

An Evaluation and Demonstrations of COTS Components to Implement Wearable Video Cameras on Spaceport Technicians

Christine Bexley

Honors undergraduate student
Department of Computer Science and Engineering
4202 East Fowler Avenue, ENB 118
University of South Florida
Tampa, Florida 33620
bexley@csee.usf.edu

Abstract

In this report we evaluate the feasibility of having Spaceport Florida technicians wear video cameras as part of their clothing to record and allow for live viewing, via wireless links, of everything they do in an operational procedure. Our focus is on low-cost, commercial-off-the-shelf (COTS) hardware and software components. With wearable video cameras, real-time consultation with offsite experts becomes possible. Safely audits and tutorial training based on archived video also become possible. Key requirements include very low delay in streaming of real-time video and no frame loss for archived video. We believe that wearable video can reduce operational costs and improve the safety and security of Spaceport Florida operations. We build a proof-of-concept test bed and evaluate four commercial streaming video software products for a range of criteria including delay, loss, storage requirements, network bandwidth consumption, resolution of detail, ability to detect dropped objects. A demonstration of the proof-of-concept system is done with a simulated technician procedure. Our conclusions are that this concept is feasible for real-time consultation with off-sight experts, but not very feasible for archiving of video. Better software products are needed to enable both real-time streaming and archiving of video.

Acknowledgement of Support

This work is funded by a Spring 2001 Florida Space Grant Education and Research Grant.

Table of Contents

1. Introduction	1
2. Previous Work in Wearable Computing and Video Cameras	1
2.1 Review of Wearable Computing	1
2.1.1 Review of Xybernaut wearable computers	2
2.1.2 Review of NFL UmpCam.....	2
2.1.3 Review of DoD Land Warrior	3
3. Requirements for a Wearable Video Camera for a Spaceport Technician	3
4. Review of a COTS Video Hardware and Software Components	3
4.1 Review of small video cameras.....	3
4.2 Review of wireless networks for video transmission.....	4
4.3 Review of portable computers for local video storage.....	4
4.4 Review of video conferencing and archiving software.....	5
4.4.1 NetMeeting.....	5
4.4.2 Windows Media Encoder	5
4.4.3 CuSeeMe 5	5
4.4.4 ICUII 5	5
5. Evaluation of Video Conferencing and Archiving Software	5
5.1 Evaluation criteria	5
5.2 Design of evaluation and results.....	6
5.3 Recommendations for software.....	7
6. Demonstration of a Prototype Video-Enabled Technician	7
6.1 Equipment used in demonstration	7
6.2 Design of demonstration.....	8
6.3 Results from demonstration	8
7. Summary and Future Work	9
7.1 Evaluation of concept	9
7.2 Future Work.....	10
References	11
Appendix A – “Eye Chart” Used in Software Evaluation	12
Appendix B – Formal Procedure for Replacing a Hard Drive in a PC	13

1. Introduction

Safety and security are very important concerns for Spaceport Florida. Video surveillance is increasingly used to insure safety and security. Live and recorded video is used for all commercial rocket launches. In the case of an incident, the recorded video can be used to assist in determining and isolating the cause. The NASA Space Shuttle program has several documented cases where video taken during a launch has allowed for isolation of problems that, if had not been found, could have become catastrophic for future launches. For example, during John Glen's most recent launch, an 11-pound aluminum panel ripped away from the space shuttle body and struck the main engine during liftoff [1]. Shuttle Discovery's launch was delayed due to a dented fuel line in the spaceship's main propulsion system [2].

It is our belief that adding a wearable video camera to the clothing of Spaceport Florida technicians can both reduce operational costs and improve safety and security. A camera worn by a technician would "see" exactly what the technician sees and allow for both real-time consultation with offsite experts and archiving of video. The archived video can be used for safety audits, incident analysis, and for training purposes. Human wearable video cameras are nothing new. For example, the NFL has employed wireless "ump cams" [3] for some time and US soldiers go into battle with wireless video as part of the Land Warrior system [4]. It is clearly time to evaluate the application of wearable video to aerospace technicians.

