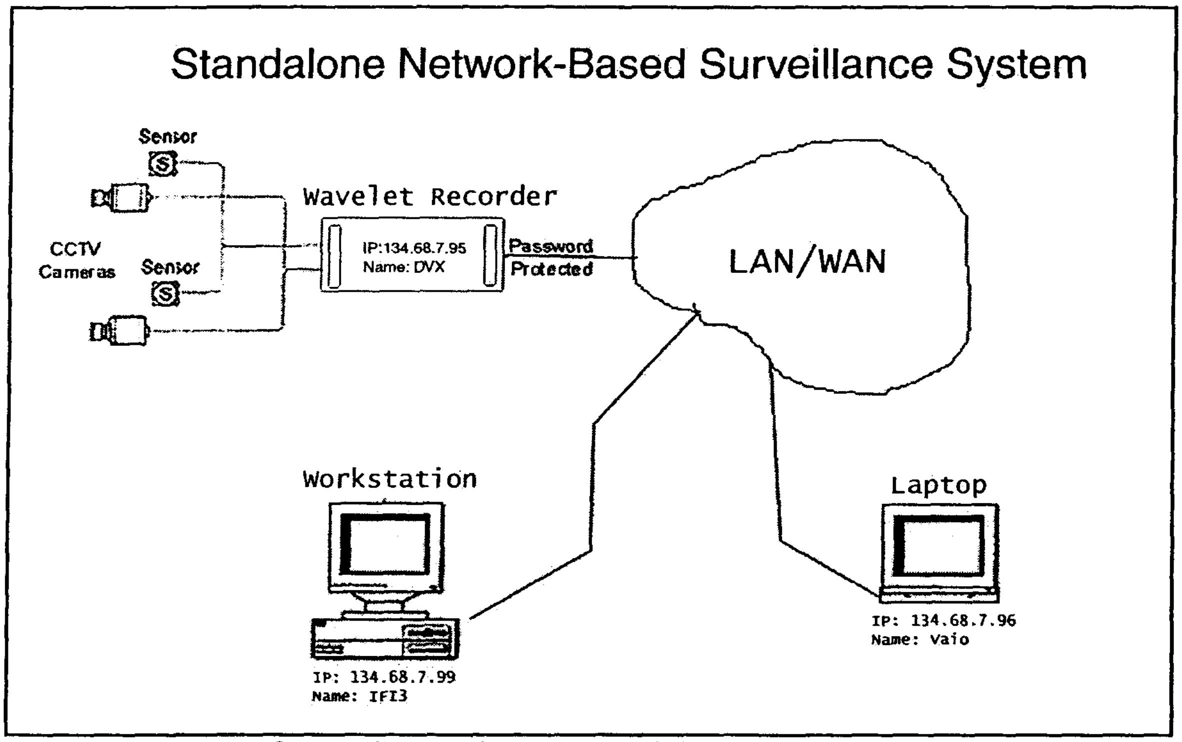


Figure 4: Setup of a standalone network-based surveillance system

4. Advance Network Based Surveillance System

In the advanced systems, there is a network switch that allows connection to a monitor and control workstation and a data storage server, comprised of a Master Tape server and a tape jukebox. This is shown in figure 5. There is provision for extracting information from the server while the rest of the system is collecting new data. Then information can be output to CD's DVD's, or tape. It also provides for the use of very sophisticated techniques for searching the database. For example, one could structure a search based upon a certain type of activity that is expected to be in the recorded video, such as entries through a particular doorway. As should be clear by now, a system such as this can be extended both in the number of cameras on the system, the number of wavelet recorders, the number of outbound controls, and the sophistication of the data retrieval and analysis programs.

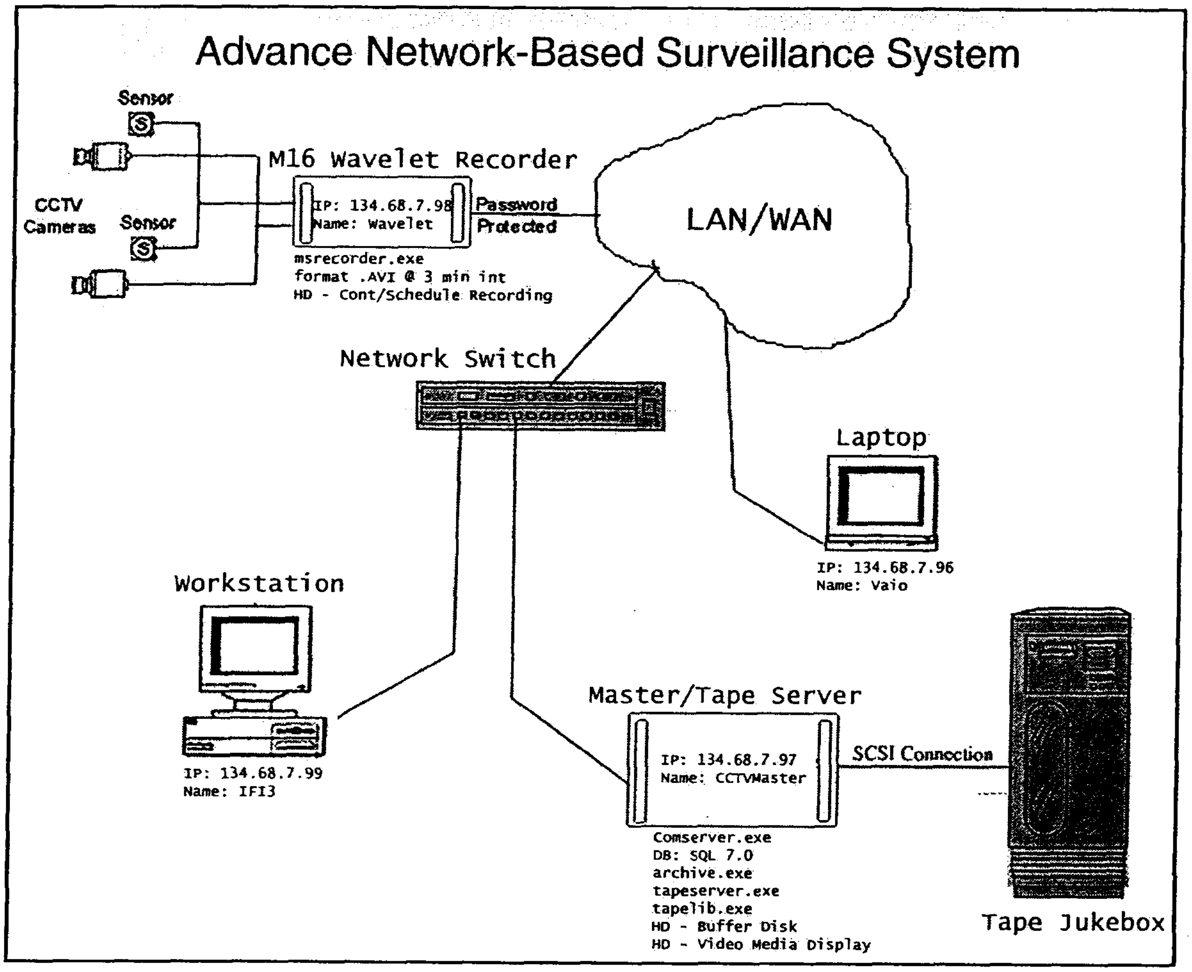


Figure 5: Setup of the advance network-based surveillance system

RESULTS OF TRIALS

We had access to three basic system configurations for the purposes of testing the concepts. These were:

- CCTV system description in here, including a listing of components used (make and model).
- Basic digital system description here, including listing of components used (make and model).
- Advanced digital system description here, including listing of components used (make and model).

Data sheets for these devices are attached at the end of this section of the report.

FINDINGS

System Use Characteristics:

CCTV Systems:

The CCTV systems are rather straightforward to use. The operator selects which cameras to activate and then watches the screens watching for specific problem incidents. If there are Pan Tilt Zoom (PTZ) cameras on the system he or she can utilize those controls as appropriate to observed incidents. Meanwhile, the system is recording the same images being viewed on videotape. At regular intervals, the operator must replace the tapes. Tapes with recent recordings are saved for a prescribed period of time. After this holding time, tapes are either recycled or discarded.

When an incident occurs, if an operator is watching the screen and recognizes a particular type of incident, he or she can take appropriate actions. Afterwards, the videotapes can be retrieved and studied. The only issue will be finding the necessary portion of the tape, which can be made easier if the images are time and date stamped. If an incident is believed to have occurred, but was not observed in real time, the tapes can be searched to see if the event was captured. This is much more tedious, however, because it may not be obvious which tape(s) need to be searched. It is not certain what the event will actually look like, and may not be definite as to when the event occurred. Once the appropriate section of tape is found, however, there are fairly common techniques, which can help with the examination.

CCTV & Computer Systems

In these systems, one can program when the various cameras should record. Scheduling is an important feature that can save a lot of storage space. There are several scheduling activities that can be controlled, including: time, event and frame rates, separately for each camera on the system. Time based scheduling allows the user to activate monitoring at specific time i.e. record surveillance only at night or only when hallways are expected to be clear, and so on. Event based scheduling will trigger the recording only when a specific event occurs. For example recording starts when lights go on, or when a door is opened in a room, or when motion is detected in the hallway, or when motion is detected in a certain part of the hallway. Figure #6 shows the scheduling screen for the First Line system, produced by Integral Technologies. The interface is rather user friendly and intuitive.

The digital video management system allows responses to both internal and external activity detection. Motion detection with masking capability is an example on an internal activity detection control. Areas of a scene, actually portions of an image from a fixed camera, can be selected for motion detection. The signal from the given camera is analyzed to see if there is a significant difference frame to frame in the stream of information from the given camera. If there is a significant difference, the system turns on and records that signal. One can select the portion(s) of the frame to scan for motion, the degree of change and the rate of change. These inputs, when captured at a significant level will trigger the system to start recording the video stream. It can also alert an operator. Since random noise can cause a one-pixel change between two frames, one usually seeks a larger number of pixels of change. There is also the question of how much of a change is really a change. Again a single gray level of change is probably too sensitive a setting. Finally there is the rate of change issue. A fixed camera scanning a fixed scene may see a gradual change due to the rising or setting of the sun – a very gradual effect. Since this is probably not what one wants to monitor, the system is set to detect faster changes only. It should be noted that most systems actually buffer several seconds of video in a temporary storage cache. In this way, if a motion detector senses a triggering event, the video in the cache becomes the first video to be recorded. In this way, the system captures a few seconds of video immediately prior to the event, then the event. Figure 7 shows the screen that is used to set these parameters. Again it is intuitive and user friendly.

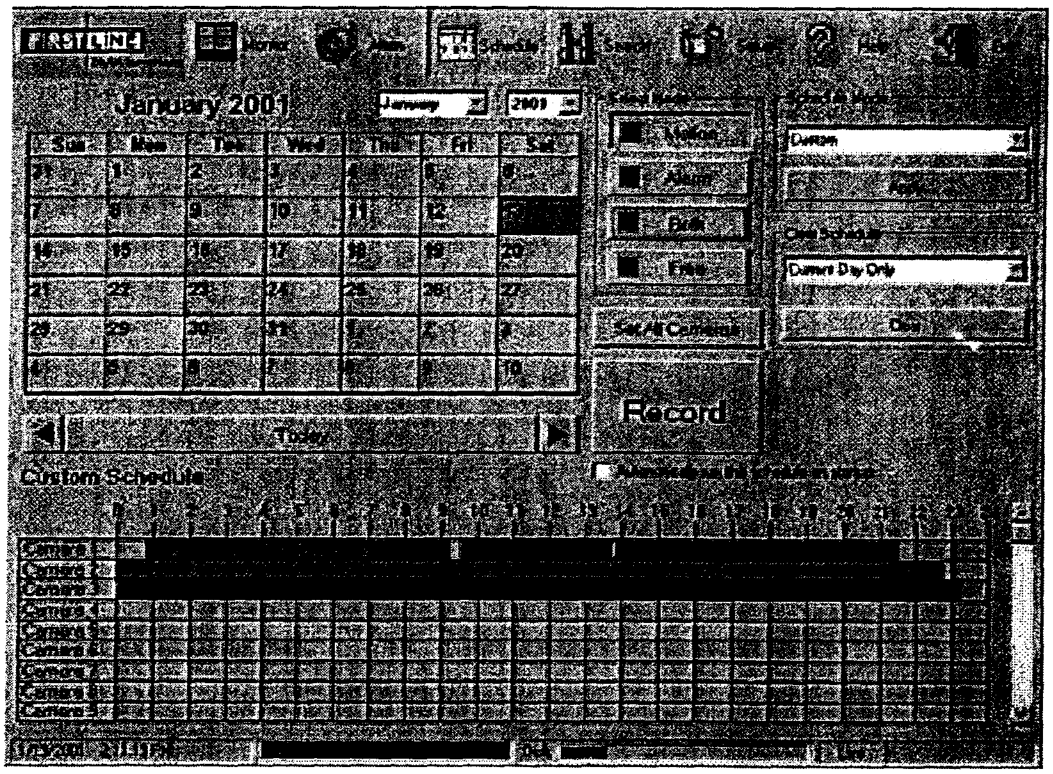


Figure 6: Sample of scheduling menu for video management system

External activity detection involves the use of non-video sensors. These could include motion detectors, fire alarms, door or window opening sensors, audio detectors and so on. With advanced systems, the operator can program responses to internal triggers, external ones, or combinations of both. As with internal triggers, video is stored in a cache and can be retrieved when the recorded video is studied. Programming these events is a bit more complex than the internal ones, mainly because the basic video systems are built for video, and external triggers must be added individually for each installation.

With automated features and built in intelligence of the digital video management system, the system can provide lots of decision aids to the operator. It can allow one operator to monitor several buildings instead of needing a few operators per building. However the system still cannot be used without an operator who is, at least, available. For example, an automated system can monitor a building at night pretty much by itself. But, if something should come up, it will be important to have a person available to check out just what may have caused a trigger and take action accordingly. For example, call the police or the fire department, or a plumber.

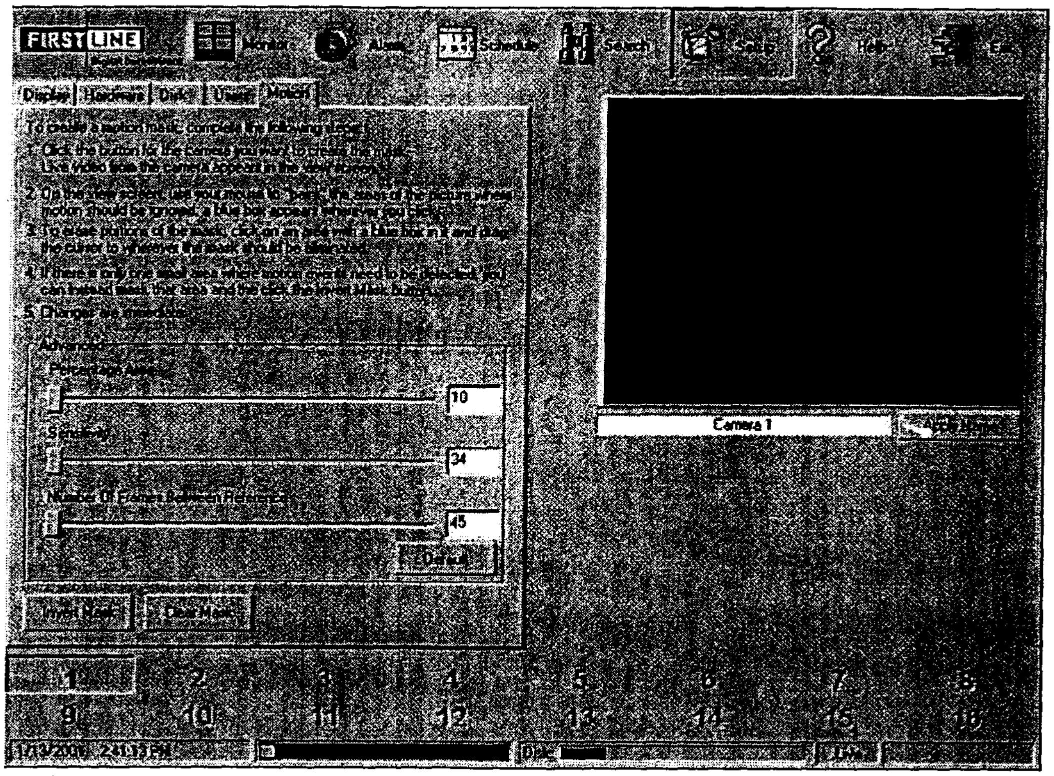


Figure 7: Sample of motion masking setup window

It should be noted that with the systems that record video digitally, all of the intelligence that can be used to scan for real time events can also be used to search recorded material. So, for example, if it is known after an event that a fight occurred in the dining room, the stored data can be searched very rapidly for key bits of information in the recordings. If it becomes known that the fight was in the southeast corner of the room, that portion of the frame can be selected for movement search, and the system will scan all of the records to find candidates. All video recordings can also be searched by time and/or camera number, and the information retrieved can be recorded to an evidence storage archive device such as CD, digital tape or VHS tape.

The advanced digital video management system has several storage devices. Each camera interface unit has its own (local) storage devices for storing video from several cameras (up to 32 cameras per interface unit). These devices store information on internal hard drives. The hard drives can be selected with very large capacity, for example, 100 gigabytes. Typically, the storage system is able to simultaneously store all the cameras inputs for about a week. The system is usually equipped with some video compression algorithm to help reduce the usage of storage space. In a networked digital video management system a larger and centralized, second level of storage device is linked to each of the standalone camera interface units through a dedicated server. Data from the interface units are tagged, labeled and copied to the centralized storage device. The central storage device may be based on a tape backup unit, or a jukebox of DVDs. The storage media for these devices can be replaced and archived off line as needed.

Image Quality:

The quality of video images stored in a digital video management system depends on many factors such as lighting, camera quality, composition, and compression level. For this project, scenes were recorded at several locations. These are shown in Figure 8. The library is well lit even though it has a large wall of windows. The location in the Mary Cable Building was a loading dock, with difficult lighting. The parking garage is dimly illuminated. It has dim artificial lighting and slatted walls that let a small amount of daylight in. The Basement area is a hallway that connects the SL and ET buildings. It is reasonably well lit by overhead fixtures and almond colored walls.

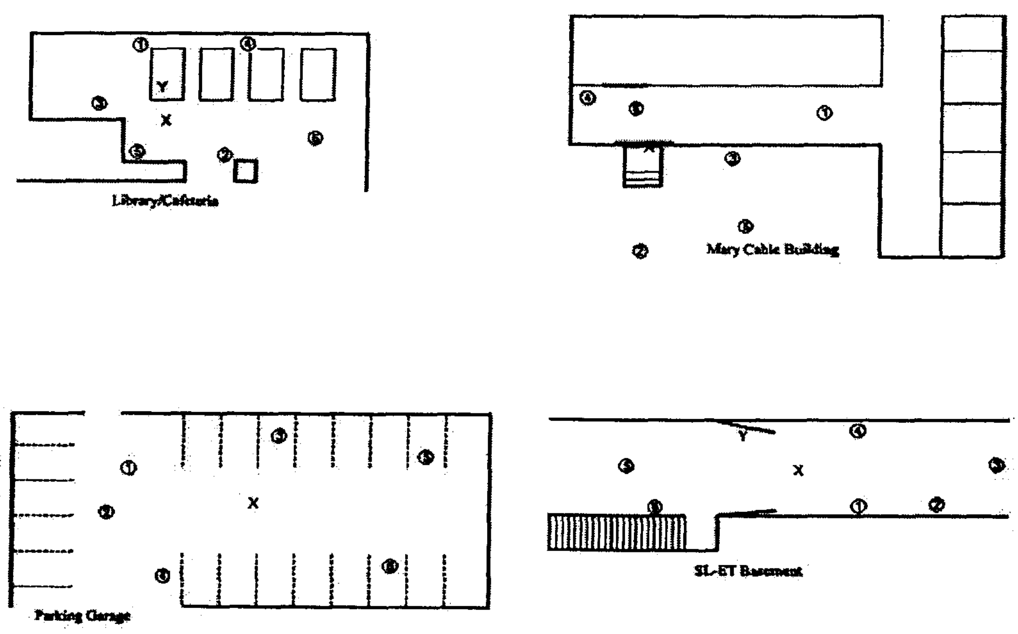


Figure 8. Location Maps

As all photography, area lighting and exposure level are major and critical factors. This can be seen in Figure 9. In the figure, shot is in the garage and not aligned with the slats in the walls. The exposure level is too low. Shot b is in the cafeteria. Here the lighting in the walkway is good, even though the lighting along the windows is too bright.

(a) (b) (c)

Figure 9 Some Effects of Lighting Amount and Distribution

This demonstrates the dynamic range limitations mentioned in the camera testing section. In shot c, the camera is aligned with the slats in the walls of the garage. The camera automatically adjusted for the bright light coming in and the subjects in the shot are mere silhouettes. Another factor that controls image quality is resolution of an image. The quality of the image captured depends first on the camera quality and specification, and then size of the frame covered by a given number of pixels. This can be seen in Figure 10, where the size of the subject within the full frame is noticeably different.

(a) (b)

Figure 10 Wide Angle vs Narrow Angle Lenses

Compression, communications and data storage

The capacity of data storage required for a video management system depends upon the resolution of the cameras, the frame rates, whether the image is in color or monochrome, and the compression routine used – if any. The table in Figure 11 summarizes the relationships. Higher quality video systems capture data at 480 by 640 pixels, while more commonly only 240 by 320 is used. The standard for network television is 30 frames per second. Home movie systems operate at 16 frames per second and a very small amount of artificiality can be seen in the motion some times. The default setting for digital video management systems is 7.5 frames per second. As can be seen in the table, a high quality color video system operating at 30 frames will need to transmit 27 megabytes per second, and if a day's data is saved, it will be necessary to hold 2,333 gigabytes of data. This means a requirement of 16,331 gigabytes if a week's worth of data is kept. And this is all for one camera! Clearly one can see that the impact of compression can be dramatic. Missing from this argument is the fact that compression will tend to degrade images. At ratios of 5:1, the effect is quite minimal. By 20:1 it is much more noticeable, and it only gets worse from that point on. In the compression process, resolution is lost, block-shaped artifacts are inserted into the images, and color will be distorted. The more the level of compression, the worse the effect.

Capacity Requirements for Storage of Recorded Video Data

Grayscale		Size in	Frames	Mbytes	Mbytes	Gbytes	Gbytes	Gbyte/day after compression			
Size V	**Size H**	**Bytes**	**per Sec**	**per Sec**	**per Min**	**Per Hr**	**Per Day**	**100 : 1**	**50 : 1**	**20 : 1**	**5 : 1**
480	640	307,200	30.0	9.00	540.0	32.4	777.6	7.8	15.6	38.9	155.5
480	640	307,200	15.0	4.50	270.0	16.2	388.8	3.9	7.8	19.4	77.8
480	640	307,200	12.0	3.60	216.0	13.0	311.0	3.1	6.2	15.6	62.2
480	640	307,200	10.0	3.00	180.0	10.8	259.2	2.6	5.2	13.0	51.8
480	640	307,200	7.5	2.25	135.0	8.1	194.4	1.9	3.9	9.7	38.9
480	640	307,200	6.0	1.80	108.0	6.5	155.5	1.6	3.1	7.8	31.1
320	240	76,800	30.0	2.25	135.0	8.1	194.4	1.9	3.9	9.7	38.9
320	240	76,800	15.0	1.13	67.5	4.1	97.2	1.0	1.9	4.9	19.4
320	240	76,800	12.0	0.90	54.0	3.2	77.8	0.8	1.6	3.9	15.6
320	240	76,800	10.0	0.75	45.0	2.7	64.8	0.6	1.3	3.2	13.0
320	240	76,800	7.5	0.56	33.8	2.0	48.6	0.5	1.0	2.4	9.7
320	240	76,800	6.0	0.45	27.0	1.6	38.9	0.4	0.8	1.9	7.8

Color		Size in	Frames	Mbytes	Mbytes	Gbytes	Gbytes	Gbyte/day after compression			
Size V	**Size H**	**Bytes**	**per Sec**	**per Sec**	**per Min**	**Per Hr**	**Per Day**	**100 : 1**	**50 : 1**	**20 : 1**	**5 : 1**
480	640	921,600	30.0	27.00	1620.0	97.2	2332.8	23.3	46.7	116.6	466.6
480	640	921,600	15.0	13.50	810.0	48.6	1166.4	11.7	23.3	58.3	233.3
480	640	921,600	12.0	10.80	648.0	38.9	933.1	9.3	18.7	46.7	186.6
480	640	921,600	10.0	9.00	540.0	32.4	777.6	7.8	15.6	38.9	155.5
480	640	921,600	7.5	6.75	405.0	24.3	583.2	5.8	11.7	29.2	116.6
480	640	921,600	6.0	5.40	324.0	19.4	466.6	4.7	9.3	23.3	93.3
320	240	230,400	30.0	6.75	405.0	24.3	583.2	5.8	11.7	29.2	116.6
320	240	230,400	15.0	3.38	202.5	12.2	291.6	2.9	5.8	14.6	58.3
320	240	230,400	12.0	2.70	162.0	9.7	233.3	2.3	4.7	11.7	46.7
320	240	230,400	10.0	2.25	135.0	8.1	194.4	1.9	3.9	9.7	38.9
320	240	230,400	7.5	1.69	101.3	6.1	145.8	1.5	2.9	7.3	29.2
320	240	230,400	6.0	1.35	81.0	4.9	116.6	1.2	2.3	5.8	23.3

Figure 11 Data Levels, Transmission Requirements, and Storage Requirements

Usefulness of Images

In the preceding sections, some of the issues surrounding the ability to record useful image information were discussed. These factors are all combined when a camera is put into place and one starts using it. In Figures 12, 13, 14, and 15 are tables summarizing subjective evaluations of images captured. Each table summarizes one of the four locations described earlier. Within each table the results for each of several scenarios simulated in that location are grouped. Each scenario was recorded simultaneously by six cameras. For each scenario and camera there is an general rating of the lighting conditions. The scales range from 1 to 10 where 1 is very poor and 10 is excellent. There are two ratings for each situation: (1) the ability to recognize a face, and (2) the ability to understand the nature of the scenario being enacted. These are based on either still images for faces or video clips for scenario. A review of the data in the figures will show that the closer the camera, the better the ability to recognize the face. But if the lighting is poor, this will not hold. As for recognizing the nature of the scenario, the cameras that were a bit further away are bit better – again only if the lighting is reasonable.

Evaluations of Video Recording Performance

				Ratings	
Location	**Scenerio**	**Camera #**	**Lighting**	**ID Face**	**ID Scenerio**
Basement ET-SL	Drug-sale	1	7	5	2
		2	7	6	4
		3	3	1	1
		4	3	4	2
		5	5	4	2
		6	6	3	2
	Fighting 1-to-1	1	7	5	7
		2	7	6	7
		3	3	1	3
		4	3	3	7
		5	5	2	6
		6	6	2	6
	Fighting Crowd	1	7	5	7
		2	7	6	7
		3	3	1	3
		4	3	3	7
		5	5	2	6
		6	6	2	5
	Graffiti	1	6	3	5
		2	5	2	5
		3	2	1	1
		4	2	1	1
		5	5	2	4

Ratings Key:

Excellent	10
Very Good	7
Good	5
Poor	3
Worst	1

Description:

Camera #:	Specific camera at a specific location as shown in the map.
Lighting:	Lighting conditions for the indicated camera location.
ID Face:	The ability to identify a participant's face from watching the video clip.
ID Scenerio:	The ability to identify the type of scenario from watching the video clip.

Figure 12 Evaluations of Video Recording Performance - Basement

Evaluations of Video Recording Performance

Location	Scenerio	Camera #	Lighting	Ratings ID Face	ID Scenerio
Mary Cable Building	Break-in	1	2	2	3
		2	6	5	7
		3	6	2	5
		4	4	3	2
		5	4	1	4
		6	5	7	3

Key:

Excellent	10
Best	7
Good	5
Poor	3
Worst	1

Description:

Camera #: Specific camera at specific location shown in location map

Lighting: Lighting condition at the location

ID Face: The ability to identify participant's face from watching the video clip

ID Scenerio: The ability to identify the type of scenerio from watching the video clip

Figure 13 Evaluations of Video Recording Performance – Mary Cable Bldg

Evaluations of Video Recording Performance

Location	Scenerio	Camera #	Lighting	Ratings ID Face	ID Scenerio
Cafeteria	Drug-sale	1	5	2	1
		2	6	5	2
		3	8	5	2
		4	3	1	1
		5	6	2	2
		6	3	1	1
	Theft	1	5	3	2
		2	6	3	2
		3	8	5	2
		4	3	1	1
		5	6	2	2
		6	3	1	1

Key:

Excellent	10
Best	7
Good	5
Poor	3
Worst	1

Description:

Camera #: Specific camera at specific location shown in location map

Lighting: Lighting condition at the location

ID Face: The ability to identify participant's face from watching the video clip

ID Scenerio: The ability to identify the type of scenerio from watching the video clip

Figure 14 Evaluations of Video Recording Performance – Cafeteria

Evaluations of Video Recording Performance

Location		Scenerio	Camera #	Lighting	Ratings ID Face	ID Scenerio
Parking Garage		Drug-sale	1	7	5	2
			2	7	6	4
			3	3	1	1
Key:			4	3	1	2
Excellent	10		5	4	2	1
Best	7		6	5	2	1
Good	5					
Poor	3	Fighting 1-to-1	1	7	5	7
Worst	1		2	7	6	7
			3	3	1	3
Description:			4	3	1	3
Camera #:	Specific camera at a specific location as shown in the map.		5	4	1	3
			6	5	2	4
		Fighting Crowd	1	7	5	7
Lighting:	Lighting conditions for the indicated camera location.		2	7	6	7
			3	3	1	3
			4	3	1	3
ID Face:	The ability to identify a participant's face from watching the video clip.		5	4	1	3
			6	5	2	4
		Weapon Exch	1	7	3	2
ID Scenerio:	The ability to identify the type of scenario from watching the video clip.		2	7	5	3
			3	3	1	2
			4	3	1	2
			5	4	1	1
			6	5	2	1

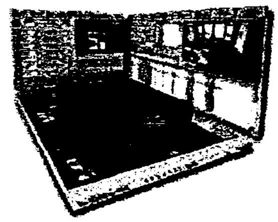
Figure 15 Evaluations of Video Recording Performance – Parking Garage

INTEGRAL TECHNOLOGIES, INC.

Integral_Navbar

First Line DVX

FIRST LINE Digital Surveillance



Plug-and-play digital CCTV recording ... what could be simpler

The First Line DVX surveillance system's digital technology far exceeds the capabilities of old analog switchers, multiplexers and time-lapse VCRs. Connect up to 32 cameras and begin recording high-quality digital video. First Line is easy-to-use and allows for simple setup, recording, retrieval and playback of recorded video.

Scalable solutions. Only First Line provides the flexibility to configure a system with as many camera inputs as needed, from one to 32 per system.

Fast retrieval. No more plodding through hours of videotape. First Line allows for immediate retrieval of video even for remote viewing. Quickly and easily search for events by time, date location, camera and more.

Simultaneous recording and playback. First Line lets you view live video from up to 16 inputs at a time, as well as retrieve and view prerecorded video while DVX continues to record live video.

IntelliSearch. Highlight a specific area on the camera's field of view and search for movement within that area only. This can significantly reduce the amount of time it takes to search for specified surveillance footage.

Tape archiving. The advantage of digital tape archiving is that video may be kept virtually forever. First Line DVX allows the user to search surveillance tapes quickly to find the video needed -- just as though the video were on the machine's hard drive.

High image quality. First Line offers high-resolution wavelet-compressed digital images, which can easily be enhanced and copied many times without losing their original quality.

Event-triggered recording. Recording rates and resolutions may be triggered by various alarms of the user's choice, including activity, and input signals from access control and point-of-sale devices, ATMs and infrared units.

Contact First Line Reps

First Line DVX brochure
Oasis Integration

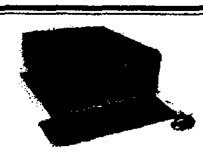
Oasis Integrates with First Line DVX

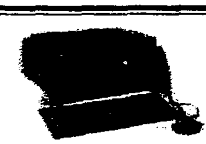
Integral's First Line DVX digital CCTV systems now are Oasis compatible -- meaning they can integrate with access control, alarm, pager and even other CCTV systems through the Oasis software package.

oasis compatible

First Line RemoteView
DVX systems include RemoteView software which allows you to access live and recorded video from a remote site.

SDM magazine ran a story entitled: ***Digital Video: How It Works*** (Adobe Acrobat file). We think this is beneficial for anyone interested in the CCTV state-of-the-art.





	DVX 4000	DVX 8000	DVX XP 9	DVX XP 16	DVX 16000	DVX 32000
# of cameras	4	8	9	16	16	32
Matrix switch outputs	0	1	1	1	5	5
Video loop-through	0	0	0	0	16	0
# of alarm inputs	8	8	16	16	16	16
Recording speed (images/sec)	12/10	12/10	20/17	20/17	60/50	60/50
Recording capacity	Virtually unlimited online recording capacity					
Remote viewing	Yes	Yes	Yes	Yes	Yes	Yes
Duplex recording	Yes	Yes	Yes	Yes	Yes	Yes
Real-time playback	Yes	Yes	Yes	Yes	Yes	Yes
Activity detection	Yes	Yes	Yes	Yes	Yes	Yes

Oasis compatibility	Yes	Yes	Yes	Yes	Yes	Yes
Networkable	Yes	Yes	Yes	Yes	Yes	Yes
Video authentication	Yes	Yes	Yes	Yes	Yes	Yes
Adjustable recording schedule	Yes	Yes	Yes	Yes	Yes	Yes
Hard-drive upgrades	Optional	Optional	Optional	Optional	Optional	Optional
Modem	Optional	Optional	Optional	Optional	Optional	Optional
Monitor	Optional	Optional	Optional	Optional	Optional	Optional
Packaging	Desktop unit	Desktop unit or 4U rackmount	4U rackmount	4U rackmount	5U total height rackmount	5U total height rackmount

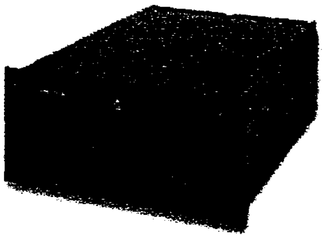
First Line DVX Specifications:

- 4, 8, 16 or 32 video inputs, NTSC or PAL
- 5 matrix switch outputs for call monitors -- DVX 16000, 32000
- 8 or 16 alarm inputs
- 7-90 days of normal recording capacity (greater capacity available)
- Activity detection on each camera
- Multiscreen display of live cameras on PC monitor (2x2, 3x3, 4x4)
- Video output to call monitor and video tape (DVX 8000 and higher)
- Up to 60 images/second (50 images/second in PAL) camera switching and recording speed
- High resolution wavelet compression (720 pixels per video line)
- Time, date, alarm and camera retrieval search filters
- CE and FCC Approved
- Power consumption: DVX 4000 and 8000: 250W, DVX 16000 and 32000: 270W

Each unit comes with: keyboard and mouse,network interface, full documentation, configuration and setup guide.

HOME | CONTACT US
SITE MAP | SEARCH

M Series Wavelet Recorder



→ Product Brochure (PDF 361kb)
→ Wavelet Technology Whitepaper

→ More Information

The CCTVware M Series Wavelet recorders simultaneously capture 7.5 images per second (ips) NTSC (6.0 ips PAL) on every input. The capture rate for each input can be independently configured from 0.5 to 15 ips, with the ability to change frame rates in response to alarms.

Wavelet technology enables digital video to be compressed by removing all obvious redundancy and using only the areas that can be perceived by the human eye. The M Series Wavelet recorders send live video frames for review to the workstation at the rate it is recorded, network bandwidth permitting.

Features & Benefits

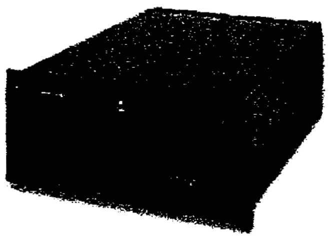
- Networkability (TCP/IP) - place components in different locations as needed.
- Quadplex Operation - simultaneously record, display live video, play video back, and send video to tape without interrupting the recording process.
- Activity Detection - save storage space by sending video to tape only when activity occurs.
- Alarm Input - connect to existing open door or access control systems.
- Signal Loss Detection - detect when any system component is not receiving video signals.
- Video Authentication - ensure the integrity of video evidence.
- Scheduled Recording - save storage space by recording only when needed.
- Customizable Alarms - define the message, color, sound, and duration of alarms.
- System Resource Management - prioritize recording and matrix instructions based on available resources.
- Recording Operations - continuous, alarm, scheduled and On-demand.

Specifications

Network	TCP/IP
Video Format Compression Type	Wavelet
Video Inputs	8, 16 or 32
Recorder Frame Rate	0.5 - 7.5 NTSC, 0.5 - 6 PAL
Resolution (NTSC)	360 x 243, 720 x 486 (high)
Resolution (PAL)	360 x 288, 720 x 576 (high)
Ethernet Adapter	100 BaseT
Dimensions (8 & 16) (HxWxD)	7" x 16¾" x 18¾"

Dimensions (32) (HxWxD)	8¾ " x 17" x 25"
Power Consumption, Peak	160 watts (8,16), 240 watts (32)
Power Consumption, Operating	85 watts (8, 16), 120 watts (32)
Activity Detection	Yes
Activity Scan	Yes
Camera Signal Loss Detection	Yes
Live Video Streaming	Yes
Video Authentication	Yes
19" Rack Mountable	Yes
Alarm Inputs	8, 16 or 32
Alarm Outputs	4, 8 or 16
Recommended Temperature	<70°F, <21°C

Remote Recorder



→ Product Brochure (PDF 361kb)
→ Wavelet Technology Whitepaper

→ More Information

The Remote recorder allows worldwide video streaming and camera control over LANs, WANs, and the Internet.

Remote recorder systems can be configured and maintained from a central management site. Remote sites can send alarms and video to a central investigation center. Video Monitoring operators can view facilities worldwide, and can immediately access real-time video at remote sites. Remote sites are also configured to store video data locally, reducing unnecessary network traffic.

Features & Benefits

- Local Time Stamp - remote sites and central investigation centers can maintain accurate video data for sites in different time zones.
- Multi-field Video Search - CCTVware Remote allows for easy and quick retrieval of video for review. Select video for review by specifying the alarm event, camera, data, time and duration.
- Quadplex Operation - simultaneously records, displays live video, plays video back, and sends video to tape. Allows for continuous recording. Recording is not interrupted for playback, live video viewing, or video storage.
- Multi Outputs - easy to export video data for review. Print to standard windows compatible printer, fax, Email or export video to VHS tape.
- Recording Operations - continuous, alarm, scheduled and On-demand.

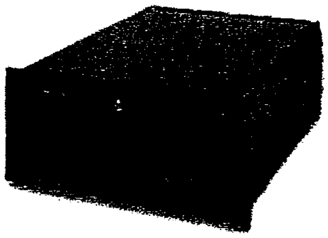
Specifications

Network	TCP/IP
Video Format Compression Type	Wavelet
Video Inputs	8 or 16
Recorder Frame Rate	0.5 - 7.5 NTSC, 0.5 - 6 PAL
Resolution (NTSC)	360 x 243
Resolution (PAL)	360 x 288
Ethernet Adapter	100 BaseT
Modem	56K (optional)
3.5" Floppy Drive	Yes
Dimensions (HxWxD)	7" x 16¾" x 18¾"
Power Consumption, Peak	160 watts

Power Consumption, Operating	85 watts
Activity Detection	Yes
Activity Scan	Yes
Camera Signal Loss Detection	Yes
Live Video Streaming	Yes
Video Authentication	Yes
19" Rack Mountable	Yes
Alarm Inputs	8 or 16
Alarm Outputs	4 or 8
Internal Storage Capacity (R8)	39GB (Standard Model) 290GB (Extended Storage Model)
Internal Storage Capacity (R16)	39GB (Standard Model) 290GB (Extended Storage Model)
Recommended Temperature	<70°F, <21°C

NOTE: An additional board is required for the High Resolution Remote Recorders.

Servers



→ Product Brochure (PDF 361kb)

→ More Information

Loronix Servers command the system together through five Windows NT Services:

- CCTVware Communications Server
- CCTVware Tape Library Server
- CCTVware Tape Server
- CCTVware Archive Server
- CCTVware Alarm Server

Depending on the number of cameras in your system and your tape storage needs, these individual services may reside on more than one server.

The Master Server
The Master Server houses the relational database, and runs the database management and CCTVware Communications Server software. The Communications Server communicates with all the other CCTVware recorders, servers, and workstations, and manages the recording schedules and alarm responses. The database stores all system setup information, tracks video stored on tapes and server disks, and maintains the history of alarms and other optional transaction or event data.

Tape Server
The Tape and Tape Library Servers use Windows NT services that control the tape library and tape drive devices. All tape handling for video storage and retrieval is computer-controlled and completely automated. The two separate tape services coordinate their activities by sending messages over the network, resulting in a very flexible and scalable system. A single Tape Server can control a library and one or more tape drives, or multiple tape servers can control tape drives mounted in the same library. Large systems can have multiple tape libraries and tape servers.

Tape server computers include hard disk storage for video that has been retrieved from tape for playback. Additional high-speed SCSI hard drives in the tape server are used for temporary storage of video data before the data is written to tape.

Server Specifications

Processor	Intel Pentium III
Network Adapter	100 BaseT Ethernet
31/2" Floppy Drive	Yes

19" Rack Mountable	Yes
Dimensions (Master Server)	8¾" x 16¾" x 25"
Dimensions (Tape Server)	7" x 16¾" x 18¾"
Dimensions (Master/Tape Server)	8¾" x 16¾" x 25"
Dimensions (Dual Tape Server)	8¾" x 16¾" x 25"
Weight	65 lbs (Master), 27 lbs (Tape)
Power Consumption, Peak	160 watts (Master) 160 watts (Tape) 200 watts (Master/Tape) 160 watts (Dual Tape)
Power Consumption, Operating	100 watts (Master) 100 watts (Tape) 120 watts (Master/Tape) 120 watts (Dual Tape)

Master Server Specifications

POTS Modem for Dial-in Diagnostics	56.6K baud
Power Supply	Dual (redundant) hot swappable
RAM	128mb - 256mb
CD-ROM	Yes
31/2" Floppy Drive	Yes
Monitor	Yes
Input Devices	Keyboard & mouse

Tape Server Specifications

RAM	64mb-128mb
CD-ROM	Yes
31/2" Floppy Drive	Yes
Monitor	Yes
Input Devices	Keyboard & mouse
Fast Ultra Wide SCSI Adapter	1 per up to 2 writeable Tape Drives; 1 for Drives/Jukebox
Fast Ultra Wide SCSI Hard Drive	2GB, 1 per up to 2 writeable Tape Drives

Dual Tape Server Specifications

RAM	64mb-128mb
CD-ROM	Yes
31/2" Floppy Drive	Yes
Monitor	Yes
Input Devices	Keyboard & mouse
Fast Ultra Wide SCSI Adapter	1 per up to 2 writeable Tape Drives; 1 for Drives/Jukebox
Fast Ultra Wide SCSI Hard Drive	2GB, 1 per up to 2 writeable Tape Drives

Tape Libraries

→ Product Brochure (PDF 361kb)
→ AIT Technology Whitepaper

→ More Information

The automated CCTVware tape libraries combined with Advanced Intelligent Tape technology provide premier capacity, high-speed data transfer, reliability and value for distributed or centralized video storage.

Long-term video is stored in a tape library as tape backup and tape archive. Tape Backup retains video during normal operations, based on the camera that recorded the event. Tape Archive stores video with special retention requirements based on an event, or user request.

The CCTVware tape libraries provide scalable capacities from 600GB to approximately 30TB. Data transfer rates per drive approach 6MB per second, expediting the storing process, and speed access concurrent to read/write ability prevents data loss while accessing archived video.

No operator action or tape cleaning is required in normal operations. Brushless motors provide higher reliability, better performance, and reduced contamination. Each drive also contains its own thermostatically controlled fan to force air to key components.

Features & Benefits

- Barcode Ready - Human and machine-readable labels for fast media inventory.
- Removable Magazines - Easy rotation and off-line storage.
- Positive Air Pressure - Reduces contamination for longer media and head life. Enhanced cooling means greater reliability.
- I/O Port - Move tapes in and out of library without opening door or stopping operation.
- No Adjustments - Advanced login and servo design eliminates all electrical and mechanical adjustments.
- Closed-loop Servo Controls - Self-calibrating. No alignment or special tools required.
- Brushless Motors - Higher reliability, better performance, & reduced contamination.
- Fan Cooling - Each drive contains its own thermostatically controlled cooling fan to force air to key components.
- Automatic Head Cleaner - Transparent to application. No operator action needed. No cleaning tapes required in normal operations.
- MIC - Provides very fast media load and file search. Allows applications to read/write to memory chip embedded in each tape.

Specifications

Model	Max. Tapes	Max. Tape Drives	Power Consumption Peak (watts)	Power Consumption Avg. (watts)	Height	Width	Depth
4210A, 4220	20	2	150	100	33 1/4"	13	21 3/8"
4440	40	4	150	100	37 1/4"	13 3/4"	25 1/4"
4660	60	6	150	100	41 5/8"	15 1/4"	25 1/4"
4480	80	4	150	100	37 1/4"	13 3/4"	25 1/4"
46120	120	6	150	100	41 5/8"	15 1/4"	25 1/4"
412360	360	12	275	200	51 3/4"	29 1/2"	25 1/2"

Section 7 Audio Surveillance Discriminator

While video systems can show movements during events, they also tend to generate huge amounts of data. This data must then be stored if one wants the ability to do follow-up viewing. This requires a larger initial cost and greater on-going expense. It also causes difficulty during information retrieval. Accordingly, it would be very desirable to only capture video when there is reason to believe that something unusual is happening. Towards this end, a few approaches were explored to see about detection schemes that might be useful in triggering the initiation of video recording. This expands the system from a *Video* system to a *Multimedia* system. The more simplistic trigger devices would include entry detectors and motion detectors. Another such device would be an intelligent audio detector. The simplest of these are the glass break detectors widely used in intrusion alarm systems. A more sophisticated approach is a device that can separate certain danger-indicating sounds from normal background sounds. A test device was constructed to show the feasibility of a simple, low cost device that could be used to "listen" to what is happening in various parts of a campus and turn on video recording whenever a particular type of sound is detected. The device could be designed to listen for footsteps in a hall that should be empty at night, or to separate gunshots from background sounds of students going about their normal business. The detection of the target sounds would be used to alert passive operators and to start to record video.

Appendix C contains a reproduction of the report prepared by James Kidd.

Section 8 Use of Automatic Behavior Detection

The following section is a reproduction of the report prepared by Dr. Jeffrey Huang.

Video Scene Analysis and Subject Behavior Detection

Report by

Jeffrey Huang, Ph.D.

Indiana University School of Informatics at IUPUI

Background

The video surveillance system has finally entered into the digital age. Through the new digital surveillance systems, digital video data are now free to wander the same diverse paths as any other digital data. Advances in data compression, storage, and telecommunications have enabled the rapid technological growth of the digital surveillance system. In these systems, video information might have been captured through cameras pointing to different locations, which could have been triggered by motion detectors, and transmitted to any number of viewers and simultaneously archived in a centralized storage device, such as video server. The volume of data from video surveillance is always overwhelming, so new techniques are needed to organize and search these vast data collections, retrieve the most relevant selections, and effectively put them to additional use.

The common approaches to automatic indexing of digital video concentrate on extracting the global spatial features such as color histograms, texture, shape, etc. (Xiong, Lee, and Ma, 1996). However, using spatial information for feature analysis is not sufficient to describe local contents of an image and the performance is easily degraded by problematic lighting conditions which compromise color and texture, and even shape rendition. A more robust approach involves the wavelet basis functions (Mallat, 1989), a self-similar and spatially localized code, are spatial frequency/ orientation tuned kernels. These provide one possible tessellation of the conjoint spatial and spectral signal domains. Its representation also provides for multi-resolution analysis (MRA) through the orthogonal decomposition of a function along basis functions. Wavelet networks ('wavenets') using stochastic gradient descent akin to back propagation (BP) (Zhang and Benveniste, 1992), are an example using wavelet decomposition coupling with feed forward neural networks for classification purposes. Huang and Wechsler (1999) introduced an approach for the eye detection task using optimal wavelet packets for eye representation and radial basis functions (RBFs) for classification ('labeling') of facial areas as eye vs. non-eye regions.

We introduce an architecture that can robustly identify video shots based on which camera captured the information and clusters contents (subjects' actions) among video frames using optimal wavelet best basis decomposition with its tree structure representation (Chang and Kuo, 1993),

1 System Architecture

The system we describe in this paper consists of three modules: (i) video break detection using conventional methods including histogram and texture analysis, (ii) video shot classification based on the camera orientation using decision trees (DTs) (Quinlan, 1986), and (iii) scene action clustering in video shots using self-organizing neural networks, (Kohonen, 1990). The optimal features generated through wavelet base basis decomposition are used to create a decision tree for camera classification as well as self-organizing networks for action clustering. Fig.1 shows the overall process built into our system, and the following subsections describe these modules in greater detail.

1.1. Detection of video break & Key Frame Extraction

Camera/video breaks are perceived as instantaneous changes from one shot to another (Lee and Ip, 1994). In other words, a break is declared when the video sequence has a change of scene. The global spatial features such as histogram, texture and the edge detection from each video frame are first extracted as feature vector. A comparison between feature vectors gives an indication whether difference between two adjacent images is significant enough to find a break and declare a new video shot. Once the shot has been located we use optical flow (motion) (Horn and Schunck, 1981), to extract a key frame within the shot. Optical flow is the distribution of apparent velocities of movement of brightness patterns in an image. It is relatively easy to detect the change in motion in two successive frames in a video sequence. We herein choose the frame showing the least motion as the key frame, where motion is given by,

$$M(t) = \sum_i \sum_j |O_x(i,j,t)| + |O_y(i,j,t)| \qquad (1)$$

where $O(i,j,t)$: optical flow of pixel i, j in frame t.

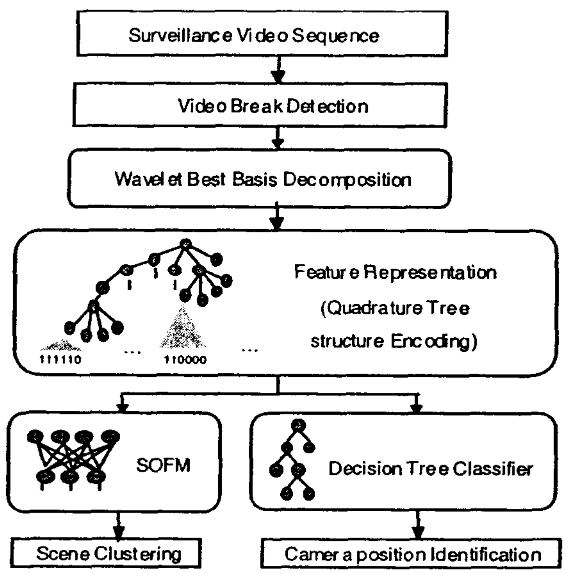


Figure 1. System Diagram

2.2 Wavelet Best Basis Representation

The wavelet hierarchical (pyramid) is obtained as the result of orientation-tuned decompositions at a dyadic (powers of two) sequence of scales. The discrete wavelet transform (DWT) is:

$$\phi_{m,n}(x) = 2^{-m/2}\phi\left(2^{-m}x - n\right) \quad (2)$$

$$\psi_{m,n}(x) = 2^{-m/2}\psi\left(2^{-m}x - n\right) \quad (3)$$

where *m*, *n* are integer numbers, and $\phi_{a,b}$, and $\Psi_{a,b}$ correspond to the scaling and mother wavelet functions dilated by *2*. The dilation equation, relating the mother wavelet to the scaling function is:

$$\psi(x) = \sqrt{2}\sum_{k} h_1(k)\phi(2x - k) \quad (4)$$

where $h_1(k) = (-1)^k h_0(1-k)$.

Daubechies (1988) has shown how one can derive the corresponding low (h_0) and high (h_1) pass filters for designing appropriate families of scaling and mother wavelet functions. Using the sequences h_0 and h_1, one computes then the Discrete Wavelet Transform (DWT) using the structure shown in Fig.2. Mallat (1989) has shown that for any orthonormal wavelet basis, the sequences of two-channel filter banks, *h* and *g* can be utilized to compute the DWT with perfect reconstruction. The design of Quadrature Mirror Filters (QMF) is a useful way to implement PR filter banks for multirate signal analysis and directly links to multi-resolution analysis (MRA) supported by wavelet theory.

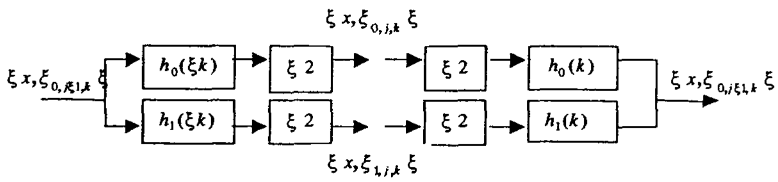


Figure 2: Computation of DWT using a filter bank

The concept of optimal sampling can be expanded using different fitness criteria. As an example, Wilson (1995) mentions the requirement for more complex approaches to signal representation, whose common feature is *adaptivity.* It should be possible to automatically adjust the resolution of the representation, i.e. its reconstruction ability, in order to provide the best 'fit' to a given data set. This approach is chosen rather than using a fixed representation, in which, resolution is bound to be a compromise between space / time and frequency. Examples of such an approach include wavelet packets (Coifman and Wickerhauser 1992), where the wavelet dictionary is drawn using maximal energy concentration and/or least Shannon entropy (μ) which is defined as

$$\mu(v) = -\Sigma \, \| v_i \|^2 \ln \| v_i \|^2 \quad (5)$$

where $v = \{v_i\}$ is the corresponding set of wavelet coefficients. The Shannon entropy measure is then used as a cost function for finding the best subset of wavelet coefficients. Note that minimum entropy corresponds to less randomness ('dispersion') and, therefore, it leads to clustering. If one generates the complete wavelet representations (called wavelet packets) as a quadature tree, the selection of the best coefficients is done by comparing the entropy of wavelet packets corresponding to successive tree levels. One compares the entropy of each adjacent pair of nodes to the entropy of their union and the subtree is expanded further only if it results in lower entropy. The difference in tree structures can be observed, encoded, and used for discriminating image contents (Chang and Kuo, 1993).

The process begins with the video key frames being fed into the best basis wavelet decomposition module and produces a quad-tree structure for each frame. We limit the decomposition to take place using up to six levels. Fig. 3 shows the quadature tree structure derived by wavelet best basis decomposition using different video shots. One can see that shots A, B, and C contain different actions, while shot B and C are from the same camera.

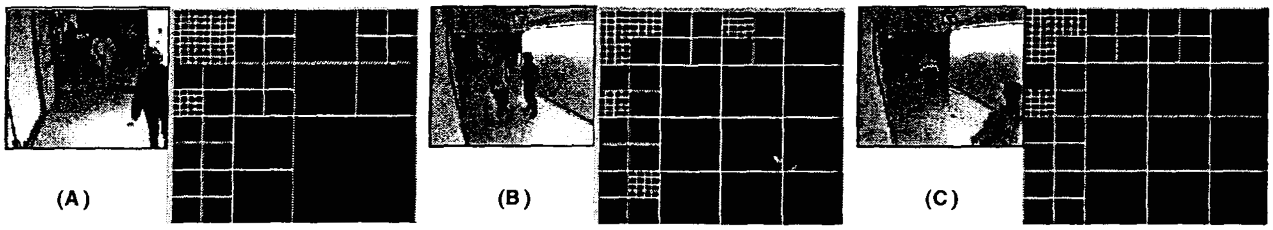


Figure 3: Wavelet best basis decomposition

The quadrature trees obtained after the best basis decomposition is encoded using the binary system in which a 1 represents a node that is further decomposed, and 0 indicates a leaf node. The tree is then summed along each of its paths going to the deepest level (level 6). Since we only decompose up to the sixth level and each value along this path can be only either a 0 or a 1, we have 1024 of such paths in the tree whose sum is bounded between 0 and 6. The vector consisting of 1024 features for each frame with the label corresponding to camera position is then fed into the following decision tree module to derive camera classifier and self-organizing module for image content/action clustering. Fig 4 shows an example of a tree that is encoded following the above coding fashion.

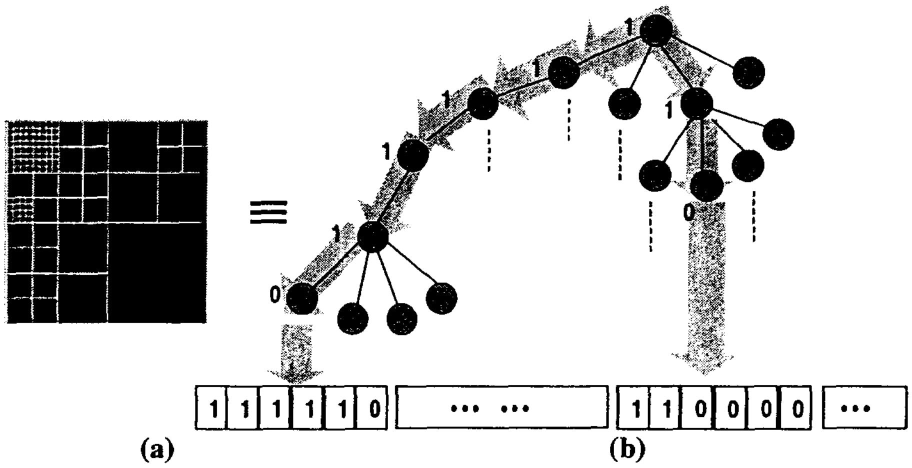


Figure 4: (a) Wavelet representation (b) Quadrature tree representation and coding scheme

2.3 Learning by Decision Trees (DTs) and Self Organizing Map (SOM)

The classification rules can be derived using C4.5, the most commonly used algorithm for the induction of decision trees (DT) (Quinlan, 1986). The C4.5 algorithm uses the entropy as an information-theoretical discriminating measure for building the decision tree. The entropy is a measure of uncertainty, or ambiguity, and characterizes the intrinsic ability of a set of features to discriminate between classes of different objects. The entropy E for a feature set $\{f\}$ is given by

$$E(f)=\sum_{k=1}^{n}\sum_{i=1}^{m}\left[-x_{i,k}^{+}\log_2\left(\frac{x_{i,k}^{+}}{x_{i,k}^{+}+x_{i,k}^{-}}\right)-x_{i,k}^{-}\log_2\left(\frac{x_{i,k}^{-}}{x_{i,k}^{+}+x_{i,k}^{-}}\right)\right] \quad (6)$$

where n is the number of classes and m_j is the number of distinct values that feature f can take on, while $x^{+}_{i,k}$ is the number of positive examples in class k for which feature f takes on its i^{th} value. Similarly $x^{-}_{i,k}$ is the number of negative examples in class k for which feature f takes on its i^{th} value.

C4.5 determines in an iterative fashion the feature that is most discriminatory and then it splits the data into two sets of classes as dichotomized by this feature. The next significant feature of each of the subsets is then used to further split them and the process is repeated recursively until each of the subsets contains only one kind of labeled ('class') data. The resulting structure is called a decision tree, where nodes stand for feature discrimination tests while their exit branches stand for those subclasses of labeled examples satisfying the test. An unknown example is classified by starting at the root of the tree, performing the sequential tests and following the corresponding branches until a leaf (terminal node) is reached indicating that some class has selected.

The Kohonen network (1990) is an unsupervised neural network that has the abilities of self-organization. Through unsupervised learning (competitive learning) process, the neural network nodes become self-organized and specifically tuned to various clusters based on input features, which finally create topological mappings between the input data and sheet-like map units. This topology map is called the self-organizing map. The locations of the responses tend to become ordered as if some meaningful coordinate system for different input features were being created over the network. The spatial location or coordinates of a cell in the network match up to a particular domain of input signal patterns. It is this feature that is of particular interest here since we need to figure out some pattern with which video shots occur and which cluster they may belong to. Using the technique of wavelet decomposition we extract features from the images. The network clusters the video frames using these features based on what kinds of actions take place in the video frames.

3 Experiments

The experimental data came from video surveillance database acquired by the Institute for Forensic Imaging at IUPUI as part of this federally sponsored project. The test bed consists of video shots of various subject actions captured by cameras mounted at different positions at a series of different sites. The actions recorded simulated several criminal scenarios. Included were: (1) a drug sale, (2) fighting, and (3) graffiti. We tested our system through three different cameras to evaluate the ability to classify camera orientation, and using a single camera capturing different types of subjects' actions taking place in and among video shots. The experiment used archived video sequence whose shots and key frames were identified using video break detection algorithms described in Sec. 2.1. The key frames were then cropped to size of 256x256 pixels for wavelet decomposition. The wavelet best basis decomposition used can employ up to six levels and produced a vector consisting of 1024 features (encoded as a tree structure) for each frame. According to our experience, an images of size 256x256, and a 6-level tree structured wavelet decomposition is sufficient to generate distinguishable features for training a decision tree and self-organized map.

450 video key frames corresponding to three different camera positions were used to assess the performance of camera classification routines. The 450 images were randomly divided into two data sets-300 images (100 images/seq.) for training and the remaining 150 images (50 image/seq.) for testing. The complexity of the decision tree was found to have 11 nodes out of 1024 features. The training and test results are shown in Table 1. Fig. 5 shows sample images corresponding to three different camera positions.

Classifiers type	Training accuracy on 100 frames per class	Testing accuracy on 50 frames per class
Camera position 1	99 %	86 %
Camera position 2	100 %	100 %
Camera position 3	100 %	100 %

Table 1. Experiment results for camera classification

To cluster subject's actions, 60 video frames were randomly chosen from video shots found earlier and used to build the self-organizing neural networks after wavelet decomposition. We did not use only key frames in this analysis. Since the previously described decision tree classifier can robustly classify camera location, background subtraction was performed to separate the foreground actions and prevent the background from dominating wavelet tree structure. The background image was generated by averaging all frames within a well-classified shot. The self-organizing neural network automatically generated clusters based on similar actions. The sample results of applying self-organizing network on test images acquired by camera no. 1 are shown in Fig. 6. One can see that the system is able to group actions into different categories, such as people walking towards each other, graffiti, people standing together and talking.

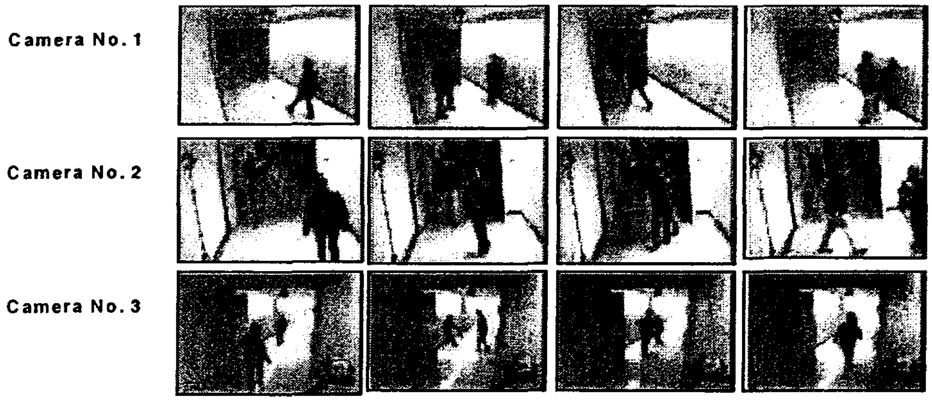


Figure 5: Sample testing images classified into three different camera positions

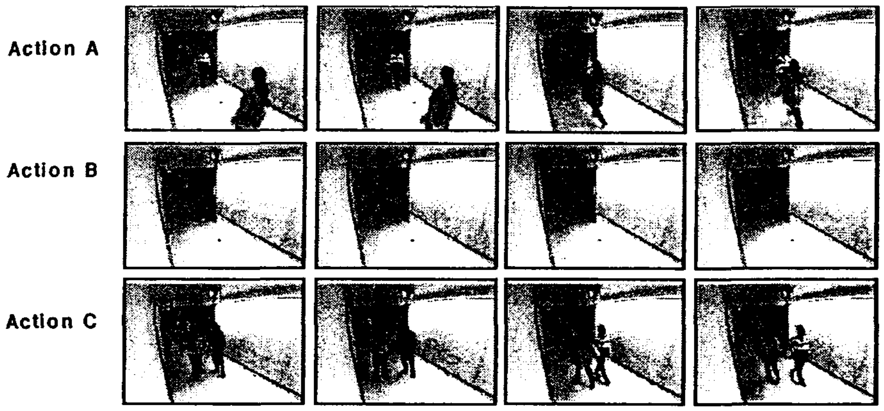


Figure 6: Test images clustered into different actions

4 Extended Work

We have constructed a video scene classification architecture that is capable of: (1) classification of camera orientation (shot) using decision tree learning methods and (2) the clustering imagery based on the contents of subjects' actions using self-organizing networks. The feasibility of this architecture using wavelet best basis decomposition and tree-structure representation on both classification and clustering tasks has been shown on video surveillance sequences consisting of three different camera orientation and several subject motions.

We are presently expanding on our architecture by considering the possibility of scene (subject movement) transitions by combining information of motion flow and sound track signals. We are also considering analyzing action patterns using narrative links among scenes. In this way, one could determine the subjects' activities based on a series of contingent actions.

An ideal video surveillance system might be expected to detect suspicious events and call the attention of a human operator. The operator will be able to view events in real time and initiate actions appropriately. A system such as this will require fewer operators and provide faster response to current events. It will also reduce the number of events that are actually reviewed. With the integration expansion of the architecture described in this report, we will be able to improve the quality and effectiveness of future surveillance systems that might be used in schools, stores, prisons, and similar facilities.

We plan to extend our work to develop new technology for law enforcement by the development and deployment of a Video-Based Perceptually Intelligent (VBPI) system, which is able to identify human motion patterns. Human identification and subject activity analysis for security purposes should be equally important keys for coming generations of surveillance systems. We have had previous successful experience in Face Recognition Technology (FERET) project and human gesture identification, we shall extend our previous research in core biometrics of face recognition and gesture recognition to develop more intensive and complete surveillance system in which perceptual intelligence is expected to provide better ability to identify human subjects and interpret human activity. The system we propose will be a prototype, but it will be architecturally complete, fully automated, and intelligent. It will be able to adapt to dynamic changes of environment and application. The architecture of proposed video-based perceptually intelligent (VBPI) system will consist of three majors modules: (i) Automated face and facial expression recognition, (ii) Gesture recognition and body motion analysis, and (iii) Interpretation of human activities. The system will be designed to be robust and adaptive with the framework where:

1.) the multi-resolution analysis (MRA) of wavelets is used for feature representation,
2.) support vector machines (SVMs) which undertake the tasks of pose discrimination,
3.) a hybrid learning system including Decision Trees (DTs) and Genetic Algorithms (GAs) is used to derive optimal feature sets,

4.) ensemble radial bases function (ERBF) neural networks is designed for pattern recognition,
5.) visual routine processor (VRP) uses the concept of behavior-based AI and is implemented as finite state automata (FSA) to undertake the tasks of detection, and
6.) evolutionary computation associated with probabilistic models can derive state transitions for interpreting human subjects' activities.

The ultimate system is expected to monitor selected venues, interpret imagery and trigger reactions within the system when pre-selected events occur. The actions triggered may include, saving records, warning operators, and/or resetting the camera or conditions settings (e.g. turn on additional the lights). False positives are expected, but these are deemed to be preferable to missed problems, since they only require that a single operator take a second, human look, and make a decision as to whether further action is needed or not. Meanwhile the rest of the system is continuing to do its work.

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Section 9 Image Quality Improvement,
Report by Jose Ramos, Ph.D.

Several approaches were taken to achieve some significant degree of image quality improvement. In general, little success was achieved. The premise for this interest is that most video surveillance systems use cameras set up to cover fairly large areas and the result is that it is almost impossible to make out enough detail to identify a person or hand-held object reliably. On occasion, it is possible to do this, but those occasions are relatively rare. The main finding, then is that one is better off to seek out other strategies to dealing with issues of identification. These strategies are discussed in the sections on camera testing and integrated systems approach above.

It was assumed that surveillance images are highly corrupted by noise, and relatively low resolution. A number of image enhancement algorithms were tested in the hope of clean out the noise in the images obtained from surveillance cameras that had fairly good performance. These algorithms, however, work under the assumption of additive, Gaussian noise. The dynamic range curves shown in the camera testing section make it clear that the response characteristics are significantly non-linear. As a result these basic assumptions of additivity and Gaussian distribution are not fully met. In addition, it was found that typical images captured from surveillance cameras contain excessive amounts of motion blur. In addition, resolution is effectively lower than expected because of quantization of brightness levels associated with compression. An investigating ways to de-blur the images and to increase resolution by subsampling or interpolation did not result in significant improvement. Below we summarize our main findings:

Image Reconstruction.

Instead of processing an image in the frequency domain, as is typically done with the fast Fourier transform, one can apply filtering techniques in the data directly. Two such filters are the autoregressive filter and the singular value decomposition filter. Test modules were constructed and these were applied to the image reconstruction problem. In the laboratory, several modified images were used to test these two methods and then applied to the noisy and blurred images. Matlab software was used for calculations. The results are concluded as follow:

1. Autoregressive (AR) modeling: By using previous values and correlation coefficients, a specific pixel correlation is calculated. The number of previous pixels determines the order of the AR model. This method gives a satisfactory result only in cases in which the images are affected by Gaussian or uniform noise, and have high signal-to-noise ratio. The appropriate order of the model relies on trial and error. Calculation of autocorrelation coefficients is a time consuming process especially for large images.

2. Single Value Decomposition (SVD) modeling: Based on an assumption that the additive Gaussian noise and the true image are orthogonal to each other, in other words, uncorrelated. The singular value decomposition of the image, leads to a good noise removal strategy. From a given singular value set, the true image can be reconstructed fairly well. For Gaussian or uniform noise, using SVD is an efficient tool to reconstruct the image, but there is a problem. It depends on signal-to-noise ratio. The higher the

signal-to-noise ratio, the better the image is reconstructed. This approach is also a time consuming process, especially for the large image.

Dynamic range expansion: In support of forensic laboratory applications, a process has been developed to increase the effective dynamic range of digital cameras by an order of magnitude by combining two still images – much the way it is done in silver-halide film. One of the images is slightly overexposed and the other is slightly underexposed. They are combined using a specially developed algorithm to merge the data from the two images. Experiments indicate that this same approach will work as well with video images, however camera design changes will be needed for a practical solution. (An invention report has been submitted on this approach and it is currently under study through the Indiana University intellectual property process.)

Current problems: Random noise that is neither uniform nor Gaussian is very hard to remove. In our case, most images contain so much noise that the image information is virtually obliterated in some areas. The other major problem is the blur effect in the images. The characteristics of blur are different from additive noise. It is quite hard to reconstruct such images without sophisticated signal processing tools. Both previous methods will have to be modified to see if this approach will work. A range of cameras were evaluated to see if there are some that have images that lower noise levels, less motion blur, and/or better resolution and then see if these algorithms are sufficient. Unfortunately the cameras all had very similar in performance characteristics.

Potential solutions: Both autoregressive filters and SVD are powerful approaches for image enhancement, providing satisfactory results when removing Gaussian or uniform noise that is present at nominal levels. SVD can also be applied to blurred images, but with only moderate success. The approaches explored in this project proved about as successful as multiple frame averaging methods and frame merging methods. They work fairly well when they work, but they don't always work.

Section 10 General Findings and Conclusions

Our study shows that video technology, especially when properly installed and combined with other sensing and analysis technologies can be a helpful addition to a school's overall safety and security program. A simple video-only system can be helpful to some degree, and an improperly installed system may be of very limited value. Many school districts are anxious to have technology to help with maintaining an orderly and safe environment, but they feel it is expensive, difficult to use, and it is believed that it may not live up to expectation. This is to say, there is a place for video technology, but it must be properly installed and carefully selected to be truly effective.

Proper installation is a key to success. The video cameras normally used for surveillance application have rather low image quality capability. As described in the preceding report, the most noticeable quality problem is that there is often not enough detail in images to identify key people and objects. There are five approaches that five might take to correct this, but only two of them are likely to be effective: use a few digital still cameras, and install all cameras properly from a photographic standpoint.

1. One could utilize video cameras with higher capability, but this leads to the generation of a larger amount of information, which, in turn causes a need for higher band width on communications links and significantly larger data storage capacity.
2. Since both bandwidth and storage are costly, is common to compress video images as a means to reduce associated problems. But this leads to degradation of an image that was relatively low-grade in the first place. So, while compression is frequently used, it has its problems.
3. The use of mathematical processing to enhance image quality is a hit or miss proposition. Most techniques are labor intensive since they are applied to one frame at a time. Also, the yield is not very high. Only certain frames are sufficiently enhancable to make them useful, and one will not know in advance which techniques will work on each frame. It becomes a sort of trial and error approach, and often none of the techniques works well at all.
4. If it is better to have better image quality than true motion, one could reduce the frame rate, or even use a few digital still cameras in strategic locations. This eases both the bandwidth and storage requirements without compromising individual frame image quality.
5. The installation mistakes commonly found in surveillance systems are based on poor photography. A good photographer will pay a lot of attention to composition, camera angle and lighting, whereas many camera installers are usually technicians and not photographers, and they seem to go out of their way to violate the photographic basics.

   Composition: If one is interested in recognizing who is in an image, the frame should be largely comprised of the individual's head and upper body. This would require tight framing of shots, but often when installing fixed cameras, one does not know where people will be most of the time so they are set for wide angle viewing. However, there are situations in which one does know where people will be. For example, it is known that people will be in doorways when they enter and leave a room. Accordingly recognition cameras can be located in these areas and set up with fairly tight framing.

The typical installation today has wide-angle lenses on all of the cameras and each is set to record as much as possible of a room or outdoor setting (e.g. a parking lot). These cameras can indicate what sort of action might be taking place in the wide areas, but will be of little to no use in determining who is involved in the activities.

Camera Angle: We normally see and recognize people by looking vertically straight on at their faces, that is at about face-to-face level. Views taken at significantly different levels can impede ability to recognize people. From too low an angle the shape of the nose is lost and from too high an angle, the eyes are not rendered well. In many surveillance systems, cameras are mounted at high levels. This is done for two reasons. First of all, a camera mounted high up is able to cover a wider field of view (see above). Secondly there is concern that a camera mounted within reach of students will be subject to mischief. Nonetheless, more and more banks are now moving to install cameras more at face-to-face angles at doorways and Automatic Teller Machines. These are mounted inside recesses and covered over with highly durable transparent material. They give much better recognition results than wide area cameras.

Lighting: There are two main lighting factors that should be considered. How much light there is and how evenly it is distributed. Clearly the system should be designed and installed so that the amount of light in the area of interest is at a general level sufficient to the needs of the cameras. This is not hard to do most of the time, but it is sometimes overlooked when surveillance of areas at night or of closed rooms is needed. As regards uniformity of lighting, this is often not considered when cameras are installed. Many rooms are lit by ceiling-mounted fixtures, with the result that the bulk of the light comes from above the heads of people in the room. There is usually some attempt to diffuse some of the light by grates or diffusers in the fixtures, but these are more successful for human vision on the scene than they are for video cameras. When too much of the light in a room comes from overhead, peoples' eyes tend to become just dark recesses and shadow-created "beards" and "mustaches" appear on peoples' faces. Another problem is a window on one side of a room and the cameras pointed towards the window side. The cameras will adjust to the high brightness from the windows and underexpose most of the people in the room. Attention should be give to lighting fixtures, their placement, wall treatments (dark walls, or shiny walls will not help diffuse lighting), and camera placements.

The material above indicates that replacing a few cameras, each with a very wide angle of view with a larger number of cameras, some with wide angles of view and others with specific target locations is likely to be a more effective system. This, however, increases the total amount of information that will be collected if all of the cameras run and record all of the time. Accordingly, it is recommended that cameras not record all of their information all of the time. This requires and intelligent system, similar to the ones tested during this project. There are three key ways that the recording can be managed with these systems.

1. The camera-generated signals themselves can be used to determine whether to record or not. For example, a camera channel can be interrogated to see if there

has been a change of scene in a particular portion of the field of view. If so the system starts to record that camera's signal. If not, no recording is saved. This notion can be extended so that an indication is sent to an operator and the operator can view, in real time the events being recorded. The operator can then take control and either keep the information or not.

2. Timers can be used to activate camera recordings at certain times of day/week per a predetermined plan. Hallway and school yard cameras can be turned on during key times such as recess, and arrival, but set to operate only by exception at other times.
3. Auxiliary sensors can be used to initiate recordings. For example entry sensors or door or window opening sensors can trigger a specific camera. Or the turning on a light that is normally off can be used as a trigger. Finally, unusual sound sensors can be used. In this project an audio discriminator was built and tested. It was shown that it could be trained to listen for certain sounds, in the particular instance gunshots, and provide a trigger signal when activated. Using these types of detectors, most cameras would not be recording most of the time, but any target event would cause them to record.

It should be noted that technology exists to actually have recorded video just prior to activation of a trigger. This is done by having the system record and keep a few seconds of video at all times in a temporary, first in first out basis register. As new information comes in, older information is discarded. If a trigger is activated, all of the information in temporary storage is saved along with the after trigger signal.

Preliminary examination of the use of mathematical modeling of video images had mixed results. Enhancement of images, for the purpose of using wide-angle videography for identification of individuals is not likely to be productive. It can provide some help some of the time, but is only useful in specific situations. However, there was promise in using analysis of motion video to interpret the basic nature of activities. For example there was reasonably good promise in the possibility that programs can be developed to identify extremely rowdy behavior, such as a fight. It is also probably possible to pick up a fire long before a sprinkler system might. There are approaches to these sorts of programs being developed in academic settings at this time, and with a bit of support it should be possible to expedite development of practical modules that could be used in support of existing systems.

Section 11 Appendices

Appendix A.

Measuring the Use of Safety Technology in American Schools:
A National Survey of School Safety Administrators
By Crystal Garcia, PhD

Appendix B

Camera Testing for School Safety
By Mike Bone

Appendix C

Audio Surveillance Discriminator
By James Kidd

Surveillance Tools for Safer Schools

Award No. 1999-LT-VX-K011

Appendix A

Measuring the Use of Safety Technology in American Schools: A National Survey of School Safety Administrators

By Crystal Garcia, Ph.D.

Submitted
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Measuring the Use of Safety Technology in American Schools: A National Survey of School Safety Administrators

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EXECUTIVE SUMMARY 1
I. INTRODUCTION 3
Sample........ 4
Research Questions 4
Procedures 4
Data 4

II. METHODOLOGY 4
III. FINDINGS 8
Research Question 1: Have recent concerns about school violence led to changes in school safety plans? 8
Research Question 2: What types of safety technology are in use in American Schools? 10
Research Question 3: How effective do these technologies appear to be? 19
Research Question 4: What types of technologies do school safety administrators wish they had? 21
Research Question 5: What technology do school safety administrators plan on acquiring in the future? 21

IV. CONCLUSIONS 22
V. REFERENCES 27
APPENDIX A: Additional Tables 28
APPENDIX B: SURVEY INSTRUMENT 30
APPENDIX C: CODEBOOK 31

EXECUTIVE SUMMARY

School crimes are down and have continued to decline over the last several years (Brener et al., 1999; Kaufman, et al., 1999). Although the general public may believe that serious violence in school is a common occurrence, it is actually a rare event (Dwyer, Osher, & Warger, 1998). For example, in 1998, only 10% percent of American schools reported a serious violent event on their campus (Kaufman et al., 1998). Yet, highly publicized tragedies such as those in Pearl, Mississippi, Littleton, Colorado, and Santee, California have captured our collective conscience and driven public policy–placing incredible pressure on legislators, school administrators, and local law enforcement to respond decisively. From the introduction of sweeping zero-tolerance policies to target hardening activities (e.g., installation of metal detectors, entry control devices, and security cameras), American schools have "altered" how they do business and how they "protect" their students. Unfortunately, little effort has been spent determining the impact or effectiveness of these policies and technologies.

In order to build knowledge in this area, the National Institute of Justice solicited requests for proposals to study school safety technology. In the fall of 1999, the Institute for Forensic Imaging (IFI) received one of these awards (#1999-9205-IN-IJ). The IFI grant consisted of three major segments: assessment of the current use of safety technology in American schools; evaluation of image enhancement methodologies and recommendations for improvements; and production of a report on best practices. The following report focuses on the first segment: current use of safety technology in American schools.

Administrators in charge of school security from 41 school districts in 15 states were interviewed. Descriptive information about school districts (including size of student population, number of schools in each district, urban/suburban/rural location, recent technology expenditures, etc.), level and impact of concern about school violence on school safety plans, current usage of safety technologies, perceived effectiveness of these technologies, and plans for future acquisition of technologies was collected. The present study addresses the following research questions:

- Have recent concerns about school violence led to changes in school safety plans?
- What types of safety technology are in use in American schools?
- How effective do these technologies appear to be?
- What type of technologies do school safety administrators wish they had?
- What do they plan on acquiring in the future?

Not surprisingly, findings indicate that there was widespread concern about school violence, leading to major changes in school safety plans across the country. Changes in safety plans included the installation of security cameras, video recorders, weapon detectors, duress alarms and entry control devices. The use of some forms of safety technology was commonplace in school districts. For example, 90% of school districts sampled had cameras, 87% utilized recording systems, and 55% metal detectors. Less common were duress alarms (40%) and entry control devices (18%).

Only school safety administrators (SSAs) from districts that had the technologies in place were asked how effective they perceived the equipment to be. Approximately two-thirds of the districts that had cameras and recording systems believed them to be either effective or very effective technologies, whereas far fewer responded that weapon detectors (44%), duress alarms (21%), and entry control devices (33%) were effective or very effective.

When asked what types of technologies they wish they had, the most common responses were entry control devices and newer camera systems. Thirteen of the 41 respondents (32%) said that they wanted entry control devices and 29% wished to either purchase more cameras or upgrade systems already in place. Interestingly, nine SSAs reported that they would like to have things beyond technology to augment their safety plans (e.g., more safety personnel, better training, and a larger mental health staff).

It was not surprising to learn that many districts plan to acquire new cameras or upgrade old systems (66%) and recording capabilities (37%); both were perceived by a majority of the districts to be effective. What was surprising was the number of districts planning to purchase entry control devices (34%), considering that only a third of the districts that had these devices found them effective.

Although the study's generalizability may be somewhat limited due to the sample size (41 school districts), some useful conclusions can be drawn from the findings because they represent the "security" climate in which several million children go to school. First, there appears to be a definite "disconnect" between the perceived effectiveness of certain technologies, such as entry control devices, and the number of districts either wishing or planning to acquire the technology in the future. Specifically, only one-third of the districts with entry control devices found them to be effective, yet 14 additional districts plan on acquiring entry control systems in the future. Complaints about these systems ranged from high cost to problems with numerous false alarms. Because there has been little communication between school districts about the efficacy of these systems, districts all over the country may be investing highly constrained resources into technologies found to be too costly or cumbersome by others.

Second, the study provides a "snapshot" of technology use and sheds light on the pervasiveness of certain technologies (i.e., cameras and recording systems) and thus helps to inform the debate surrounding targeting hardening activities and the fortifying of American schools. Because a full 90% of the districts in sample utilize cameras and 87% recording systems and two-thirds of the respondents believed that these technologies are effective, perhaps public policy should focus on: (1) funding the further development of technologies considered by practitioners to be most effective (e.g., computer-based camera networks and digital storage) and (2) acknowledging what can realistically be expected of these forms of technology. Next generation camera and recording systems will never be able to prevent all violent events, nor can any other technologies discussed in this report. However, smarter, more efficient camera/recording systems will not only continue to serve as a visual deterrent and assist in the investigation of crimes once committed, but more importantly aid in the *earlier detection* of serious events–allowing for *more appropriate and timely responses*!

I. INTRODUCTION

American schools are relatively safe places for youth to be. According to Small and Tetrick (2001), students are less likely to be victims of serious violent and non-fatal crimes at school than away from them. Though the general public may believe that serious violence in school is a common occurrence, it is actually a rare event (Dwyer, Osher, & Warger, 1998). In recent surveys, only 10% percent of American schools reported a serious violent event on their campus (Kaufman et al., 1998). It must be noted that "serious violent events" can include typical fights and threats of violence. This figure should not appear daunting, when one considers that school crime is down and has continued to decline over the last several years (Brener et al., 1999; Kaufman, et al., 1999). In reality, schools are as safe today as they were in the 1970s. For example, in 1968, there were 26 homicides on school campuses, compared to 11 in the 1999-2000 school year. School homicides (figures do not include suicides) peaked in the early 1990s (45 individuals were murdered on or near a campus during the 1992-93 and the 1993-94 school years), but have continued to decline for most of the rest of the decade. In particular, between 1997-98 and 1998-99 (the year of the Columbine tragedy), the number of school-associated violent deaths actually dropped by 40% (National School Safety Center, 2000). Obviously, the good news is that school homicide and violence is down, the bad news is that the number of rare multiple-victim school shootings increased in the 1990s. During the 1992-93 school year there were two multiple victim incidents; five in 1995-96; and eight in 1997-98 (School Safety Center, 2000). Although the increase in the number of incidents has not resulted in increases in the overall number of deaths at school, this trend is still disturbing.

American students do not have a high likelihood of becoming a victim of a violent crime at school. In fact, during the 1998-99 school years, students faced a one in two million chance of dying on campus (Brooks, Schraldi, & Zeidenberg, 1999). Yet, highly publicized tragedies such as those in Pearl, Mississippi, West Paducah, Kentucky, Jonesboro Arkansas, Littleton, Colorado, and Santee, California have captured our collective conscience and driven public policy–placing incredible pressure on legislators, school administrators, and local law enforcement to respond decisively. From the introduction of sweeping zero-tolerance policies such as mandatory expulsion for possession of a weapon and the development of intricate safety plans consisting of evacuation routes and SWAT maneuvers (Harper, 2000), to target hardening activities including the installation of metal detectors, entry control devices, and security cameras, American schools have "altered" how they do business and how they "protect" their students. While countless districts have spent hundreds of thousands of dollars on safety measures (Lawrence, 2000), little is known about their relative impact. While concern over student safety is warranted and expenditures necessary, sound public policy demands that effort be spent determining the effectiveness of these safety policies and technologies.

In order to build knowledge in this area, the National Institute of Justice solicited requests for proposals to study school safety technology. In the fall of 1999, the Institute for Forensic Imaging (IFI) received one of these awards (#1999-9205-IN-IJ). The IFI grant consisted of three major segments: assessment of the current use of safety technology in American schools; evaluation of image enhancement methodologies and recommendations for improvements; and production of a report on best practices. The following report focuses on the first segment, current usage of safety technology in American schools.

Sample
School Safety administrators (SSAs), individuals who oversee security and are charged with the implementation of school safety plans, were identified as being the most appropriate individuals to interview regarding current usage of safety technology in schools. Due to time and monetary constraints a sample of convenience consisting of participants in the 1999 School Security Officer's Forum sponsored by the U.S. Department Education's Safe and Drug Free Schools Program was identified. The target sample included 38 SSAs. The names of other knowledgeable SSAs were provided by participants and contacted later. A total of 41 SSAs from 15 states were interviewed.

Research Questions
The present study answers the following questions:

- Have recent concerns about school violence led to changes in school safety plans?
- What types of safety technology are in use in American schools?
- How effective do these technologies appear to be?
- What type of technologies do school safety administrators wish they had?
- What do they plan on acquiring in the future?

Procedures
Subjects were initially notified about the study by mail. One week later they were contacted by the research team and asked to participate. All surveys were conducted over the telephone and took between 30 minutes and 1 hour and 10 minutes to complete.

Data
Descriptive information about school districts (including size of student population, number of schools in each district, urban/suburban/rural location, recent technology expenditures, etc.), level and impact of concern about school violence on school safety plans, types of safety technologies currently used and how widespread the use is, perceived effectiveness of these technologies, and plans for future acquisition of technologies was collected.

This descriptive report includes data from 41 school districts in 15 states about the use of school safety technology. The following sections include: a detailed description of the methods employed, a thorough discussion of the study's findings, and policy recommendations to consider.

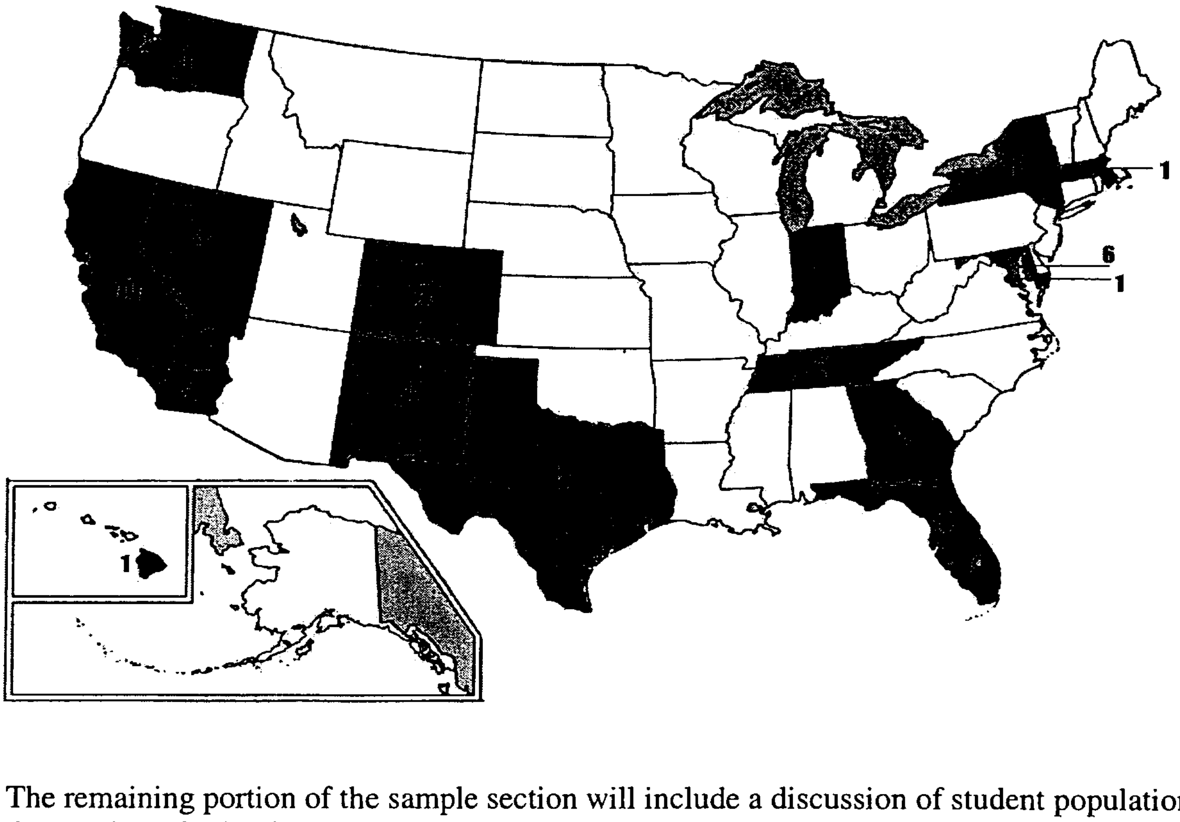
II. METHODOLOGY

Study Sample
Target Sample. School Safety administrators (SSAs), individuals who oversee security and are charged with the implementation of school safety plans, were identified as being the most appropriate individuals to interview regarding current usage of safety technology in schools. Due to time and monetary constraints a sample of convenience consisting of participants in the

1999 National School Security Officer's Forum sponsored by the U.S. Department Education's (USDOE) Safe and Drug Free Schools Program was identified. The USDOE forwarded a list of 38 names and contact information and gave the research team permission to speak with these individuals. At least five attempts were made to contact each SSA. Of the 38 original targets, 28 were eventually interviewed (a 74% response rate); one refused to participate and no contact was made with the remaining nine. Subjects who agreed to participate were asked to provide the names and contact information of other SSAs who might be interested in participating in the study.

Actual Sample. In order to increase the sample size, a snowball sample technique was employed. Study participants provided an additional 17 names to the research team, thirteen of which agreed to participate. The final sample included 41 SSAs from 15 states.
The majority of the SSAs interviewed were employed by school districts located in the West (13), South (12), and Northeast (9). States with the largest representation were California (10 districts) and Florida (9 districts). See Figure 1 below for location of participating districts.

Figure 1. Participating Districts in Sample



The remaining portion of the sample section will include a discussion of student population and the number of schools in each district, as well as a brief overview of recent safety technology expenditures. The majority of school districts included in the study were located in urban areas (53%). A quarter of districts were in suburban settings, 10% in rural areas, and 12% of districts claimed that they served a mixed area (e.g., suburban and rural).

It should be noted that the vast number of school districts in the sample served large student populations (50,000+)–not surprising, considering that most districts were located in urban and suburban areas (see Table 1 below). Only four districts had student populations less than 25,000. Fully 55% of the sample had student populations between 50,000 and 150,000, with 15% serving over 150,000.

Table 1: Student Populations in Participating School Districts

Population	# of School Districts	% of Total
1-2,500	1	3
2,501-5,000	0	0
5,001-10,000	1	3
10,001-25,000	2	5
25,001-50,000	8	20
50,001-100,000	15	37
100,001-150,000	7	18
150,000-and over	6	15

*due to rounding, percentage total may not =100.

As seen in Table 2, one-fifth of districts were comprised of less than 50 schools, while the majority (51%) had between 51 & 150 schools in their jurisdictions. Other districts in the sample were quite large: one-third of districts were made up of over 150 schools and one district had more than 300 schools. Districts tended to have far more elementary than middle or high schools. Seventy-two percent of the sample had between 1 and 100 elementary schools (with an average of 68); 84% had between 1 and 30 middle schools (with an average of 20); and 79% had between 1 and 20 high schools (with an average of 14). For a full breakdown of the number school of types by district, see Tables 26-28 in Appendix A.

Table 2: Number of Schools in Each School District

# of Schools	# of Districts	% of Total
1-50	8	20
51-100	9	23
101-150	11	28
151-200	7	17
201-300	4	10
300 and over	1	2

*due to rounding, percentage total may not =100.