This report describes our evaluation of COTS software and hardware component for enabling technicians with wearable video. We limited our equipment budget to less than \$500. Our evaluation shows that technology may not be "quite there" yet, but a video enabled technician will soon become feasible. The question, we believe, in a few years will be not be "why", but rather "why not". The remainder of this report is organized as follows:

- **Section 2** describes work done by others in wearable computing and video.
- **Section 3** gives the requirements for wearable video for a Florida Spaceport technician.
- **Section 4** is a review of applicable COTS video hardware and software.
- **Section 5** describes our wearable video system test bed and the evaluation of COTS video software.
- **Section 6** describes a demonstration, or test drive, of the proof-of-concept wearable video system we developed.
- **Section 7** summarizes our findings and discusses future directions.

2. Previous Work in Wearable Computing and Wearable Video Cameras

In this section we overview wearable computing technology are wearable video cameras. We specifically review NFL ump cams and several other existing systems.

2.1 Review of wearable computing

Computing technology has dropped in price, size, and power-consumption and increased in performance all at the same time. Wearable computing is an emerging field with its own conferences, research groups, and companies. Steve Mann, now at the University of Toronto [5], is often credited with inventing the field while a graduate student at MIT. The MIT Media Lab [6] continues to explore both wearable computing technologies and new paradigms of social interaction made possible by wearable technology. Georgia Tech [7] is exploring manufacturing, and other pragmatic applications of wearable computing. Significant computing power can now be comfortably worn in, or on, clothing. Wireless links make possible tether-free communications between the wearable computer and the rest of the world. Display technology has improved to the point where a full-screen monitor can be delivered via a "floating" heads-up display. Video camera technology has improved to where a camera and video display can all be readily hidden in a pair of eyeglasses. Figure 1, taken directly from [8], shows the evolution of wearable computers from bulky "contraptions" in the early 1980's to a hidden appliance in the late 1990's. The camera and floating display are hidden in the sunglasses in the fourth image showing a late 1990's wearable computer (the computer is worn on the belt and is about the size of the original Sony Walkman). In 2000, the NFL approved "ump cams" for professional football [9]. This is an example of video-enabling a human with low-cost and highly portable video cameras and wireless links.

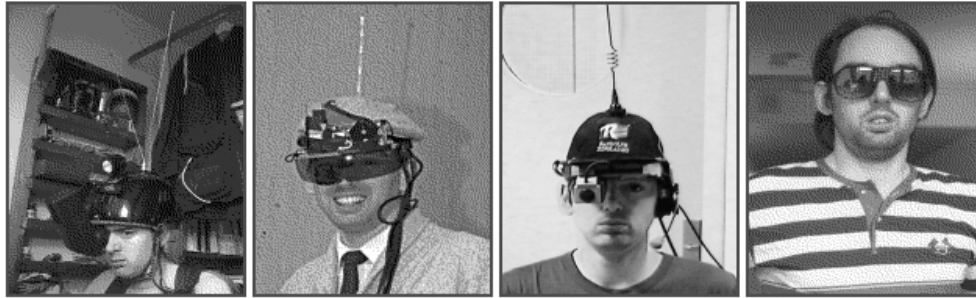


Figure 1. Photograph of Steve Mann showing wearable computing technology (copied directly from [8])

2.1.1 Review of Xybernaut wearable computers

The Xybernaut Corp. of Fairfax, Va., is the patent holder for the wearable PC. The company has designed systems for use both in industry and the military. The units typically consist of the following: a belt pack containing the computer processor, hard drive, and battery; a keyboard which straps to the wrist; and either a headset with display, or a wrist-mounted touch screen. The computers carry the same power as some laptops. These fully functional PCs implement a company's existing software, and allow instant access to schematics and technical manuals at remote job sites. Bell Canada has entered into a large-scale market trial of Xybernaut's wearable computers, equipping its pole climbers with the Mobile Assistant V. The unit contains a 500 MHz Intel Celeron processor, 128-MB of RAM, and a 2-GB hard drive that can be worn in a vest or on a belt. It runs all major PC operating systems, including Linux and Windows 2000/NT. The computer is manipulated either through the use of a wrist-mounted keyboard, an SVGA flat panel touch screen, or voice recognition software. Service technicians using the wearables reported saving 50 minutes per day, when compared to the use of traditional truck-mounted laptops. After 10 months of field-testing, Bell has committed to the technology, and plans to eventually outfit all of its technicians with wearable computers. [10]

Xybernaut has teamed up with Hitachi to create the newest wearable designed for the general public. The Poma was released this month at the 2002 Consumer Electronics show in Las Vegas. The PC is small enough to slip into a pocket, while the headset allows the user to view a high-resolution image. The unit runs Microsoft's Windows CE operating System. It contains a Hitachi 128-MHz RISC processor and 32 MB of RAM. It also includes a Compact Flash slot, USB port, 32 MB of ROM, a custom optical mouse and a removable internal rechargeable battery. The unit costs \$ 1,499, (as of 1/2/2002) which includes a lightweight head mounted display [11].



Figure 2 – Photograph of Xybernaut wearable computer (copied directly from [12])

2.1.2 Review of NFL UmpCam

The NFL's use of the UmpCam has made it one of the more well known examples of wearable technology. The umpires wear the tiny cameras affixed to the brim of their cap, while a wireless connection affords a ground-level view of the line of scrimmage. The miniature camera is the brainchild of ABC Adelaide's sporting director Paul Chadwick and was perfected by technical supervisor Hans Sanders. The camera, which costs about \$1000 to make, took just eight weeks to perfect and has been tested successfully by the ABC over the past few weeks. Attached to the side of the peaked cap, it is linked by cable to a battery-powered transmitter on the umpire's belt.

Images are transmitted to a receiver in a plastic box on the boundary fence behind the umpire. The receiver is connected to the broadcasting van by cable. One potential problem, however, can occur if the umpire's cap is not cap completely level. This results in a slanted image. Introduced in the 2000 football season, umpires considered the product a success, remarking that it gave them better insight into the game.

2.1.3 Review of DoD Land Warrior

The U.S. Department of Defense has shown interest in wearable technology, instituting the Land Warrior project. The Land Warrior links soldiers in a platoon to a wireless local area network and includes wearable Xybernaut computers that use Microsoft Windows 2000 and Intel chips. The Land Warrior's assault helmet can stop a 9-millimeter round and transmit digital radio signals. A helmet-mounted eyepiece allows a soldier to see video and thermal images. A computer rests inside silicon gel in a sealed metal pack that the soldier carries on his back. The Army expects to equip an infantry regiment or brigade with the Land Warrior equipment by 2004. [4] The units are currently used mostly for military repairs, allowing wearers to crawl around helicopters, tanks and trucks, while accessing technical manuals on-line. [13]



Figure 3 – Photograph of soldier outfitted with Land Warrior (copied directly from [14])

3. Requirements for a Wearable Video Camera for a Spaceport Technician

We envision that a wearable video camera on an aerospace technician will be used for real-time consultation on procedures and recording of procedures for later safety audits and training. For real-time consultation, the video must be transportable across existing IP networks and viewable on desktop PC's. To achieve the desired uses of real-time consultation and archiving of video, the following requirements must be met:

- 1) The system must be light-weight and not physically obtrusive to the technician
- 2) The system must be low-cost
- 3) The system must provide one-way video and two-way audio
- 4) The end-to-end delay must be less than 150-milliseconds for human-scale real-time performance
- 5) Real-time video and audio quality must be "acceptable"
- 6) Archived video must not have any lost video frames or audio. This is a must-have requirement.