SSAs were asked:

> *In your estimation, approximately how much money has your district spent on acquiring or replacing school safety technology (e.g., metal detectors, cameras, video recorders, etc) in the last two years?*

Total expenditures are summarized in Table 3. While 14% of the sample estimated that they had spent a total of less than $5,000 on safety technology for their entire district, a number of districts (61%) spent over $100, 000 in two years–with 40% spending over $500,000.

Table 3: School District Expenditures for Safety Technology

Expenditures	# of School Districts	% of Total
$0	4	11
<$5,000	1	3
$5,001 – 10,000	3	8
$10,001 - 25,000	2	5
$25,001 – 50,000	2	5
$50,001 – 100,000	3	8
$100,001 – 500,000	8	21
$500,001 and Over	15	40

*due to rounding, percentage total may not =100.

Procedures

Once individuals were identified as potential subjects, they were sent a letter describing the project and informed that a member of the research team would contact them by phone within a few days. One week after letters were mailed, follow-up calls were made. The interviewer explained the purpose of the project, obtained informed consent, and either proceeded with the interview or set up an appointment for a later date. All interviews were conducted over the telephone and took between 30 minutes and 1 hour and 10 minutes to complete.

Survey Instrument. The telephone survey included a total of 311 questions from six separate domains. Domains included:

- changes in security plans (12 questions);
- perceptions of safety (100 questions);
- technologies employed (162 questions);
- perceived effectiveness of the technologies used (25 questions);
- future plans (2 questions); and
- school district descriptive data (10 questions).

In order to be asked all of the questions, a district had to have been using all five technology types (cameras, recording systems, weapon detection systems, duress alarms and entry control devices) included in the survey.

School districts were assigned identification numbers and answers to all questions were immediately recorded on the survey instrument. Data was later coded and entered into the database.

Strengths and Weaknesses of Data

Strengths. The data generated in this study is truly unique. Although school safety is currently a popular research topic, this study is the first of it kind. Not only does it survey the types of safety technology in place, but examines the perceived effectiveness of the equipment, plans for future acquisitions, and key policy questions surrounding the expanded utilization of technology in schools. The dataset was enriched by the variety of domains incorporated in the survey (changes in security plans, perceptions of safety, technologies employed, perceived effectiveness of the technologies, future plans, and school district descriptive data).

Weaknesses. As with any research project, the current data has limitations. The must crucial limitation is that the study design did not allow for the random selection of school districts. Due to time and monetary constraints, the study was designed with a sample of convenience, which can introduce bias and reduce external validity. Clearly, biases do exist in this dataset. In particular, potential subjects were identified because of their involvement in a School Security Officer's Forum sponsored by the USDOE's Safe and Drug Free School Program. By their very participation in the forum, it is clear that these officers represent districts highly cognizant of school security issues and educated in the use of safety technologies. As such, findings from this study may appear to over-represent the use of safety technology in American schools. Furthermore, the somewhat small sample size (41 districts) may limit generalizability. Nevertheless, conclusions drawn from the study are important because they offer a "snapshot" of current technology use and how those in the trenches perceive the performance of this technology in the real world.

III. FINDINGS

Answering the Research Questions

Although the major intent of this study was to measure the current use of safety technology and its perceived effectiveness, the research team identified several other areas of interest related to the purchase and integration of safety technology into schools. SSAs were queried regarding their concern about violence and changes in school safety plans, feelings of safety on campus, perceived increases in crime and violence in schools, how districts perceived themselves when compared to other districts in terms of disorder behaviors and crime, the level of support various constituencies show for the use of safety technology in schools, and the locations on campus most vulnerable to disorder behaviors and crime.

Research Question 1: Have recent concerns about school violence led to changes in school safety plans?

SSAs were asked to rate, using a 5 point Likert Scale (with 1 being "minor" and 5 being "major"), how much concern there was over school violence in the their districts; how extensive changes to school security plans have been in the last two years; and how much of an impact stories about school shootings had on school safety reforms. Not surprisingly, findings indicate that there was widespread concern about school violence (See Table 4 below). Two-thirds of the sample responded that there was either somewhat major or major concern about school violence in the districts they represented, and a full seventy-one percent of SSAs claimed that there had been major or somewhat major changes to school safety plans in the last two years–indicating that the "concern" is what drove the reforms. Fifty-four percent of districts reported school shooting stories had had an impact, whereas a mere 17% claimed that these stories had little impact on changes in safety plans. "Changes in safety plans" included the implementation of evacuation drills and crisis response actions as well as the installation of security cameras, video recorders, weapon detectors, duress alarms and entry control devices. The current study focuses only on the safety technology aspect.

Table 4: Concern About School Violence

Responses	**% School Districts Responding**		
	Minor or Somewhat Minor	Average	Somewhat Major Or Major
Concern About School Violence	12	22	66
Changes to School Security	15	15	71
Impact of School Shooting Stories	17	29	54

*due to rounding, percentage total may not =100.

Although concern about school violence appears high–the majority of SSAs believed that faculty and students felt safe at school (please refer to Table 23 in Appendix A). Sixty-six percent of respondents agreed or strongly agreed with the statement, *"Faculty/staff feel safe at our schools,"* while the proportion agreeing or strongly agreeing with the statement, *"Students feel safe at our schools,"* was somewhat lower at 54%. Relatively few SSAs held the belief that teachers and students felt unsafe.

School safety administrators were also questioned about possible increases in crime and violence in their jurisdictions. As seen in Table 5, one-fifth of the sample agreed or strongly agreed that student on student assaults had increased; 24% agreed or strongly agreed that student on teacher assaults had increased; 34% agreed or strongly agreed that there appeared to be an increase in threats of violence; and 20% agreed or strongly agreed that crime, in general, had been increasing in their school districts. A far larger proportion of the sample did not perceive there to be increases in student on student or student on teacher assaults. Moreover, a majority of respondents believed that crime had not increased in their districts. These later figures mirror national school crime trends that indicate crime on campus is not rising (Small & Tetrick, 2001).

Table 5: Perceived Increases in Crime

Statement	% School Districts Responding		
	Strongly Disagree or Disagree	Neutral	Agree or Strongly Agree
In the last 2 years, we have experienced an increase in student on student assaults.	49	32	20
In the last 2 years, we have experienced an increase in student on teacher assaults.	54	22	24
In the last 2 years, we have experienced an increase in threats of violence on school grounds.	39	27	34
In the last 2 years, we have experienced an increase in crime in general.	61	20	20

*due to rounding, percentage total may not =100.

Finally, SSAs were asked to rate their districts (as either much better, better, same, worse or much worse), relative to other local districts with regard to disorder behaviors (e.g., bullying, smoking, loitering), drug crimes (e.g., sales or possession), property crimes (e.g., vandalism, theft, etc), and violent crimes (e.g., assault, rape, etc.). Across the board, SSAs saw their districts as similar to other districts (see Table 6 below). Only in the property crimes category, did more than 20% of respondents see themselves as having more of a problem than their neighbors.

Table 6: Comparison of School Districts to Other Local Districts Regarding Disorder Behaviors and Crime

Statement: Relative to other school districts in your area, how would you rate the following:	% School Districts Responding		
	Much Better or Better	Same	Worse or Much Worse
Disorder Behaviors	36	49	15
Drug Crimes	39	46	15
Property Crimes	26	46	28
Violent Crimes	44	39	18

*due to rounding, percentage total may not =100.

Research Question 2: What types of safety technology are in use in American Schools?

Before detailed information is offered about the current use of technology in schools, a few points of interest should be considered. Offered below, is a discussion of who SSAs believe are supportive of the use of technology in schools (Table 7), and what areas in a school appear to be most vulnerable to disorder behaviors, drug crimes, property crimes, and violent crimes (Table 8). Both of these issues are important to bear in mind when districts devise safety plans and install security equipment.

Considering the public outcry over violence and school shooting incidents, one might think that there would be overwhelming support for the widespread use of safety technology in schools. This, however, is not necessarily the case. The individuals whom would most likely benefit from the technology (students and teachers) are perceived by SSAs to be the least supportive of its use. According to the figures in Table 7, less than half of SSAs perceived teachers to be in major support of the use of safety technology. Even fewer (33%), perceived students to lend major support to its use. Not surprisingly, the groups that appear to be most supportive of the technology are safety personnel, law enforcement, school administrators, and community leaders.

Table 7: Perceived Support for Use of School Safety Technology

Constituencies (n=# of respondents answering questions)	**% School Districts Responding** Minor or Somewhat Minor	Average	Somewhat Major Or Major
Administration (n=40)	10	29	61
Teachers (n=40)	20	32	49
Students (n=39)	41	26	33
Parents (n=40)	18	28	55
Safety Personnel (n=38)	5	8	87
Law Enforcement (n=39)	15	13	72
Community Leaders (n=38)	13	26	61
Gov. Officials (n=38)	16	26	58

*due to rounding, percentage total may not =100.

Another important issue to examine when studying the use of technology in schools, is to ascertain where the experts (i.e., school safety administrators) believe are the most vulnerable to behavior disorders and crimes. Behavior disorders are incidents that are not necessarily actions defined in the criminal code, but behaviors that break school rules and norms (e.g., smoking in buildings, initiating false alarms, or bullying, etc.). Drug crimes include events such as the possession of drugs or drug paraphernalia, sales of narcotics, or being under the influence of alcohol or drugs. Property crimes can include vandalism, theft, and arson. Violent crimes refer to crimes against another person (e.g., fighting, assault, rape and homicide). Knowing which locations in a school are most vulnerable is essential when identifying what technology, if any, is appropriate to combat the problem and where it should be placed. A comparison of perceived location vulnerability and where SSAs actually placed safety technology will be discussed at length at the end of the "effectiveness" section. To determine location vulnerability, SSAs were asked to rate the degree of risk of disorder behaviors, drug crimes, property crimes and violent crimes for 30 separate locations, using a Likert Scale from 1 to 5 (with 1 being "very low risk" and 5 "being very high risk"). Locations included areas such as hallways, playgrounds, science labs, and primary entrances. Location ratings were averaged by crime type across districts to develop overall means. The five most vulnerable locations to disorder behaviors, drug, property, and violent crime are included in Table 8. Refer to Table 24 in Appendix A for a complete list of locations and means. The most vulnerable areas to behavior disorders, drug crime, and violent crime are the bathrooms–an area where none of the technologies under review are placed. Parking lots, on the other had, are believed to be the most vulnerable location to property crime. Clearly, the two most vulnerable places on campus are bathrooms and parking lots; however, hallways and buses were also commonly cited trouble spots. Finally, in addition to bathrooms, parking lots, hallways, and the bus, stairways also appear to be vulnerable to drug and violent crime.

Table 8: Locations Most Vulnerable to Disorder Behaviors and Crime (mean scores of crime types across school districts)

Disorder Behaviors	Drug Crimes	Property Crimes	Violent Crimes
Bathroom (3.32)	**Bathrooms (3.61)**	**Parking Lots (3.15)**	**Bathrooms (3.22)**
On Bus (3.23)	**Parking Lots (3.20)**	**Bathrooms (3.07)**	**Parking Lots (3.00)**
Hallways (3.05)	Hallways (2.80)	Locker Room (2.83)	Hallways (2.90)
Cafeteria (3.05)	Stairs (2.55)	Hallways (2.68)	Stairs (2.72)
Parking Lots (2.90)	On Bus (2.53)	Equipment Shed (2.61)	On Bus (2.70)

Use of Technology

School safety administrators were asked what types of technologies were currently in place in their school districts. Technologies were divided into the five most commonly used safety technologies in schools: cameras, recording systems, weapon detection systems, duress alarms, and entry control devices. In the following section, data is presented regarding the overall use of these technologies by category and where in the districts (i.e., elementary, middle, and high schools) they are deployed.

Cameras

Upon review of the literature, several different camera types were identified. SSAs were asked if they had any cameras in their districts, and if so, which of the following list they had: monitor fed to viewer in real time, computer-based camera network, closed circuit TV system, or color, pan/tilt/zoom, hidden, false, bullet-resistant, interior, and exterior cameras. As seen in Table 9, the overwhelming majority of districts surveyed had cameras in place. In fact, cameras were the most common safety technology used by school districts in the sample. Ninety percent of districts reported the use security cameras in their schools–with the most common type of camera technology being a closed circuit TV system. Moreover, most districts with cameras fed signals to monitors in real time and only one-third utilized computer-based camera networks. A number of districts used both interior (85%) and exterior cameras (80%). Only four districts in the sample reported that they had no camera technology.

Table 9: Percentage of School Districts with Various Camera Technologies

Type of Technology (n=# of respondents answering question)	**% of School Districts with the Technology**
Video Cameras (n=40)	90
Monitor Fed to Viewer in Real Time (n=40)	78
Computer Based Camera Networks (n=40)	35
Closed Circuit TV System (n=39)	82
Cameras with Color Images (n=40)	58
Cameras with Pantilt Zoom (n=40)	60
Wireless Cameras (n=39)	21
Hidden Cameras (n=40)	40
False Cameras (n=40)	15
Bullet Resistant Cameras (n=40)	5
Interior Cameras (n=40)	85
Exterior Cameras (n=40)	80

Approximately one-half of the districts that utilized camera technology had not installed cameras in their elementary schools. Usage of camera technology was far higher in middle and high schools. Specifically, more than two-thirds of districts with this technology placed cameras in middle schools and 97% had installed cameras in their high schools (see Table 10 below).

Table 10: Breakdown of Schools within Districts having Camera Technologies

# of Schools within District with Cameras	**Elementary Schools**		**Middle Schools**		**High Schools**	
	# of Districts	% of Total	# of Districts	% of Total	# of Districts	% of Total
0	17	53	10	31	1	3
1-5	8	25	14	44	17	53
6-10	0	0	2	6	4	13
11-20	3	9	4	13	6	19
21-30	0	0	1	3	4	13
31-40	0	0	1	3	0	0
41 and above	4	12	0	0	0	0

*due to rounding, percentage total may not =100.

Recording Systems
SSAs were asked if schools in their districts had some form of recording capability. If they answered yes, they were then asked which of the following recording systems they used: VCRs, multiplexers, time-lapse recorders, event recorders, digital recorders, and/or continuous monitoring. Results are summarized in Table 11. Note: multiplexers combine two or more camera signals and send them to a single recorder; time-lapse systems incrementally record frames at specified intervals; and event recorders store images when an intrusion detection alarm notifies the system that an incident should be recorded.

All but five SSAs reported that they had recording capabilities in their districts. Of the 87% that reported having recording systems, the majority utilized VCRs (83%), multiplexers (78%), timelapse recorders (69%), and continuous monitoring (64%). Although seen by many in the security field to be the best technology to record images (Green, 1999), less than one-third of districts (31%) had converted to digital recording systems.

Table 11: Percentage of Districts with Various Recording Technologies

Type of Technology (n=# of respondents answering question)	**% of School Districts with the Technology**
Recording System of Some Type (n=40)	88
VCR (n=40)	83
Multiplexers (n=40)	78
Timelapse Recorders (n=39)	69
Event Recording (n=39)	23
Digital Recorders (n=39)	31
Continuous Monitoring (n=39)	64

While less than half of the districts with camera technology (43%) placed them in elementary schools, even fewer (37%) installed recording systems in them. As seen in Table 12, a larger percentage of districts with this technology used recording systems in middle and high schools (64% and 97% respectively). Clearly, those developing safety plans and implementing security measures found camera and recording systems far more useful in high schools than in the other educational institutions.

Table 12: Breakdown of Schools within Districts having Recording Technologies

# of Schools within District with Recording Systems	Elementary Schools		Middle Schools		High Schools	
	# of Districts	% of Total	# of Districts	% of Total	# of Districts	% of Total
0	19	63	11	37	1	3
1-5	5	17	12	40	16	54
6-10	0	0	2	7	4	13
11-20	2	7	2	7	5	17
21-30	0	0	2	7	4	13
31-40	0	0	1	3	0	0
41 and above	4	13	0	0	0	0

*due to rounding, percentage total not may =100.

Weapon Detection Systems (WDS)

SSAs were queried about the use of WDS in their districts. For purposes of this study, weapon detection systems refers only to metal detectors and excludes all forms of bomb or chemical detectors. In addition to the general question about the use of WDS, respondents were asked if their districts employed metal detector wands, walk through metal detectors, and x-ray baggage scanners. Hand held metal detector wands, walk through (or portal) metal detectors, and x-ray baggage scanners, all of which are encountered at airports worldwide, scan persons or things for any material that would conduct electrical currents. As such, this technology is efficient at detecting metal objects–most specifically guns and knives.

Metal detection systems were much less common than cameras and recorders. Slightly more than half (55%) of districts reported having some form of weapon detection system (see Table 13). Of the districts that utilized theses systems, hand held metal detecting wands were the most popular form of the technology. And although they can be fairly expensive, almost one-quarter of the sample utilized walk through metal detectors. Finally, one of the largest districts in the sample had, at their disposal, the most expensive of the metal detection systems–an x-ray baggage scanner.

Table 13: Percentage of School Districts with Various Weapon Detection Systems

Type of Technology (n=# of respondents answering question)	**% of School Districts with the Technology**
Weapon Detection of Some Type (n=40)	55
Metal Detector Wands (n=39)	56
Walk Through Metal Detectors (n=40)	23
X-Ray Baggage Scanners (n=40)	3

As seen in Table 14, the use of weapon detection systems in elementary schools was quite rare. Only one district used a WDS (specifically a metal detector wand) in elementary schools. Conversely, 10 districts (24% of the total sample) utilized metal detectors in middle schools and 14 (34% of the total sample) in high schools. Of the districts that employed WDS, most utilized metal detectors wands, though some had both wands and walk through detectors. Anecdotally, many of the SSAs that had metal detectors at their disposal claimed that scanning activities occurred at random intervals.

Table 14: Breakdown of Schools within Districts having Weapon Detection Systems

# of Schools within District with Weapon Detection Systems	Elementary Schools		Middle Schools		High Schools	
	# of Districts	% of Total	# of Districts	% of Total	# of Districts	% of Total
0	14	93	5	33	1	7
1-5	1	7	3	20	5	33
6-10	0	0	1	7	2	13
11-20	0	0	1	7	6	40
21-30	0	0	4	27	1	7
31-40	0	0	1	7	0	0

*due to rounding, percentage total may not =100.

Duress Alarms (DAs)

Duress alarms are electronic devices that allow a person to summon help. Although duress alarms can be categorized into several subsets, for the purposes of this study they were divided into two types: strategically placed alarms and alarms worn by personnel. Strategically placed alarms or "panic buttons" are buttons placed in specific areas in the school vulnerable to violence or troubling events. For example, panic buttons are commonly found in cafeterias, administration offices, teacher's lounges, and sometimes in classrooms. Alarms worn by personnel are devices worn as necklaces or clipped to belts or waistbands that when pushed sound an alarm in a central location or monitoring area. More sophisticated systems allow computers to locate where in the building the person who triggered the alarm is located. Many of these systems also provide the option of two-way communication between the safety personnel and the individual in distress, however, these systems can be fairly expensive.

The use of duress alarm systems was far less common than that of cameras, recorders, or weapon detectors. Sixteen SSAs (40%) reported the use of DAs in their districts (see Table 15 below). The most commonly used form of DAs was strategically placed panic alarms, with 15 of 16 districts employing this technology. Although there has been much discussion in the field about giving school personnel panic alarms to wear (much like those worn in detention facilities throughout the country), it appears this practice is yet to become commonplace. School personnel had access to this type of duress alarm in only two of the districts surveyed (5%).

Table 15: Percentage of School Districts with Duress Alarms

Type of Technology (n=# of respondents answering question)	**% of School Districts with the Technology**
Duress Alarm of Some Type (n=40)	40
Strategically Placed Alarms (n=40)	38
Alarms Worn by Personnel (n=40)	5

Not all of the SSAs reporting the use of duress alarms in their districts were able to provide information about where they were employed (please refer to Table 16). Of the 12 districts that were able to provide this level of detail, five had duress alarms in elementary schools, seven in middle schools, and 11 in high schools.

Table 16: Breakdown of Schools within Districts having Duress Alarms

# of Schools within District with Duress Alarms	**Elementary Schools**		**Middle Schools**		**High Schools**	
	# of Districts	% of Total	# of Districts	% of Total	# of Districts	% of Total
0	7	58	5	42	1	8
1-5	1	8	1	8	4	33
6-10	0	0	2	17	1	8
11-20	1	8	2	17	5	42
21-30	1	8	2	17	1	8
31-40	0	0	0	0	0	0
41 and above	2	17	0	0	0	0

*due to rounding, percentage total may not = 100.

Entry Control Devices (ECDs)

SSAs were asked if entry control devices were used in their districts. If so, they were asked which of the following ECDs were in place: turnstiles, scanner cards, password/pincodes, or biometric identifiers. ECDs were the least commonly used of all the technologies discussed in this report. As seen in Table 17, of the 40 SSAs responding to this question, seven (18%) reported utilizing some form of entry control device. Although biometric identifiers (systems in which a computer scans the retinal, pupil, or palm/finger prints) are of great interest to many in the school security field, they are extremely expensive and somewhat easy to damage–thus no districts in the sample currently use this technology. Turnstiles are found at the other end of the technology spectrum. Installation is straightforward and they are easy to maintain, however, they are also simple to "outsmart," are seen as cumbersome when trying to admit large numbers of students into schools in a fairly short period of time, and thus were not favored by the SSAs interviewed for this study. Districts that had ECD technology, preferred to limit access and control entry into schools using scanner cards (which were usually a combination school ID /scanner card) and individual student pincode entry systems.

Table 17: Percentage of School Districts with Various Entry Control Devices

Type of Technology (n=# of respondents answering question)	**% of School Districts with the Technology**
Entry Control Devices (n=40)	18
Turnstiles (n=40)	0
Scanner Cards (n=40)	10
Password/Pincode (n=40)	10
Biometric Identifiers (n=40)	0

Of the seven districts utilizing ECDs, only four were able to report exactly where the technology was used. One district used entry control devices in elementary schools, one in middle schools and three in high schools (see Table 18 below). Even though few districts in the sample are currently using this technology, many SSAs intimated that they either wished they had this technology or were planning to purchase it in the near future.

Table 18: Breakdown of Schools within Districts having Entry Control Devices

# of Schools within District with Entry Control Devices	**Elementary Schools**		**Middle Schools**		**High Schools**	
	# of Districts	% of Total	# of Districts	% of Total	# of Districts	% of Total
0	3	75	3	75	1	25
1-5	1	25	1	25	3	75
6-10	0	0	0	0	0	0
11-20	0	0	0	0	0	0

Research Question 3: How effective do these technologies appear to be?

Only school safety administrators from districts that had the technologies in place were asked about perceived effectiveness. In particular, the following items were included in the survey:

- Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective"), please estimate how effective, **overall**, you believe cameras; recorders; weapon detectors; duress alarms; and entry control devices are at preventing and controlling crime on campus.

- Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective"), estimate how effective cameras; recorders; weapon detectors; duress alarms; and entry control devices are at preventing or minimizing **disorder behaviors, drug crimes, property crimes, and violent crimes** in your district.

As seen in Table 19, cameras and recorders were seen as the most effective school safety technologies utilized by districts in the sample. Specifically, 67% believed cameras to be either effective or very effective and 64% believed recording systems to be effective or very effective at preventing or controlling crime on campus. When breaking effectiveness down by crime type, cameras were seen to be most effective at preventing or minimizing property crimes (with 78% of SSAs having this technology reporting they are effective or very effective), however, many also saw cameras as effective technologies for dealing with disorder behaviors (68%), drug crime (59%), and violent crime (59%). Recording "effectiveness ratings" were similar to those of cameras. Eighty percent reported that recording systems were effective or very effective for property crimes, 72% for disorder behaviors, 69% for violent crimes, and 63% for drug crimes.

Overall, perceptions about the effectiveness of weapon detection systems were mixed. Forty-five percent of SSAs with this technology thought they were effective or very effective, however, ratings dropped further when they were assessed by crime type. It was expected for weapon detectors to receive low effectiveness ratings for disorder behaviors (36%), drug crimes (14%), and property crimes (5%), because they are not designed to deal with these issues. Because metal detectors are specifically designed to discover weapons what can be used to perpetrate violent crimes, it was assumed that SSAs would offer high praise for this technology with regard to violent crime–this assumption was incorrect. Only 32% of SSAs with WDS, perceived this technology to be effective for preventing or minimizing violent crime.

Approximately one-fifth of the districts utilizing duress alarms found them to be effective or very effective. Duress alarms should not be expected to be effective for drug crimes or property crimes in that they are designed to summon help in emergency situations; and they were not. Six percent of SSAs reported that duress alarms were effective for drug crimes and 19% for property crimes. There should, however, be a reasonable expectation of effectiveness for duress alarms when dealing with disorder behaviors (e.g., fighting) and violent crime (e.g., assault), yet few SSAs perceived duress alarms to be effective for dealing with these offenses (19% and 25%, respectively).

Finally, one-third of districts with entry control devices believed them to be effective for the overall prevention or control of crime on campus. Moreover, none thought the technology was effective for drug crimes and only 13% saw them as useful in the control of disorder behaviors. Slightly more, however, (25%) rated them as effective for preventing and minimizing property and violent crime.

Table 19: Effectiveness of Technologies

Type of Technology (n=# of respondents answering question)	**Perceived Effectiveness**		
	% Responding Not Effective or Somewhat Effective	% Responding Neutral	% Responding Effective or Very Effective
Cameras (n=40)	19	14	67
Recording (n=33)	21	15	64
Weapon Detectors (n=18)	28	28	45
Entry Control (n=6)	33	33	33
Duress Alarms (n=14)	36	43	21

*due to rounding, percentage total may not = 100.

A discussion of perceived effectiveness would not be complete without addressing whether or not the technologies assessed were placed in locations that SSA perceived as vulnerable to the various crime types discussed above. In general, it appears that little of the technology used in schools are placed in areas deemed most vulnerable to disorder behaviors, drug crimes, property crimes, and violent crimes (refer back to Table 8). Cameras and recording systems were most often located in common areas such as hallways, stairwells, and cafeterias, but missing from the two places considered most vulnerable across crime types (bathrooms and parking lots). This is likely the case for good reason: (1) privacy and legal constraints would prohibit the placement of cameras and recording devices in bathrooms, and (2) it is very costly to have the quality and number of cameras, proper recording devices and ample storage, and appropriate lighting necessary to generate useful images in sizeable parking areas. Large districts with high crime and sufficient resources have implemented such programs, however, for districts not in this position, well surveilled parking areas are often a low priority.

Duress alarms were most often located in offices and classrooms. While it makes absolute sense to place this technology there, these areas were not described by SSAs as particularly vulnerable to crime. In fact, administration offices scored less than 2.0 in all crime categories, while classrooms received fairly low means in all categories except behavior disorders. Although no districts reported having duress alarms in the most vulnerable areas (bathrooms or parking lots), two had placed them in common areas (i.e., hallways, stairwells, and cafeterias) also deemed as vulnerable.

Logically, weapon detection systems and entry control devices were most heavily concentrated at building entry points. Interestingly enough, entrances were not considered highly vulnerable to crime. Mean vulnerability scores for primary entrances were 2.46 for disorder behaviors, 1.83 for drug crimes, 2.03 for property crimes, and 2.17 for violent crime. The expenditure of valuable resources on technologies not seen as overwhelmingly effective in areas not deemed highly vulnerable, may be explained by the fact that some SSAs reported that the mere act of having a weapon detection systems served as a deterrent, to some degree, and limiting access to school buildings added to the "sense of safety" felt on campus.

Research Question 4: What types of technologies do school safety administrators wish they had?

When asked what types of technologies SSAs wish they had, the most common responses were entry control devices and newer camera systems. Thirteen of the 41 respondents (32%) said that they wanted entry control devices–explaining that it is easier to secure an environment if you control who enters it. Another 29% wished to either purchase more cameras or upgrade systems already in place. Additionally, six SSAs (15%) wished to either have or upgrade recording systems and five (12%) wanted metal detections systems for their school districts. None of the subjects interviewed reported wanting duress alarm technology. Interestingly, nine school safety administrators reported that they would like to have things other than "just technology" to augment their safety plans. Many mentioned the need for more school safety personnel, better training, and a larger mental health staff.

Research Question 5: What do they plan on acquiring in the future?

Near the end of the survey, school safety administrators were asked: (1) to describe their district's prospects for increased spending on safety technology in the future; and (2) what safety technology they planned to acquire in the next several years. Lack of funding for new safety technology did not appear to be a major concern for a large number of the districts in the sample and may explain the rather extensive plans for future acquisitions discussed below. Fifteen percent of districts claimed that their prospects for increased safety spending was "excellent," while another 64% described their prospects as "fair" to "good." Only 21% of the SSAs described their prospects for increased spending as "poor" or "very poor."

It was not surprising that so many districts plan to acquire or upgrade their camera systems (66%) and recording capabilities (37%); both were perceived by a majority of the districts that had them to be effective safety technologies. What was unexpected was the number of districts that planned to purchase entry control devices (34%). Only a third of the districts that had these devices found them to be effective, yet fourteen more districts intended to acquire some form of this technology. In addition to cameras, recorders, and entry control devices, a number of districts plan to acquire other technologies to enhance the safety environment in their schools. In particular, four districts (10%) intend on purchasing technology that allows for two-way communication between classrooms and safety personnel/ administration; three (7%) will purchase and install metal detection systems; three (7%) will purchase an ID badge system for students and staff; and one district has plans to install a personal duress system. Moreover, SSAs from seven districts commented that they would be hiring more safety staff, implementing better training programs, and purchasing smart doors or alternative locking systems, while one administrator reported the possibility of purchasing Global Positioning Satellite and Geographic Information System technology.

IV. CONCLUSIONS

Summary

School districts included in the sample were fairly large, with 70% having over 50,000 students and 15% over 150,000. The majority of these districts reported that as a result of major concern about school violence in their districts, they revised their school safety plans. In addition to implementing evacuation plans and emergency response teams, most districts spent over $100, 000 (with 40% spending more than $500,000) on safety technology in the past two years.

Few districts reported increases in assaults or general crime, although a third of the sample claimed that there had been increases in threats of violence. On the whole, most districts appeared to be somewhat content with the "state of crime" on their campuses. When asked to assess their crime situation relative to that of other local school districts, the majority of SSAs described their crime situations as the "same" or "better" than neighboring districts.

Cameras and recording systems were not only the most commonly used safety technologies, but considered to be the most effective–especially in preventing and minimizing disorder behaviors, drug crimes, and violent crime. When asked what were the most positive aspects of these technologies, SSAs overwhelmingly believed that cameras and recorders served as a visual deterrent. Moreover, they were believed to be valuable technologies because of their ability to document events. Nine of the 36 districts with cameras claimed that having this technology could actually reduce the number of personnel needed, however, the same number argued that cameras increased staffing needs. The top two complaints about both cameras and recorders were: (1) they were not cost effective; and (2) they were intrusive and could violate civil liberties.

Less than half of the districts using metal detectors believed they were effective, however, one-third did report that metal detection systems were effective in preventing and minimizing violent crime. Eleven of the 22 districts with metal detection systems reported that the most positive aspect of this technology was that it served as a deterrent and six SSAs said that the ability to detect weapons was a useful function of the technology. While describing the negative side of metal detectors, SSAs related that they were very time consuming and labor intensive and presented the opportunity to invade an individual's privacy.

Perceived performance of duress alarms and entry control devices was less than impressive. About one-half of respondents with duress alarm technology stated that the positive aspects of this technology were that they allowed for quick response to emergencies, while one-third reported that they provided a sense of security in schools, while many SSAs complained that false alarms were problematic and commonplace. Relative to the other technologies discussed above, there were few positive comments about entry control devices. Four of the seven districts with this technology reported that the most positive attribute of ECDs was that these systems could limit access to school buildings. The negatives aspects of ECDs included high false alarm rates and the complicated and time-consuming nature of the technology.

Depending on the type of systems employed, school safety technology can be extremely expensive. The "cost issue" was referred to by SSAs numerous times throughout the study. The only technology referred to by any of the SSAs as "cost effective" was recording systems. Twenty-six percent of respondents with recording capabilities mentioned the low cost of recording as a positive attribute of the technology. Conversely, half of SSAs with cameras (18 of 36) complained that cameras were either "expensive" or not "cost effective." Finally, one administrator claimed that weapon detection systems were too costly and one asserted that ECDs were not "cost effective."

Policy Implications

District Level

Clearly, the cost of safety technology is an important issue and needs to be closely examined. Perhaps resources spent on technologies considered not very effective by those using them, (e.g., entry control devices, duress alarms, and some forms of weapons detections systems) should be redirected. Purchasing technology for technology sake is a poor public policy and could prove to be a dangerous practice. For instance, entry control devices (can cost between $1,200 and $50,000 to purchase and even more to maintain) may limit access to unauthorized persons, but will do little to prevent an angry, isolated, determined student from entering school and committing violence. Moreover, weapon detection systems (which can range between $150-200 for hand held wands, $1,000 to $30,000 for walk through detectors, and approximately $30,000 for x-ray baggage machines, excluding service contracts), can be easy to circumvent and are only as good as the individual operating the system. Thus, the appropriate number of persons must be available to operate the detectors and all such individuals must receive sufficient and continual training. Therefore, the cost to operate effective and efficient metal detection programs can be exceedingly expensive. WDS that rely solely on hand held detector wands are not always thorough or efficient. If districts are truly concerned with the existence of knives and guns in their schools they must combine weapon detection technologies and use them regularly. As Green (1999) stated in the publication, *The Appropriate and Effective Use of Security Technologies in the U.S. Schools*, "it is highly recommended that any routine metal detection program incorporates the use of x-ray baggage equipment for book bags and purses because of the ease with which a contraband item or material could be hidden within carried baggage,"(68). When the costs of training, personnel, hand held wands and x-ray or walk through (portal) detectors and their maintenance are combined, all but the largest districts may determine that the costs incurred and the time it takes to operate these programs, makes a comprehensive weapon detection system impractical. The implication provided here is not to avoid purchase, implementation, or continuation of weapon detection programs, rather to carefully assess the actual threat each school faces with regard to weapons and then develop a system that addresses that particular need. All of this must be kept in mind while accepting the fact that even the most sophisticated of systems will not detect all weapons, especially when the technology is improperly used or seldom employed.

If funds are diverted from expensive technologies such as intricate metal detection programs, complicated entry control devices or inefficient duress alarms systems, school districts should consider funneling resources into one or more of the following policies: recruiting parent volunteers; hiring more safety personnel, on-site counselors, and mental health service providers; enhancing the training offered to school safety officers, teachers, and administrators regarding troubled youth; expanding the cadre of youth-led violence reduction programs; implementing mentoring programs; providing after-school opportunities; offering meaningful alternative programming for suspended/ expelled youth; and reinstating many of the extra-curricular activities recently removed from school budgets.

Parents
A small amount of money could be used to design and implement a campaign to recruit parent volunteers. Parents could be used to assist in patrol activities in areas that are vulnerable to disorder and crime, but where it is nearly impossible to install technology that would be effective in thwarting these activities (e.g., bathrooms and parking lots).

Personnel & Training
At many points during the survey, school safety administrators complained that they simply did not have access to enough "human resources." Many claimed that they wished they could hire more safety staff, guards, or off-duty police officers, while other explained that the "real problem" was that there were not enough counselors available to kids and that there are so many kids that "no one knows." If there are weak attachments to school and little knowledge of how a child is progressing socially and emotionally, then it can be extremely difficult for school personnel to identify those that are struggling and intervene early. Obviously, throwing more staff at the problem will not fix it; staff must be properly trained. New staff (as well in-service employees) should receive updated training in child development, conflict resolution, mediation, and the identification and treatment of at-risk youth.

Programming
Extensive and varied programming is important to the development of a healthy school environment. Currently, hundreds of schools across the nation have implemented youth-led violence reduction programs focusing on peer-mediation and conflict resolution. While widespread, comprehensive evaluations are ongoing, preliminary results demonstrate promise. Students participating in these programs showed healthier attitudes toward conflict, improved communication and problem-solving skills, demonstrated enhanced abilities to avoid dropping out of school and participating in gangs (Crawford & Bodine, 1996). Additionally, some anti-bullying programs appeared to reduce bullying behaviors (Arnette & Wasleben, 1998).

The majority of youth crime occurs between the hours of 2:00pm-7:00pm. And while after-school programs may not directly reduce the portion of this crime that occurs on campus directly, they may have an indirect impact on the school environment by structuring the free time of what would be unsupervised youth, strengthening students' bonds to their schools, and creating a sense of "community" on campus. Related to after-school programs, are extra-curricular activities. The reality is not all students will excel in academics–their talents may lie in the music or athletic arenas. If the programs are cut, these students are at risk of becoming behavioral problems or dropping out and need a compelling reason to behave and stay in school. Extra-curricular activities, in some cases, provide such an avenue. Unfortunately, dwindling resources forced numerous districts to completely cut or scale back the extra-curricular activities they offer. In order to invest as many students as possible into the school culture, districts should rethink and reinvest in the activities they provide. Moreover, the cost of providing these activities may be far less than purchasing and maintaining less than effective, expensive technologies.

Finally, providing alternative programming for suspended and expelled students, which offer meaningful educational opportunities (e.g., skilled-based trades and computer training), is drastically needed. Many districts currently provide these programs, but many do not. A number of suspended or expelled students will refuse to attend these programs, yet it remains important to provide supervision and structure for youth that have already been removed from mainstream schools and offer skill development so that these individuals may earn gainful employment in the future.

Federal Level

As discussed above, much needs to be done by way of programming and technology at the district level to combat school crime and violence. While district response is vital, there is much that the federal government can do in terms of technology to aid in the control of school crime and violence. Specifically, the federal government should: (1) invest in the development of next generation technologies; (2) fund future studies focusing on usage and effectiveness of school safety technologies; and (3) direct major effort towards the dissemination of research findings in this area and develop a framework to enhance communication and information sharing between safety experts, administrators, and school boards.

Resources should continue to be earmarked for the further development of next generation technologies such as "smart" computer-based camera networks that are programmed to detect specific events (e.g., flashes of fire or gun reports), which trigger alarms that notify safety personnel of important events and communicate with recording systems to store images picked up immediately prior to the "identified" event, during the event, and for a specified period after the event. In segments two and three of the current grant, these efforts were initiated, however, far more resources are needed to develop and test more elaborate systems outside of the "laboratory."

The survey of school safety administrators discussed in this report is merely a first step. Information from 41 school districts is not sufficient to provide definitive statements about the nature, extent, and effectiveness of the safety technology used in American schools. The next logical step would be to complete a large-scale, follow-up survey of school safety administrators. Districts receiving federal educational dollars could be required to participate. Once completed, great lengths should be taken to widely disseminate the findings, not only in academic, educational, and trade journals, but in the popular media and through direct mailings to school districts. Finally, the federal government should expand its efforts to enhance communication between school districts with regard to school safety practices (e.g., increase the number of forums about school safety offered by the Department of Education and develop an annual conference on school safety technology sponsored by the Office of Juvenile Justice and Delinquency Prevention).

Concluding Remarks

Although the study's generalizability may be somewhat limited due to the sample size (41 school districts), some useful conclusions can be drawn from the findings because they represent the "security climate" in which several million children go to school. First, there appears to be a definite "disconnect" between the perceived effectiveness of certain technologies, such as entry control devices, and the number of districts either wishing or planning to acquire the technology in the future. Specifically, only one-third of the districts with entry control devices found them to be effective, yet 14 additional districts plan on acquiring entry control systems in the future. Complaints about these systems ranged from high cost to numerous false alarms. Because there has been little communication between school districts about the efficacy of these systems, districts all over the country may be investing highly constrained resources into technologies found to be too costly or cumbersome by others. Clearly, far more needs to be done to improve information sharing in this area.

Second, the current study provides a brief "snapshot" of technology use and sheds light on the pervasiveness of certain technologies (i.e., cameras and recording systems) and thus helps to inform the debate surrounding targeting hardening activities and the fortifying of American schools. Because a full 90% of the districts in sample utilize cameras and 87% recording systems, and two-thirds of the respondents believed these technologies are effective, perhaps public policy should focus on: (1) funding the further development of technologies considered by practitioners to be most effective (e.g., computer-based camera networks and digital storage) and (2) acknowledging what can realistically be expected of these forms of technology. Next generation camera systems will never be able to prevent all violent events, nor can any other technology discussed in this report. However, smarter, more efficient camera/recording systems will not only continue to serve as a visual deterrent and assist in the investigation of crimes once committed, but more importantly aid in the *earlier detection* of serious events–allowing for *more appropriate and timely responses*!

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APPENDIX A: Additional Tables

Table 20: Number of Elementary Schools in Each District

# of Elementary Schools	# of Districts	% of Total
0	1	3
1-50	14	39
51-100	12	33
101-150	7	20
151-200	1	3
201 and above	1	3

*due to rounding, percentage total may not = 100.

Table 21: Number of Middle Schools in Each District

# of Middle Schools	# of Districts	% of Total
0	1	3
1-10	9	25
11-20	10	28
21-30	11	31
31-40	3	8
41-50	0	0
51 and above	2	6

*due to rounding, percentage total may not = 100.

Table 22: Number of High Schools in Each District

# of High Schools	# of Districts	% of Total
0	0	0
1-10	15	41
11-20	14	38
21-30	5	14
31-40	3	8

*due to rounding, percentage total may not = 100.

Table 23: Perceptions of Safety

Responses	% School Districts Responding		
	Strongly Disagree or Disagree	Neutral	Agree or Strongly Agree
Faculty/Staff Feel Safe at Our Schools	7	27	66
Students Feel Safe at Our Schools	12	34	54

Table 24: Perceived Vulnerability of Location to Disorder Behavior and Crime (mean score across school districts)

Location	Disorder Behaviors	Drug Crimes	Property Crimes	Violent Crimes
Auditorium (n=39)	1.82	1.58	1.62	1.54
Auxiliary Rooms (n=37)	2.41	2.38	2.19	2.32
Band Hall (n=39)	1.56	1.46	1.79	1.49
Bathrooms (n=41)	3.32	3.61	3.07	3.22
Boiler Room (n=33)	1.18	1.30	1.26	1.15
Bus Zones (n=39)	2.69	2.15	1.97	2.38
Cafeteria (n=41)	3.05	2.24	2.29	2.63
Classrooms (n=41)	2.51	1.66	2.23	2.24
Computer Room (n=39)	1.59	1.41	2.15	1.46
Driveways (n=38)	1.97	1.87	1.79	1.82
Elevators (n=19)	1.05	1.11	1.00	1.11
Equipment Shed (n=37)	1.78	1.95	2.61	1.68
Fire Alarm Pull Station (n=39)	2.20	1.44	1.54	1.49
Foyer (n=35)	2.51	2.03	2.06	2.29
Gymnasium (n=41)	2.44	2.02	2.15	2.39
Hallways (n=41)	3.05	2.80	2.68	2.90
Key Pad Viewer (n=12)	1.42	1.42	1.42	1.27
Library (n=41)	1.49	1.37	1.66	1.39
Locker Room (n=41)	2.56	2.27	2.83	2.46
Lounge (n=39)	1.03	1.03	1.23	1.08
On Bus (n=40)	3.23	2.53	2.35	2.70
Parking Lots (n=41)	2.90	3.20	3.15	3.00
Pay Phones (n=37)	1.62	1.65	1.41	1.47
Playgrounds (n=40)	2.10	2.08	1.80	2.13
Primary Entrance (n=39)	2.46	1.83	2.03	2.17
School Store (n=32)	1.34	1.25	1.59	1.34
Science Lab (n=39)	1.56	1.36	1.44	1.59
Sports Fields (n=41)	2.39	2.34	2.12	2.44
Stairs (n=38)	2.84	2.55	2.27	2.72
Student Activity Center (n=29)	1.83	1.66	1.66	1.62

APPENDIX B: SURVEY INSTRUMENT

APPENDIX C: CODEBOOK

1. (id#) Interview ID number

____

2. (intertype) Interview type

1=federal 2=Indiana

3. (distname) School District Name

____

4. (state) Interview State

1=CA
2=CO
3=FL
4=GA
5=HI
6=IN
7=MA
8=MD
9=NM
10=NV
11=NY
12=TN
13=TX
14=WA
15=DC

I. Changes

5. (concern) In the following section you are asked to rate various issues facing School Safety Administrators. Using a scale of 1 to 5 (with 1 being "minor" and 5 being "major"), how much concern is there over the issues of school violence in your district?

1=minor
2=somewhat minor
3=average
4=somewhat major
5=major
9=missing

6. (changes) How extensive have changes to your school security plans been in the last 2 years?

1=minor
2=somewhat minor
3=average
4=somewhat major
5=major
9=missing

7. (impact) How much of an impact have stories of school shootings throughout the country had on school safety reforms in your district?

1=minor
2=somewhat minor
3=average
4=somewhat major
5=major
9=missing

On a scale of 1 to 5 (with 1 being "minor" and 5 being "major"), please indicate the level of support (e.g., attend meetings, serve on committees, voice their opinions, etc.,) you perceive the following groups give to the implementation and use of school safety/surveillance technology such as video cameras, video recorders, and metal detectors.

8. (admin) School Administrators?

1=minor
2=somewhat minor
3=average
4=somewhat major
5=major
9=missing

9. (teachers) Teachers?

1=minor
2=somewhat minor
3=average
4=somewhat major
5=major
9=missing

10. (students) Students?

1=minor
2=somewhat minor
3=average
4=somewhat major
5=major
9=missing

11. (parents) Parents?

1=minor
2=somewhat minor
3=average
4=somewhat major
5=major
9=missing

12. (polsafe) School Police/School Safety Officials?

1=minor
2=somewhat minor
3=average
4=somewhat major
5=major
9=missing

13. (lawenf) Community Law Enforcement?

1=minor
2=somewhat minor
3=average
4=somewhat major
5=major
9=missing

14. (comlead) Community Leaders?

1=minor
2=somewhat minor
3=average
4=somewhat major
5=major
9=missing

15. (govoff) Government Officials?

1=minor
2=somewhat minor
3=average
4=somewhat major
5=major
9=missing

16. (moneyspent) In your estimation, approximately how much money has your district spent on acquiring or replacing school safety/surveillance technology (e.g., metal detectors, cameras, video recorders, etc) in the last two years?

$______________________________________
9=missing

17. (fundsource) What funding sources did your district rely upon to acquire the new equipment?

1=local foundation
2=state grants-from Indiana Criminal Justice Institute
3=state grants-other
4=federal grants
5=other specify ___________
9=missing

II. Perceptions of Safety

On a scale of 1 to 5 (with 1 being "strongly disagree" and 5 being "strongly agree"), please indicate how much you agree with the following statements.

18. (facperc) Faculty and Staff feel safe at schools in our district.

1=strongly disagree
2=disagree
3=neutral
4=agree
5=strongly agree
9=missing

19. (stuperc) Students feel safe at schools in our district.

1=strongly disagree
2=disagree
3=neutral
4=agree
5=strongly agree
9=missing

20. (stutostu) In the last two years, we have experienced an increase in the number of student on student assaults in our district.

1=strongly disagree
2=disagree
3=neutral
4=agree
5=strongly agree
9=missing

21. (stutoteach) In the last two years, we have experienced an increase in the number of student on teacher assaults.