4. Review of COTS Video Hardware and Software Components

4.1 Review of small video cameras

Practical wearable technology should consist of small, lightweight components. Many extremely small video cameras that suit this purpose have been successfully introduced. For some time, doctors have been performing colonoscopies to detect cancer. This procedure is accomplished by passing a tube containing a tiny video camera through the patient's large intestine. A newer event in camera technology is the Capsule endoscopy, introduced by Given Imaging Inc. This procedure requires a patient to swallow a capsule with a tiny camera that sends back pictures of his or her innards.

The encapsulated camera is approximately the size of a large vitamin pill -- 11 millimeters by 26 millimeters. Twice per second for the eight-hour life of its battery, the camera sends back digital images that are captured by a data recorder the patient wears on a belt around his or her waist. The data recorder is roughly the size of a paperback book. The physician can project the view from inside the patient's gastrointestinal tract onto a computer screen for detailed analysis. The cost of the computer workstation is approximately \$15,000, and the portable data recorder costs approximately \$5,500 (2001). The camera transmitters come in packs of 10, at \$4,500 per pack. [15]



Figure 4 – Photograph of Capsule used in capsule endoscopy (copied directly from [16])

The PenCam is a device that combines a pen and video camera and is used to document autographed items. PenCam uses a tiny video camera at the end of a pen to digitally record an autograph as it is being signed on a piece of memorabilia [17].

Football fans in New Zealand perfecting a system allowing tiny cameras to be placed at each end of the oval ball to give TV viewers an unprecedented view of the game. A pair of 14-gram cameras at each end of the ball pick up images through tiny holes. The video is then relayed via antennae to gyroscope software which steadies the picture, after which the video is relayed to a broadcasting unit [18].

4.2 Review of wireless networks for video transmission

Although the promise and the reality of wireless video are light years apart, some companies are pioneering promising solutions. PacketVideo continues to boast about its ability to deliver video over wireless networks using MPEG-4-based server technology. PacketVideo and Sprint have held a small trial delivering video at 14.4-kbits/sec over the latter's existing PCS network. Though some systems reach 19.2kb/s, faster networks will be required for mass adoption by users accustomed to television and film.

Although streaming video is possible today using some PDAs, the penetration of these devices is low compared to cellular phones. Consequently, companies have been improving wireless phones by increasing the screen size, adding color to the display and adding memory, processor power and battery strength. The MPEG-4-capable Samsung SPH-X2000 handset incorporates the A2 video ASIC chip, designed by Emblaze Systems. The SPH-X2000 can play video over many current IS-95B and IS-95C networks. The video phone currently is compatible with existing CDMA and 1X networks at speeds from 9.6kb/s to 144kb/s. [19]

The Voyager Lite backpack is another innovation for wireless video applications. Weighing about 4.5 pounds, Voyager Lite is a wearable video camera and transmission device. Voyager Lite does not need a line-of-sight for transmission, and delivers microwave signals free from ghosting and other multipath interference. The device can be used with a variety of bit rates and includes a MPEG-2 video encoder and an integrated COFDM modulator/upconverter. It outputs a 2.4 GHz RF signal back to an ENG van or the station, and sells for \$45,000 (2001). [20]

4.3 Review of portable computers for local video storage

The Toshiba E570 is a personal digital assistant (PDA) which runs Windows' PocketPC operating system. The E570 is powered by a 206MHz Intel StrongARM processor and carries 32Mb of flashable ROM and 64Mb of RAM. The E570 includes slots for Compact Flash (with memory cards available from 16Mb all the way up to 1Gb) and the latest Secure Digital cards (available in 32Mb and 64Mb). [21]



Figure 5 –The Toshiba E570 PDA (copied directly from [23])

4.4 Review of video conferencing and archiving software

The following are commercial-off-the-shelf (COTS) video conferencing software products that enable streaming video and audio. All four of them were evaluated with the prototype.