1=strongly disagree
2=disagree
3=neutral
4=agree
5=strongly agree
9=missing

22. (threats) In the last two years, we have experienced an increase in threats of violence on school grounds.

1=strongly disagree
2=disagree
3=neutral
4=agree
5=strongly agree
9=missing

23. (genincr) In the last two years, we have experienced a general increase in crime on school grounds.

1=strongly disagree
2=disagree
3=neutral
4=agree

5=strongly agree
9=missing

Please rate the degree of risk using a scale of 1 to 5 (with 1 being "very low risk" and 5 being "very high risk") of disorder/nuisance behaviors, drug, property, and violent crimes occurring in each of the locations listed below. For example, if in your opinion the cafeteria is at very high-risk for violent crimes, you would rate that area as a "5."

24. (sheddis) Materials/equipment shed for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

25. (sheddrug) Materials/equipment shed for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

26. (shedprop) Materials/equipment shed for Property Crimes (theft, vandalism)

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

27. (shedviol) Materials/equipment shed for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

28. (boilerdis) Boiler Room for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk

5=very high risk
8=not applicable
9=missing

29. (boilerdrug) Boiler Room for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

30. (boilerprop) Boiler Room for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

31. (boilerviol) Boiler Room for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

32. (primdis) Primary Entrances for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

33. (primdrug) Primary Entrances for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

34. (primprop) Primary Entrances for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

35. (primviol) Primary Entrances for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

36. (keydis) Key Pad Viewers for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

37. (keydrug) Key Pad Viewers for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

38. (keyprop) Key Pad Viewers for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

39. (keyviol) Key Pad Viewers for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk

5=very high risk
8=not applicable
9=missing

40. (foyerdis) Foyers for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

41. (foyerdrug) Foyers for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

42. (foyerprop) Foyers for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

43 (foyerviol) Foyers for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

44. (cafdis) Cafeterias for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

45. (cafdrug) Cafeterias for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

46. (cafprop) Cafeterias for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

47. (cafviol) Cafeterias for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

48. (libdis) Libraries for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

49. (libdrug) Libraries for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

50. (libprop) Libraries for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk

5=very high risk
8=not applicable
9=missing

51. (libviol) Libraries for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

52. (gymdis) Gymnasiums for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

53. (gymdrug) Gymnasiums for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

54. (gymprop) Gymnasiums for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

55. (gymviol) Gymnasiums for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

56. (halldis) Hallways for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

57. (halldrug) Hallways for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

58. (hallprop) Hallways for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

59. (hallviol) Hallways for Violent Crimes (fights, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

60. (onbusdis) On-board School Buses for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

61. (onbusdrug) On-board School Buses for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium

4=high risk
5=very high risk
8=not applicable
9=missing

62. (onbusprop) On-board School Buses for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

63. (onbusviol) On-board School Buses for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

64. (paydis) Pay phones for Disorder/ Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

65. (paydrug) Pay phones for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

66. (payprop) Pay phones for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

67. (payviol) Pay phones for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

68. (elevdis) Elevators for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

69. (elevdrug) Elevators for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

70. (elevprop) Elevators for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

71. (elevviol) Elevators for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

72. (stairdis) Stairwells for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium

4=high risk
5=very high risk
8=not applicable
9=missing

73. (stairdrug) Stairwells for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

74. (stairprop) Stairwells for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

75. (stairviol) Stairwells for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

76. (firedis) Fire Alarm Pull Stations for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

77. (firedrug) Fire Alarm Pull Stations for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

78. (fireprop) Fire Alarm Pull Stations for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

79. (fireviol) Fire Alarm Pull Stations for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

80. (auxdis) Auxiliary Entrances for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

81. (auxdrug) Auxiliary Entrances for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

82. (auxprop) Auxiliary Entrances for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

83. (auxviol) Auxiliary Entrances for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk

3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

84. (bathdis) Bathrooms for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

85. (bathdrug) Bathrooms for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

86. (bathprop) Bathrooms for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

87. (bathviol) Bathrooms for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

88. (lockerdis) Locker Rooms for Disorder/Nuisance Behavior (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

89. (lockerdrug) Locker Rooms for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

90. (lockerprop) Locker Rooms for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

91. (lockerviol) Locker Rooms for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

92. (parkdis) Parking Lots for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

93. (parkdrug) Parking Lots for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

94. (parkprop) Parking Lots for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk

3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

95. (parkviol) Parking Lots for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

96. (fieldsdis) Sports Fields/Stadium for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

97. (fieldsdrug) Sports Fields/Stadium for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

98. (fieldsprop) Sports Fields/Stadium for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

99. (fieldsviol) Sports Fields/Stadium for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

100. (playdis) Playgrounds for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

101. (playdrug) Playgrounds for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

102. (playprop) Playgrounds for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

103. (playviol) Playgrounds for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

104. (loungedis) Teacher's Lounge for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

105. (loungedrug) Teacher's Lounge for Drug Crimes (use, sales)?

1=very low risk
2=low risk

3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

106. (loungeprop) Teacher's Lounge for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

107. (loungeviol) Teacher's Lounge for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

108. (classdis) Classrooms for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

109. (classdrug) Classrooms for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

110. (classprop) Classrooms for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

111. (classviol) Classrooms for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

112. (auditdis) Auditoriums for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

113. (auditdrug) Auditoriums for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

114. (auditprop) Auditoriums for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

115. (auditviol) Auditoriums for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

116. (buszondis) Bus Loading Zones for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk

3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

117. (buszondrug) Bus Loading Zones for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

118. (buszonprop) Bus Loading Zones for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

119. (buszonviol) Bus Loading Zones for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

120. (drivedis) School Driveways for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

121. (drivedrug) School Driveways for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

122. (driveprop) School Driveways for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

123. (driveviol) School Driveways for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

124. (sciencdis) Science Laboratories for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

125. (sciencdrug) Science Laboratories for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

126. (sciencprop) Science Laboratories for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

127. (sciencviol) Science Laboratories for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk

3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

128. (compdis) Computer Rooms for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

129. (compdrug) Computer Rooms for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

130. (compprop) Computer Rooms for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

131. (compviol) Computer Rooms for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

132. (storedis) School Store for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

133. (storedrug) School Store for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

134. (storeprop) School Store for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

135. (storeviol) School Store for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

136. (banddis) Band Hall for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

137. (banddrug) Band Hall for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

138. (bandprop) Band Hall for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk

3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

139. (bandviol) Band Hall for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

140. (actcendis) Student Activity Center for Disorder/Nuisance Behaviors (bullying, harassment, drinking)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

141. (actcendrug) Student Activity Center for Drug Crimes (use, sales)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

142. (actcenprop) Student Activity Center for Property Crimes (theft, vandalism)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable
9=missing

143. (actcenviol) Student Activity Center for Violent Crimes (fights, assaults)?

1=very low risk
2=low risk
3=medium
4=high risk
5=very high risk
8=not applicable

9=missing

Relative to other school districts in your area, how would you rate the following problems? (Circle one answer per question)

144. (rateprobdis)Disorder/Nuisance Behavior?

Much Better.....5
Better.....4
Same.....3
Worse.....2
Much Worse.....1
Missing.....9

145. (rateprobdrug) Drug Crimes?

Much Better.....5
Better.....4
Same.....3
Worse.....2
Much Worse.....1
Missing.....9

146. (rateprobprop) Property Crimes?

Much Better.....5
Better.....4
Same.....3
Worse.....2
Much Worse.....1
Missing.....9

147. (rateprobviol) Violent Crimes?

Much Better.....5
Better.....4
Same.....3
Worse.....2
Much Worse.....1
Missing.....9

III. Technologies Employed

Included in the next section are several questions about specific types of technologies. You will be asked whether or not your district employs these technologies and how widespread their use is.

If your district does have a specific technology, please estimate the number of schools in your district who use it according to educational levels (i.e., elementary, middle, and high school).

148. (video) Video Cameras?

1=Yes, 2=No

9=missing

149. (videoes) # ES with Video Cameras

_____
99=missing
88=not applicable

150. (videoms) # MS with Video Cameras

_____
99=missing
88=not applicable

151. (videohs) # HS with Video Cameras

_____
99=missing
88=not applicable

152. (realtime) Monitor fed to viewer in realtime? (=whether a person is watching the monitor as events occur)

1=Yes, 2=No
9=missing

153. (reales) # ES with realtime

_____
99=missing
88=not applicable

154. (realms) # MS with realtime

_____
99=missing
88=not applicable

155. (realhs) # HS with realtime

_____
99=missing
88=not applicable

156. (camnet) Computer-based Camera Networks?

1=Yes, 2=No
9=missing

157. (netes) # ES with Computer-based Camera Networks

_____
99=missing
88=not applicable

158. (netms) # MS with Computer-based Camera Networks

____
99=missing
88=not applicable

159. (neths) # HS with Computer-based Camera Networks

____
99=missing
88=not applicable

160. (change) And when connected to a computer, is the image recorded only when a change occurs?

1=Yes, 2=No
9=missing

161. (circuit) Closed circuit TV system?

1=Yes, 2=No
9=missing

162. (circuites) # ES with Closed circuit TV system

____
99=missing
88=not applicable

163. (circuitms) # MS with Closed circuit TV system

____
99=missing
88=not applicable

164. (circuiths) # HS with Closed circuit TV system

____
99=missing
88=not applicable

165. (color) Color images?

1=Yes, 2=No
9=missing

166. (colores) # ES with Color images

____
99=missing
88=not applicable

167. (colorms) # MS with Color images

____
99=missing

88=not applicable

168. (colorhs) # HS with Color images

_____
99=missing
88=not applicable

169. (pantilt) Pan-tilt Zoom?

1=Yes, 2=No
9=missing

170. (pantiltes) # ES with Pan-tilt Zoom

_____
99=missing
88=not applicable

171. (pantiltms) # MS with Pan-tilt Zoom

_____
99=missing
88=not applicable

172. (pantilths) # HS with Pan-tilt Zoom

_____
99=missing
88=not applicable

173. (wireless) Wireless?

1=Yes, 2=No
9=missing

174. (wirelesses) # ES with Wireless

_____
99=missing
88=not applicable

175. (wirelessms) # MS with Wireless

_____
99=missing
88=not applicable

176. (wirelesshs) # HS with Wireless

_____
99=missing
88=not applicable

177. (hidden) Hidden Cameras?

1=Yes, 2=No
9=missing

178. (hiddenes) # ES with Hidden Cameras

______
99=missing
88=not applicable

179. (hiddenms) # MS with Hidden Cameras

______
99=missing
88=not applicable

180. (hiddenhs) # HS with Hidden Cameras

______
99=missing
88=not applicable

181. (interior) Interior Cameras?

1=Yes, 2=No
9=missing

182. (interiores) # ES with Interior Cameras

______
99=missing
88=not applicable

183. (interiorms) # MS with Interior Cameras

______
99=missing
88=not applicable

184. (interiorhs) # HS with Interior Cameras

______
99=missing
88=not applicable

185. (exterior) Exterior Cameras?

1=Yes, 2=No
9=missing

186. (exteriores) # ES with Exterior Cameras

______
99=missing
88=not applicable

187. (exteriorms) # MS with Exterior Cameras

______
99=missing
88=not applicable

188. (exteriorhs) # HS with Exterior Cameras

______
99=missing
88=not applicable

189. (fake) Fake Cameras?

1=Yes, 2=No
9=missing

190. (fakees) # ES with Fake Cameras

______
99=missing
88=not applicable

191. (fakems) # MS with Fake Cameras

______
99=missing
88=not applicable

192. (fakehs) # HS with Fake Cameras

______
99=missing
88=not applicable

193. (bullet) Bullet Resistant Cameras?

1=Yes, 2=No
9=missing

194. (bulletes) # ES with Bullet Resistant Cameras

______
99=missing
88=not applicable

195. (bulletms) # MS with Bullet Resistant Cameras

______
99=missing
88=not applicable

196. (bulleths) # HS with Bullet Resistant Cameras

____
99=missing
88=not applicable

197. (focal) What is the focal length most commonly used in your cameras? (If respondent does not know answer "unk").

________________________________MM
9=missing 8=unknown

198. (vidloc) In the schools that have video cameras, where are the cameras most commonly located?

1=entrances/exits
2=walkways/stairways/hallways
3=administration offices
4=high traffic areas
5=low traffic areas
6=common areas
7=storage/equipment rooms
8=other
88=not applicable
9=missing

199. (vidpositive) What are the positive aspects of this technology?

1=deterrence/prevention
2=documentation of events
3=increased supervision/decreased staffing needs
4=good public relations
5=access control
6=sense of safety
7=other
8=not applicable
9=missing

200. (vidnegative) What are the negative aspects of this technology?

1=intrusiveness/civil liberty issues
2=not cost effective/expensive
3=reliability issues
4=can foster a false sense of security
5=limitations of current technology
6=can actually increase amount of personnel needed
7=other
8=not applicable
9=missing

201. (videodis) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective", estimate how effective video cameras are at preventing or minimizing **disorder/nuisance behaviors** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective

5=very effective
8=not applicable
9=missing

202. (videodrug)

Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective", estimate how effective video cameras are at preventing or minimizing **drug crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

203. (videoprop)

Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective", estimate how effective video cameras are at preventing or minimizing **property crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

204. (videoviol)

Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective", estimate how effective video cameras are at preventing or minimizing **violent crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

205. (record)

Video Recording?

1=Yes, 2=No
9=missing

206. (recordes)

ES with Video Recording

____
99=missing
88=not applicable

207. (recordms)

MS with Video Recording

____
99=missing
88=not applicable

208. (recordhs) # HS with Video Recording

____
99=missing
88=not applicable

209. (vcr) VCR's?

1=Yes, 2=No
9=missing

210. (vcres) # ES with VCR's

____
99=missing
88=not applicable

211. (vcrms) # MS with VCR's

____
99=missing
88=not applicable

212. (vcrhs) # HS with VCR's

____
99=missing
88=not applicable

213. (multiplex) Multiplexers?

1=Yes, 2=No
9=missing

214. (multies) # ES with Multiplexers

____
99=missing
88=not applicable

215. (multims) # MS with Multiplexers

____
99=missing
88=not applicable

216. (multihs) # HS with Multiplexers

____
99=missing
88=not applicable

217. (timelapse)	Time-lapse recorders? 1=Yes, 2=No 9=missing
218. (timees)	# ES with Time-lapse recorders ________ 99=missing 88=not applicable
219. (timems)	# MS with Time-lapse recorders ________ 99=missing 88=not applicable
220. (timehs)	# HS with Time-lapse recorders ________ 99=missing 88=not applicable
221. (event)	Event recording only? 1=Yes, 2=No 9=missing
222. (eventes)	# ES with Event recording only ________ 99=missing 88=not applicable
223. (eventms)	# MS with Event recording only ________ 99=missing 88=not applicable
224. (evenths)	# HS with Event recording only ________ 99=missing 88=not applicable
225. (digital)	Digital recorders? 1=Yes, 2=No 9=missing
226. (digitales)	# ES with Digital recorders ________ 99=missing 88=not applicable

227. (digitalms) # MS with Digital recorders

____
99=missing
88=not applicable

228. (digitalhs) # HS with Digital recorders

____
99=missing
88=not applicable

229. (contmon) Continuous Monitoring?

1=Yes, 2=No
9=missing

230. (contmones) # ES with Continuous Monitoring

____
99=missing
88=not applicable

231. (contmonms) # MS with Continuous Monitoring

____
99=missing
88=not applicable

232. (contmonhs) # HS with Continuous Monitoring

____
99=missing
88=not applicable

233. (recordloc) In the schools that have video recorders, where are the recorders most commonly located?

1=administration offices
2=video surveillance room
3=security offices
4=storage and equipment room
5=common student areas (e.g. cafeteria, lobby)
6=other
8=not applicable
9=missing

234. (recpositive) What are the positive aspects of this technology?

1=documentation of events
2=cost effective
3=deterrence/prevention
4=liability protection
5=sense of security

6=other
8=not applicable
9=missing

235. (recnegative) What are the negative aspects of this technology?

1=intrusive/civil liberties
2=not cost effective/expensive
3=false sense of security
4=reliability problems (e.g. poor id, inability to capture event)
5=unexpected negative outcomes
6=displacement of problem behaviors
7=maintaining data library
8=technology does not meet expectations
9=other
88=not applicable
99=missing

236. (recorddis) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective", estimate how effective video recorders are at preventing or minimizing **disorder/nuisance behaviors** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

237. (recorddrug) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective", estimate how effective video recorders are at preventing or minimizing **drug crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

238. (recordprop) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective", estimate how effective video recorders are at preventing or minimizing **property crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

239. (recordviol) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective", estimate how effective video recorders are at preventing or minimizing **violent crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

240. (weapon) Weapons Detection?

1=Yes, 2=No
9=missing

241. (weapones) # ES with Weapons Detection

______
99=missing
88=not applicable

242. (weaponms) # MS with Weapons Detection

______
99=missing
88=not applicable

243. (weaponhs) # HS with Weapons Detection

______
99=missing
88=not applicable

244. (wands) Metal Detector Wands?

1=Yes, 2=No
9=missing

245. (wandses) # ES with Metal Detector Wands

______
99=missing
88=not applicable

246. (wandsms) # MS with Metal Detector Wands

______
99=missing
88=not applicable

247. (wandshs) # HS with Metal Detector Wands

______

99=missing
88=not applicable

248. (walk) Walk through Metal Detectors?

1=Yes, 2=No
9=missing

249. (walkes) # ES with Walk through Metal Detectors

____
99=missing
88=not applicable

250. (walkms) # MS with Walk through Metal Detectors

____
99=missing
88=not applicable

251. (walkhs) # HS with Walk through Metal Detectors

____
99=missing
88=not applicable

252. (xray) X-ray Baggage Scanners?

1=Yes, 2=No
9=missing

253. (xrayes) # ES with X-ray Baggage Scanners

____
99=missing
88=not applicable

254. (xrayms) # MS with X-ray Baggage Scanners

____
99=missing
88=not applicable

255. (xrayhs) # HS with X-ray Baggage Scanner

____
99=missing
88=not applicable

256. (weaploc) In the schools that have weapon detection technology, where are the detectors most commonly located?

1=entrances/exits
2=administration
3=with security personnel

4=other
8=not applicable
9=missing

257. (weappositive) What are the positive aspects of this technology?

1=deterrence/prevention
2=sense of safety
3=detects weapons
4=non-intrusive
5=technology easily employed
6=other
8=not applicable
9=missing

258. (weapnegative) What are the negative aspects of this technology?

1=invasion of privacy/civil liberty issues
2=not cost effective
3=false sense of security
4=time consuming and labor intensive
5=system can be circumvented
6=doesn't pick up everything
7=other
8=not applicable
9=missing

259. (metaldis) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective"), estimate how effective metal detectors are at preventing or minimizing **disorder/nuisance behaviors** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

260. (metaldrug) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective"), estimate how effective metal detectors are at preventing or minimizing **drug crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

261. (metalprop) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective"), estimate how effective metal detectors are at preventing or minimizing **property crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

262. (metalviol) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective"), estimate how effective metal detectors are at preventing orminimizing **violent crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

263. (entrycontrol) Entry-Control Devices?

1=Yes, 2=No
9=missing

264. (entryes) # ES with Entry-Control Devices

____
99=missing
88=not applicable

265. (entryms) # MS with Entry-Control Devices

____
99=missing
88=not applicable

266. (entryhs) # HS with Entry-Control Devices

____
99=missing
88=not applicable

267. (turnstile) Turnstile entries?

1=Yes, 2=No
9=missing

268. (turnes) # ES with Turnstile entries

____
99=missing
88=not applicable

269. (turnms)	# MS with Turnstile entries ________ 99=missing 88=not applicable
270. (turnhs)	# HS with Turnstile entries ________ 99=missing 88=not applicable
271. (scanner)	Scanner cards? 1=Yes, 2=No 9=missing
272. (scanneres)	# ES with Scanner cards ________ 99=missing 88=not applicable
273. (scannerms)	# MS with Scanner cards ________ 99=missing 88=not applicable
274. (scannerhs)	# HS with Scanner cards ________ 99=missing 88=not applicable
275. (psswdpin)	Password/PIN entries? 1=Yes, 2=No 9=missing
276. (psswdes)	# ES with Password/PIN entry ________ 99=missing 88=not applicable
277. (psswdms)	# MS with Password/PIN entry ________ 99=missing 88=not applicable
278. (psswdhs)	# HS with Password/PIN entry ________

99=missing
88=not applicable

279. (biometric) Biometric Identifiers?

1=Yes, 2=No
9=missing

280. (biometes) # ES with Biometric Identifiers

____
99=missing
88=not applicable

281. (biometms) # MS with Biometric Identifiers

____
99=missing
88=not applicable

282. (biometrhs) # HS with Biometric Identifiers

____
99=missing
88=not applicable

283. (entryloc) In the schools that have entry-control devices, where are they most commonly located?

1=entrances
2=exterior doors
3=secluded areas
4=other
8=not applicable
9=missing

284. (entrypositive) What are the positive aspects of this technology?

1=access cards can restrict access and take attendance
2=limits access to buildings
3=increases staff and building safety
4=minimizes theft
5=other
8=not applicable
9=missing

285. (entrynegative) What are the negative aspects of this technology?

1=costly
2=restricts public entry
3=time consuming and can be complicated
4=false alarms
5=other
8=not applicable
9=missing

286. (entrydis) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective"), estimate how effective entry control devices are at preventing or minimizing **disorder/nuisance behaviors** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

287. (entrydrug) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective"), estimate how effective entry control devices are at preventing or minimizing **drug crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

288. (entryprop) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective"), estimate how effective entry control devices are at preventing or minimizing **property crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

289. (entryviol) Using a scale of 1 to 5 (with 1 being "not effective" and 5 being "very effective"), estimate how effective entry control devices are at preventing or minimizing **violent crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

290. (duress) Duress Alarms?

1=Yes, 2=No
9=missing

291. (duresses) # ES with Duress Alarms

____
99=missing
88=not applicable

292. (duressms) # MS with Duress Alarms

____
99=missing
88=not applicable

293. (duresshs) # HS with Duress Alarms

____
99=missing
88=not applicable

294. (strategic) Strategically placed panic alarms?

1=Yes, 2=No
9=missing

295. (strates) # ES with Strategically placed panic alarms

____
99=missing
88=not applicable

296. (stratms) # MS with Strategically placed panic alarms

____
99=missing
88=not applicable

297. (straths) # HS with Strategically placed panic alarms

____
99=missing
88=not applicable

298. (worn) Panic alarms worn by personnel?

1=Yes, 2=No
9=missing

299. (wornes) # ES with Panic alarms worn by personnel

____
99=missing
88=not applicable

300. (wornms) # MS with Panic alarms worn by personnel

____
99=missing
88=not applicable

301. (wornhs) # HS with Panic alarms worn by personnel

____
99=missing
88=not applicable

302. (duressloc) In the schools that utilize duress alarms, where are they most commonly located?

1=classrooms
2=common areas with high traffic
3=offices
4=alarm panels/keypads
5=portable building
6=worn by personnel
7=other
8=not applicable
9=missing

303. (duresspositive) What are the positive aspects of this technology?

1=sense of security
2=quick response
3=deterrence
4=safety for teachers
5=other
8=not applicable
9=missing

304. (duressnegative) What are the negative aspects of this technology?

1=slow response time
2=false alarms
3=false sense of security
4=risk of system breakdown
5=other
8=not applicable
9=missing

305. (duressdis) Using a scale of 1 to 5 (with 1 being "not effective" an 5 being "very effective"), estimate how effective duress alarms are at preventing or minimizing **disorder/nuisance behaviors** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

306. (duressdrug) Using a scale of 1 to 5 (with 1 being "not effective" an 5 being "very effective"), estimate how effective duress alarms are at preventing or minimizing **drug crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

307. (duressprop) Using a scale of 1 to 5 (with 1 being "not effective" an 5 being "very effective"), estimate how effective duress alarms are at preventing or minimizing **property crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

308. (duressviol) Using a scale of 1 to 5 (with 1 being "not effective" an 5 being "very effective"), estimate how effective duress alarms are at preventing or minimizing **violent crimes** in your district?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

IV. Effectiveness

On a scale of 1 to 5 (with 1 being not effective and 5 being very effective), please rate how effective you believe the technologies used by your district are at preventing and controlling crime on campus.
(List the technology categories mentioned above (i.e., video cameras, video recorders, metal detectors, entry-control devices, and personal duress alarms).

309. (cameras) Video Cameras?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

310. (vidrec) Video Recorders?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

311. (detectors) Metal detection systems?
1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

312. (entry) Entry-control devices?
1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

313. (personduress) Personal duress alarms?

1=not effective
2=somewhat effective
3=neutral
4=effective
5=very effective
8=not applicable
9=missing

IV. Future Acquisition

314. (plans) What technologies, if any, are you planning on acquiring in the next 2 years?
1=video cameras or upgrade of them
2=video recorders or upgrade of them
3=metal detection systems or upgrade of them
4=entry-control devices or upgrade of them
5=personal duress alarms or upgrade of them
6=portable radio systems
7=more security staff
8=id badge systems
9=phones/radios in classrooms
10=GPS and GIS
11=smart doors
12=alternative locking systems
13=other
88=not applicable
99=missing

315. (wish) Beyond these plans for the acquisitions mentioned above, are there any forms of technology you wished your district had available to them?
1=video cameras or upgrade of them
2=video recorders or upgrade of them
3=metal detection systems or upgrade of them
4=entry-control devices or upgrade of them
5=personal duress alarms or upgrade of them
6=telephones in classrooms
7=coordinated radio system
8=GPS
9=increased training
10=increased staff
11=other
88=not applicable
99=missing

316. (studpop) Please estimate the size of the student population in your school district?

____
99=missing

317. (#schools) How many individual schools are in your district?

____
99=missing

How do they break down in terms of education level?

318. (#elem) # of elementary schools?

____
99=missing

319. (#middle) # of middle schools?

____
99=missing

320. (#high) # of high schools?

____
99=missing

Please estimate the percentage of your district's student population that is:
(Note: be sure the total = 100%)

321. (percwhite) White?

______%
99=missing

322. (percnon) Non-white?

_______%
99=missing

323. (rusuburb) Is your school district mostly rural, suburban, or urban? (circle one).

1=rural
2=suburban
3=urban
4=rural, suburban, and urban
5=rural and suburban
6=rural and urban
7=suburban and urban
9=missing

324. (lunchprog) What percentage of the student population in your district is enrolled in the *National School Lunch & School Breakfast Program*? (Note: aka *Child Nutrition Program*)

_______%
99=missing

325. (finsit) On a scale of 1 to 5, (with 1 being very poor and 5 being excellent), please describe the financial situation in your school district.
1=very poor
2=poor
3=fair
4=good
5=excellent
9=missing

326. (futspend) On a scale of 1 to 5, (with 1 being very poor and 5 being excellent), please describe future prospects for increased spending in your school district for school safety.
1=very poor
2=poor
3=fair
4=good
5=excellent
9=missing

327. (issues) Are there any issues you believe we should have included that were not? If so, what were they?
1=crime prevention education
2=training of both school security staff and educators
3=more emphasis on security personnel
4=crisis intervention
5=alternative schools
6=impact of external influences on school
7=handheld radios
8=other
88=not applicable
9=missing

328. (time) Time it took to complete the interview.

_____min.
999=missing

Surveillance Tools for Safer Schools

Award No. 1999-LT-VX-K011

Appendix B

Camera Testing for School Safety

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Submitted
January 30, 2002

Camera Testing for School Safety

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June 7, 2001

1 Introduction

This report presents the results of testing performed on several commercially available video cameras that are typical of those used in surveillance applications. The tests described in this report were performed by personnel from NAVSEA Crane as part of a larger testing effort being conducted by the Institute for Forensic Imaging (IFI), located on the campus of Indiana University Purdue University Indianapolis (IUPUI). Funding was provided by a grant from the National Institute of Justice (NIJ). Laboratory assistance was provided by Jeff Withem of NAVSEA Crane and procedural guidance was provided by Suzali Suyut of IFI.

Tests were conducted on seven cameras in the IFI laboratory. A resolution test was performed to determine the number of separate linepairs per unit length that each camera can resolve. A dynamic range test was performed to determine the ratio of the highest to lowest light levels that each camera can sense. A color fidelity test was performed to determine how closely the color values reported by the camera match the color of the light incident on the camera lens. The images were then processed using a method of tone correction that forces the proportional change in image gray values to match the proportional change in target density values. The color fidelity test was then repeated to determine the effects of tone correction on color reproduction.

Each camera was connected to a digital recording system to capture video frames for analysis. In this setup, the combined effects of the camera and recorder were tested rather than just the camera, but this situation closely resembles that of a real-world security application.

2 Testing Model

The tests described here use a total system approach. This means that the entire system is being tested rather than just the camera. The system is made up of a camera and a digital recorder. This approach was chosen because it closely represents a video surveillance scenario using modern, digital equipment. Isolating the camera and analyzing its output would give a better understanding of its effects alone, but would have required expensive test equipment to either analyze the analog camera ouput or digitize it and store it in an uncompressed format.

Adding the digital recorder to the system affects the captured video in several ways. First, the video is digitized and compressed. Some of the color information is lost during digitization through a process known as chroma subsampling. This process involves taking the average color value of either two or four adjacent pixels and storing this average value instead of the value for each individual pixel. This process degrades the color signal, but reduces the storage requirements. The brightness component for each pixel is retained.

After digitization, the resulting video frames are compressed using a lossy compression algorithm. This means that when a compressed frame is uncompressed for display, it doesn't exactly match the original frame, but minimizes the difference perceived by the human vision system.

Once the video has been compressed, it is stored by the digital video recorder. To analyze the video, it must be exported to a format that is more widely supported by desktop video applications. This final step involves compression that further changes each frame from the original frame output by the camera.

In a real world surveillance scenario, a similar system would likely be used to capture video from a camera. If a portion of the video is needed for evidence in a criminal trial, video would need to be exported from the system for submission and would undergo the degradation described above. So the setup used for this test provides a better prediction of the performance expected in actual operation than would a test that isolates the camera.

3 Test Setup

3.1 Equipment

3.1.1 Cameras and Lens

A total of seven cameras were used for this test. All seven underwent the resolution test and dynamic range test, while only the three color cameras were used for the color fidelity test. Table 1 shows the specific camera models tested. The same lens was used for each camera: a Cosmicar/Pentax TV lens with a focal length of 37mm and a 1:1.6 aperture.

Table 1: *Cameras tested for this report.*

ID	Manufacturer	Model	Type
1	Philips	LTC 0450/21 A	Color
2	Philips	LTC 0350/21 A	B&W
3	Philips	LTC 0330/21	B&W
4	Philips	LTC 0430/61 A	Color
5	Philips	LTC 0350/21 A	B&W
6	Philips	LTC 0500/20	B&W
7	Panasonic	WV-CP460	Color

3.1.2 Video Recorder

For recording the video, each camera was connected separately to a model DVX-16 digital recording system manufactured by First Line Digital Surveillance. The system is capable of simultaneously recording up to 16 video inputs, however, only one camera at a time was connected for these tests.

The digital recorder allows the capture framerate to be varied. For all tests, values of 1/10, 1, 10, and Max frames per second (fps) were used. The Max setting instructs the recorder to capture video at the highest rate possible for the number of cameras connected (one camera for all tests described in this report). The actual framerate achieved with the Max setting was approximately 60fps.

3.1.3 Camera Targets

A different target was used for each of the tests. For the resolution test, the 1951 US Air Force test pattern was used. For the dynamic range test, a custom 14 step gray transmissive target developed by IFI was used. For the color fidelity test, the Macbeth Color Checker was used. For each test, the camera was positioned so that the area of interest on the target approximately filled the camera's field of view. The distance between the camera and target is given in the individual test descriptions below.

3.1.4 Lighting Equipment

Table 2 shows the three different lighting configurations used for the resolution and color fidelity tests. All three configurations were used for the color fidelity test while only the tungsten/fluorescent and fluorescent configurations were used for the resolution test. The tungsten and Solux lamps were placed beside the camera at approximately the same distance from the target as the lens. The fluorescent tubes were mounted in the ceiling fixtures throughout the testing room. For the dynamic range test, a tungsten source was built into the light box, so no external lighting was needed.

Table 2: *Lighting conditions used for testing.*

ID	Description
1	(2) Photoflex Starlite fixtures (3200°K tungsten) plus overhead fluorescent lights
2	Overhead fluorescent lights only
3	(4) Solux 4700°K, 36° beamspread halogens

In order to analyze the color fidelity test results, the spectral power distribution (SPD) of each of the lamps needs to be known. It was not possible to measure the SPD for the lamps, as explained below in the description of the color fidelity test. However, the SPDs for the lamps used in this test were approximated using published data for similar lamps. Figure 1 shows the SPD for CIE standard illuminant A [2]. This SPD is for a theoretical device, but it should serve as an approximation for the tungsten lamps used in testing. Figure 2 shows the SPD for an unknown brand of cool white fluorescent lamp [2]. The actual fluorescent lamps used in the testing area are probably different from those represented by this curve, but the approximation should suffice in the absence of measured data. Figure 3 shows the manufacturer-supplied SPD for the Solux lamps [9]. The actual lamps used for this test may be slightly different due to manufacturing variations and ageing, but this should be the closest approximation of the three types of lamps used. The SPDs in Figures 1–3 have each been normalized with reference to the highest value to show the relative intensity at each wavelength.

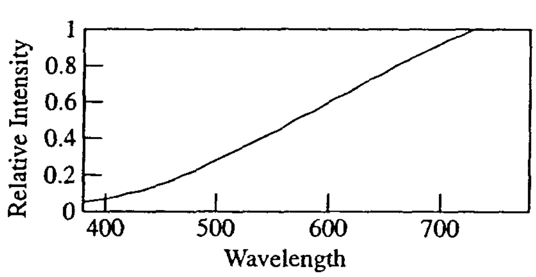

Figure 1: *Spectral Power Distribution for CIE Illuminant A.*

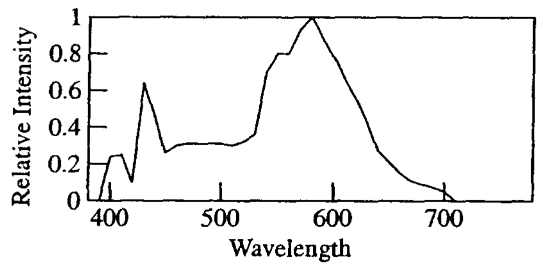

Figure 2: *Spectral Power Distribution for Cool White Fluorescent lamps.*

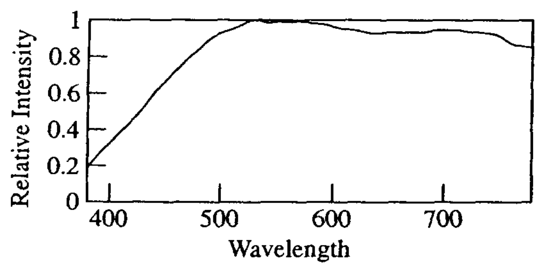

Figure 3: *Spectral Power Distribution for Solux 4700°K lamps.*

3.2 Data Collection

For each test, the camera, framerate, and lighting conditions were varied for separate trials. For each trial, at least three frames were captured. The video clip for each trial was exported from the digital video recorder in AVI format using the default Indeo Video v3.2 codec. The AVI files were processed on another computer to extract the first three frames for each trial and save them as individual, uncompressed bitmap files for analysis. The first three frames for each trial were analyzed separately then averaged to obtain the results reported here.

For the dynamic range test and color fidelity test, each frame contained a number of target patches. The red, green, and blue color values of each patch were obtained by using software developed by IFI. The software works as a plugin for Adobe Photoshop 5 and reports the spatial average of the RGB values for a manually selected area of the image. The size of the selected area varied according to the size of the patches in each image.

4 Test Description

4.1 Resolution Test Description

For the resolution test, the 1951 US Air Force test pattern was used as the target. Each of the 7 tested cameras was placed, one at a time, so that the framed area of the target approximately filled the field of view. This turned out to be a distance of 35cm from the target for all cameras except the Philips LTC 0500/20, which required a distance of 26cm. Trials were performed using the first two lighting configurations shown in Table 2.

The individual frames were inspected visually using Photoshop to determine the most closely spaced linepairs resolvable. The indexes for these linepairs were then used to determine the resolution at the location of the target using the chart provided with the target. The resolution at the location of the camera's charge coupled device (CCD) was then calculated using Equation (1), where d is the distance between the CCD and the target, and f is the focal length of the lens (3.7mm).

$$(1) \qquad Resolution_{CCD} = \frac{d-f}{f} Resolution_{target}$$

The camera to target distances given above were measured from the front of the lens to the target, but the distance required for Equation (1) should be measured from the CCD to the target. The distance measured from the front of the lens to the CCD was 5cm, so this was added to the measurements given above before using them in the calculation.

For each trial, the average resolution was calculated using the first three frames of the video clip. The results are shown in Table 5.

4.2 Dynamic Range Test Description

A dynamic range test was performed to assess the range of scene brightness levels that each camera is capable of detecting. The target used for this test is a 14 step gray transmissive target constructed by IFI. The density of the target patches were measured using an X-Rite model 820 densitometer. The three-reading average of the measurements for each patch is shown in Table 3.

Table 3: *Density measurements for dynamic range test target (three-reading average).*

Step	Density
0	0.00
1	0.33
2	0.64
3	0.94
4	1.27
5	1.58
6	1.88
7	2.19
8	2.50
9	2.78
10	3.09
11	3.35
12	3.57
13	3.84

The target was placed on a custom light box created by IFI. The box contained tungsten lamps and was masked so that light from the box would not show through areas outside the target area. Each camera was positioned so that the target fit in the field of view. Distances ranged from 21.5cm to 30cm. An infrared (IR) filter was placed in front of the lens because the tungsten lamps emit light in the IR range, and the transmissive material used for the target allows some of this IR light to pass even when visible light is blocked. Since the camera CCD is sensitive to IR light, it must be filtered out to allow only light in the visible part of the spectrum to enter the camera. For all trials, the room lights were turned off while video was being captured.

Video was captured for each camera while varying the framerate for each trial. The first three video frames for each trial were analyzed to find the spatial average of the RGB values for each target patch. The values for each patch were then averaged across three frames and the separate R, G, and B values were plotted against the measured density of each patch. The results are shown in Figures 5–32.

4.3 Color Fidelity Test Description

A color fidelity test was performed on the color cameras to determine how closely the captured color values match the actual colors reflected by the target. This test is somewhat limited by the fact that the exact color values reflected by the target are not known. However, with the information that was available, approximations were made.

The target used for this test is the Macbeth Color Checker, a set of color patches with carefully chosen spectral properties commonly used to calibrate photographic color film [3]. For this test, the only patches that were analyzed were the red, green, blue, cyan, magenta, yellow, and the six gray patches. The camera to target distance ranged from 22cm to 30cm.

Each color camera was used to capture video of the target for each of the three different lighting conditions shown in Table 2. The first three frames of each trial were analyzed to find the spatial average of the R, G, and B values for each of the twelve patches of interest. The values for each patch were then averaged for the three frames.

To determine how closely the cameras report color information, it is necessary to know the SPD of the light reaching the camera. To measure the SPD, an instrument known as a spectroradiometer can be used [10]. A spectroradiometer has a lens aperture much like a camera and can be placed at the location of the camera under test to measure the amount of light energy reflected by the target as a function of wavelength. Such an instrument was not available for these tests, so approximations were made about the SPD of the incoming light. The model used for this is

$$C(\lambda) = E(\lambda)S(\lambda) \tag{2}$$

where $C(\lambda)$ is the spectrum of the light reflected by the target, $E(\lambda)$ is the spectrum of the light incident on the target, and $S(\lambda)$ is the reflectance spectrum of the target for each patch [11]. A spectroradiometer could be used to measure $E(\lambda)$ and $S(\lambda)$ separately, in which case the vectors could be multiplied to obtain $C(\lambda)$, or it could be used to measure $C(\lambda)$ directly.

The reflectance spectra for the Macbeth color patches have been measured and published in several color science research articles, so those published values were used for this test [2]. The actual target used may have slightly different spectra due to manufacturing variations and ageing.

The spectral properties of the lamps were approximated using the SPDs shown in Figures 1–3. For the configuration using the tungsten and fluorescent lamps, the SPDs for each lamp were simply added together in equal amounts. Note that the analysis for this test would be more accurate with the use of a spectroradiometer, but this description serves as a demonstration of the general method used for analyzing color.

The approximated values for the lamp SPDs and reflectance spectra of the target patches were used in Equation (2) to calculate the approximate SPD of the light entering the camera for each patch. These values were then converted to CIE (1931) chromaticity coordinate pairs as described in [5, 7]. These represent the approximate theoretical color values for each target patch in a device independent color space.

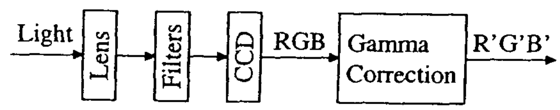

Figure 4: *Assumed camera model.*

In order to compare the color values reported by the cameras to the theoretical values, the camera values needed to be converted to CIE (1931) chromaticity coordinates. The calculations used for this conversion are based on the assumed camera model shown in Figure 4 [6]. In this model, the CCD outputs linear RGB intensity values. These linear values are then transformed to nonlinear R'G'B' values by a process known as gamma correction in order to account for the nonlinearities in display monitors. This is defined by the Rec. 709 transfer function shown in Equation (3) [6] where L is the linear intensity value and E'_{709} is the gamma corrected value.

$$E'_{709} = \begin{cases} 4.5L, & L \leq 0.018 \\ 1.099L^{0.45} - 0.099, & 0.018 < L \end{cases} \tag{3}$$

It is assumed that the gamma corrected values output by the camera are stored by the digital recorder in nonlinear R'G'B' form. In order to convert these values to the CIE (1931) color space, the linear RGB values must first be recovered. This can be accomplished by inverting the gamma correction using Equation (4) [6].

$$L = \begin{cases} \frac{E'_{709}}{4.5}, & E'_{709} \leq 0.081 \\ \left(\frac{E'_{709}+0.099}{1.099}\right)^{\frac{1}{0.45}}, & 0.081 < E'_{709} \end{cases} \quad (4)$$

The linear values are referred to as R, G, and B, while the nonlinear values are referred to as R', G', and B'. The recovered linear components were converted to CIE (1931) chromaticity coordinates as described in [5, 7] using the Rec. 709 primaries and white reference.

The predicted and measured chromaticity coordinates for each patch were plotted in Figures 33–104. The arrows point from the predicted values to the corresponding measured values. The label next to the predicted value indicates the Macbeth patch number. The numbers 13–18 indicate blue, green, red, yellow, magenta, and cyan, respectively. The plots in the left column show the results before tone correction (described below) and the plots in the right column show the corresponding results after tone correction.

4.3.1 Tone Correction

Once the color fidelity performance of each camera was determined, the video frames were altered using a simple tone correction process. The resulting frames were analyzed for color fidelity again to determine if the color accuracy was improved. The tone correction process is described below.

For each of the six gray patches on the Macbeth Color Checker, a density measurement was made using an X-Rite model 820 densitometer. The measured values are shown in Table 4. The nonlinear R'G'B' values returned by the camera should have equal amounts of R', G', and B' for each of the gray patches. The proportional density change between patches should also match the proportional change in R', G', and B' values. The purpose of the tone correction is to modify the image values so that these conditions are satisfied. This was accomplished by setting the gray value for the lightest patch to the highest R'G'B' value measured for the six gray patches and setting the gray value for the darkest patch to the lowest R'G'B' value. The gray values for the other patches were set so that the proportional change between patches matched that of the density measurements. The measured R'G'B' values and the target gray values for each of the six patches were used as input and output values, respectively, for the Photoshop curves tool. The resulting tone corrected images were then analyzed for color fidelity as before.

Table 4: *Density measurements for Macbeth Color Checker gray patches.*

Patch	Density
19	0.05
20	0.25
21	0.47
22	0.74
23	1.11
24	1.57

5 Suggested Improvements

There are several improvements that could be made in future tests to increase the accuracy of the results reported here. First, a better understanding of the internal workings of the cameras and digital recorder would be helpful. The assumed camera model shown in Figure 4 is a simplified version of the processing performed inside most cameras. The video signals output by the tested cameras were likely affected by additional processing steps not shown in the simplified model. Likewise, the digital video recorder may have further processed the captured video in ways that affected the test results.

The results of the resolution test were affected by the compression applied by the digital video recorder during export. The default compression method is Intel Indeo R3.2. This uses a lossy, vector quantization method to compress the frames, resulting in blocking artifacts in the final output [4]. These blocking artifacts made it difficult to visually judge the most closely spaced line pairs resolvable for the resolution test. It would be helpful if the video could be exported in an uncompressed format to avoid the ambiguity caused by these artifacts.

The results of the color fidelity test could be improved in a couple of ways. First, a spectroradiometer could be used to measure the actual color properties of the light entering the cameras, as mentioned above. Second, it might be useful to also report the results using a perceptually uniform color space. The CIE (1931) chromaticity plot does not have this property, meaning that a human observer may not perceive the same difference between two points on one area of the plot as with two equally spaced points on a different area of the plot. There are other color spaces, namely $L^*a^*b^*$ and $L^*u^*v^*$, that are perceptually uniform and could be used to report the color differences as they relate to human perception.

Finally, it would be very helpful to automate the analysis process as much as possible. The process used for finding the spatial average of image intensity values involved manually selecting areas of the image, initiating an averaging routine, then manually entering the returned values into a spreadsheet for calculation. An automated program could be developed that attempts to find the areas of interest in each image, allows manual adjustment of the automatic selections, then performs the calculations automatically. Such a program would save a great deal of time, especially in the color fidelity analysis.

6 Test Results

6.1 Resolution Test Results

Table 5: *Measured resolution for different lighting conditions and framerates. Both horizontal and vertical resolutions are given in linepairs/mm at the location of the CCD.*

Framerate (fps)	Tungsten/ Fluorescent (hor)	(vert)	Fluorescent Only (hor)	(vert)
Philips LTC 0450/21 A				
60	42.5	42.5	42.5	42.5
10	37.9	37.7	37.9	37.9
1	37.9	37.9	37.9	37.9
0.1	37.9	37.9	37.9	37.9
Philips LTC 0350/21 A				
60	33.7	30.1	42.5	30.1
10	35.3	30.1	30.1	30.1
1	30.1	30.1	30.1	30.1
0.1	30.1	30.1	30.1	30.1
Philips LTC 0330/21				
60	26.8	26.8	30.1	30.1
10	26.8	26.8	30.1	30.1
1	26.8	26.8	30.1	30.1
0.1	26.8	26.8	33.8	33.8
Philips LTC 0430/61 A				
60	42.5	42.5	42.5	33.7
10	37.9	37.9	37.9	37.9
1	37.9	37.9	37.9	37.9
0.1	37.9	37.9	42.5	37.9
Philips LTC 0350/21 A				
60	37.9	37.9	30.1	33.7
10	37.9	33.7	26.8	26.8
1	37.9	37.9	35.1	35.1
0.1	33.7	37.9	37.9	37.9
Philips LTC 0500/20				
60	33.7	42.5	33.7	33.7
10	33.7	33.7	33.7	33.7
1	33.7	33.7	33.7	33.7
0.1	33.7	33.7	33.7	33.7
Panasonic WV-CP460				
60	47.7	42.5	47.7	42.5
10	47.7	42.5	47.7	37.9
1	47.7	37.9	47.7	37.9
0.1	47.7	37.9	47.7	37.9

6.2 Dynamic Range Test Results

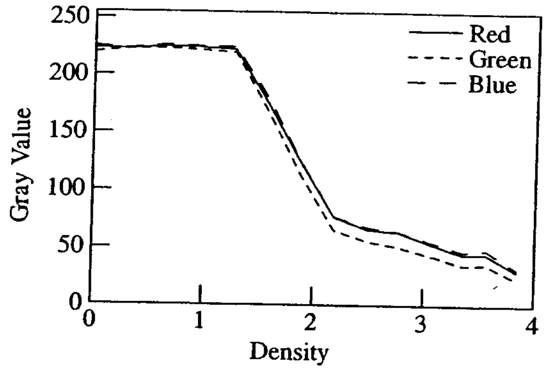

Figure 5: *Philips LTC 0450/21 A, 60fps.*

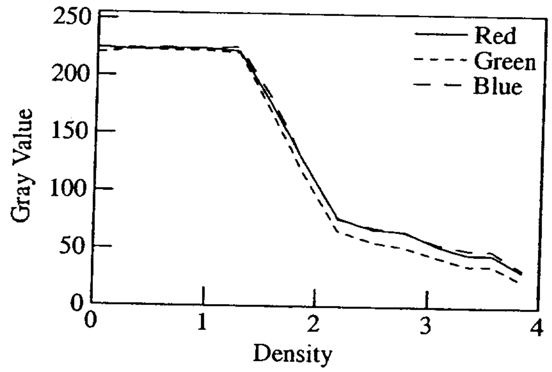

Figure 6: *Philips LTC 0450/21 A, 10fps.*

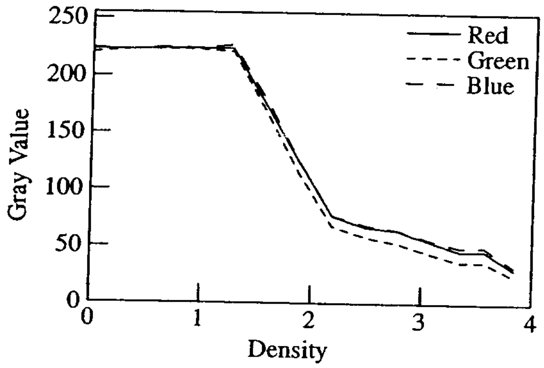

Figure 7: *Philips LTC 0450/21 A, 1fps.*

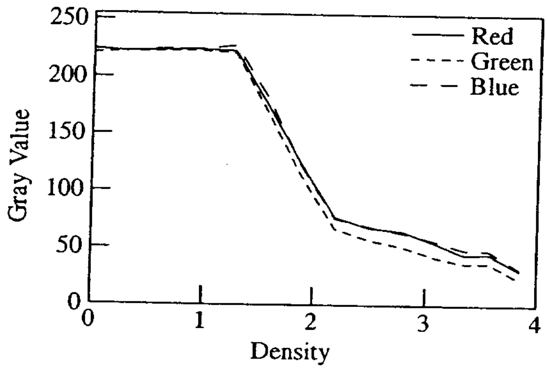

Figure 8: *Philips LTC 0450/21 A, 0.1fps.*

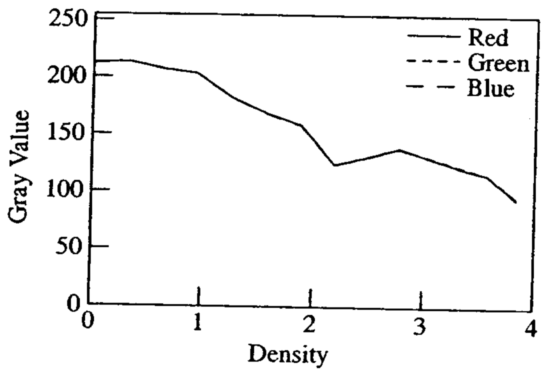

Figure 9: *Philips LTC 0350/21 A, 60fps.*

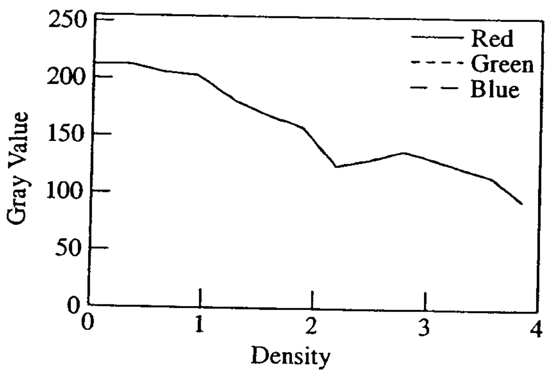

Figure 10: *Philips LTC 0350/21 A, 10fps.*

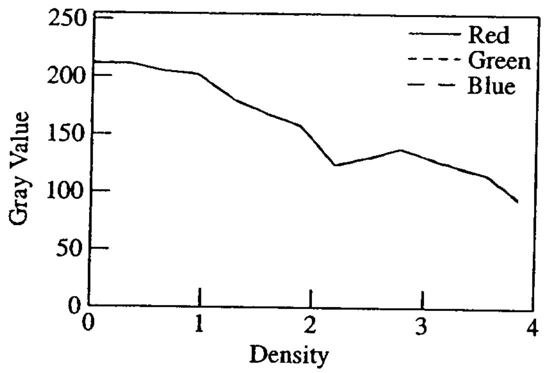

Figure 11: *Philips LTC 0350/21 A, 1fps.*

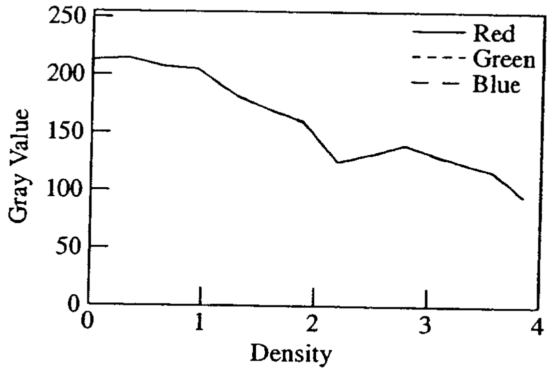

Figure 12: *Philips LTC 0350/21 A, 0.1fps.*

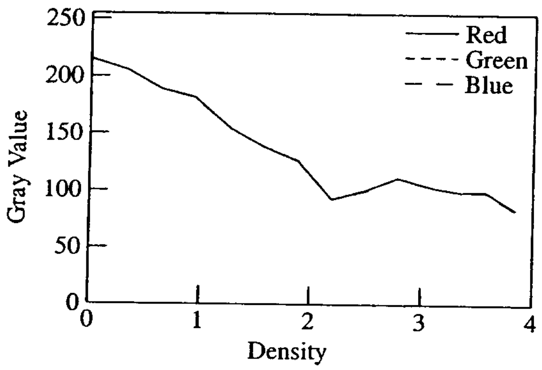

Figure 13: *Philips LTC 0330/21, 60fps.*

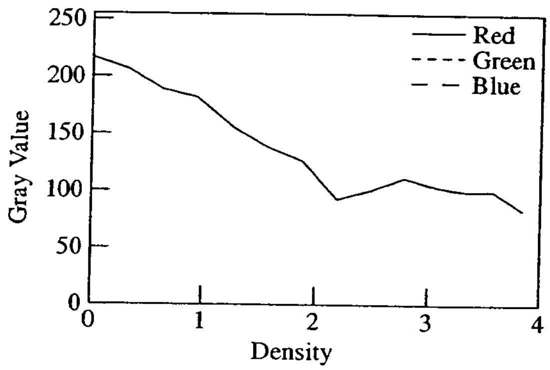

Figure 14: *Philips LTC 0330/21, 10fps.*

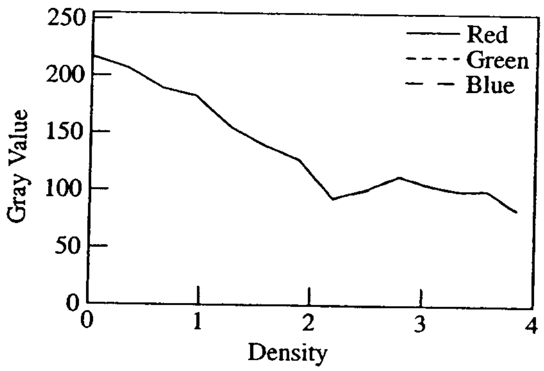

Figure 15: *Philips LTC 0330/21, 1fps.*

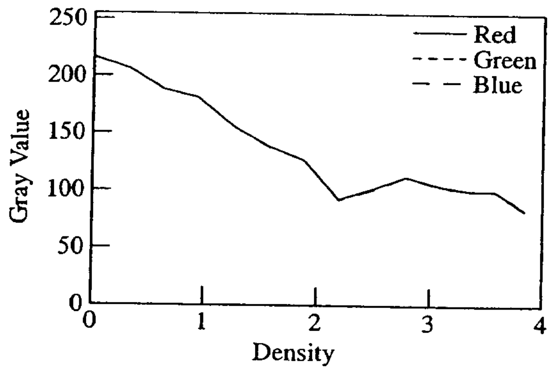

Figure 16: *Philips LTC 0330/21, 0.1fps.*

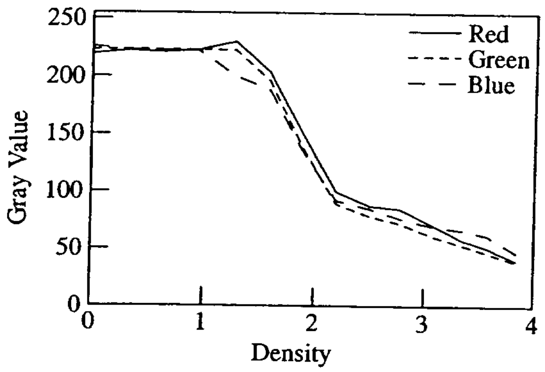

Figure 17: *Philips LTC 0430/61 A, 60fps.*

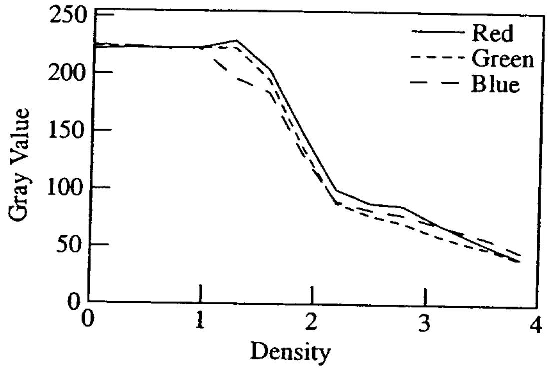

Figure 18: *Philips LTC 0430/61 A, 10fps.*

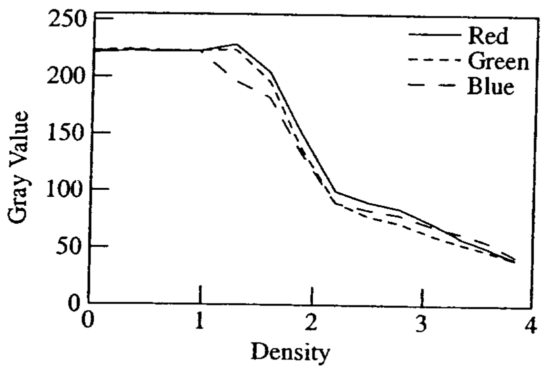

Figure 19: *Philips LTC 0430/61 A, 1fps.*

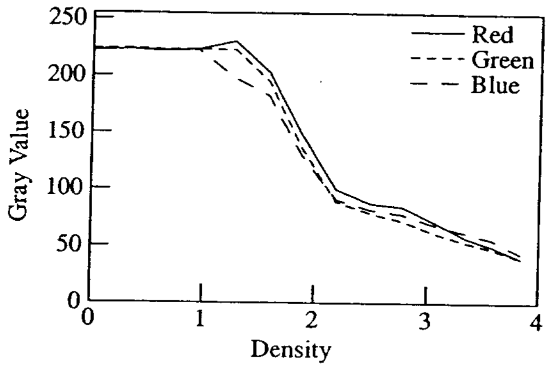

Figure 20: *Philips LTC 0430/61 A, 0.1fps.*

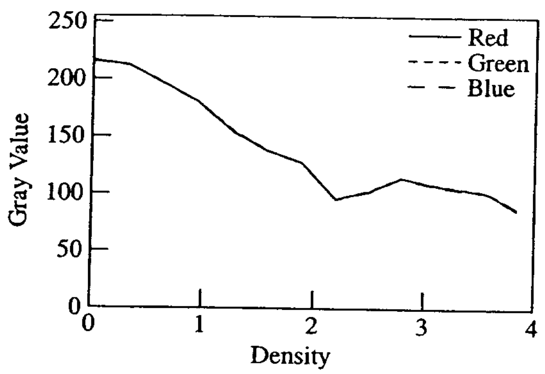

Figure 21: *Philips LTC 0350/21 A, 60fps.*

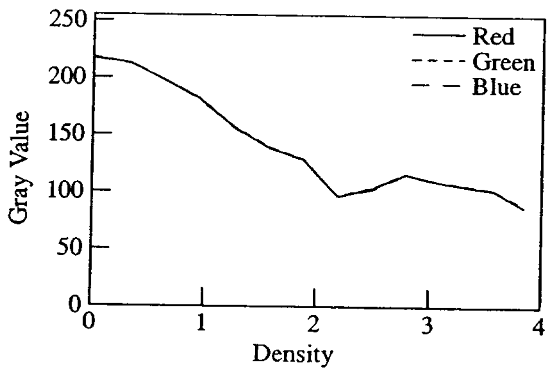

Figure 22: *Philips LTC 0350/21 A, 10fps.*

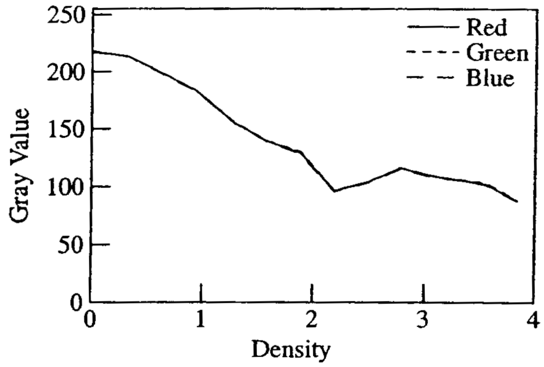

Figure 23: *Philips LTC 0350/21 A, 1fps.*

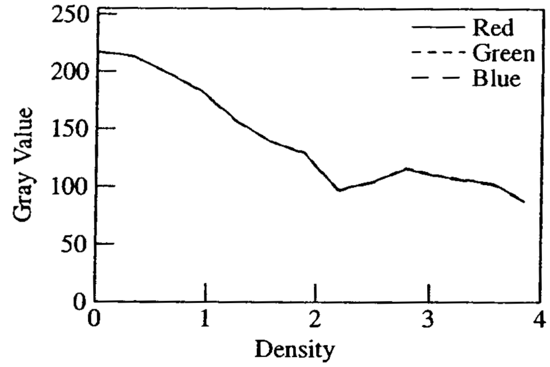

Figure 24: *Philips LTC 0350/21 A, 0.1fps.*

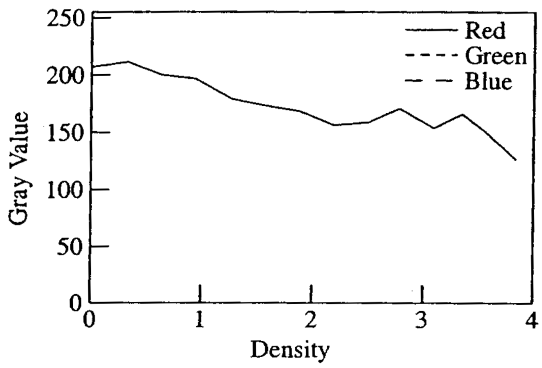

Figure 25: *Philips LTC 0500/20, 60fps.*

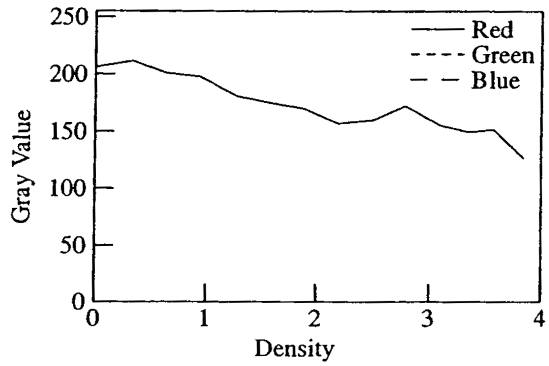

Figure 26: *Philips LTC 0500/20, 10fps.*

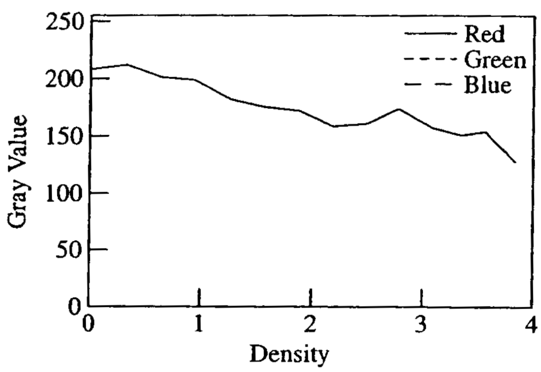

Figure 27: *Philips LTC 0500/20, 1fps.*

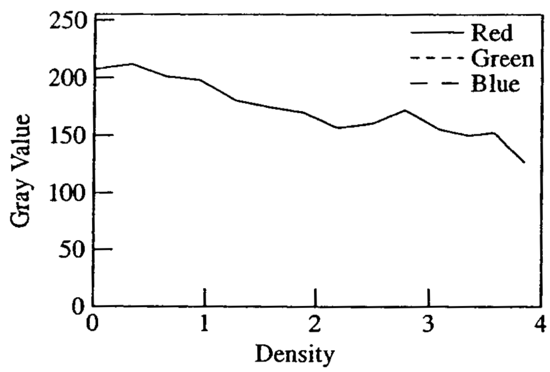

Figure 28: *Philips LTC 0500/20, 0.1fps.*

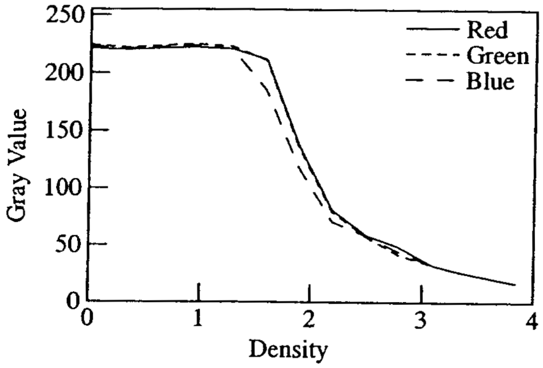

Figure 29: *Panasonic WV-CP460, 60fps.*

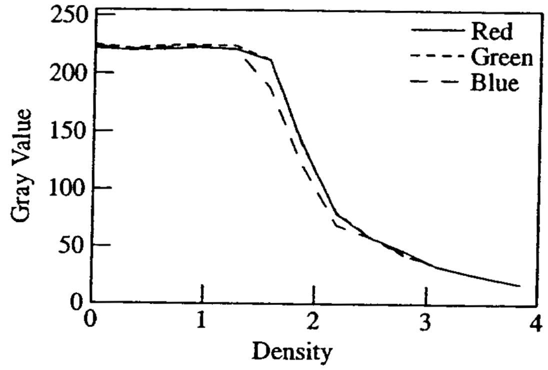

Figure 30: *Panasonic WV-CP460, 10fps.*

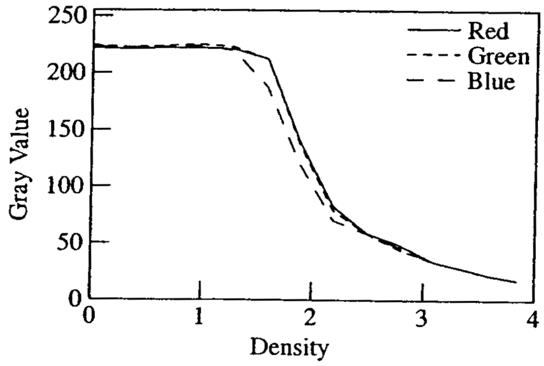

Figure 31: *Panasonic WV-CP460, 1fps.*

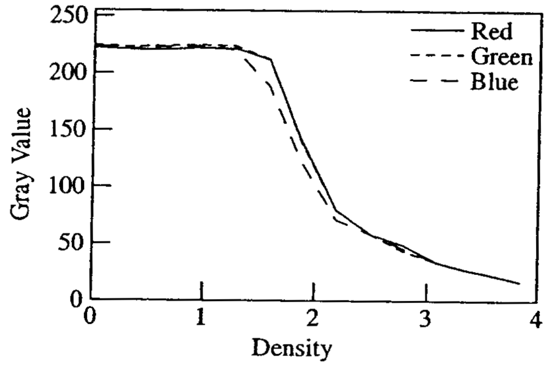

Figure 32: *Panasonic WV-CP460, 0.1fps.*

6.3 Color Fidelity Test Results

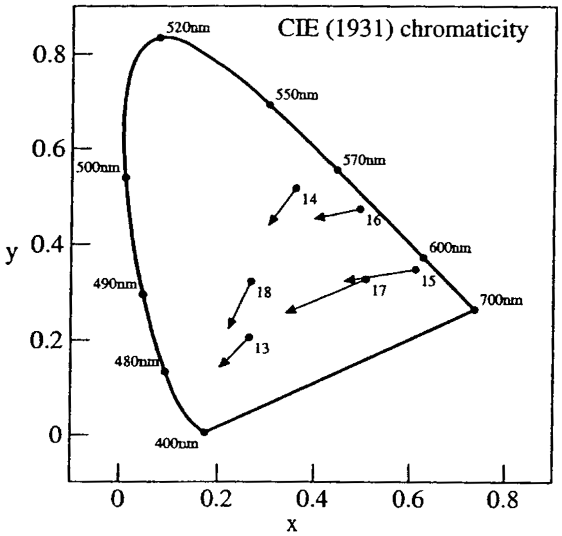

Figure 33: *Philips LTC 0450/21 A, tungsten and fluorescent, 60fps, before tone correction.*

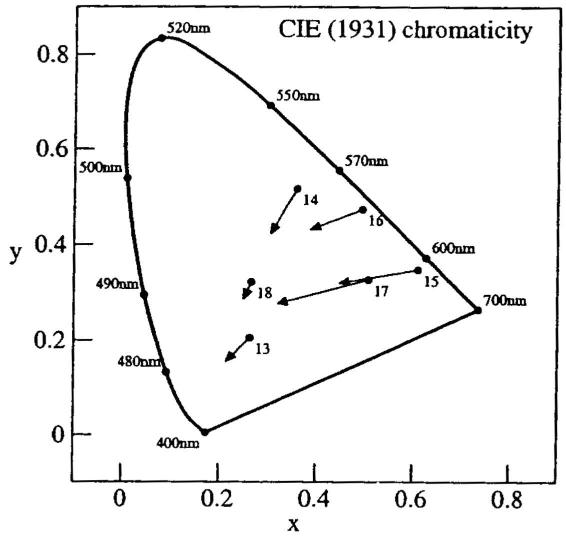

Figure 34: *Philips LTC 0450/21 A, tungsten and fluorescent, 60fps, after tone correction.*

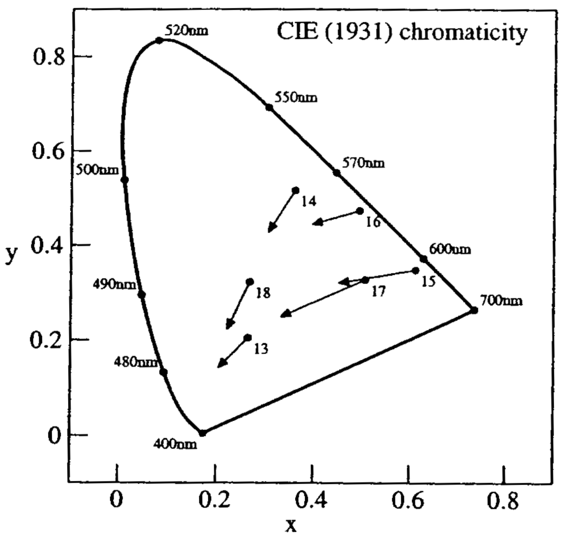

Figure 35: *Philips LTC 0450/21 A, tungsten and fluorescent, 10fps, before tone correction.*

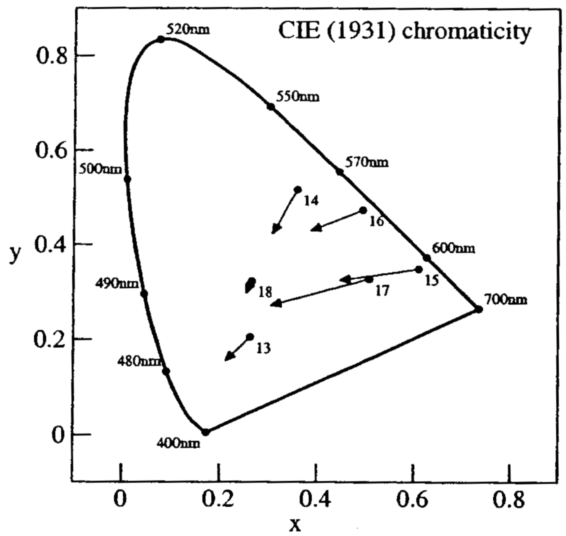

Figure 36: *Philips LTC 0450/21 A, tungsten and fluorescent, 10fps, after tone correction.*

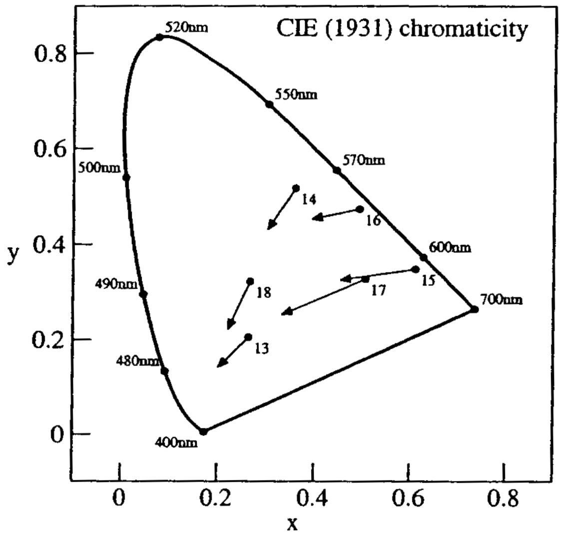

Figure 37: *Philips LTC 0450/21 A, tungsten and fluorescent, 1fps, before tone correction.*

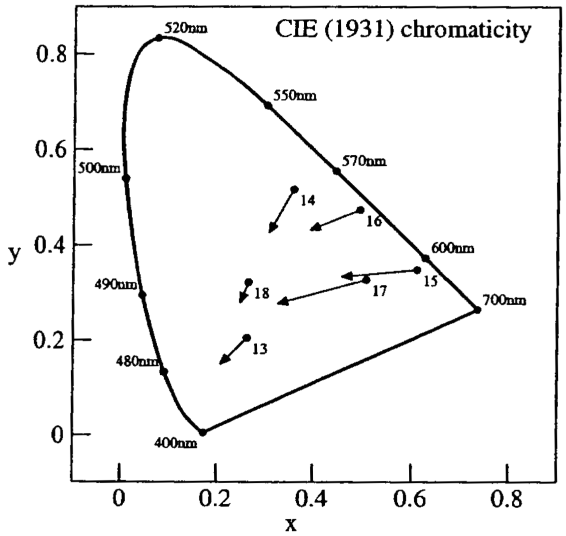

Figure 38: *Philips LTC 0450/21 A, tungsten and fluorescent, 1fps, after tone correction.*

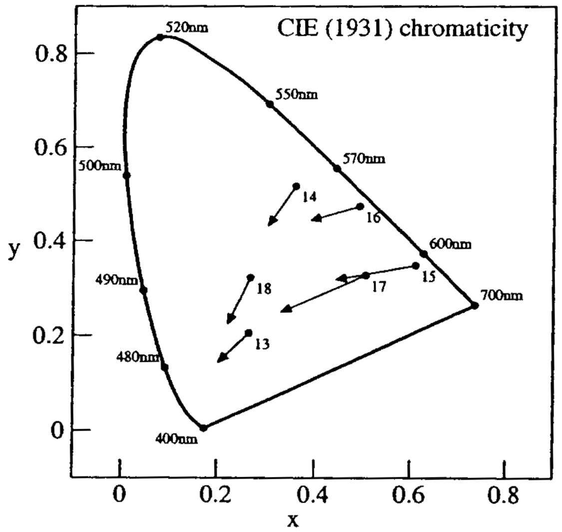

Figure 39: *Philips LTC 0450/21 A, tungsten and fluorescent, 0.1fps, before tone correction.*

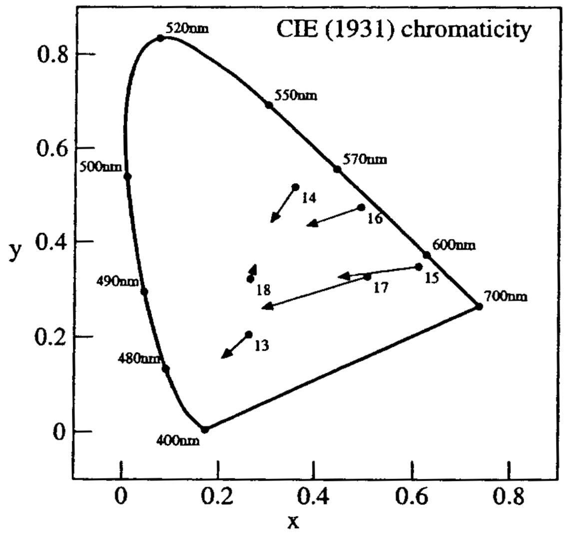

Figure 40: *Philips LTC 0450/21 A, tungsten and fluorescent, 0.1fps, after tone correction.*

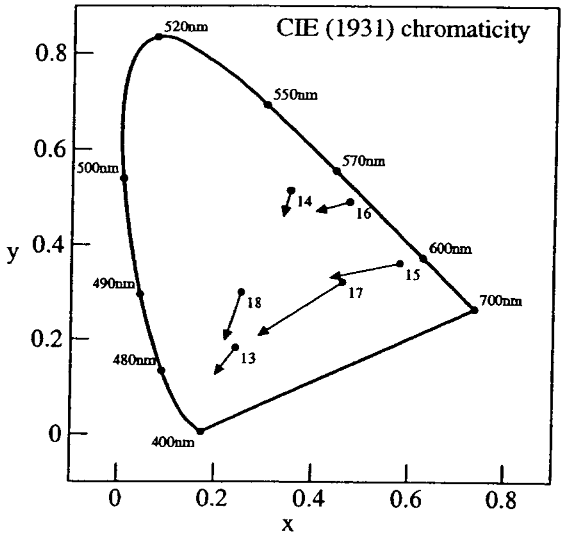

Figure 41: *Philips LTC 0450/21 A, fluorescent, 60f-ps, before tone correction.*

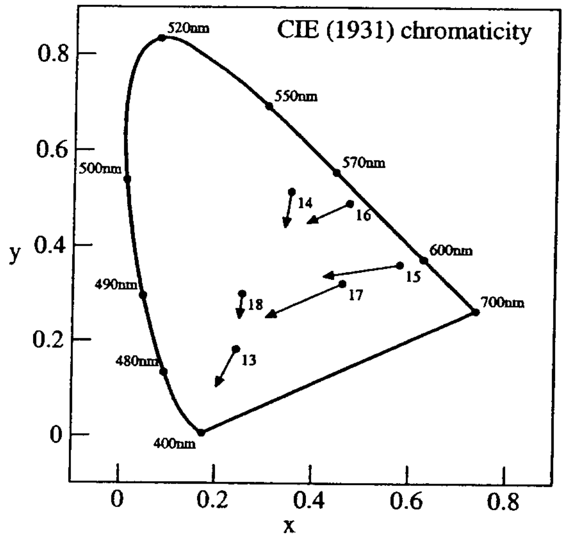

Figure 42: *Philips LTC 0450/21 A, fluorescent, 60f-ps, after tone correction.*

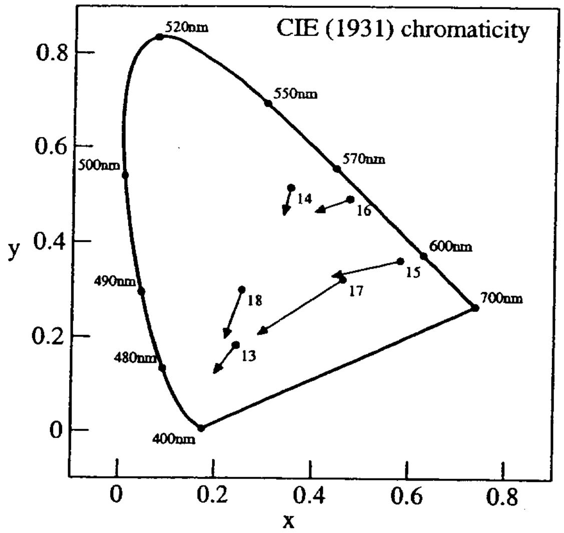

Figure 43: *Philips LTC 0450/21 A, fluorescent, 10f-ps, before tone correction.*

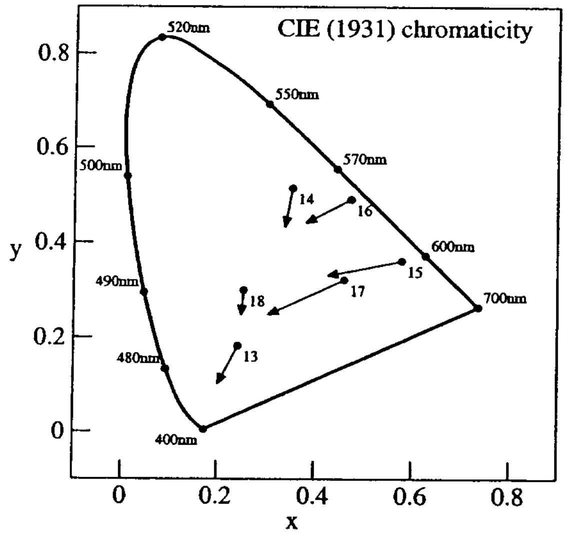

Figure 44: *Philips LTC 0450/21 A, fluorescent, 10f-ps, after tone correction.*

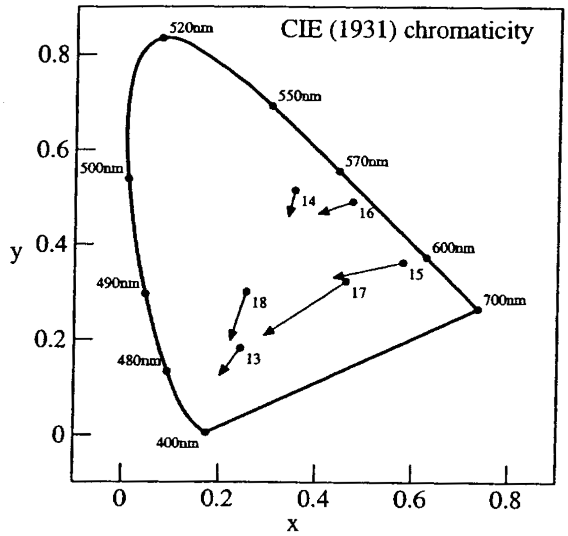

Figure 45: *Philips LTC 0450/21 A, fluorescent, 1fps, before tone correction.*

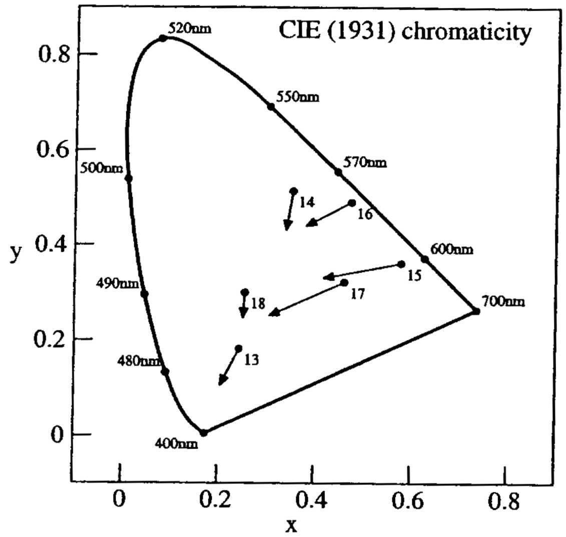

Figure 46: *Philips LTC 0450/21 A, fluorescent, 1fps, after tone correction.*

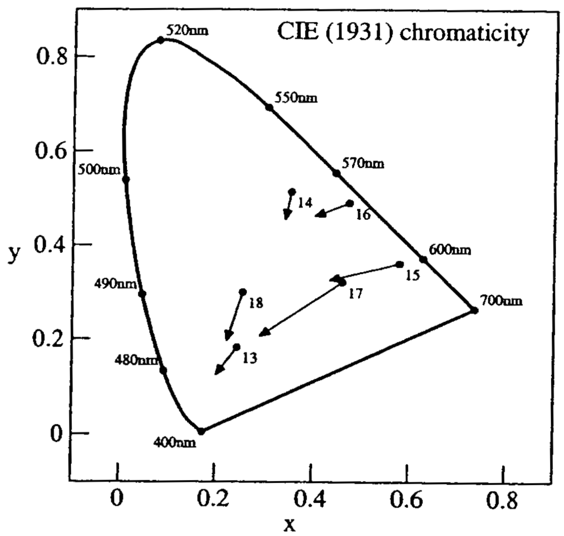

Figure 47: *Philips LTC 0450/21 A, fluorescent, 0.1f-ps, before tone correction.*

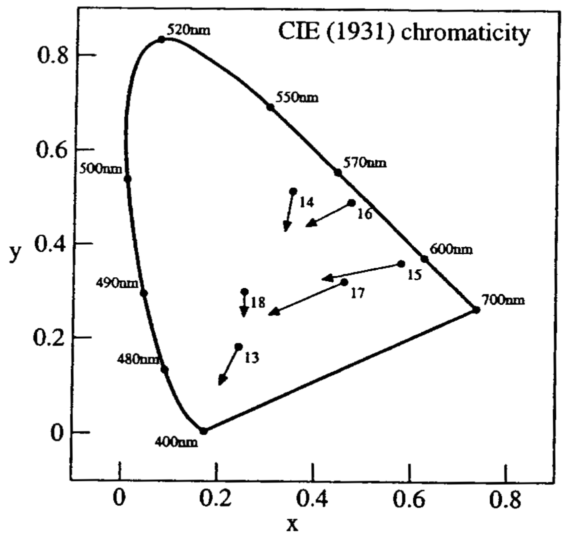

Figure 48: *Philips LTC 0450/21 A, fluorescent, 0.1f-ps, after tone correction.*

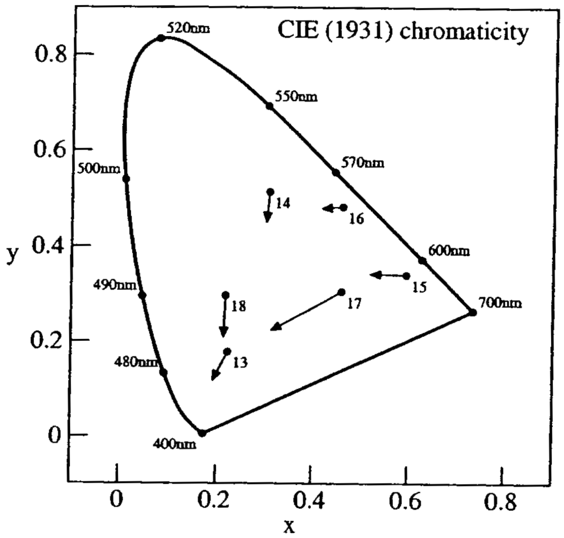

Figure 49: *Philips LTC 0450/21 A, Solux 4700°K, 60fps, before tone correction.*

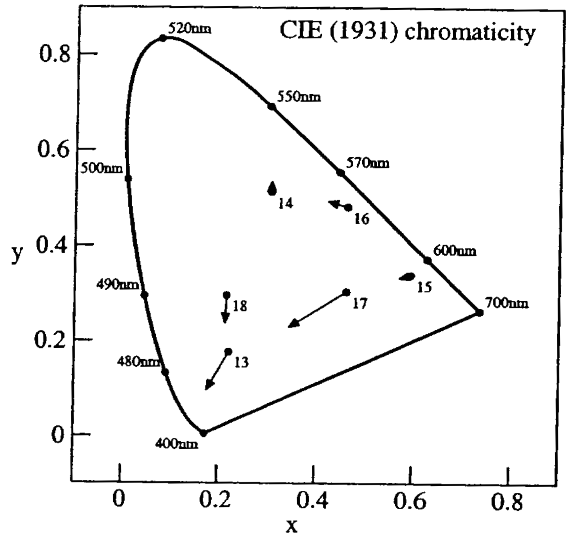

Figure 50: *Philips LTC 0450/21 A, Solux 4700°K, 60fps, after tone correction.*

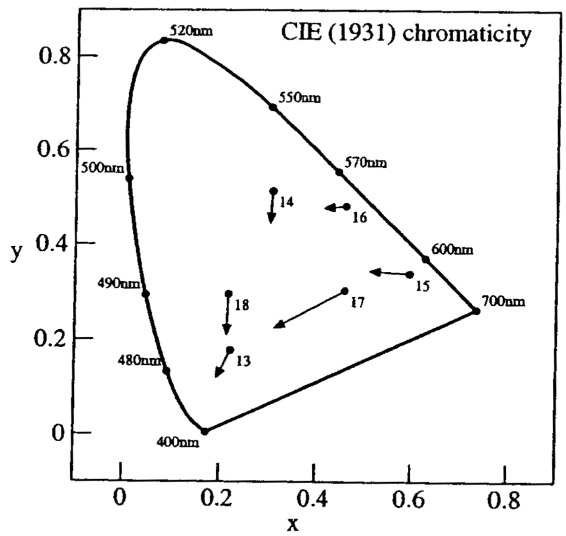

Figure 51: *Philips LTC 0450/21 A, Solux 4700°K, 10fps, before tone correction.*

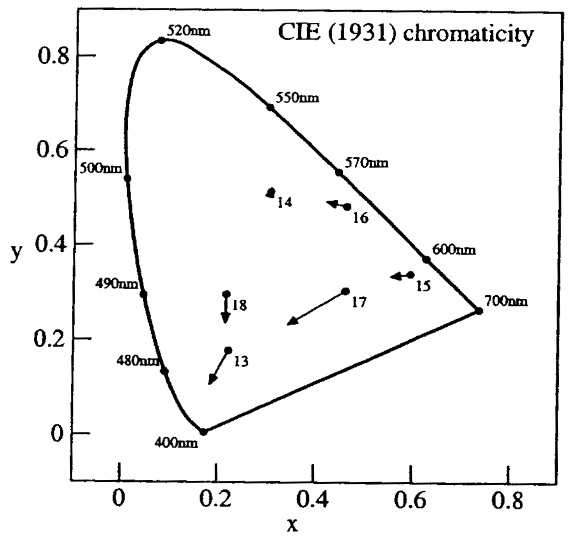

Figure 52: *Philips LTC 0450/21 A, Solux 4700°K, 10fps, after tone correction.*

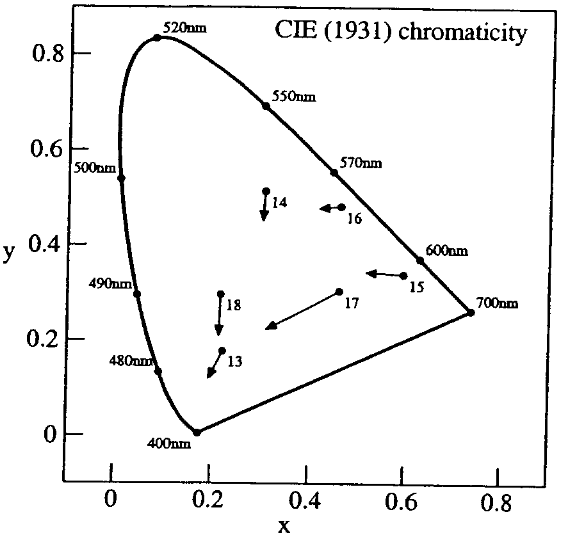

Figure 53: *Philips LTC 0450/21 A, Solux 4700°K, 1fps, before tone correction.*

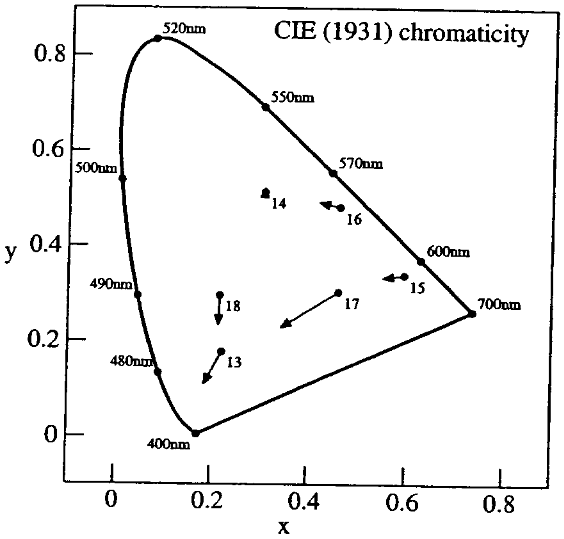

Figure 54: *Philips LTC 0450/21 A, Solux 4700°K, 1fps, after tone correction.*

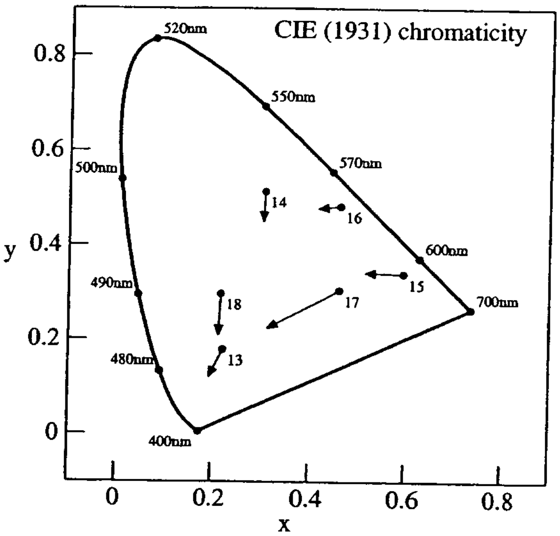

Figure 55: *Philips LTC 0450/21 A, Solux 4700°K, 0.1fps, before tone correction.*