4.4.1 NetMeeting [24]

NetMeeting is offered as a free download from Microsoft and is compatible with CuSeeMe 5. It offers security features and the ability to remotely choose between faster video performance and better image quality.

4.4.2 Windows Media Encoder 8 [25]

Windows Media Encoder captures Windows Media Video 8 content in real-time for streaming delivery and archiving, and creates Windows Media Audio 8 for streaming and download. When performing the wireless network evaluation, Windows Media Player was used to view the video. This is a unified player which supports streaming and downloadable digital audio, video, and other Internet content. Both the Encoder and the Player are available as free downloads from Microsoft.

4.4.3 CuSeeMe 5 [26]

CUseMe is the original videochat client and is the only such product that allows twelve video windows to be viewed simultaneously. It has network, firewall, and gatekeeper options which give the user the ability to optimize videochat based on the network environment. The cost is \$39.99 (March 2002).

4.4.4 ICUII 5 [27]

ICUII 5 is a video-conferencing client that is not compatible with any other software. The newest version has just been released (5.5.3) and includes optimized video output to the preview and video windows. The cost is \$39.95 (March 2002).

5. Evaluation of Video Conferencing and Archiving Software

5.1 Evaluation criteria and design of experiment

Since the focus of this experiment of this project is on low-cost, commercial-off-the-shelf (COTS) hardware and software components, the prototype's performance was evaluated using four off-the-shelf software products. The evaluation criteria were as follows:

- 1) The price of the software. In accordance with our purpose, the price should not be prohibitive.
- 2) The maximum frames per second afforded by the software (fps).
- 3) A determination as to whether the software includes security features.
- 4) A determination as to whether the software carries audio. This is a necessary feature if technicians are to consult with off-site experts.
- 5) A determination as to whether the software comes with the ability to archive. Since archived video is necessary for safety audits, incident analysis, and for training purposes, a separate recording device may be necessary.
- 6) A determination as to whether the software provides for multiple receivers. This feature allows the technician to be viewed or coached by more than one party.
- 7) The system requirements necessary to successfully run the software.
- 8) Compatibility of the software with other software products used for receiving.
- 9) A record of the real-time time delay for a) video and b) audio. For the purposes of this project, any significant (or perceivable) delay is unacceptable.
- 10) Object Dropping Evaluation: This is an evaluation of the percentage of times an object can be seen when it is dropped at a fixed distance from the camera. This experiment is repeated for four small objects of increasing size. Each of the four items is dropped ten times.

- 11) Color Detection Evaluation: Six colored wires are placed next to each other on a circuit board, and the percentage of correctly identified colors is determined.
- 12) Eye Chart Evaluation: This evaluation requires a simulated eye chart to be placed at a distance of six feet from the video-enabled technician. The smallest line of font that is readable is recorded (out of ten lines, with line 1 being the largest font and decreasing to the smallest font on line 10)

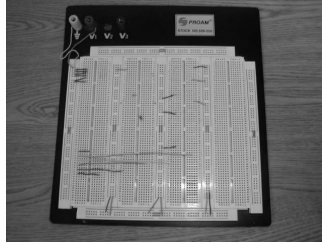


Figure 6 – Photograph of circuit board used in color detection evaluation

5.2 Design of evaluation and results

Tables 1 and 2 show the result for the evaluation. Table 1 shows items (1) through (8) and Table 2 the remaining items.

Table 1: Results for Specification Items

	Netmeeting	Windows Media Encoder	CuseeMe 5	ICUII 5
1) Price	Free download from Microsoft	Free download from Microsoft	\$39.99	\$39.95
2) Maximum frames per second	30 fps	60 fps	30 fps	
3) Security Features	Yes	No	Yes	No
4) Audio	Yes	Yes	Yes	Yes
5) Archiving capabilities	No	Yes	No	No
6) Multipoint conferencing	Yes	Yes	Yes	Yes
7) System Requirements	90 MHz Pentium processor, WinNT: 24 MB RAM, All other Win: 16 MB RAM	300 MHz processor, 128 MB of RAM, Win2000	Win98/2000/ME, 64 MB RAM, Pentium III, 500 MHz	Win 95/98/NT, Pentium 233, 16 MB RAM
8) Product Compatibility	NetMeeting/ CUSeeMe	Receiver: Windows Media Player	NetMeeting/ CUSeeMe	none