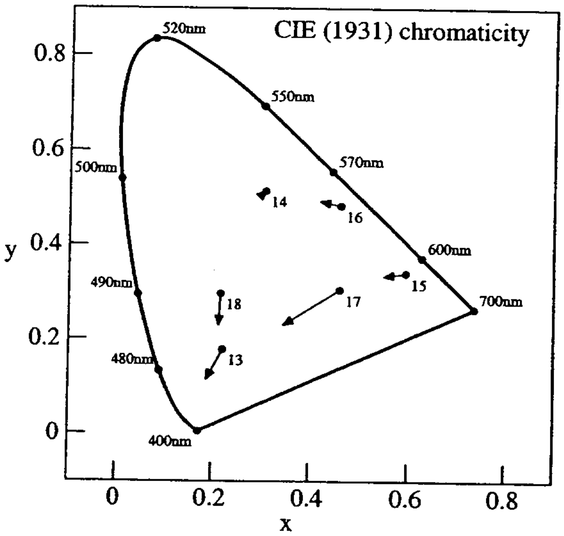

Figure 56: *Philips LTC 0450/21 A, Solux 4700°K, 0.1fps, after tone correction.*

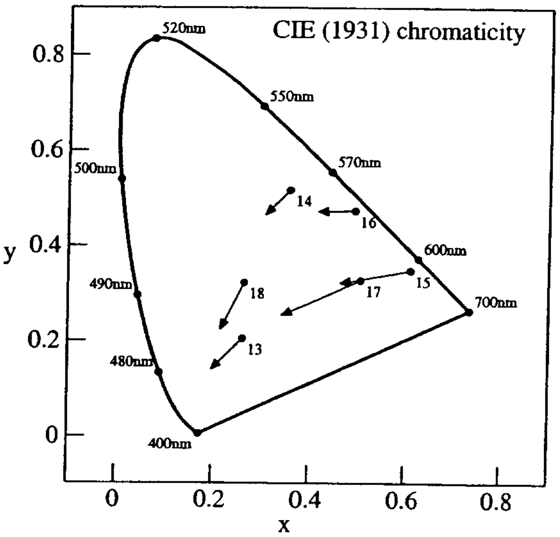

Figure 57: *Philips LTC 0430/61 A, tungsten and fluorescent, 60fps, before tone correction.*

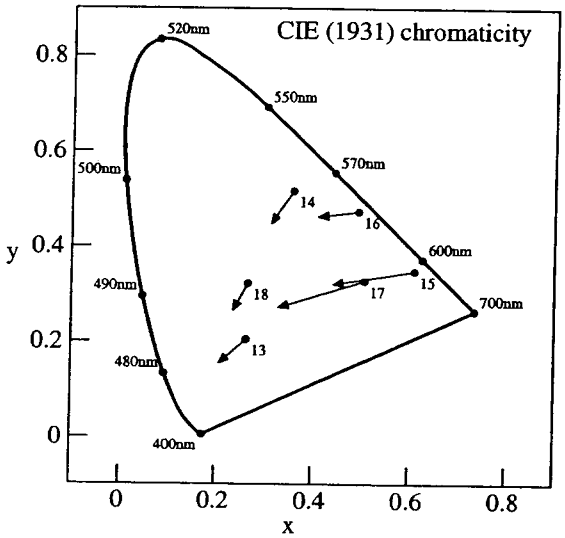

Figure 58: *Philips LTC 0430/61 A, tungsten and fluorescent, 60fps, after tone correction.*

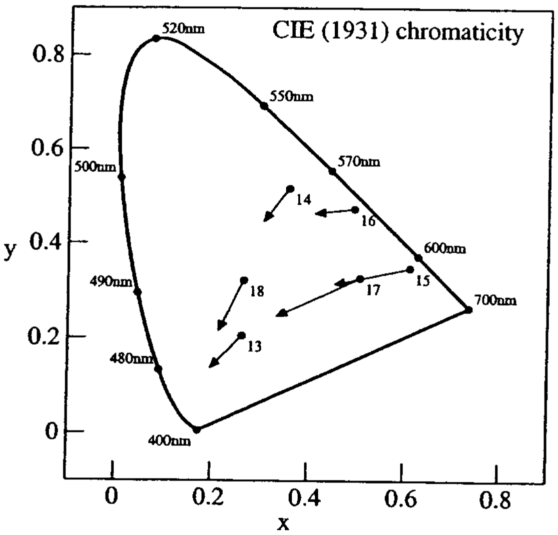

Figure 59: *Philips LTC 0430/61 A, tungsten and fluorescent, 10fps, before tone correction.*

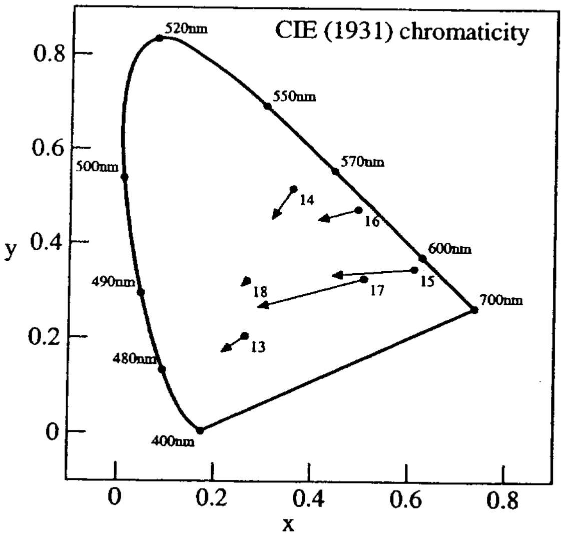

Figure 60: *Philips LTC 0430/61 A, tungsten and fluorescent, 10fps, after tone correction.*

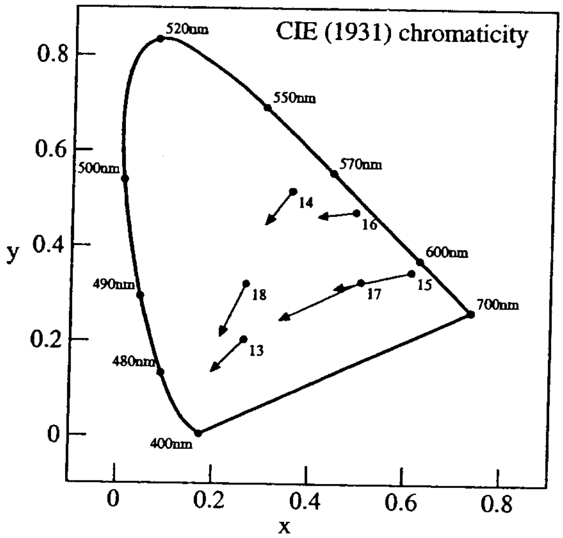

Figure 61: *Philips LTC 0430/61 A, tungsten and fluorescent, 1fps, before tone correction.*

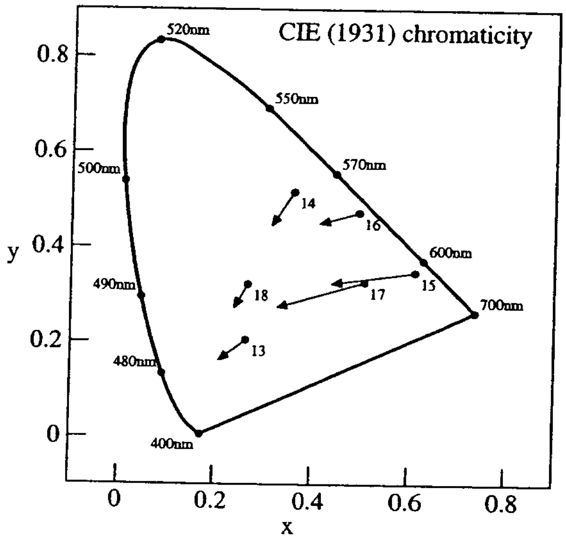

Figure 62: *Philips LTC 0430/61 A, tungsten and fluorescent, 1fps, after tone correction.*

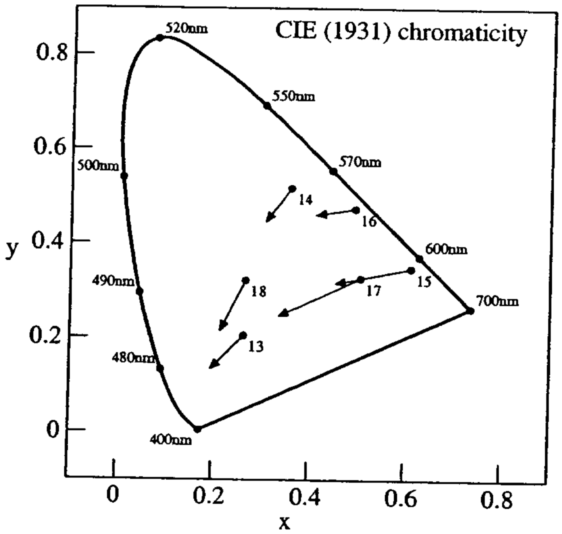

Figure 63: *Philips LTC 0430/61 A, tungsten and fluorescent, 0.1fps, before tone correction.*

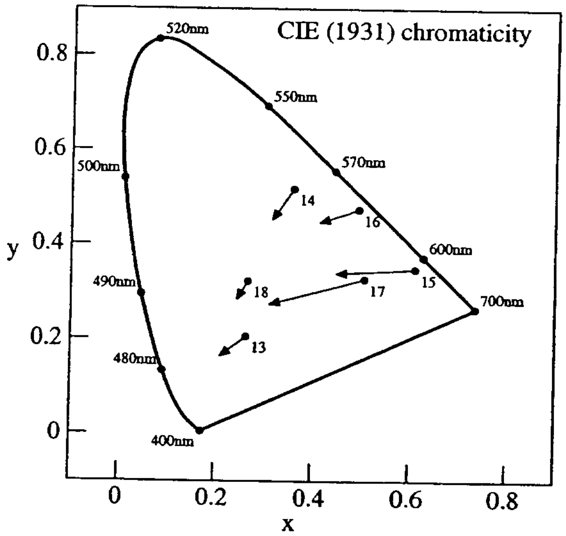

Figure 64: *Philips LTC 0430/61 A, tungsten and fluorescent, 0.1fps, after tone correction.*

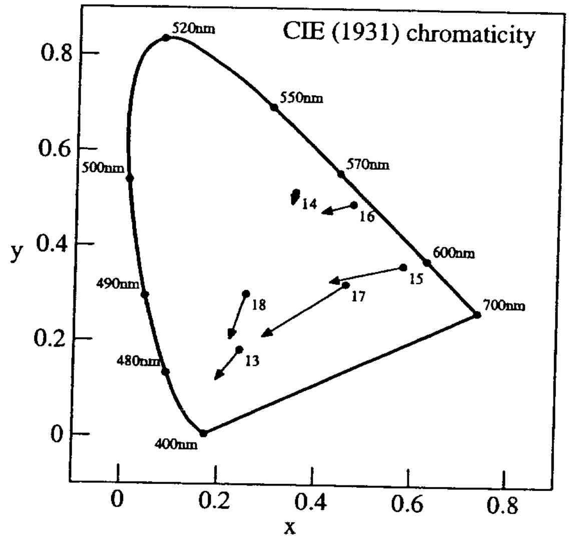

Figure 65: *Philips LTC 0430/61 A, fluorescent, 60f-ps, before tone correction.*

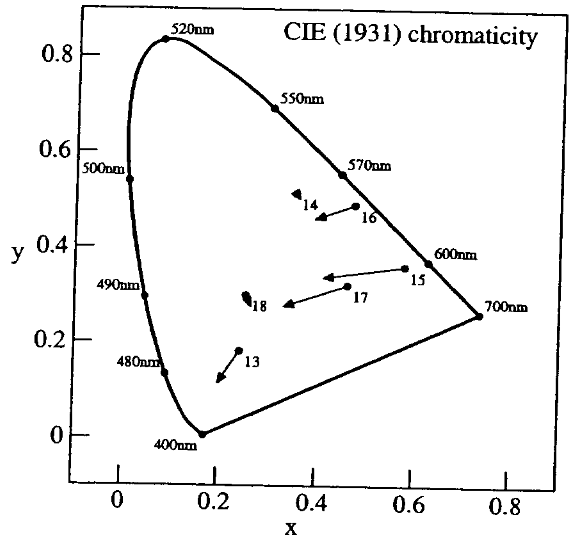

Figure 66: *Philips LTC 0430/61 A, fluorescent, 60f-ps, after tone correction.*

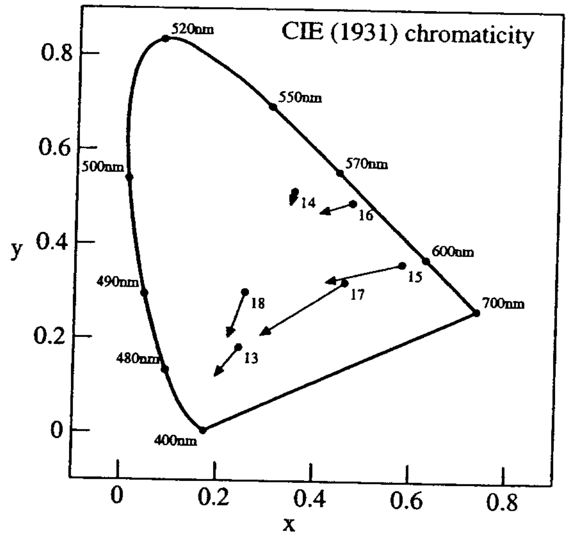

Figure 67: *Philips LTC 0430/61 A, fluorescent, 10f-ps, before tone correction.*

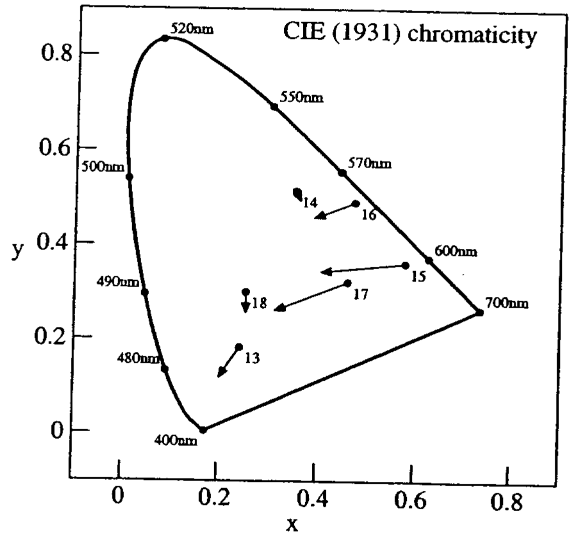

Figure 68: *Philips LTC 0430/61 A, fluorescent, 10f-ps, after tone correction.*

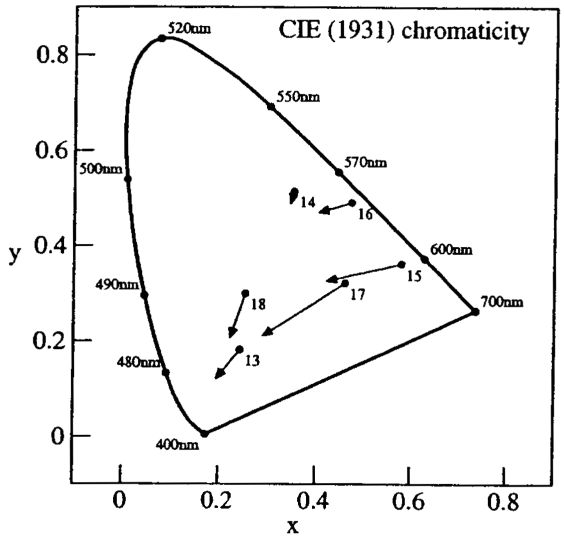

Figure 69: *Philips LTC 0430/61 A, fluorescent, 1fps, before tone correction.*

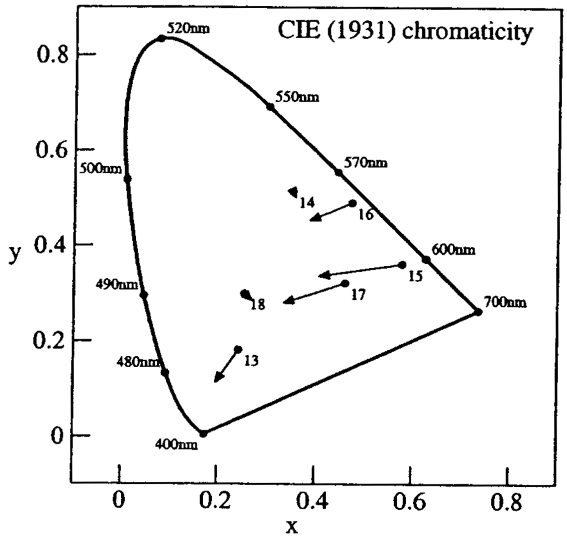

Figure 70: *Philips LTC 0430/61 A, fluorescent, 1fps, after tone correction.*

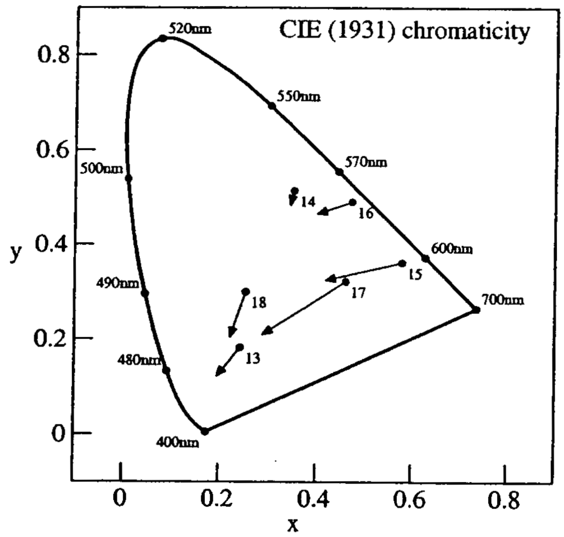

Figure 71: *Philips LTC 0430/61 A, fluorescent, 0.1f-ps, before tone correction.*

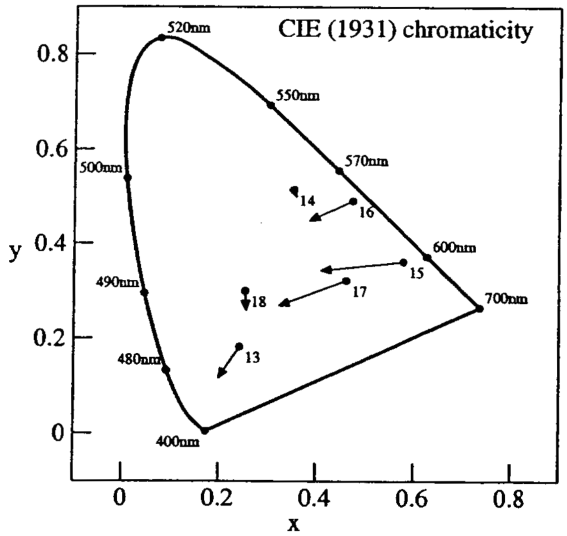

Figure 72: *Philips LTC 0430/61 A, fluorescent, 0.1f-ps, after tone correction.*

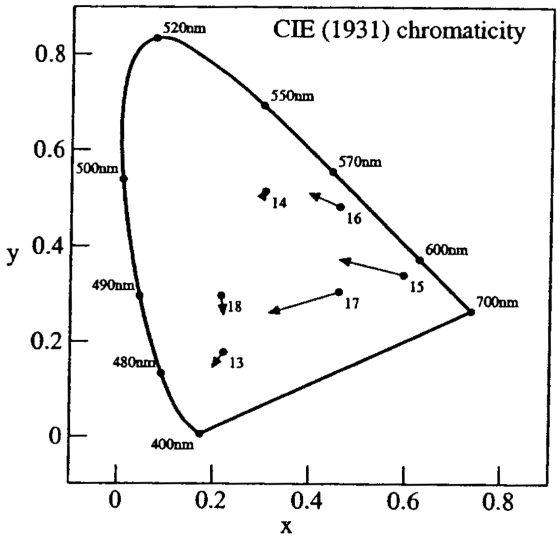

Figure 73: *Philips LTC 0430/61 A, Solux 4700°K, 60fps, before tone correction.*

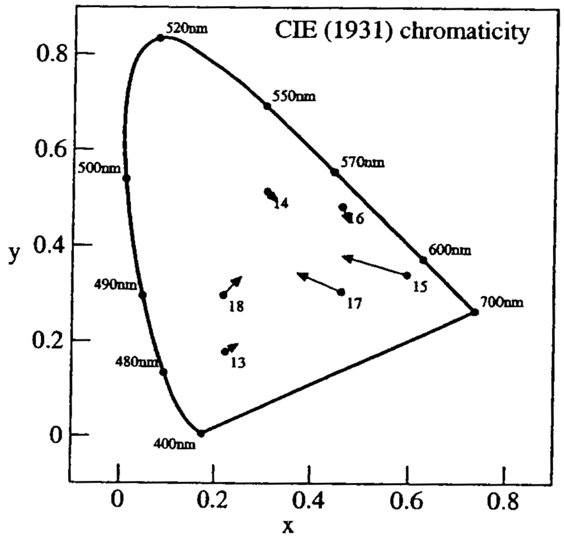

Figure 74: *Philips LTC 0430/61 A, Solux 4700°K, 60fps, after tone correction.*

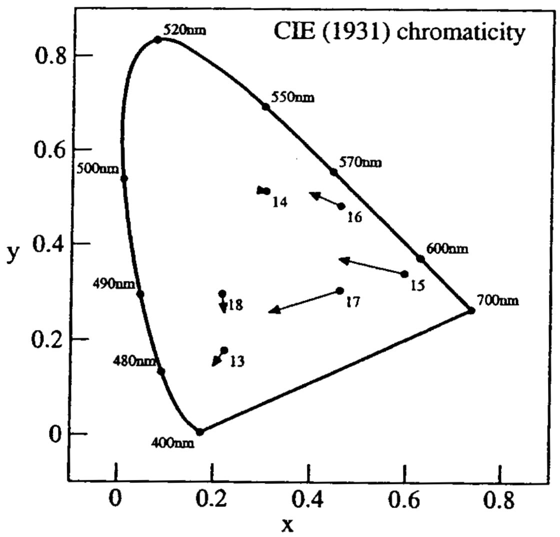

Figure 75: *Philips LTC 0430/61 A, Solux 4700°K, 10fps, before tone correction.*

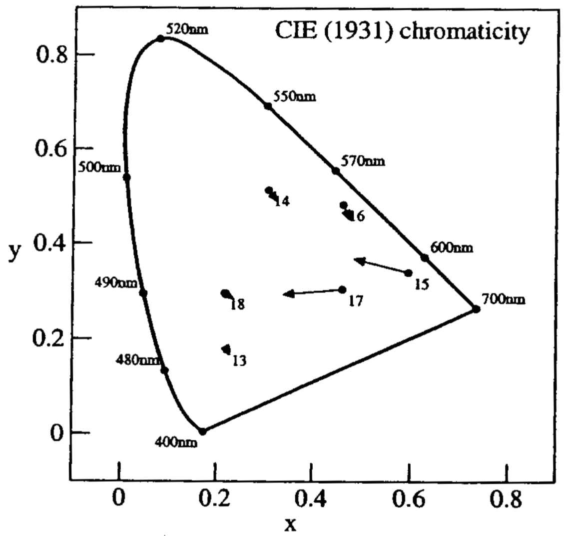

Figure 76: *Philips LTC 0430/61 A, Solux 4700°K, 10fps, after tone correction.*

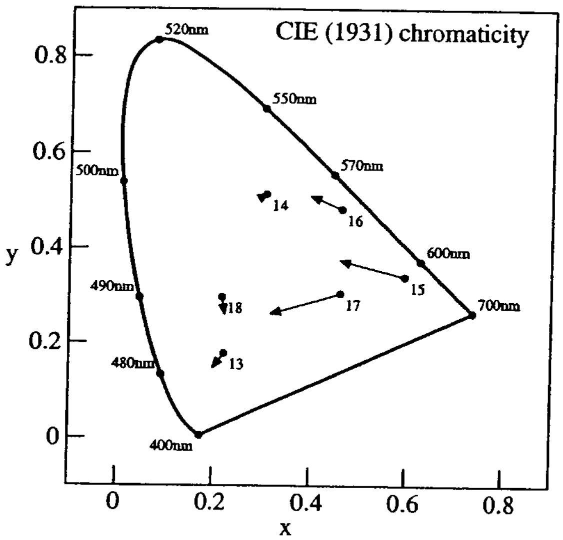

Figure 77: *Philips LTC 0430/61 A, Solux 4700°K, 1fps, before tone correction.*

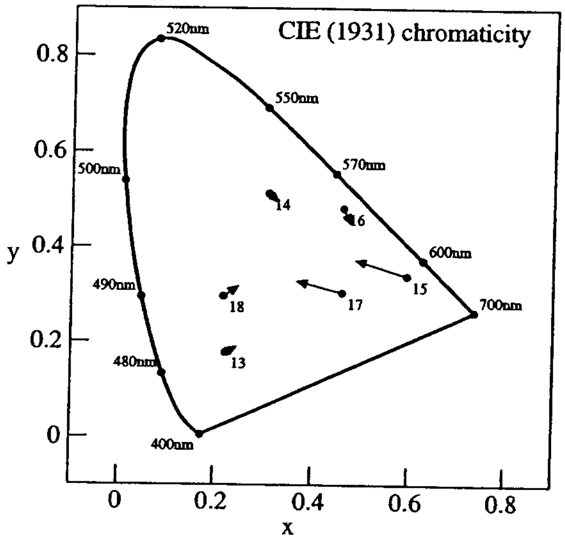

Figure 78: *Philips LTC 0430/61 A, Solux 4700°K, 1fps, after tone correction.*

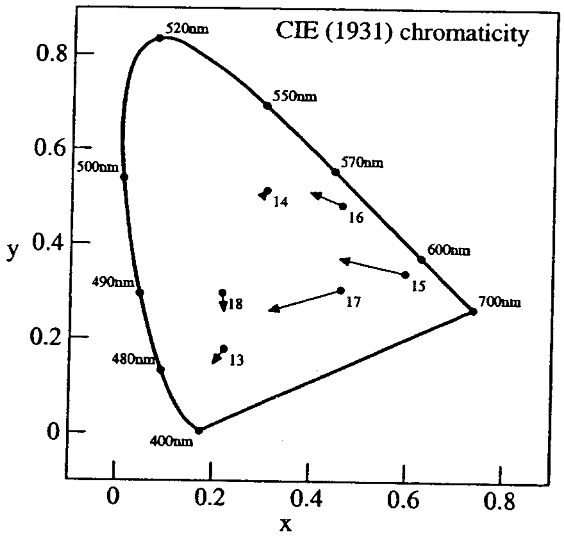

Figure 79: *Philips LTC 0430/61 A, Solux 4700°K, 0.1fps, before tone correction.*

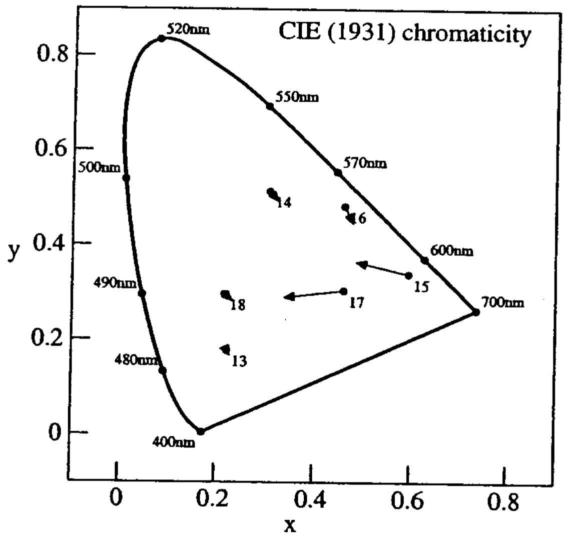

Figure 80: *Philips LTC 0430/61 A, Solux 4700°K, 0.1fps, after tone correction.*

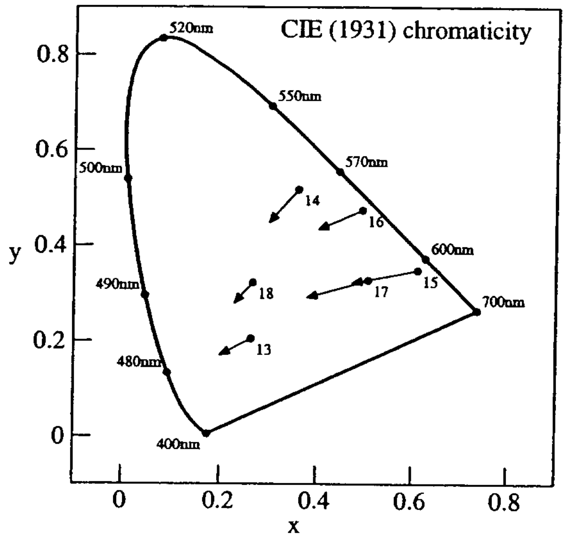

Figure 81: *Panasonic WV-CP460, tungsten and fluorescent, 60fps, before tone correction.*

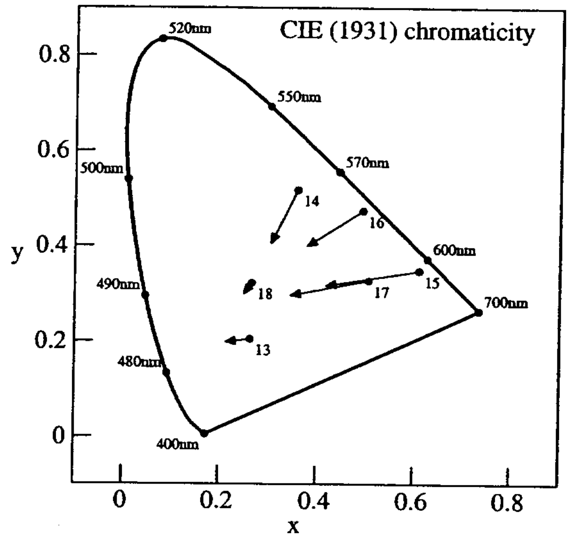

Figure 82: *Panasonic WV-CP460, tungsten and fluorescent, 60fps, after tone correction.*

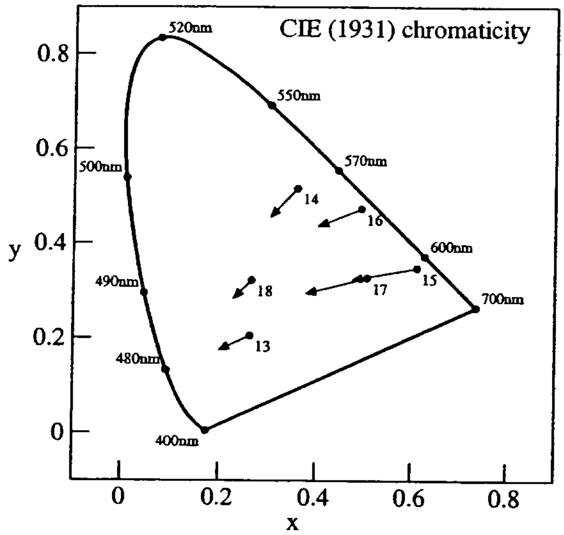

Figure 83: *Panasonic WV-CP460, tungsten and fluorescent, 10fps, before tone correction.*

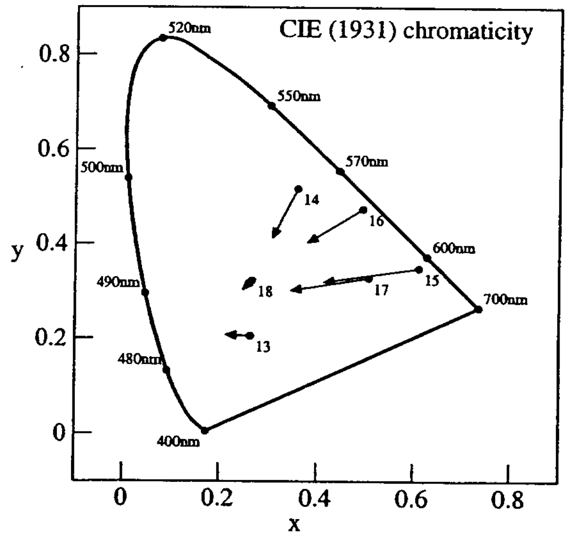

Figure 84: *Panasonic WV-CP460, tungsten and fluorescent, 10fps, after tone correction.*

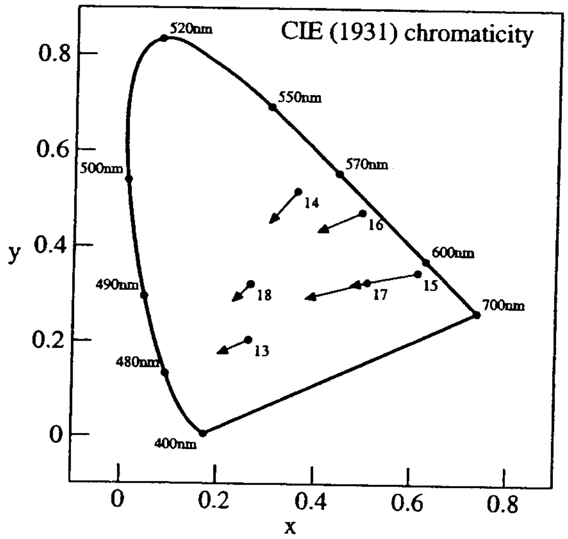

Figure 85: *Panasonic WV-CP460, tungsten and fluorescent, 1fps, before tone correction.*

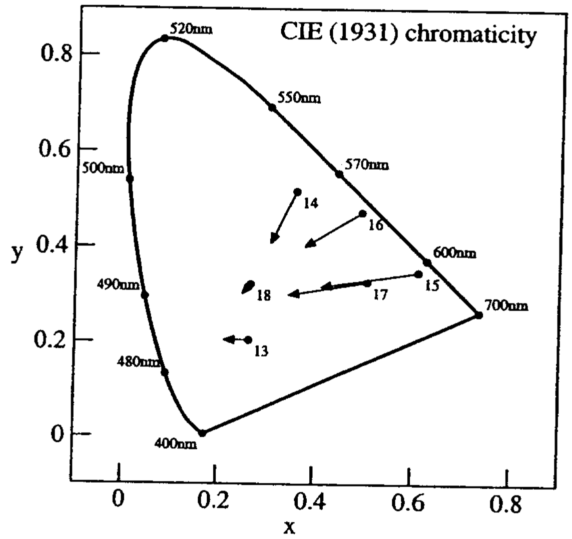

Figure 86: *Panasonic WV-CP460, tungsten and fluorescent, 1fps, after tone correction.*

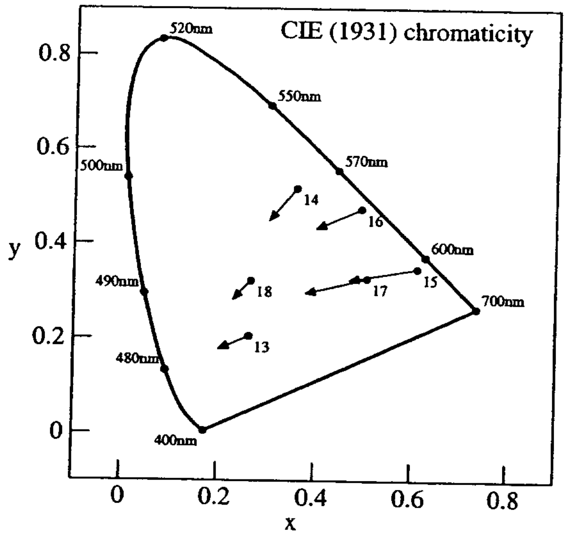

Figure 87: *Panasonic WV-CP460, tungsten and fluorescent, 0.1fps, before tone correction.*

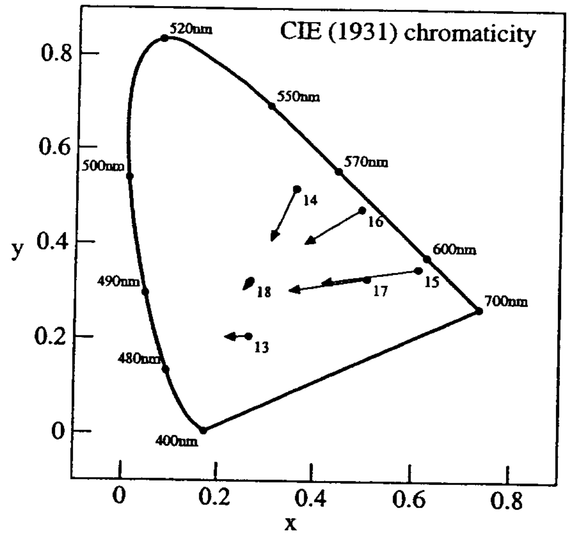

Figure 88: *Panasonic WV-CP460, tungsten and fluorescent, 0.1fps, after tone correction.*