Table 2: Results for Wireless Network Evaluation

	Netmeeting	Windows Media Encoder	CuSeeMe 5	ICUII 5	NetMeeting/ CuSeeMe5
9a) Real-time Time Delay: <u>Video</u>	none	10 seconds	none	0.5 seconds	none
9b) Real-time Time Delay: <u>Audio</u>	0.5 seconds	10 seconds	none	2 seconds	0.5 seconds
10) Dropping Objects Results	25 % detection	20 % detection	100 % detection	0 % detection	95 % detection
11) Color Detection Results	100 % detection	100 % detection	100 % detection	100 % detection	100 % detection
12) Eye Chart Results (Line 1 is largest font, 10 is smallest)	Line 3	Line 5	Line 4	Line 5	Line 3

5.3 Recommendations for software

The evaluation results showed CuSeeMe to be the strongest product overall. This product does not archive, but its wireless network evaluation results were the most impressive in five out of six categories. It performed slightly worse than ICUII and Windows Media Encoder on the “eye chart”, a test designed to measure picture quality. These two products read five lines from the eye chart while CUSeeMe read only four lines. However, CUSeeMe and CuSeeMe/NetMeeting were the only products which came close to having acceptable results for the dropped objects evaluation (which was designed to detect frame loss). This finding rules out ICUII and Windows Media Encoder as appropriate products for archiving. While they are still possible choices for real-time consultation, CuSeeMe or CuSeeMe/NetMeeting provides a significantly smaller time delay and less frame loss.

6. Demonstration of a Prototype Video-Enabled Technician

6.1 Equipment used in demonstration

The following equipment were used in the demonstration:

- Model CW9900 Clover 2.4 GHz wireless Audio/Video Sender (1 transmitter and 1 receiver) . The system is a wireless audio/video sender that delivers up to 300 feet away; uses a directional 2.4 GHz antenna (\$124.95 as of March, 2002) [28].
- D-Link DSB-V100 USB video capture device (\$59 each as of March 2002) [29].
- Model WDB-5407SS Color DSP Waterproof Bullet Style Camera With Standard Lens (\$233.52 as of March, 2002) [30].



Figure 7 – Photograph of video-enabled Technician



Figure 8 – Photograph of equipment used in demonstration; clockwise from top-left: Clover 2.4 GHz wireless Audio/Video Sender, 1/3 inch submersible color bullet camera, microphone, D-Link DSB-V100 USB video capture device

6.2 Design of demonstration

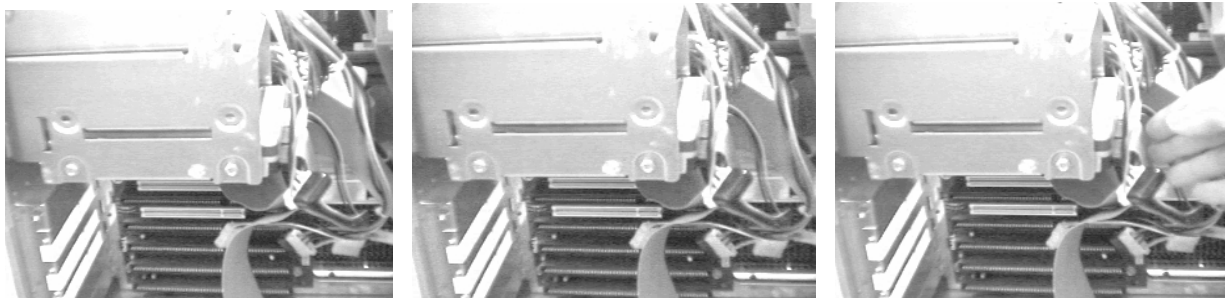
A demonstration experiment was used to evaluate the prototype. The video-enabled technician removed and replaced the hard drive in a PC, archiving the video. Stills from the video output are seen in Figures 9 through 13. This demonstration was chosen to test the limits of the prototype and includes the manipulation of small and large objects, in both easy-to-teach and less accessible areas.