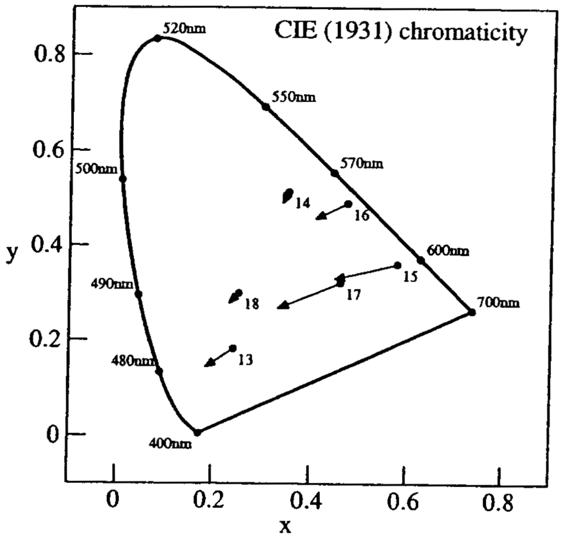

Figure 89: *Panasonic WV-CP460, fluorescent, 60fp-s, before tone correction.*

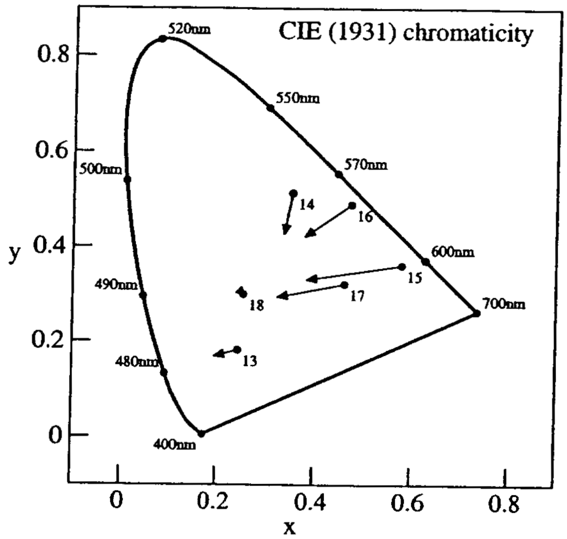

Figure 90: *Panasonic WV-CP460, fluorescent, 60fp-s, after tone correction.*

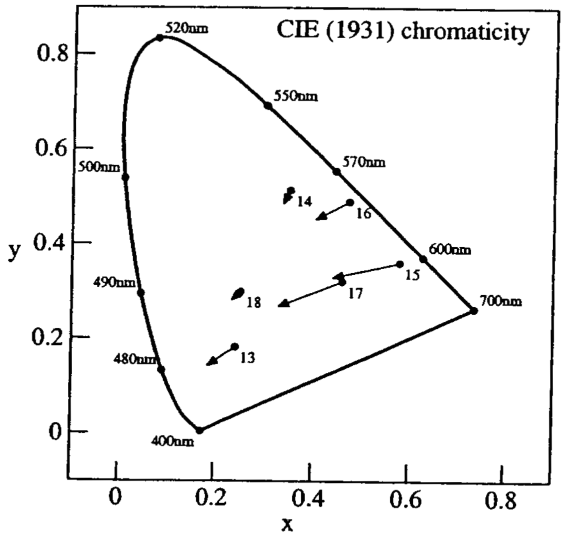

Figure 91: *Panasonic WV-CP460, fluorescent, 10fp-s, before tone correction.*

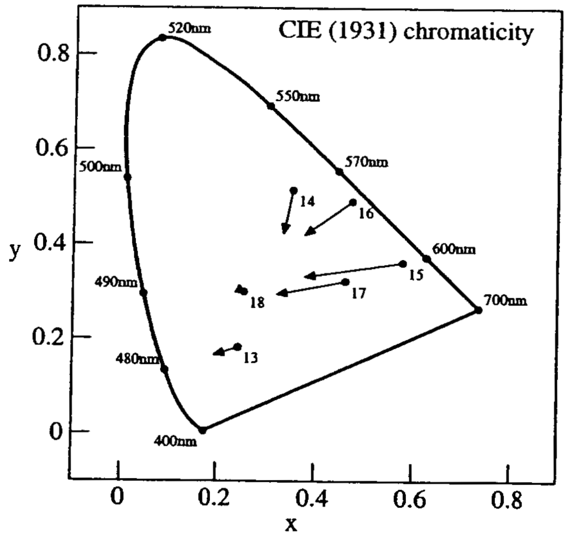

Figure 92: *Panasonic WV-CP460, fluorescent, 10fp-s, after tone correction.*

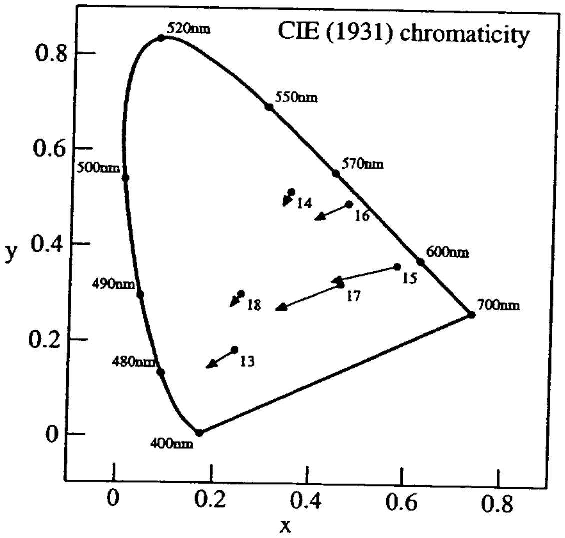

Figure 93: *Panasonic WV-CP460, fluorescent, 1fps, before tone correction.*

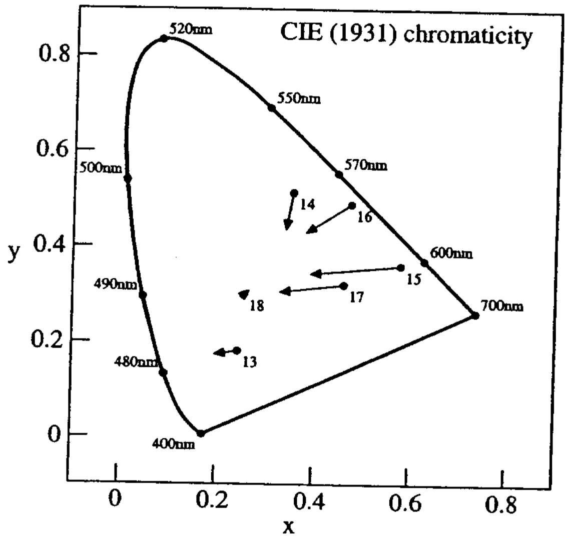

Figure 94: *Panasonic WV-CP460, fluorescent, 1fps, after tone correction.*

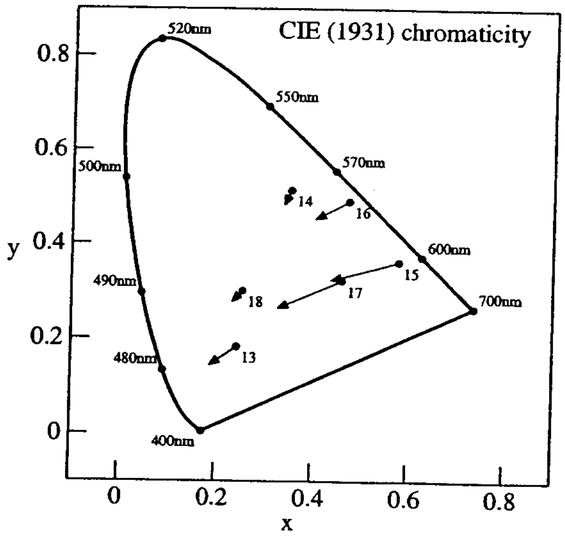

Figure 95: *Panasonic WV-CP460, fluorescent, 0.1f-ps, before tone correction.*

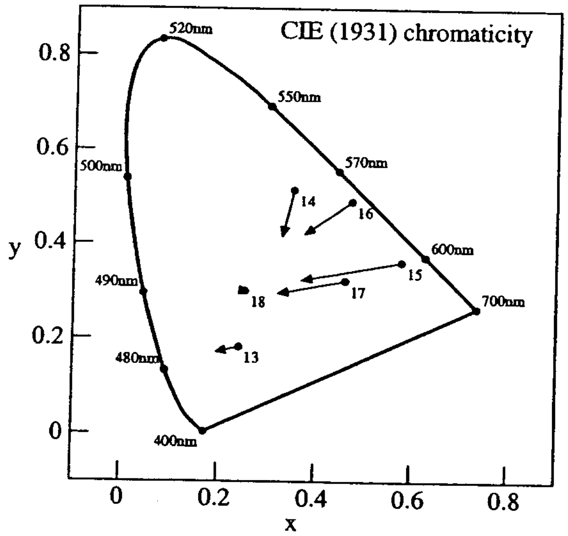

Figure 96: *Panasonic WV-CP460, fluorescent, 0.1f-ps, after tone correction.*

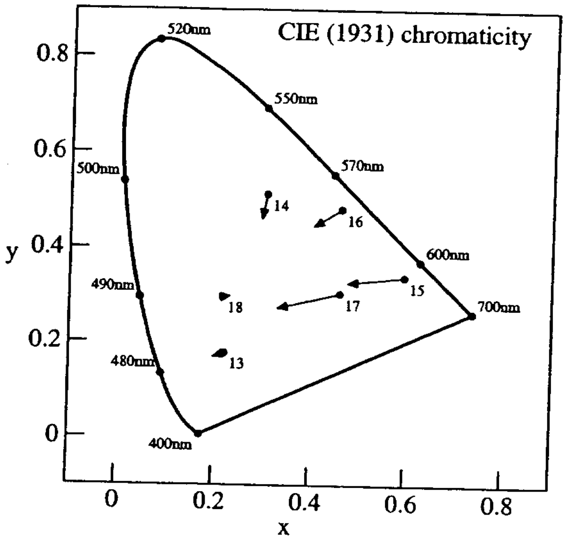

Figure 97: *Panasonic WV-CP460, Solux 4700°K, 60fps, before tone correction.*

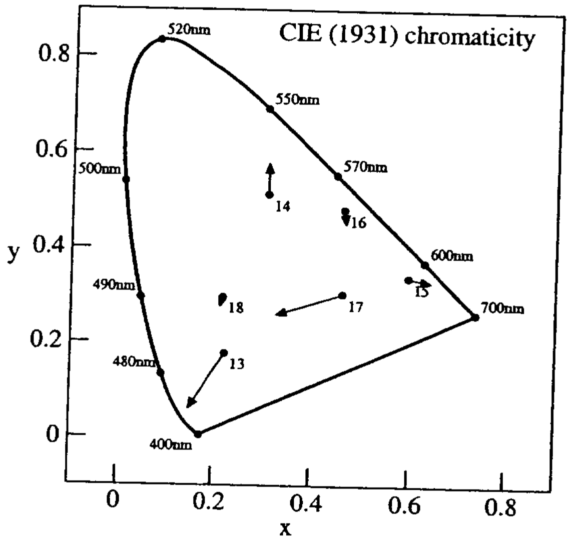

Figure 98: *Panasonic WV-CP460, Solux 4700°K, 60fps, after tone correction.*

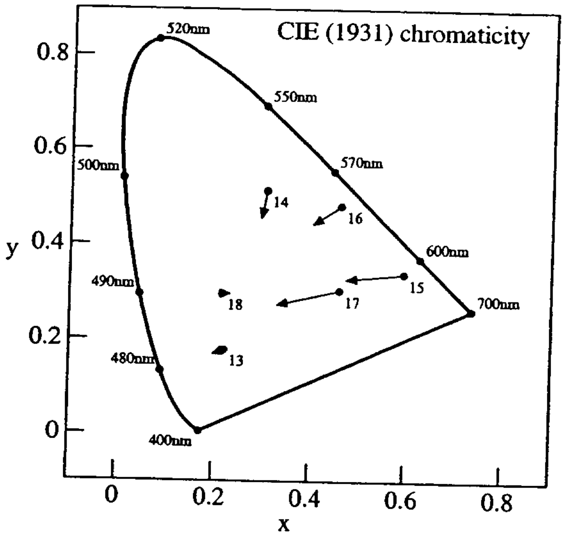

Figure 99: *Panasonic WV-CP460, Solux 4700°K, 10fps, before tone correction.*

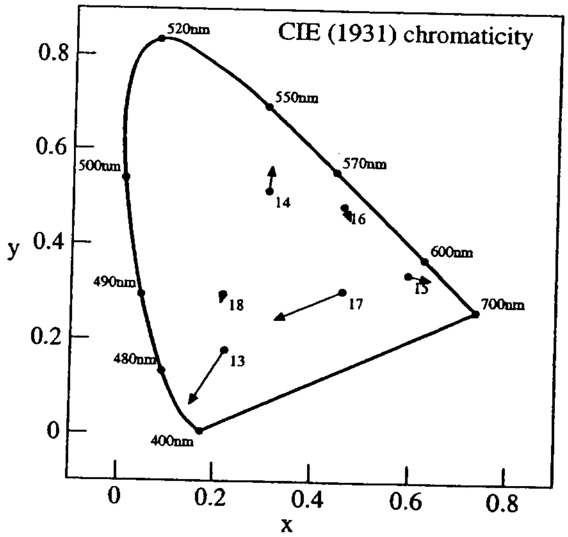

Figure 100: *Panasonic WV-CP460, Solux 4700°K, 10fps, after tone correction.*

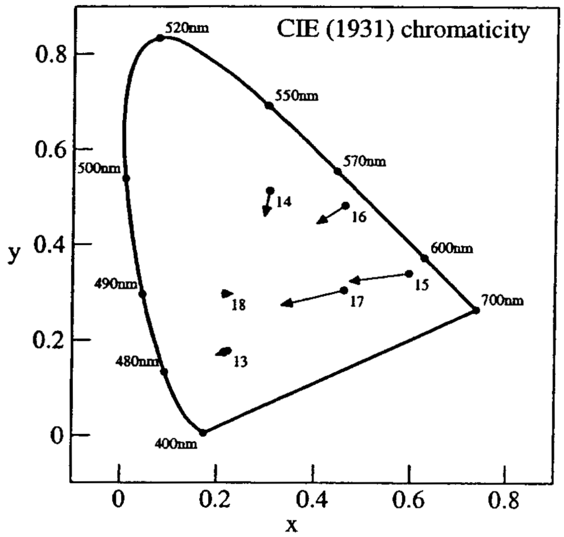

Figure 101: *Panasonic WV-CP460, Solux 4700°K, 1fps, before tone correction.*

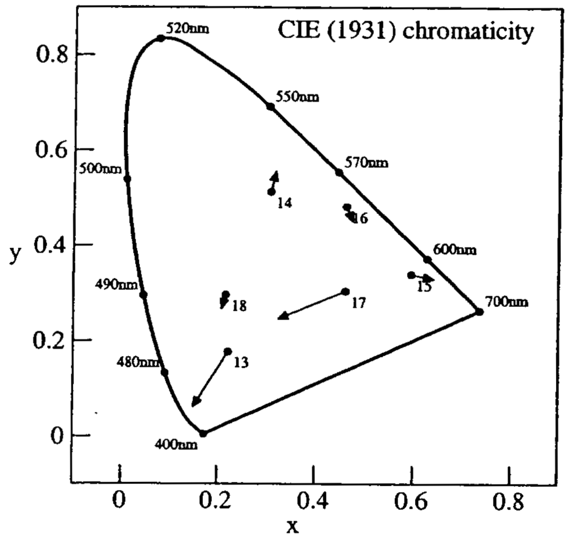

Figure 102: *Panasonic WV-CP460, Solux 4700°K, 1fps, after tone correction.*

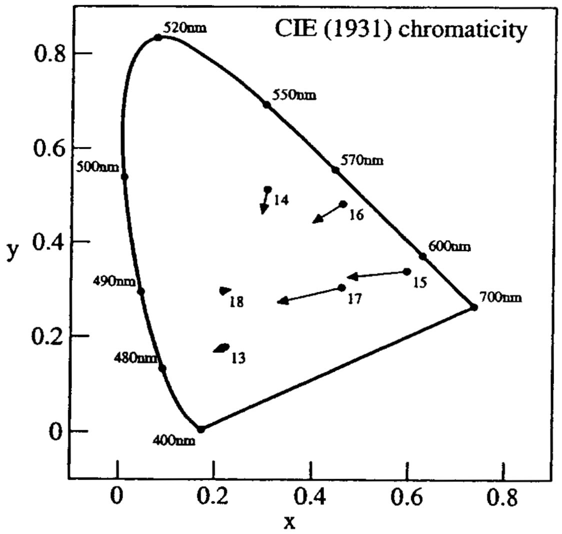

Figure 103: *Panasonic WV-CP460, Solux 4700°K, 0.1fps, before tone correction.*

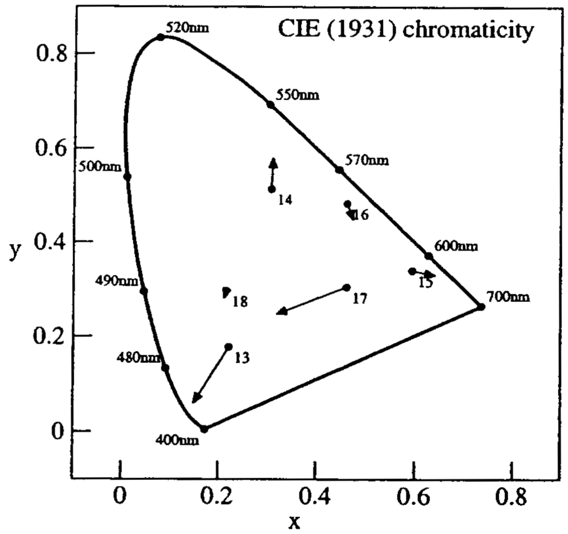

Figure 104: *Panasonic WV-CP460, Solux 4700°K, 0.1fps, after tone correction.*

7 Analysis

The results of the resolution test, presented in Table 5, show that the measured resolution for each camera did not change significantly as the framerate and lighting conditions were varied. The variations that did occur can probably be attributed to degradation of the images caused by the compression artifacts discussed above. Most cameras seem to have approximately equal resolution in both the horizontal and vertical directions, but the Panasonic WV-CP460 seems to have slightly higher resolution in the horizontal direction. The Panasonic camera also seems to have higher overall resolution than the other cameras tested.

The results of the dynamic range test, plotted in Figures 5–32, also showed very little change as the framerate was varied. Each of the color cameras (Philips LTC 0450/21 A, Philips LTC 0430/61 A, and Panasonic WV-CP460) showed relatively good tracking among the three color channels, meaning that the curves for the red, green, and blue signals are nearly parallel. The monochrome cameras show three parallel curves as expected. Each of the color cameras show a shelf at the low density end of the curves. This means that once the scene brightness reaches a certain level, the camera CCD becomes saturated and returns the same gray value even as the brightness increases. The region to the right of the shelf is the usable portion of the curve, so the existence of the shelf reduces the usable density range of the cameras. The curves for the monochrome cameras do not exhibit a shelf, but the range of attainable gray values is significantly smaller than that of the color cameras. The monochrome curves also show local maxima and minima which could make it difficult to use certain methods of tone correction on images captured with these cameras.

The results of the color fidelity test, plotted in Figures 33–104, do not show significant variation as the framerate was changed. However, as the lighting conditions were varied, the magnitude and direction of the errors changed noticeably. The images that underwent tone correction had improved color accuracy for the cyan patch in most cases, and the green patch in some cases. For the other patches, no significant improvements were made, and in some cases the results were worse than in the original images. Visual analysis of the tone corrected images revealed that in some cases, the image had lower contrast than the original and clipping had occurred in some regions. This may indicate that a more sophisticated method of tone correction is needed. Without using measured spectral data, it is not known whether the color reproduction errors can be attributed to the camera or to the coarse approximations used.

8 Conclusions

Tests were performed on seven video cameras to determine the resolution, dynamic range, and color fidelity under different lighting conditions. The resolution results were presented as a table of horizontal and vertical resolution values measured in linepairs/mm. The dynamic range results were plotted as brightness values vs. target density. The color fidelity test results were presented graphically showing how far the measured values deviated from the predicted values in CIE (1931) color space. The tone correction applied to the video did not improve the accuracy of the color and actually made some frames appear worse to a human observer. The accuracy of the color fidelity test cannot be fully trusted because of the coarse approximations used in the calculations, but could be improved with the use of additional test equipment.

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Surveillance Tools for Safer Schools

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Appendix C

The Audio Surveillance Discriminator

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Submitted
January 30, 2002

THE AUDIO SURVEILLANCE DISCRIMINATOR

By

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ABSTRACT

This paper explores sound recognition using small-scale digital signal processing (DSP). The experimental hardware platform used is the Motorola DSP56307EVM evaluation board. The device conditions an input signal and converts the signal from the time to the frequency domains. The unique frequency spectrum that identifies the target sounds is stored as weighing factors. A recognition engine determines if a sound matches a previously trained one within the weighing factors. Upon detection of a target sound, the signal from the device toggles the state of an LED on the evaluation board, which serves as an indicator of performance on this prototype. The project utilizes a number of standard mathematical manipulations to extract the pertinent information such as Hamming windowing; fast Fourier transforms, and back propagation.

PREFACE

The aim of this project was to detect sounds such as gunfire, breaking glass, and screams in the presence of background noises. The intended environment for this device is in public schools. The last few years have shown an increase in extremely violent behavior in schools. Many of our high schools now sport metal-detectors at entrances and surveillance cameras in numerous halls. Lack of respect and violent acts perpetrated on teachers and school property has brought us to this point where we must take unusual methods to make sure that school will still be a safer place

TABLE OF CONTENTS

ABSTRACT....ii
PREFACE....iii
LIST OF FIGURES....v
ACKNOWLEDGMENTS.... vi
I.- Introduction.... 1
II - Project Goals....2
Discriminate unusual noises from normal background 2
Prove small-scale DSP technology possibilities 2
III - Gunfire Characteristics....3
Characteristics of tested rounds 3
IV - Sampling methods. 5
Gunfire sounds 5
Student sounds 5
Recording methods 5
V - Audio analysis and modeling....7
Audio Characteristics 7
Neural Networking 9
VI - Implementation....12
Test Platform 12
Windowing 12
Spectrum Analysis and target detection 13
Assembly Language Programming 13
VII - Operations....14
Training 14
Detection 17
VIII - Conclusions and recommendations....19
Conclusions 19
Recommendations 19
Reference: 21
Appendix 23
Assembly Code....23
Matlab....43

LIST OF FIGURES

Number	*Page*
1 – Typical Gunfire audio profiles	7
2 – Typical Student audio profiles	8
3 – Partial Message	9
4 - Simplified Neural Network	10
5 – Averaged gunfire and student samples	12

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I.- INTRODUCTION

Frequency spectrum analysis is at the heart of this application of signal processing. Spectrum analysis is performed daily, unknowingly, and for the most part no attention is made to the benefits it brings. People talk to one another and recognize the unique characteristics of each other's voices. Regional dialects and accents mark us as natives of our country. Citizens of other lands arrive here and learn to recognize and speak a new and different language. Speech patterns contain unique frequency characteristics that identify us as individuals. This simple task of listening is frequency spectrum analysis, but in many ways, the process of learning is just this. When presented with something that is unfamiliar, most people will reason that it could be similar to something already known. Similarly, the device that will have to recognize specific harmonic patterns has to be trained to recognize it. If the target sound is then embedded into background noise, the device should still be able to pick the harmonic pattern out of the noise. The unique characteristics of gunshots are similar to spoken words in that both have specific harmonic patterns and frequency spectrums. In times past, detectors capable of this type of pattern recognition have normally been designed to run on powerful workstations or mainframe type computers [20]. Small-scale digital signal processing (DSP) hardware is currently being improved daily and has reached a point where this type of application is possible. This paper seeks to chronicle the design and implementation of a DSP sound recognition application. Neural networking is used as a recognition engine in this work. In detailing the steps taken to implement this study mathematical methods will be translated in layman's terms, thus unraveling the mystery for those interested.

II - PROJECT GOALS

Discriminate unusual noises from normal background

Schools while in daytime operations are the source of many impulse type sounds. Normal sounds like locker doors slamming as students retrieve books and go to classes, occasional screaming as excited students joke with one another are for the most part a normal part of the average school day. The device will have to be able to determine the unique differences between normal and abnormal sounds like gunfire within the context of normal occurring background noise.

Prove small-scale DSP technology possibilities

Most sound recognition applications have always been implemented on mainframe to microcomputer platforms. Some small scale and embedded systems are running on DSP sized platforms. Memory space and processor limitations have for the most part limited DSP sound recognition to relatively simple applications such as voice recognition in cellular phones. Some cellular applications are able to recognize simple word commands such "call home" where this command has been repeated numerous times. The phone is able detect only the owners voice for the most part and then only limited to a few commands [3]. This project will prove that relatively inexpensive DSP chips can be used for sound recognition applications of a more complex nature than voice recognition.

III - GUNFIRE CHARACTERISTICS

Characteristics of tested rounds

Handguns used to gather the sound samples used in the implementation of this project included the Glock models 17 (9mm), 21 (45 caliber), and 23 (40 caliber), along with the Smith & Wesson model 15 (38 caliber). The muzzle velocities varied from 1100 to 850 ft/sec. The various muzzle velocities accounted for some of the differences in sound. The 9mm and 38 caliber rounds were nearly the same mass at 124 and 129 grains respectively. Their muzzle velocities differed by 170 fps. The 38 caliber exhibited a lower frequency profile than the faster 9mm round. All rounds exceeded 120 dB in sound pressure at a distance of roughly 25 feet. The sounds can best be described as ranging from a sharp crack to a deafening boom.

Once a round has left the muzzle of the weapon, its momentum is acted upon by the surrounding air cylinder using the following approximation. [21]

$$dP/dt = \frac{Kr\pi d^2}{4} \bullet v^2$$

where:

P = Momentum of Projectile
K = the constant for generally unknown forces acting upon the bullet such as barometric pressure, shape of the bullet and the like.
r = the density of air
d = the diameter of the bullet
v = the velocity

This force accounts to some extent the cause of the sound wave that proceeds from the muzzle of the gun. There are two components to the sound. The pressure exerted by the rapidly expanding gases behind the bullet and the sonic wave the bullet produces as it pushes through the air. The sonic component of the bullet is directly proportional to its velocity. Slower rounds such at the 38 caliber do not exceed the speed of sound and sound very different than faster rounds such as the 40 caliber or 9mm.

IV - SAMPLING METHODS.

Gunfire sounds

All sample gunfire sounds were gathered in an indoor range located at the Indiana Law Enforcement Academy. The range has stalls for about a dozen shooters, with the downrange target area about 50 feet away. The room is constructed of concrete block with paper fiber dropped ceiling panels. The bullet stop at the end of the range consisted of 4-5 parallel heavy gauge steel plates running the width of the room, angled toward a large sand pit at the floor and rear of the range. The microphone was positioned about 25 feet from the shooter approximately 8 feet above the ground. The microphone was channeled through a 20 dB attenuation cable to help insure quality full range recording with a minimum of overdriven distortion. Each handgun was fired 4-5 times, about one second apart. Solid jacket and hollow point rounds were used during the recording session. An echo effect of the solid walls elongated the gunfire sounds to some extent.

Student sounds

The student sounds were recorded at Plainfield Community Middle school during the morning after the buses dropped off around 400 students within a 5 minute period. Recorded samples were gathered in a large main hall with tiled floors with walls lined with numerous lockers. Additional samples were taken in halls where the floors were covered with carpeting. There was an audible echo noted in the large halls with a somewhat muted level in the carpeted areas. Student sounds ranged from tennis shoe squeaking on tile floors, locker slams, books being dropped loudly, and the normal conversations of excited students. The 20 dB attenuation cable was not needed during the recording session at the school.

Recording methods

A Sony model R37 mini-disk recorder was used to obtain the gunfire and student samples. A Core Sound Binaural microphone set with battery box and selectable bass roll off filter was used to obtain both categories of samples. The high quality stereo microphone is designed for recording of high impact sound.

Recordings from both the school and shooting range were transferred to '.wav' files on the computer thru a Yamaha DS1 based sound card using Total Recorder software. The sampling rate on the mini-disk recorder was 44.1 kHz. The same sampling rate was used to transfer the sounds to the computer. Each gunfire sample was separated into a number of different time durations ranging from 0.020 seconds to one second.

V - AUDIO ANALYSIS AND MODELING

Audio Characteristics

Over 60 sound samples were examined using Matlab version 5.0. The sound files were read in and evaluated using the power spectral density and spectrogram functions within Matlab. Sample differences between solid and hollow point gunfire showed slight differences in frequency profiles. The differences were not consistent between the solid and hollow point rounds of the differing handguns. Initial study was devoted to determining if high frequency components uniquely identified gunfire from all other sounds. Time domain profiles of gunfire samples (Figure 1) show an intense pulse of sound having a duration of about 50 milliseconds.

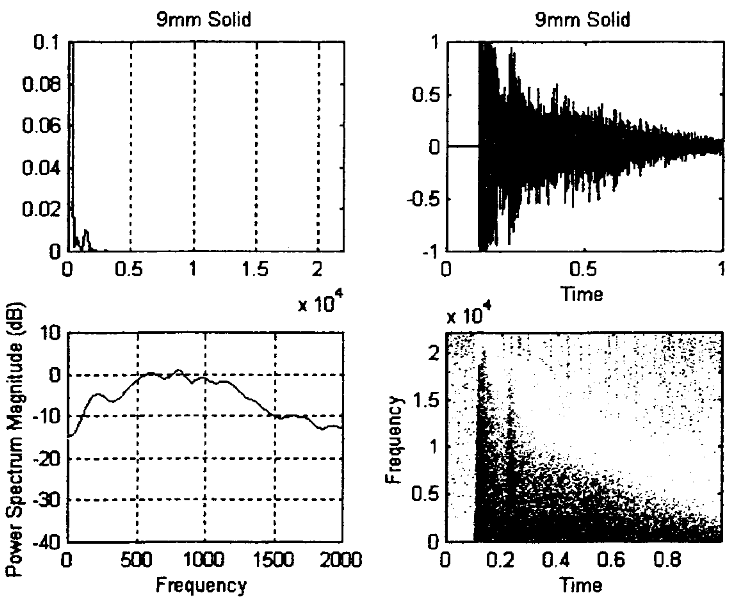

Figure 1 – Typical Gunfire audio characteristics

Spectrograms taken of gunfire revealed that the initial 20 milliseconds or so contained all frequency harmonics from 0 to 20kHz. Power spectral density examination revealed however that the bulk of magnitude was centered around 800 to 1000 hz. Harmonics above 2000 hz were noted but due the reduced amplitude they amounted to white noise. Student sounds (figure 2) exhibited a markedly different profile.

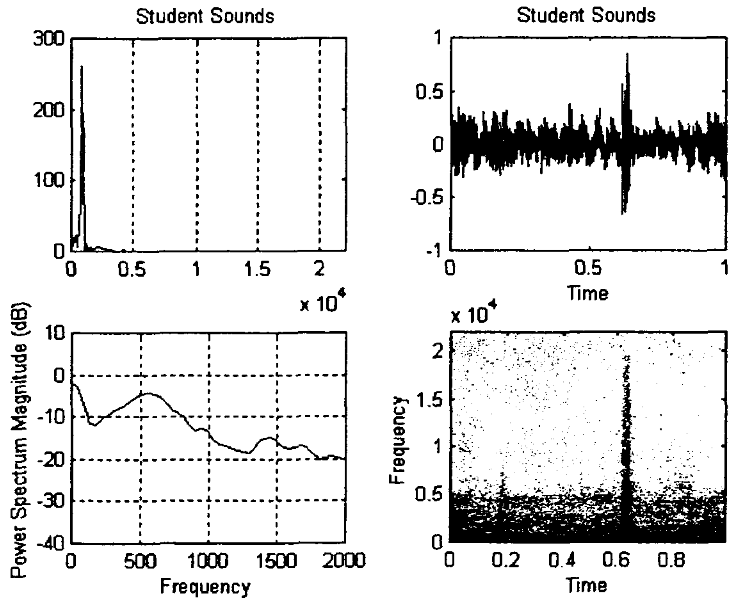

Figure 2 – Typical Student audio characteristics

They were comprised of a number of sounds. Students talking, locker slamming shut, impact sounds of books being dropped and other sounds associated with normal school activities. Spectrograms revealed that the student sounds were rich in the harmonics that are consistent with speech. Power spectral density showed that most of the sound pressure for student samples centered around 100-200 hz.

Spectral analysis revealed that the key to the unique tonal qualities were the lower frequency components. The 38 caliber samples averaged lower frequency profile from the other weapons. The larger caliber samples were consistent with each other and maintained a very similar profile from one sample to another. The 38 caliber samples' frequency profile stayed in the same range, but each round was different from the next. The major difference between the 38 and other handguns was that it had the shortest barrel length at 2 inches. The larger handguns all had barrels of at least 4 inches.

Neural Networking

If given the following (figure 3) illustration,

Figure 3 – Partial message

our minds have the ability to determine that the picture is the top half of the message 'This is a text message'. The ability to recognize or 'fill in' a pattern of letters even though the bottom half is missing serves a simple explanation for the process of neural networking. Human minds are a complex form of neural networks that are constantly learning new skills and patterns. The audio surveillance system uses this type of recognition to determine if a sample sound is gunfire or something else.

The neural network is based on the Bayesian theory of summing probabilities, This process known as back propagation works on the principal of summing up inputs multiplied by error factors. Each input to the network is assigned a certain weight or magnitude of importance. The weights are optimized or adjusted through repetitive iterations until the end sum that the targeted patterns are 'recognized' from different samples.

In the following illustration a simple neural net is explained:

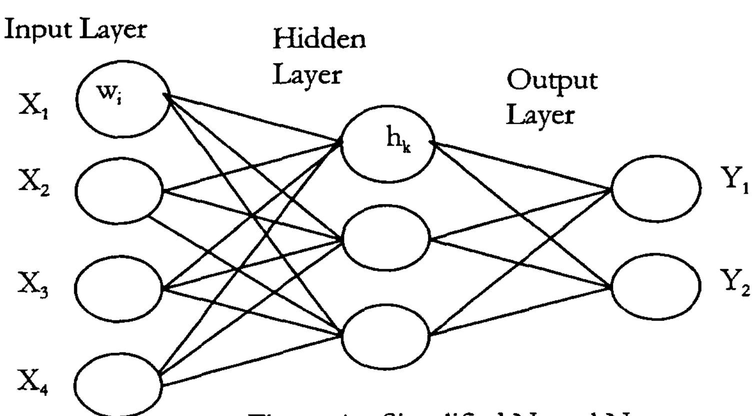

Figure 4 – Simplified Neural Net

X_1 through X_4 are inputs to the system. If we look at just one of the outputs, for example Y_1 It is described mathematically thus:

$$h_k = \frac{1}{1 + e^{-\left(\sum_{i=1}^{n} (w_i x_i + z_k)\right)}}$$

Where

w_i = *the weighing factor*

x_i = *the input signal component*

$_i$ = *the ordinal input node*

z = *an initial bias applied to the hidden node.*

h_k = *the hidden layer probability. at this particular node*

$_k$ = *the ordinal hidden node*

$Y_1$is then determined in a similar fashion to the hidden nodes:

$$Y_1 = \frac{1}{1 + e^{-\left(\sum_{k=1}^{n} (w_k h_k + b_1)\right)}}$$

Where

w_k = *the weighing factor*

h_k = *the hidden node component*

$_k$ = *the ordinal hidden node*

b_1 = *an initial bias applied to the Y_1 output node.*

Y_1 represents the probability that the sum of the errors of all the inputs and all hidden nodes is the target sound for that output node. Neural nets are flexible enough that any number of outputs can be trained into the system through the optimization of weighing factors. The only limiting factor to the neural net design is the size of memory, processor speed and the performance desired out of the system. At least visually, it is conceivable to see that if just one of the inputs were significant to a specific output it would likely have a larger weighing factor. It is important to note that both location of the frequency component and its relative magnitude are important in this application. If a net is trained to recognize a sine wave centered on zero amplitude, it may not recognize that same pattern if it has a DC offset of +1 volts. This is because its weights are optimized for signals centered at zero. The following profiles show averaged samples of gunfire and students.(figure 5).

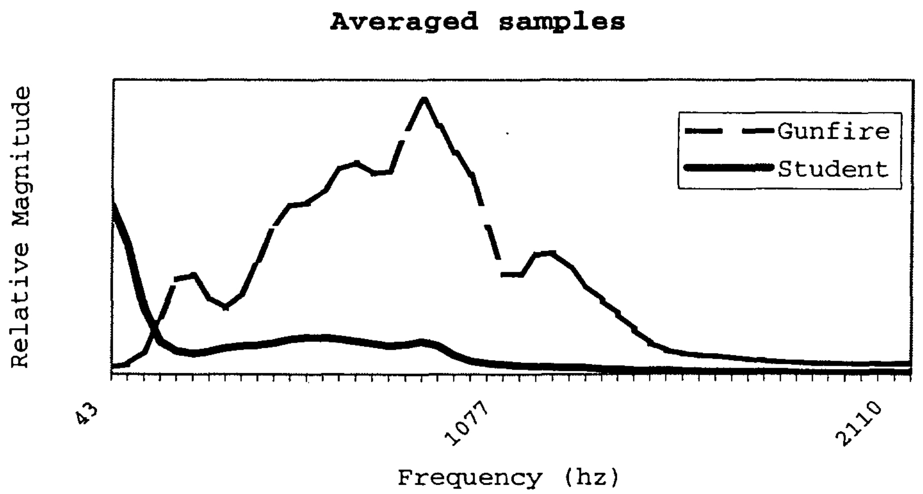

Figure 5 Averaged gunfire and student samples

VI - IMPLEMENTATION

Test Platform

The test evaluation platform for the project is the Motorola general purpose model DSP56307EVM evaluation board. The DSP56307 evaluation module from Motorola met most of the requirements necessary for the design. It has very fast processing, ample onboard memory, and separate on chip processing for DSP filtering of the input signal. It can easily be connected to most current computers. Initially the DSP56009EVM, another Motorola board, was evaluated. It turned out to be fast enough, but had limited onboard memory, and needed for two separate power supplies. Texas Instruments line of DSP technology had many attributes that could have easily met the design criteria but fell short in standard features. Texas Instruments website had an enormous amount of information on implementing a sound recognition engine using their hardware. The enormity of tested solutions was almost enough to make them the preferred platform alone. The DSP56307 evaluation module from Motorola however had an expandable memory feature, less complicated hardware interface, and a more complete package.

Windowing

Hamming type windowing was used for this application. The effect of the windowing was to reduce the amount of information that the FFT had to process.[22] The smoothing effect reduced the amount of noise that the FFT tended to amplify. The Hamming calculation method is outlined below:

$$w_n = 0.56 - 0.46 \bullet \cos(n2\pi / N)$$

where

w_n = amplitude of the input sample
n = the number of the sample being calculated
N = the size of the FFT being calculated

N

Spectrum Analysis and target detection

The purpose of this section is to convert the analog signal to the frequency domain by taking the fast Fourier transform of the signal. These unique characteristics are stored to a block of memory to be used as a database containing target sound weighing factors. The weighting factors are needed for the neural networking algorithms. When the device is monitoring background noise the frequency spectrum peaks will be passed through the neural network where the algebraic sum of the background noise and the weighing factors are combined. The output of this stage consists of an indication of whether the target sound is detected or not. If the output of the detection stage is positive, meaning the desired target sound is detected; the state of an LED on the board is toggled.

Assembly Language Programming

The primary development language for the DSP56307EVM is Assembly. The language itself is compact and executes quickly. A wealth of pre-written routines for FFTs and filtering are available from the Motorola website and other sites on the net. Two sample programs that were included with the EVM were adapted for the purposes of this project. The neural net implementation in assembly was performed by duplicating the detection process from Batchnet. The executable code was compiled into Motorola's COFF format for uploading into the EVM via serial cable.

VII - OPERATIONS

Training

Choosing samples

The frequency spectral characteristics for 41 gunshots and 21 student background noise samples were extracted to '.wav' files. The training set used in this project consisted of 31 gunfire and 15 student samples, randomly selected. Ideally, the training set should come from a wide variety of the intended target sounds. Some problems with detection can occur if the targeted sounds are very specific. One example that was very clear from the aspect of this project turned out to be the 38 caliber samples. The 38 caliber samples shared some similar characteristics with the other gunfire samples. They were different enough from the others, however, that if only 38 caliber samples had been used in the training set, it would have been very likely that the neural net would ignore the other gunfire samples. Similarly, if only locker slams were used as student samples, conceivably tennis shoes squeaking on the floor could be wrongly interpreted. The remaining 16 sound (those not used for training the net) samples were withheld to use as a test of the final weighing factors.

Matlab modeling

Matlab was used to generate a power spectral density of all the samples. The first 50 frequency components were output to text files specially formatted for use as input to the Batchnet software. Because the Motorola 56307 chip is integer based and is only able to store floating point values that range between –1 and 1, care must be taken to insure that none of the training set sample values exceed this range. After the power spectral density was output, each sample was divided by two.

<u>Batchnet</u>

Batchnet is a neural network evaluation tool. The software reads in input in the form of frequency components output by the power spectral density analysis by Matlab. Batchnet's outputs a number of files that detail the errors, weighing factors, and test results. The neural net model used for this application used 50 input nodes with 10 hidden layer nodes followed by 2 outputs. The outputs matched the number of category samples either gunfire or student sound.

The software error output showed that the two categories of samples were very different from each other. Under simulation using the training set of 31 gunshots and 15 student sounds, the system could predict with greater than 90 percent accuracy that a sample sound was either a gunshot or student sound. (table 1)

Test Run	Prob. of Gunfire	Prob. Of Student	Sample Num.
0	0.956	0.044	1001
1	0.986	0.013	1002
2	0.983	0.017	1003
3	0.988	0.012	1004
4	0.954	0.047	1005
5	0.960	0.040	1006
6	0.941	0.058	1007
7	0.993	0.007	1008
8	0.990	0.010	1009
9	0.996	0.004	1010
10	0.996	0.004	1011
11	0.995	0.005	1012
12	0.992	0.008	1013
13	0.990	0.010	1014
14	0.992	0.008	1015
15	0.991	0.009	1016
16	0.978	0.022	1017
17	0.975	0.025	1018
18	0.988	0.012	1019
19	0.953	0.047	1020
20	0.988	0.012	1021
21	0.976	0.024	1022
22	0.988	0.012	1023

23	0.980	0.020	1024
24	0.989	0.011	1025
25	0.995	0.005	1026
26	0.990	0.011	1027
27	0.994	0.006	1028
28	0.992	0.008	1029
29	0.993	0.007	1030
30	0.991	0.009	1031
31	0.002	0.998	101
32	0.063	0.937	102
33	0.009	0.991	103
34	0.022	0.977	104
35	0.057	0.943	105
36	0.023	0.977	106
37	0.038	0.962	107
38	0.043	0.957	108
39	0.019	0.981	109
40	0.001	0.999	110
41	0.012	0.988	111
42	0.050	0.951	112
43	0.008	0.992	113
44	0.019	0.981	114
45	0.019	0.981	115

Table 1 – Neural Net training results

When using the remaining 16 gunshot and student samples to test the system's ability to discern sounds not previously used in training, the system was able to again predict with greater than 90 percent accuracy that the test sample was either a gunshot or a student sound. (table 2)

Test Run	Prob. of Gunfire	Prob. Of Student	Sample Num.
0	0.987	0.013	2001
1	0.970	0.030	2002
2	0.994	0.007	2003
3	0.997	0.003	2004
4	0.992	0.008	2005
5	0.992	0.008	2006
6	0.982	0.018	2007

7	0.971	0.029	2008
8	0.990	0.011	2009
9	0.993	0.008	2010
10	0.013	0.987	201
11	0.022	0.978	202
12	0.019	0.981	203
13	0.024	0.977	204
14	0.018	0.982	205
15	0.020	0.980	206

Table 2 – Neural Net Testing

Weighing factors

The weighing factors contain the algebraic memory of the training samples. Batchnet runs iterative processing on the training set by rerunning the samples over and over by a set parameter, reducing the differences between actual and desired output. Once the set number of interations is complete, Batchnet outputs the optimized weights to a text file. The optimized weight values could exceed the limits of the 56307 chips floating point storage ability, and need to be scaled back by 10 to insure they would fit into the memory spaces of the evaluation board. After scaling, the weights were converted to an assembly language equivalent that could be loaded into the evaluation board.

Detection

Sample sound creations

It would be difficult if not frightening to test this device under real life conditions. It would mean firing weapons in student hallways with the students going about there normal business. In order to simulate real life conditions, a test recording of gunfire mixed with student sound is passed through the system via the line input to the evaluation board. The sample recording of students and gunfire is constructed by mixing a three minute segment of four sample gunfire sounds mixed with the student noises using Quartz Studio. The mixed sounds are then re-recorded onto minidisk. The minidisk line output was input to the evaluation board's left line input.

Uploading to EVM

Domain Technologies provides a development system with the EVM board. Once an executable object is compiled using Motorola's assembler/linker software, the file can be loaded in the EVM board memory by Domain Technologies terminal emulator software. The system is then executes and continues to monitor the line input on the EVM.

Detection

While monitoring, the program fills up an input buffer. After reaching 1024 samples, a Hamming window calculation is performed on the input buffer and the samples are written back to a separate buffer location. The FFT calculation uses the output of the Hamming window calculation as its input. The FFT's output is fed back to its input location, one sample at a time. After the FFT has completed its calculation, the neural net scans through the first 50 locations of the FFT output and determines the probability that the input contains gunfire signals or not. If the output of the net is a probability of at least 85 percent chance of being a gunshot, then it toggles the state on an LED on the EVM board. The program then returns to the input routine and repeats the process.

VIII - CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The project was a success in that it did discriminate gunfire from student background sounds. It showed that neural networking could be adapted to work reliably on the 56307 platform. Since the basic output of neural networks is a recognized pattern it should be adaptable for a variety of recognition applications. While this application explored the use of the technology for detecting gunfire sounds in student environments, it could just as easily be adapted for a variety of tasks. Here are a three possible uses:

1. Security companies could use this type of system to monitor buildings remotely by training in samples of footsteps, breaking glass or other noises that might alert them to possible criminal activity.

2. Certain frequencies are noted in mechanical equipment when it begins to fail. Examples would include fan bearings. They exhibit high pitched sounds after they have failed. Equipment makes other noises before failure. An early alert of impending failure could save thousands of dollars in down time.

3. A medical heart monitoring device that can alert patients to heart rhythms outside of normal limits.

Recommendations

Floating-point microprocessor

One of the problem areas of this implementations that prevented more sensitivity in detection was the weakness of floating point operations. Input signals had to be passed through a 20 dB attenuation cable plus some attenuation in the input routine was necessary to insure that the input signal did not exceed the ability of the microprocessor to store floating point data in 24 bit address space. The neural net's ability to discern target sound is dependent on the input signal frequency and amplitude. The reliability and accuracy of the net's detection ability is dependent on unaltered input signal. This problem is compounded additionally by the weights having to be scaled back as well to fit in the 24-bit space. The 56307 processor is an integer-based chip. These types of chips are relatively low cost to produce and are perfectly suited for a great deal of audio application. However, a floating-point processor and storage memory would most likely yield better results in detection.

Shorter windowing

This application used the entire input as the Hamming window size. This supplied a great deal of frequency components to the FFT calculation and probably contributed to the 'noise' or unwanted harmonics generated by the calculation process. The input buffer used in this project has a size of 1024 samples. Increasing input buffer size to 4096 samples and then taking 512 sample windows would yield less noise in the FFT calculations.

C based development environment

While Assembly language while is efficient in execution, it is moderately difficult to program. Although a C compiler was included with the Motorola software, it only allowed using one memory model. It is very easy to program in C and it allows for easy tracking of pointer operations and algorithm development. Additionally it still allows use of assembly code in inline statements and so could still make use of existing assembly routines. All eight address registers along with their modulo and some offset registers were allocated during the execution of the program code. A lowpass filter section was attempted, but interfered with FFT processing because both the filter and the FFT used some of the same registers. The design could either have a lowpass filter or a reliable FFT calculation but not both. Using C as a development environment would have allowed having both lowpass filtering and FFT calculations. Since both routines would have enabled the use of pointers and localized variables, this would reduce problems associated with register pointer interactions.

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APPENDIX

Assembly Code

IOEQU.ASM

```
;**************************************************************************
;
;   EQUATES for DSP56307 I/O registers and ports
;
;   Copyright (c) MOTOROLA 1998
;            Semiconductor Products Sector
;            Digital Signal Processing Division
;
;**************************************************************************

        page    132,55,0,0,0
        opt     mex

ioequ   ident   1,0

;-----------------------------------------------------------------------
;
;       EQUATES for I/O Port Programming
;
;-----------------------------------------------------------------------

;       Register Addresses

M_PCRC   EQU     $FFFFBF         ; Port C Control Register
M_PRRC   EQU     $FFFFBE         ; Port C Direction Register
M_PDRC   EQU     $FFFFBD         ; Port C GPIO Data Register

M_PRRD   EQU     $FFFFAE         ; Port D Direction Data Register
M_PDRD   EQU     $FFFFAD         ; Port D GPIO Data Register

;-----------------------------------------------------------------------
;
;       EQUATES for Synchronous Serial Interface (SSI)
;
;-----------------------------------------------------------------------

;
;       Register Addresses Of SSI0

M_TX00   EQU     $FFFFBC         ; SSI0 Transmit Data Register 0
M_RX0    EQU     $FFFFB8         ; SSI0 Receive Data Register
M_SSISR0 EQU     $FFFFB7         ; SSI0 Status Register
M_CRB0   EQU     $FFFFB6         ; SSI0 Control Register B
M_CRA0   EQU     $FFFFB5         ; SSI0 Control Register A

;-----------------------------------------------------------------------
;
;       EQUATES for Exception Processing
;
;-----------------------------------------------------------------------

;       Register Addresses

M_IPRP   EQU     $FFFFFE         ; Interrupt Priority Register Peripheral
```

```
;------------------------------------------------------------------------
;
;       EQUATES for TIMER
;
;------------------------------------------------------------------------

;       Register Addresses Of TIMER0
M_TCSR0  EQU     $FFFF8F         ; TIMER0 Control/Status Register

;------------------------------------------------------------------------
;
;       EQUATES for Phase Locked Loop (PLL)
;
;------------------------------------------------------------------------

;       Register Addresses Of PLL

M_PCTL   EQU     $FFFFFD         ; PLL Control Register

;------------------------------------------------------------------------
;
;       EQUATES for BIU
;
;------------------------------------------------------------------------

;       Register Addresses Of BIU

M_BCR    EQU     $FFFFFB         ; Bus Control Register

INTEQU.ASM
;*************************************************************************
;
;   EQUATES for 56307 interrupts
;
;   Copyright (c) MOTOROLA 1998
;            Semiconductor Products Sector
;            Digital Signal Processing Division
;
;*************************************************************************
        page    132,55,0,0,0
        opt     mex

intequ  ident   1,0

        if      @DEF(I_VEC)
        ;leave user definition as is.
        else
I_VEC       EQU $0
        endif
;------------------------------------------------------------------------
; Non-Maskable interrupts
;------------------------------------------------------------------------
I_RESET  EQU  I_VEC+$00   ; Hardware RESET
I_STACK  EQU  I_VEC+$02   ; Stack Error
I_ILL    EQU  I_VEC+$04   ; Illegal Instruction
I_DBG    EQU  I_VEC+$06   ; Debug Request
I_TRAP   EQU  I_VEC+$08   ; Trap
I_NMI    EQU  I_VEC+$0A   ; Non Maskable Interrupt

;------------------------------------------------------------------------
; Interrupt Request Pins
;------------------------------------------------------------------------
I_IRQA   EQU  I_VEC+$10   ; IRQA
I_IRQB   EQU  I_VEC+$12   ; IRQB
I_IRQC   EQU  I_VEC+$14   ; IRQC
I_IRQD   EQU  I_VEC+$16   ; IRQD

;------------------------------------------------------------------------
; DMA Interrupts
;------------------------------------------------------------------------
I_DMA0   EQU  I_VEC+$18   ; DMA Channel 0
I_DMA1   EQU  I_VEC+$1A   ; DMA Channel 1
```

```
I_DMA2   EQU  I_VEC+$1C   ; DMA Channel 2
I_DMA3   EQU  I_VEC+$1E   ; DMA Channel 3
I_DMA4   EQU  I_VEC+$20   ; DMA Channel 4
I_DMA5   EQU  I_VEC+$22   ; DMA Channel 5

;------------------------------------------------------------------------
; Timer Interrupts
;------------------------------------------------------------------------
I_TIM0C  EQU  I_VEC+$24   ; TIMER 0 compare
I_TIM0OF EQU  I_VEC+$26   ; TIMER 0 overflow
I_TIM1C  EQU  I_VEC+$28   ; TIMER 1 compare
I_TIM1OF EQU  I_VEC+$2A   ; TIMER 1 overflow
I_TIM2C  EQU  I_VEC+$2C   ; TIMER 2 compare
I_TIM2OF EQU  I_VEC+$2E   ; TIMER 2 overflow

;------------------------------------------------------------------------
; ESSI Interrupts
;------------------------------------------------------------------------
I_SI0RD  EQU  I_VEC+$30   ; ESSI0 Receive Data
I_SI0RDE EQU  I_VEC+$32   ; ESSI0 Receive Data With Exception Status
I_SI0RLS EQU  I_VEC+$34   ; ESSI0 Receive last slot
I_SI0TD  EQU  I_VEC+$36   ; ESSI0 Transmit data
I_SI0TDE EQU  I_VEC+$38   ; ESSI0 Transmit Data With Exception Status
I_SI0TLS EQU  I_VEC+$3A   ; ESSI0 Transmit last slot
I_SI1RD  EQU  I_VEC+$40   ; ESSI1 Receive Data
I_SI1RDE EQU  I_VEC+$42   ; ESSI1 Receive Data With Exception Status
I_SI1RLS EQU  I_VEC+$44   ; ESSI1 Receive last slot
I_SI1TD  EQU  I_VEC+$46   ; ESSI1 Transmit data
I_SI1TDE EQU  I_VEC+$48   ; ESSI1 Transmit Data With Exception Status
I_SI1TLS EQU  I_VEC+$4A   ; ESSI1 Transmit last slot

;------------------------------------------------------------------------
; SCI Interrupts
;------------------------------------------------------------------------
I_SCIRD  EQU  I_VEC+$50   ; SCI Receive Data
I_SCIRDE EQU  I_VEC+$52   ; SCI Receive Data With Exception Status
I_SCITD  EQU  I_VEC+$54   ; SCI Transmit Data
I_SCIIL  EQU  I_VEC+$56   ; SCI Idle Line
I_SCITM  EQU  I_VEC+$58   ; SCI Timer

;------------------------------------------------------------------------
; HOST Interrupts
;------------------------------------------------------------------------
I_HRDF    EQU     I_VEC+$60   ; Host Receive Data Full
I_HTDE    EQU     I_VEC+$62   ; Host Transmit Data Empty
I_HC      EQU     I_VEC+$64   ; Default Host Command

;------------------------------------------------------------------------
; EFCOP Interrupts
;------------------------------------------------------------------------
I_FDIBE   EQU     I_VEC+$68   ; EFCOP Input Buffer Empty
I_FDOBF   EQU     I_VEC+$6A   ; EFCOP Output Buffer Full

;------------------------------------------------------------------------
; INTERRUPT ENDING ADDRESS
;------------------------------------------------------------------------
I_INTEND EQU  I_VEC+$FF   ; last address of interrupt vector space

ADA_EQU.ASM
        page    132,60
;***************************************************************************
;   ADA_EQU.ASM
;   Initialization constants to facilitate initialization of the CS4218
;
;   Copyright (c) MOTOROLA 1998
;            Semiconductor Products Sector
;            Digital Signal Processing Division
;
;***************************************************************************
;Upper 16 bits of control word CTRL_WD_12
MASK            equ     $400000
DO1             equ     $200000
```

```
MAX_LEFT_ATTN     equu      $1f0000         ; -46.5 dB
MAX_RIGHT_ATTN    equ       $00f800         ; -46.5 dB
LEFT_ATTN         equ       $180000
RIGHT_ATTN        equ       $00c000
MIN_LEFT_ATTN     equ       $000000         ; 0 dB
MIN_RIGHT_ATTN    equ       $000000         ; 0 dB
MUTE              equ       $000400
LIN2              equ       $000200         ; use LIN2 on EVM
RIN2              equ       $000100         ; use RIN2 on EVM

;Lower 16 bits of control word CTRL_WD_34
MAX_LEFT_GAIN     equ       $f00000         ; 22.5 dB
MAX_RIGHT_GAIN    equ       $0f0000         ; 22.5 dB
LEFT_GAIN         equ       $500000         ; 1.5 * 5 = 7.5 dB
RIGHT_GAIN        equ       $050000         ; 1.5 * 5 = 7.5 dB
MIN_LEFT_GAIN     equ       $000000         ; 0 dB
MIN_RIGHT_GAIN    equ       $000000         ; 0 dB

VECTORS.ASM
        page    132,60
;***************************************************************************
;   VECTORS.ASM
;   Vector table for the 56307
;
;   Copyright (c) MOTOROLA 1998
;           Semiconductor Products Sector
;           Digital Signal Processing Division
;
;***************************************************************************
;
        ORG         P:0

vectors jmp         START               ;- Hardware RESET

        jmp         *
        NOP                             ;- Stack Error

        jmp         *
        NOP                             ;- Debug Request Interrupt

        jmp         *
        NOP                             ;- Debug Request Interrupt

        jmp         *
        NOP                             ;- Trap

        jmp         *
        NOP                             ;- NMI

        NOP                             ;- Reserved
        NOP

        NOP                             ;- Reserved
        NOP

        jmp         *
        NOP                             ;- IRQA

        jmp         *
        NOP                             ;- IRQB

        jmp         *
        NOP                             ;- IRQC

        jmp         *
        NOP                             ;- IRQD

        jmp         *
        NOP                             ;- DMA Channel 0

        jmp         *
        NOP                             ;- DMA Channel 1
```

```
jmp     *
NOP                     ;- DMA Channel 2
jmp     *
NOP                     ;- DMA Channel 3
jmp     *
NOP                     ;- DMA Channel 4
jmp     *
NOP                     ;- DMA Channel 5
jmp     *
NOP                     ;- Timer 0 Compare
jmp     *
NOP                     ;- Timer 0 Overflow
jmp     *
NOP                     ;- Timer 1 Compare
jmp     *
NOP                     ;- Timer 1 Overflow
jmp     *
NOP                     ;- Timer 2 Compare
jmp     *
NOP                     ;- Timer 2 Overflow
jsr     ssi_rx_isr      ;- ESSI0 Receive Data
jsr     ssi_rxe_isr     ;- ESSI0 Receive Data w/ Exception Status
jsr     ssi_rxls_isr    ;- ESSI0 Receive Last Slot
jsr     ssi_tx_isr      ;- ESSI0 Transmit Data
jsr     ssi_txe_isr     ;- ESSI0 Transmit Data w/ Exception Status
jsr     ssi_txls_isr    ;- ESSI0 Transmit Last Slot
NOP                     ;- Reserved
NOP
NOP                     ;- Reserved
NOP
jmp     *
NOP                     ;- ESSI1 Receive Data
jmp     *
NOP                     ;- ESSI1 Receive Data w/ Exception Status
jmp     *
NOP                     ;- ESSI1 Receive Last Slot
jmp     *
NOP                     ;- ESSI1 Transmit Data
jmp     *
NOP                     ;- ESSI1 Transmit Data w/ Exception Status
jmp     *
NOP                     ;- ESSI1 Transmit Last Slot
NOP                     ;- Reserved
NOP
NOP                     ;- Reserved
NOP
```

```
jmp     *
NOP                     ;- SCI Receive Data
jmp     *
NOP                     ;- SCI Receive Data w/ Exception Status
jmp     *
NOP                     ;- SCI Transmit Data
jmp     *
NOP                     ;- SCI Idle Line
jmp     *
NOP                     ;- SCI Timer
NOP                     ;- Reserved
NOP
NOP                     ;- Reserved
NOP
NOP                     ;- Reserved
NOP
jmp     *
NOP                     ;- Host Receive Data Full
jmp     *
NOP                     ;- Host Transmit Data Empty
jmp     *
NOP                     ;- Host Command (Default)
NOP                     ;- Reserved
NOP
jmp     *
NOP                     ;- EFCOP Data Input Buffer Empty
jmp     *
NOP                     ;- EFCOP Data Output Buffer Full
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
NOP                     ; Available for Host Command
jmp     *
```

```
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
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NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
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NOP                    ; Available for Host Command
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NOP                    ; Available for Host Command
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NOP                    ; Available for Host Command
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NOP                    ; Available for Host Command
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NOP                    ; Available for Host Command
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NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
NOP                    ; Available for Host Command
jmp   *
```

```
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
        jmp     *
        NOP                             ; Available for Host Command
OUTDATA.ASM
;*************************************************************************************
; DESCRIPTION:
; OUTDATA.ASM
;  This macro outputs FFT results to specified files for test purpose.
;
; REVISION HISTORY:
; Date          Change
; 10-18-1998    Initial implementation on Motorola DSP56300
;*************************************************************************************
;
outdata   macro    points,data,output
;outdata   ident     1,1
;
; Complex input data
;       Real data in X memory
;       Imaginary data in Y memory
;
; Macro Call - outdata   points,data
;
;       points     number of points (2-32768, power of 2)
;       data       start of data buffer
;
```

```
        move    #-1,m0          ;linear addressing
        move    #-1,m4          ;linear addressing
        ;--------------------------------------------------------------
        move       #-1,m5
        ;--------------------------------------------------------------
        move    #data,r0        ;initialize real input pointer
        move    #data,r4        ;initialize image input pointer
        ;--------------------------------------------------------------
        move    #output,r3      ;initialize output pointer
        ;--------------------------------------------------------------
        do      #points,end_output
        move    x:(r0)+,x0
        move    y:(r4)+,y0
        mpy     x0,x0,a
        mac     y0,y0,a
;sqrt
; y  = double precision (48 bit) positive input number
; b  = 24 bit output root, a  = temporary storage
; x0 = guess, x1 = bit being tested, y1:y0 = input number

        nop
        move    a,y1
        move    a0,y0
        clr     b    #<$40,x0           ; init root and guess
        move    x0,x1                       ; init bit to test
        do      #23,_endl
                                        ;START OF LOOP
        mpy     -x0,x0,a                ; square and negate the guess
        add     y,a                     ; compare to double precision input
        tge     x0,b                    ; update root if input >= guess
        tfr     x1,a                    ; get bit to test
        asr     a                       ; shift to next bit to test
        nop
        add     b,a      a,x1               ; form new guess
        nop
        move             a,x0               ; save new guess
_endl                                   ;END OF LOOP
        asl     #@cvi(@log(points)/@log(2)+0.5),b,b     ;scale up the FFT results
        rep #8
        asr b

        ;movep  b,y:$fffffd     ; output location - input to neural net
        nop
        move b1,x:(r3)+         ;output location
end_output
        endm

BITREV.ASM
;*******************************************************************************
; DESCRIPTION:
; BITREV.ASM    Transforming bit-reversed data into normal-ordered data
;
; REVISION HISTORY:
; Date           Change
; 08-18-1988     Initial placement
; 11-06-1998     Implementation on Motorola DSP56300
;*******************************************************************************
;
bitrev  macro   points,coef
bitrev  ident   1,0
;
;
;       POINTS:    number of points (2 - 32768, power of 2)
;       COEF:      base address of sine/cosine table
;                   negative cosine (Wr) and negative sine (Wi) in X memory
;
;
;

        move    #coef,r0                ;twiddle factor start address
        move    #0,m0                   ;bit reverse address
        move    #-1,m1                  ;linear address
```

```
        move    m1,m4                    ;linear address
        move    m1,m5                    ;linear address

        move    #points/2,n0             ;half of FFT length
        move    #coef+1,r1               ;r1 ptr to normal order data
        nop
        nop
        move    (r0)+n0                  ;r0 ptr to bitrev
        do      #points-1,_end_bit       ;do N-1 points swap
        move    r1,x0
        move    r0,a
        cmp     x0,a
        jle     _incr                    ;if r0 less than r1, no swap
        move    r1,r5
        move    r0,r4
        nop
        nop
        move    x:(r1),x0       y:(r5),y0
        move    x:(r0),a        y:(r4),b
        move    x0,x:(r0)+n0    y0,y:(r4)
        move    a,x:(r1)+       b,y:(r5)
        jmp     _wast
_incr
        move    (r1)+                    ;no swap but update points
        move    (r0)+n0
_wast
        nop
_end_bit
        endm    ;end of bitrev macro
```

FFTR2A.ASM

```
;*******************************************************************************
; DESCRIPTION:
; FFTR2A.ASM    Radix 2, Decimation-In-Time In-Place FFT Routine
;                       Please refer to the file FFTR2A.HLP for detailed information
;                        about this program.
;
; REVISION HISTORY:
; Date              Change
; 09-30-1986        Initial placement
; 10-29-1998        Implementation on Motorola DSP56300
;*******************************************************************************
;
fftr2a  macro     points,data,coef
fftr2a  ident     1,0
;
;    Complex input and output data
;        Real data in X memory
;        Imaginary data in Y memory
;    Normally ordered input data
;    Bit reversed output data
;        Coefficient lookup table
;        -Cosine values in X memory
;        -Sine values in Y memory
;
; Macro Call - fftr2a   points,data,coef
;
;        points     number of points (2-32768, power of 2)
;        data       start of data buffer
;        coef       start of sine/cosine table
;
; Alters Data ALU Registers
;        x1     x0  y1      y0
;        a2     a1  a0      a
;        b2     b1  b0      b
;
; Alters Address Registers
;        r0     n0  m0
;        r1     n1  m1
;               n2
;
;        r4     n4  m4
```

```
;       r5      n5  m5
;       r6      n6  m6
;
; Uses 6 locations on System Stack
;
        move    #points/2,n0                    ;initialize butterflies per group
        move    #1,n2                           ;initialize groups per pass
        move    #points/4,n7                    ;initialize C pointer offset
        move    #-1,m0                          ;initialize A and B address modifiers
        move    m0,m1                           ;for linear addressing
        move    m0,m4
        move    m0,m5
        move    #0,m7                           ;initialize C address modifier for
                                                ; reverse carry (bit-reversed) addressing
;
; Perform all FFT passes with triple nested DO loop
;
        do      #@cvi(@log(points)/@log(2)+0.5),_end_pass
        move    #data,r0                ;initialize A input pointer
        move    r0,r4                   ;initialize A output pointer
        move    n0,n1                   ;initialize pointer offsets
        move    n0,n4
        lua     (r0)+n0,r1              ;initialize B input pointer
        move    #coef,r7                ;initialize C input pointer
        move    n0,n5
        lua     (r1)-,r5                ;initialize B output pointer

        do      n2,_end_grp
        move    x:(r1),x1  y:(r7),y0    ;lookup -sine and -cosine values
        move    x:(r5),a   y:(r0),b     ;preload data
        move    x:(r7)+n7,x0            ;update C pointer

        do      n0,_end_bfy
        mac     x1,y0,b    y:(r1)+,y1     ;Radix 2 DIT butterfly kernel
        macr    -x0,y1,b   a,x:(r5)+   y:(r0),a
        nop
        subl    b,a        x:(r0),b    b,y:(r4)
        mac     -x1,x0,b   x:(r1),x1
        macr    -y1,y0,b   x:(r0)+,a   a,y:(r5)
        subl    b,a
        move    b,x:(r4)+  y:(r0),b
_end_bfy
        move    a,x:(r5)+n5     y:(r1)+n1,y1    ;update A and B pointers
        move    x:(r0)+n0,x1    y:(r4)+n4,y1
_end_grp
        move    n0,b1
        lsr     b   n2,a1               ;divide butterflies per group by two
          nop
        lsl     a   b1,n0               ;multiply groups per pass by two
          nop
        move    a1,n2
_end_pass
        endm

MAIN.ASM
;-----------------------------------------------------------------------
;      Program:     main.asm
;       Author:     James Kidd
;         Date:     07may2001
;
;   Parameters:     none
;
;   Copyright (c) 2001 James Kidd
;
;    Narrative:    This program serves at the main starting point for the
;                  Audio Surveillance Discriminator.  This program code
;                  reads in audio signals from the left line input and passes
;                  the signal through a hamming window function.  The hamming
;                  window passes the modified signal to an FFT section.  The
;                  output of the FFT is passed to the neural network section.
;                  The neural net calculates probability of gunfire by
;                  summing the first 50 inputs times their respective weights.
```

```
;
;               If the probability is higher than 85 percent, TCSR0 is
;               toggled either turn on or off the LED3 (TIO0) on the EVM board.
;--------------------------------------------------------------------------
      nolist
      include 'ioequ'         ; equates specific to the 56300 chips
      include 'intequ'        ; equates used by the CS4218 audio chip
      include 'ada_equ'       ; initialization routines for the CS4218
      include 'vectors'       ; interrupt vectors used by the input routine
      include 'outdata'       ; output data conversion used by FFT routine
      include 'bitrev'        ; part of FFT routine
      include 'fftr2a'        ; FFT macro routine
      list

;--------------------------------------------------------------------------
;     Setup constants
;--------------------------------------------------------------------------

fft_pts         equu    1024    ; number of FFT points
i_nodes         equ     50      ; number of input nodes to the neural net
h_nodes         equ     10      ; number of hidden nodes
o_nodes         equ     2       ; number of neural net outputs

idata           equ     $2000   ; starting location for input
odata           equ     $2500   ; starting location for output
fft_coef        equ     $850    ; FFT coefficient stored in X and Y memory
                                ; starting at this location index
win_coef        equ     $1000   ; hamming window coefficients

n_idata         equ     $2500  ; neural net input layer location
n_hdata         equ     $3000  ;            hidden
n_odata         equ     $35C0  ;            output
sigmoid         equ     $1100  ; occupies y memory space
weights         equ     $600   ;           y
calc_sum        equ     $c00   ;           y

pi              equ     3.141592654
freq            equ     2.0*pi/@cvf(fft_pts)

CTRL_WD_12      equ     MIN_LEFT_ATTN+MIN_RIGHT_ATTN+LIN2+RIN2
CTRL_WD_34      equ     MIN_LEFT_GAIN+MIN_RIGHT_GAIN

       org    x:0

RX_BUFF_BASE    equ     *
RX_data_1_2     ds      1       ; data time slot 1/2 for RX ISR (left audio)
RX_data_3_4     ds      1       ; data time slot 3/4 for RX ISR (right audio)

TX_BUFF_BASE    equ     *
TX_data_1_2     ds      1       ; data time slot 1/2 for TX ISR (left audio)
TX_data_3_4     ds      1       ; data time slot 3/4 for TX ISR (right audio)

RX_PTR          ds      1       ; pointer for RX buffer
TX_PTR          ds      1       ; pointer for TX buffer


FOO             ds       3      ; Setup a location for temporary values
INDEX           ds       9

                org     x:INDEX
                dc    $80,$40,$20,$10,$8,$4,$2,$1,0


;--------------------------------------------------------------------------
;       Generate the sine and cosine tables used by the FFT routine
;--------------------------------------------------------------------------
                org     x:fft_coef
count           set     0
                dup     fft_pts/2
                dc      -@cos(@cvf(count)*freq)
count           set     count+1
                endm
```

```
                      org      y:fft_coef
count                 set      0
                      dup      fft_pts/2
                      dc       -@sin(@cvf(count)*freq)
count                 set      count+1
                      endm

         org      x:win_coef
count    set      0
         dup      fft_pts
         dc       0.54-0.46*@cos(@cvf(count)*freq)
count    set      count+1
         endm


         org      y:sigmoid
count    set      512
         dup      1024
         dc       1/(1+@xpn(-@cvf(count)*(@cvf(14)/@cvf(1024)))) ; The sigmoid function
count    set      count-1
         endm

         org      y:calc_sum
count    set      512
         dup      1024
         dc       @cvf(count)*(@cvf(14)/@cvf(1024))*0.1
count    set      count-1
         endm

         org      y:weights
;        Weights generated from inputs scaled by two
         dc       0.0831199,0.0627419,0.0392404,0.0191184,0.0226808,-0.00476507
         dc       0.0134713,-0.00381944,0.0142447,-0.0250405,-0.0507432,-0.0114748
         dc       -0.0143119,0.00361496,-0.0478461,-0.0443924,-0.00123273,-0.0000367
         dc       -0.0518751,-0.0532268,-0.0388477,-0.044102,-0.0632451,0.00349662
         dc       -0.00343292,-0.0420256,-0.0412565,-0.0466678,-0.0403692,-0.0111914
         dc       -0.0144006,-0.0185224,-0.0107583,-0.00644106,-0.0162269,0.020372
         dc       0.00271417,0.0210791,-0.0115673,-0.000496551,-0.00106955,-0.00554395
         dc       0.00742905,-0.0244616,0.0120791,0.0160847,0.00229645,-0.0131057
         dc       0.018795,-0.00420555,0.0367785,-0.0901466,-0.0211717,-0.0317078
         dc       -0.000253684,0.0077219,0.0231971,0.0107353,-0.00419812,-0.00262172
         dc       0.0285107,0.0489298,0.011636,0.0330797,0.0339364,0.0507279
         dc       0.0661526,0.0417649,0.0521138,0.0432576,0.0273202,0.0604961
         dc       0.0383106,0.0739486,0.043123,0.0248474,-0.00896509,0.036815
         dc       0.0343652,0.0471773,0.0368059,0.0280429,0.026746,-0.00930335
         dc       -0.0188764,-0.0204533,-0.0105364,0.00604439,0.000146875,0.029462
         dc       0.0246296,0.0044237,0.00300747,-0.00340485,0.0176898,0.0256129
         dc       -0.00828985,-0.00616427,-0.0213896,-0.0207717,0.0298322,-0.0891765
         dc       0.0532267,0.0261385,-0.0067518,0.0240277,0.0123977,0.00355056
         dc       0.00686948,-0.00503989,0.0188176,-0.0182487,0.00687873,-0.0491117
         dc       0.00160987,-0.0360594,-0.0399551,-0.0487662,-0.0400159,-0.0216431
         dc       -0.0352666,-0.019919,-0.0120356,-0.0456238,-0.0531986,-0.0194759
         dc       -0.0344619,-0.0431068,-0.0485219,-0.0347914,-0.0212905,-0.00107124
         dc       -0.0207205,0.00456013,-0.0128873,-0.00277332,0.0167332,-0.00612515
         dc       0.00427594,-0.018009,0.00550993,-0.0108271,0.0209672,0.019789
         dc       0.00808823,-0.0271889,-0.0110381,-0.0115832,-0.0145508,-0.0106051
         dc       -0.0109418,-0.0149656,0.0221434,0.053265,0.0265135,0.0158549
         dc       -0.0209177,0.0234343,-0.0398469,-0.00099251,0.0137639,-0.00714203
         dc       -0.0127017,-0.0309285,-0.0368204,-0.0226556,-0.0375425,-0.0318593
         dc       -0.00992029,-0.0491818,-0.0333039,-0.0620561,-0.0411228,-0.0152516
         dc       -0.0514187,-0.0447997,-0.0174691,-0.0198792,0.00159468,-0.00980068
         dc       -0.0451921,0.00395411,-0.0415867,-0.0150185,0.0162012,-0.0255905
         dc       -0.0171559,-0.0136034,-0.0283763,-0.00255267,0.0111625,-0.0122261
         dc       0.00943258,0.00709553,-0.016991,-0.03053,-0.0275316,0.0133469
         dc       0.00241252,-0.0270818,0.0033941,0.00830686,-0.0250329,0.0548597
         dc       0.0401101,0.0226117,0.0242243,-0.00428363,-0.0300143,0.00729634
         dc       0.0218089,-0.0301396,0.0127662,0.0105004,0.013437,-0.0139232
         dc       -0.0317379,-0.0342821,-0.0033306,-0.0260706,-0.0371871,-0.0189554
         dc       0.00953685,-0.0212111,-0.0306,-0.0321146,-0.0300242,-0.0130154
         dc       -0.00660224,-0.0354326,-0.0386143,0.0161399,-0.00216562,-0.020467
         dc       0.020373,-0.0148786,0.00742543,0.0213634,0.00578043,0.0135075
```

```
dc      -0.00169454,0.0279553,-0.0304416,0.0289602,0.0242395,0.0143279
dc      -0.00348343,0.00351436,0.0158111,0.000963201,0.0200893,0.0170306
dc      0.00440081,0.0285611,0.00932622,-0.127082,-0.0605742,0.00015364
dc      -0.0176279,-0.021545,0.0490352,0.0107636,0.0287198,-0.00643527
dc      0.0166398,0.0664866,0.0661176,0.0482227,0.0515745,0.0832025
dc      0.0866457,0.061821,0.0649412,0.0477407,0.102384,0.0218076
dc      0.0777303,0.0874229,0.0040972,-0.00997167,0.0149337,0.0246889
dc      0.0208857,0.0371132,0.0398918,-0.0123257,0.0117834,0.000017626
dc      0.002086,-0.00416432,0.0166208,0.000168377,0.0203506,-0.0272268
dc      0.0296095,0.0224336,0.000577793,-0.0179391,0.0271237,0.0106961
dc      0.0240987,-0.0218938,0.00316645,0.00825146,0.0279418,-0.153809
dc      -0.0329249,-0.0107543,-0.0336455,0.0177053,0.00259653,0.0282656
dc      -0.0123878,0.000156068,0.00734198,0.0343275,0.0145405,0.00219097
dc      0.00914571,-0.00402188,0.0060647,0.0439475,0.0318136,0.0367595
dc      0.0608871,0.0606084,0.0135213,0.0156307,0.0322121,-0.0128516
dc      -0.0212739,0.0328432,0.0485609,0.0147891,0.00538379,0.0108887
dc      0.0345237,0.0189576,-0.0183934,-0.0239027,0.0298804,-0.0168341
dc      0.0131901,0.00783216,-0.00397295,-0.0188922,0.00103178,0.0141395
dc      -0.0151135,-0.0225362,-0.020545,-0.00891808,0.0258806,-0.00427143
dc      0.00700096,-0.015893,-0.0388667,-0.0427581,-0.0305809,-0.0325301
dc      -0.0189387,-0.0030767,0.0398976,-0.00553618,-0.0115662,0.0109672
dc      -0.00760663,0.015696,0.0468397,-0.00345622,0.0110518,0.00366494
dc      0.0172504,0.0489052,0.00620123,0.00479855,0.0627797,0.0415316
dc      0.0475922,0.0214341,0.0180311,0.0218757,0.0122684,0.0406844
dc      0.0175699,0.0484798,0.0253105,0.0186604,0.0240843,-0.0113866
dc      0.0238154,0.0145296,-0.0158025,-0.00443469,0.0254179,-0.027151
dc      -0.00198783,0.0101363,0.00666151,-0.0236586,0.0298422,0.0013719
dc      -0.0192096,0.0110458,-0.0208855,-0.00802736,0.0108543,-0.013957
dc      0.138744,0.0750338,0.00123676,0.0439606,-0.00115622,-0.0466318
dc      -0.0245909,-0.0297657,-0.00577807,-0.0353656,-0.0519051,-0.067316
dc      -0.00269218,-0.0300536,-0.0490593,-0.0934455,-0.0512165,-0.0639098
dc      -0.0637451,-0.0792011,-0.0196356,-0.0479334,-0.0592318,-0.0364532
dc      -0.023827,-0.0110685,-0.0431889,-0.036926,-0.0311078,-0.000148911
dc      -0.0426362,-0.0245382,-0.0340694,-0.0266385,-0.0266542,-0.00486445
dc      0.0208486,-0.0256465,0.0160973,-0.0156938,0.0142907,0.00605783
dc      -0.0252862,0.015747,-0.00658396,-0.00648232,-0.0114139,-0.00169194
dc      0.0131099,0.0115207,0.121562,0.0420854,0.0525588,-0.00612954
dc      0.00991836,-0.0158235,-0.00952904,0.0121846,0.0202485,-0.0132225
dc      -0.011196,-0.0436575,-0.00900132,-0.0051165,0.00538045,-0.0186444
dc      -0.0640938,-0.0569221,-0.0390333,-0.0616327,-0.06826,-0.0160331
dc      -0.0236846,-0.0522156,-0.009726,-0.00173927,0.0097429,-0.0473184
dc      -0.0458725,-0.0155257,0.00465034,0.00180275,0.0171618,-0.0114385
dc      0.0181128,-0.0302391,-0.0158207,0.009346,-0.00969997,0.0182648
dc      -0.00632167,-0.00904365,-0.0252616,0.00413511,-0.0314741,0.0135572
dc      -0.00941057,-0.0104188,0.0176267,-0.0183061,0.000628229,0.0390457
dc      -0.147794,0.166674,-0.145618,-0.114073,-0.0782424,0.259481
dc      0.0857562,0.103586,-0.254248,-0.143348,0.000104385,0.145945
dc      -0.181619,0.106085,0.142134,0.050009,-0.271258,-0.0876888
dc      -0.0956738,0.250874,0.140089,0.0289543

;-----------------------------------------------------------------------------
;Main Program
;-----------------------------------------------------------------------------

        org     p:$100

START
        movep   #$040006,x:M_PCTL  ; PLL 7 X 12.288 = 86.016MHz
        movep   #$012421,x:M_BCR   ; AARx - 1 wait state
        movep   #$000800,x:M_TCSR0 ; set timer 0 in GPIO mode and output
        ori     #3,mr              ; mask interrupts
        movec   #0,sp              ; clear hardware stack pointer
        move    #0,omr             ; operating mode 0
        move    #$40,r6            ; initialise stack pointer
        move    #-1,m6             ; linear addressing
        jsr     ada_init           ; initialize codec

        do #fft_pts,_init
        jset    #3,x:M_SSISR0,*    ; wait for RX frame sync
        jclr    #3,x:M_SSISR0,*    ; wait for RX frame sync

        move    x:RX_BUFF_BASE,y0   ; receive left
```

```
        move    x:RX_BUFF_BASE+1,y1 ; receive right

        nop                         ; pass data straight through
        nop
_init

setpointers
        move    #idata,r0
        move    #-1,m0              ;#fft_pts-1,m0
        move    #idata,r4
        move    #-1,m4              ;#fft_pts-1,m4
        move    #0,x0


        do #fft_pts,end_input
        jset    #3,x:M_SSISR0,*     ; wait for RX frame sync
        jclr    #3,x:M_SSISR0,*     ; wait for RX frame sync

        move    x:RX_BUFF_BASE,a    ; receive left
        move    x:RX_BUFF_BASE+1,b  ; receive right

        rep     #2
        asr     b                   ;scale back input by 2 shifts to the right
        nop

        move    b,x:(r0)+           ;input real value
        move    x0,y:(r4)+          ;input imaginary value
end_input
;-------------------------------------------------------------------------------
;       Window processing
;-------------------------------------------------------------------------------

        move    #idata,r0           ;reset r0 pointer to beginning of data
        move    #win_coef,r4        ;set hamming coefficient pointer to beginning
        do #fft_pts,hamming
        move    x:(r0),x1           ;move data point to register
        move    x:(r4)+,x0          ;move hamming coefficient to register
        mpy     x0,x1,a             ;multiply hamming window and store in a
        nop
        move    a,x:(r0)+           ;move result back to input buffer
hamming

;-------------------------------------------------------------------------------
;       FFT processing sections
;-------------------------------------------------------------------------------

        fftr2a  fft_pts,idata,fft_coef
        bitrev   fft_pts,idata
        move    #odata,r3           ; initialize address register to output location
        outdata  fft_pts,idata,odata

;-------------------------------------------------------------------------------
;       neural network processing
;-------------------------------------------------------------------------------
;       Start of input layer processing
;-------------------------------------------------------------------------------

        move    #n_idata,r0          ; point to neural input array
        move    #n_hdata,r1          ; point to hidden array layer
        move    #n_odata,r2          ; point to output array layer
        move    #sigmoid,r3        ; point to sigmoid array
        move    #500,n3            ; initialize sigmoid offset register
        move    #weights,r4        ; point to input weight array
        move    #50,n4             ; initialize bias offset pointer
        move    #calc_sum,r5       ; point to calculated sum array
        move    #500,n5            ; initalize sum array off set register
        move    n5,x0
        move    x0,x:FOO           ; store offset value in temp location


        do      #h_nodes,_hidden_layer
        move    #n_idata,r0          ; point to neural input array
```

```
        move    x:(r0),x0        ; input first harmonic
        move    y:(r4),y0        ; input first weight
        move    y:(r4+n4),a      ; move initial bias value to a

        do      #i_nodes-1,_input    ; loop through input layer processing

        mac     x0,y0,a          x:(r0)+,x0       y:(r4)+,y0
_input
        macr    x0,y0,a          (r4)+

        move    y:(r4)+,y0       ; move next weight to in order to properly
                                 ; weight register for bias value

        move    #0,b             ; summed error where sigmoid = 0.5
                                 ; raw summed error for net_input
                                 ; and set weight pointer for next iteration
        jsr     get_sigmoid

_hidden_layer
;-------------------------------------------------------------------------------
;       End of input layer processing
;-------------------------------------------------------------------------------

;-------------------------------------------------------------------------------
;       Start of hidden layer processing
;-------------------------------------------------------------------------------

        move    #n_odata,r1        ; point to output layer

        move    #h_nodes,n4      ; set new offset value for hidden layer
        move    #10,n4           ; initialize bias offset pointer

        move    #n_hdata,r0        ; point to hidden array layer
                                 ; loop through hidden layer processing
        move    x:(r0),x0        ; input hidden layer value

        do      #o_nodes,_output_layer
        move    y:(r4),y0        ; input first weight
        move    y:(r4+n4),a      ; move initial bias value to a

        do      #h_nodes-1,_input_hidden    ; loop through input layer processing

        mac     x0,y0,a          x:(r0)+,x0       y:(r4)+,y0
_input_hidden
        macr    x0,y0,a          (r4)+

        move    y:(r4)+,y0       ; move next weight to in order to properly
                                 ; weight register for bias value

        move    #0,b             ; summed error where sigmoid = 0.5
                                 ; raw summed error for net_input
                                 ; and set weight pointer for next iteration
        jsr     get_sigmoid

_output_layer
;-------------------------------------------------------------------------------
;       End of hidden layer processing
;-------------------------------------------------------------------------------
        move    #n_odata,r0
        move    #0.85,b
        move    x:(r0),x1
        cmp     x1,b
        jgt     setpointers              ; keep on scanning

        bchg    #13,x:M_TCSR0            ;Turn on or turn off LED

        jmp     setpointers              ; keep on scanning

;------------------------------------------
;       Get sigmoid routine
;------------------------------------------
```

```
get_sigmoid
         move   #INDEX,r7          ; point to beginning of index table

        cmp     b,a                ; is summed error positive or negative?
        bmi     _negx              ; if negative jump to negative sum process
_posx
        move    x:FOO,b1           ; x:FOO contains current offset value
        move    x:(r7)+,x0         ; get next offset value
        sub     x0,b               ; subtract offset from b1
        nop
        move    b1,n5              ; transfer new value to offset register
        move    b1,x:FOO           ; update foo with new value
        move    y:(r5+n5),x1       ; move last positive calc_sum into x0
        move    x:(r7),x0          ; load current offset into x0
        move    #0,b               ; load zero into b
        cmp     x0,b               ; is the current offset = zero
        jeq     _store_sigmoid     ; go to store sigmoid routine
        cmp     x1,a
        jgt     _posx              ; if sample_sum > calc_sum get next greater sum
        jmp     _negx              ; if sample_sum < calc_sum get next lesser sum

_negx
        move    x:FOO,b1           ; x:FOO contains current offset value
        move    x:(r7)+,x0
        add     x0,b
        nop
        move    b1,n5
        move    b1,x:FOO           ; update foo with next value
        move    y:(r5+n5),x1       ; move last positive calc_sum into x0
        move    x:(r7),x0          ; load current offset into x0
        move    #0,b               ; load zero into b
        cmp     x0,b               ; is the current offset = zero
        jeq     _store_sigmoid     ; go to store sigmoid routine
        cmp     x1,a
        jle     _negx              ; if sample_sum < calc_sum get next lesser sum
        jmp     _posx              ; if sample_sum > calc_sum get next greater sum

_store_sigmoid
        move    x:FOO,x0
        move    x0,n3              ; move the calc_sum offset to sigmoid offset
        move    y:(r3+n3),x1       ; move the sigmoid value to register
        nop
        move    x1,x:(r1)+         ; move sigmoid value to calling layer

        move    #500,x1
        move    x1,x:FOO           ; set index back to the middle of
                                   ; the calc_sum table
        rts                        ; go back to calling function

        include 'ada_init.asm'
        end

ADA_INIT.ASM
        page    132,60
;**************************************************************************
;       ADA_INIT.ASM    Ver 1.1
;       Example program to initialize the CS4218
;
;       Copyright (c) MOTOROLA 1995, 1996, 1998
;                     Semiconductor Products Sector
;                     Wireless Signal Processing Division
;
;**************************************************************************

        org     x:
CTRL_WD_HI      ds      1
CTRL_WD_LO      ds      1

                                   ; ESSI0 - audio data
                                   ; DSP                    CODEC
                                   ; ---------------------------
CODEC_RESET     equ     0          ; bit0  SC00    --->     CODEC_RESET~
```

```
FSYNC           equ     2       ; bit2  SC02    <---    FSYNC
SCLK            equ     3       ; bit3  SCK0    <---    SCLK
SRD0            equ     4       ; bit4  SRD0    <---    SDOUT
STD0            equ     5       ; bit5  STD0    --->    SDIN

                                ; ESSI1 - control data
                                ; DSP                   CODEC
                                ;-------------------------
CCS             equ     0       ; bit0  SC10    --->    CCS~
CCLK            equ     1       ; bit1  SC11    --->    CCLK
CDIN            equ     2       ; bit2  SC12    --->    CDIN

;*************************************************************************
; Initialize the CS4218 codec
; --------------------------
;
; Serial Mode 4 (SM4), DSP Slave/Codec Master, 32-bits per frame
;
; After a reset, the control port must be written once to initialize it
; if the port will be accessed to read or write control bits.  The initial
; write is a "dummy" write since the data is ignored by the codec.  A second
; write is needed to configure the codec as desired.  Then, the control port
; only needs to be written to when a change is desired, or to obtain status
; information.
;
; Although only 23 bits contain useful data in CDIN, a minimum of 31 bits
; must be written.
;
; CDIN
;-----------------------------------------------
; bit 31                0
;-----------------------------------------------
; bit 30                mask interrupt
;                       0=no mask on MF5:\INT pin
;                       1=mask on MF5:\INT pin
;-----------------------------------------------
; bit 29                DO1
;-----------------------------------------------
; bits 28-24            left output D/A sttenuation  (1.5dB steps)
;                       00000=No attenuation 0dB
;                       11111=Max attenuation -46.5dB
;-----------------------------------------------
; bits 23-19            right output D/A attenuation (1.5dB steps)
;                       00000=No attenuation 0dB
;                       11111=Max attenuation -46.5dB
;-----------------------------------------------
; bit 18                mute D/A outputs
;                       0=outputs ON
;                       1=outputs MUTED
;-----------------------------------------------
; bit 17                input mux, left select
;                       0=RIN1
;                       1=RIN2 (used on EVM)
;-----------------------------------------------
; bit 16                input mux, right select
;                       0=LIN1
;                       1=LIN2 (used on EVM)
;-----------------------------------------------
; bits 15-12            left input A/D gain (1.5dB steps)
;                       0000=No gain 0dB
;                       1111=Max gain +22.5dB
;-----------------------------------------------
; bits 11-8             right input A/D gain (1.5dB steps)
;                       0000=No gain 0dB
;                       1111=Max gain +22.5dB
;-----------------------------------------------
; bits 7-0              00000000
;-----------------------------------------------
;*************************************************************************

        org     p:
ada_init
        movep   #$0000,x:M_PCRC         ; disable ESSI0 port (for now)
```

```
        movep   #$101807,x:M_CRA0       ; 12.288MHz/16 = 768KHz SCLK
                                        ; prescale modulus = 8
                                        ; frame rate divider = 2
                                        ; 16-bits per word
                                        ; 32-bits per frame
                                        ; 16-bit data aligned to bit 23

        movep   #$ff330c,x:M_CRB0       ; Enable REIE,TEIE,RLIE,TLIE,
                                        ; RIE,TIE,RE,TE0
                                        ; network mode, synchronous,
                                        ; out on rising/in on falling
                                        ; shift MSB first
                                        ; external clock source drives SCK
                                        ; (codec is master)
                                        ; RX frame sync pulses active for
                                        ; 1 bit clock immediately before
                                        ; transfer period
                                        ; positive frame sync polarity
                                        ; frame sync length is 1-bit

        movep   #$0001,x:M_PRRC         ; set PC0=CODEC_RESET~ as output
        movep   #$0007,x:M_PRRD         ; set PD0=CCS~ as output
                                        ; set PD1=CCLK as output
                                        ; set PD2=CDIN as output

        bclr    #CODEC_RESET,x:M_PDRC   ; assert CODEC_RESET~
        bclr    #CCS,x:M_PDRD           ; assert CCS~

;Reset delay for codec
        do      #1000,_delay_loop
        rep     #1000                   ; minimum 50 ms delay
        nop
_delay_loop

;Send control data to codec
        bset    #CODEC_RESET,x:M_PDRC   ; deassert CODEC_RESET~
        movep   #$000c,x:M_IPRP         ; set int priority level for ESSI0 to 3
        andi    #$fc,mr                 ; enable interrupts

dummy_control
        move    #0,x0
        move    x0,x:CTRL_WD_HI         ; send dummy control data
        move    x0,x:CTRL_WD_LO
        jsr     init_codec
set_control
        move    #CTRL_WD_12,x0
        move    x0,x:CTRL_WD_HI         ; LIN2 and RIN2 are inputs

        move    #CTRL_WD_34,x0
        move    x0,x:CTRL_WD_LO         ; 16 bit data aligned to bit 23
        jsr     init_codec

        movep   #$003e,x:M_PCRC         ; enable ESSI0 except SC00=CODEC_RESET
        movep   #$101807,x:M_CRA0       ; 12.288MHz/16 = 768kHz SCLK,
                                        ; 16 bits per word, 2 words per frame
        movep   #$ff330C,x:M_CRB0       ; Enable REIE,TEIE,RLIE,TLIE,
                                        ; RIE,TIE,RE,TE0
                                        ; network mode, synchronous,
                                        ; out on rising/in on falling,
                                        ; shift MSB first,
                                        ; external clock source drives SCK
        rts

;*************************************************************************
; Initialization routine
;*************************************************************************
init_codec
        clr     a
        bclr    #CCS,x:M_PDRD           ; assert CCS
        move    x:CTRL_WD_HI,a1         ; upper 16 bits of control data
        jsr     bit_bang                ; shift out upper control word
        move    x:CTRL_WD_LO,a1         ; lower 16 bits of control data
```

```
        jsr     bit_bang                ; shift out lower control word
        bset    #CCS,x:M_PDRD           ; deassert CCS
        rts

;*************************************************************************
; Bit-banging routine
;*************************************************************************
bit_bang
        do      #16,end_bit_bang        ; 16 bits per word
        bset    #CCLK,x:M_PDRD          ; toggle CCLK clock high
        jclr    #23,a1,bit_low          ; test msb
        bset    #CDIN,x:M_PDRD          ; CDIN bit is high
        jmp     continue
bit_low
        bclr    #CDIN,x:M_PDRD          ; CDIN bit is low
continue
        rep     #2                      ; delay
        nop
        bclr    #CCLK,x:M_PDRD          ; toggle CCLK clock low
        lsl     a                       ; shift control word to 1 bit to left
end_bit_bang
        rts

;**************************************************************************
;       SSI0_ISR.ASM    Ver.2.0
;       Example program to handle interrupts through
;       the 56307 SSI0 to move audio through the CS4218
;
;       Copyright (c) MOTOROLA 1998
;                     Semiconductor Products Sector
;                     Digital Signal Processing Division
;
;****************************************************************************
;************************ SSI TRANSMIT ISR *********************************
ssi_txe_isr
        bclr    #4,x:M_SSISR0           ; Read SSISR to clear exception flag
                                        ; explicitly clears underrun flag
ssi_tx_isr
        move    r0,x:(r6)+              ; Save r0 to the stack.
        move    m0,x:(r6)+              ; Save m0 to the stack.
        move    #1,m0                   ; Modulus 2 buffer.
        move    x:TX_PTR,r0             ; Load the pointer to the tx buffer.
        movep   x:(r0)+,x:M_TX00        ; SSI transfer data register.
        move    r0,x:TX_PTR             ; Update tx buffer pointer.
        move    x:-(r6),m0              ; Restore m0.
        move    x:-(r6),r0              ; Restore r0.
        rti

;******************** SSI TRANSMIT LAST SLOT ISR *************************
ssi_txls_isr
        move    r0,x:(r6)+              ; Save r0 to the stack.
        move    #TX_BUFF_BASE,r0        ; Reset pointer.
        move    r0,x:TX_PTR             ; Reset tx buffer pointer just in
                                        ; case it was corrupted.
        move    x:-(r6),r0              ; Restore r0.
        rti

;************************* SSI receive ISR ********************************
ssi_rxe_isr
        bclr    #5,x:M_SSISR0           ; Read SSISR to clear exception flag
                                        ; explicitly clears overrun flag
ssi_rx_isr
        move    r0,x:(r6)+              ; Save r0 to the stack.
        move    m0,x:(r6)+              ; Save m0 to the stack.
        move    #1,m0                   ; Modulus 2 buffer.
        move    x:RX_PTR,r0             ; Load the pointer to the rx buffer.
        movep   x:M_RX0,x:(r0)+         ; Read out received data to buffer.
        move    r0,x:RX_PTR             ; Update rx buffer pointer.
        move    x:-(r6),m0              ; Restore m0.
        move    x:-(r6),r0              ; Restore r0.
        rti
```

```
;********************** SSI receive last slot ISR *************************
ssi_rxls_isr
        move    r0,x:(r6)+              ; Save r0 to the stack.
        move    #RX_BUFF_BASE,r0        ; Reset rx buffer pointer just in
                                        ; case it was corrupted.
        move    r0,x:RX_PTR             ; Update rx buffer pointer.
        move    x:-(r6),r0              ; Restore r0.
        rti
```

Matlab

```
  STUDENT.M
%
%  Program: Student.m
%   Author: James Kidd
%     Date: 07may2001
%
%Narrative: This program reads in a .wav file, calculates an FFT and plots
%                 the results along with a time domain, spectrogram, and power
%     spectral density results
%
v=wavread('C:\SeniorProject\sounds\students\student_sounds_Locker7_boom.wav');

aa = length(v);
a = (1:length(v))/44100;
V = fft(v,255);
k = length(V);
vpower = abs(V(1:k/2)).^2;
nyquist = 1/2;
vfreq = (1:k/2)/(k/2)*nyquist.*44100;

figure;
subplot(2,2,1);  % upper left corner plot
plot(vfreq,vpower); zoom on   %Plot the FFT verses power curve
axis([0 22050 0 300])
title('Student Sounds');
set(gca,'XGrid','on','YGrid','off'); %turn on the gridlines for x and y axis

subplot(2,2,2);   %upper right corner plot
plot(a,v)    %plot time domain signal
xlabel('Time');
title('Student Sounds');

subplot(2,2,3);    %lower left corner plot
psd(v,1024,44100,kaiser(512,5)); %Power spectral density function
axis([0 2000 -40 10])

subplot(2,2,4);    %lower right corner plot
specgram(v,1024,44100,kaiser(500,5),475);%Spectro gram of Students

GUNFIRE.M

%
%  Program: Gunfire.m
%   Author: James Kidd
%   Date:  07may2001
%
%Narrative:  This program reads in a .wav file, calculates an FFT and plots
%              the results along with a time domain, spectrogram, and power
%       spectral density results
%

v=wavread('C:\SeniorProject\sounds\2cd_sounds\1second\9mm_solid_2');

aa = length(v);
a = (1:length(v))/44100;
V = fft(v,255);
k = length(V);
```

```
vpower = abs(V(1:k/2)).^2;
nyquist = 1/2;
vfreq = (1:k/2)/(k/2)*nyquist.*44100;

figure;
subplot (2,2,1);     % upper left corner plot
plot(vfreq,vpower); zoom on   %Plot the FFT verses power curve
axis([0 22050 0 .1])
title('9mm Solid');
set(gca,'XGrid','on','YGrid','off'); %turn on the gridlines for x and y axis

subplot(2,2,2);      %upper right corner plot
plot(a,v)       %plot time domain signal
xlabel('Time');
title('9mm Solid');

subplot(2,2,3);      %lower left corner plot
psd(v,1024,44100,hamming(1024)); %Power spectral density function
axis([0 2000 -40 10])

subplot(2,2,4);      %lower right corner plot
specgram(v,512,44100,hamming(1024),475); %Spectro gram of Gunfire
```

SAMPLE_TRAIN.M

```
%
%  Program: sample_train.m
%   Author: James Kidd
%   Date:  07may2001
%
%Narrative:  This program reads in a number .wav files, takes the Power
%       spectral density results and outputs the first 50 values to
%              a text file to be used as input to Batchnet
%
spl={
'C:\SeniorProject\sounds\2cd_sounds\1second\9mm_hollow_sxt_4';
'C:\SeniorProject\sounds\2cd_sounds\1second\38cal_jacketed_hollow_1';
'C:\SeniorProject\sounds\2cd_sounds\1second\38cal_jacketed_hollow_4';
'C:\SeniorProject\sounds\2cd_sounds\1second\38cal_jacketed_hollow_5';
'C:\SeniorProject\sounds\2cd_sounds\1second\38cal_solid_2';
'C:\SeniorProject\sounds\2cd_sounds\1second\38cal_solid_3';
'C:\SeniorProject\sounds\2cd_sounds\1second\38cal_solid_4';
'C:\SeniorProject\sounds\2cd_sounds\1second\40cal_hollow_hydro_shock_1';
'C:\SeniorProject\sounds\2cd_sounds\1second\40cal_hollow_hydro_shock_5';
'C:\SeniorProject\sounds\2cd_sounds\1second\40cal_solid_1';
'C:\SeniorProject\sounds\2cd_sounds\1second\40cal_solid_3';
'C:\SeniorProject\sounds\2cd_sounds\1second\40cal_solid_4';
'C:\SeniorProject\sounds\2cd_sounds\1second\45cal_hollow_golden_saber_2';
'C:\SeniorProject\sounds\2cd_sounds\1second\45cal_hollow_golden_saber_3';
'C:\SeniorProject\sounds\2cd_sounds\1second\45cal_solid_1';
'C:\SeniorProject\sounds\2cd_sounds\1second\45cal_solid_3';
'C:\SeniorProject\sounds\2cd_sounds\1second\45cal_solid_4';
'C:\SeniorProject\sounds\2cd_sounds\1second\45cal_solid_5';
'C:\SeniorProject\sounds\2cd_sounds\1second\9mm_hollow_hydro_shock_1';
'C:\SeniorProject\sounds\2cd_sounds\1second\9mm_hollow_hydro_shock_2';
'C:\SeniorProject\sounds\2cd_sounds\1second\9mm_hollow_hydro_shock_4';
'C:\SeniorProject\sounds\2cd_sounds\1second\9mm_hollow_hydro_shock_5';
'C:\SeniorProject\sounds\2cd_sounds\1second\9mm_hollow_sxt_1';
'C:\SeniorProject\sounds\2cd_sounds\1second\9mm_hollow_sxt_3';
'C:\SeniorProject\sounds\2cd_sounds\1second\38cal_jacketed_hollow_2';
'C:\SeniorProject\sounds\2cd_sounds\1second\9mm_solid_1';
'C:\SeniorProject\sounds\2cd_sounds\1second\9mm_solid_2';
'C:\SeniorProject\sounds\2cd_sounds\1second\9mm_solid_3';
'C:\SeniorProject\sounds\2cd_sounds\1second\40cal_hollow_hydro_shock_2';
'C:\SeniorProject\sounds\2cd_sounds\1second\40cal_hollow_hydro_shock_3';
'C:\SeniorProject\sounds\2cd_sounds\1second\9mm_solid_5';
};
fid=0;

fid = fopen('d:\seniorproject\batchnet\scaled_wts\sample_train1.pat','w')
```

```
for a=1:length(spl)
   b=spl(a);
   x=wavread(char(b));
   z=psd(x,1024,44100,hamming(1024));
   w=z(1:50);
   fprintf(fid,'%12.8f',w/2);
   fprintf(fid,'\n1 0 %3.0f\n',a+1000);
end;
status= fclose(fid)
```