Figure 9 – Photograph of PC and workspace showing tools, etc.

6.3 Results from Demonstration

Figure 10 shows still images captured from an archived demonstration video. The still images clearly show the technician removing a connector.



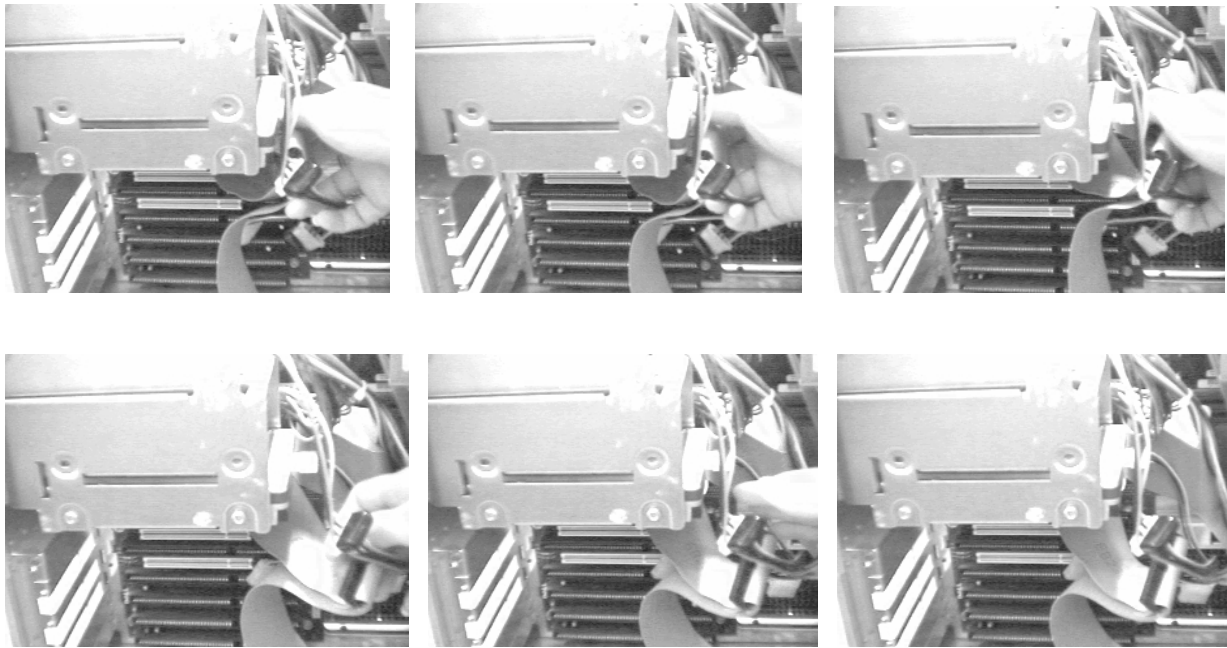


Figure 10 - Still photos captured at 1 second intervals

7. Summary and Future Work

7.1 Evaluation of concept

The wireless network evaluation revealed that CuSeeMe is the only practical product for use with the prototype. CuSeeMe had no real-time time delay, and both the audio and video were in sync. For a product to be effective for real-time consultation, it must meet the following criteria

- The end-to-end video and audio delay must be less than 150-milliseconds to achieve human-scale real-time performance
- Real-time video and audio quality must be acceptable

CuSeeMe accomplishes both of these tasks and is recommended as the best of the evaluated products in regards to real-time consultation.

Archived video must not have any lost video frames or audio if the prototype is to be used for safety audits. CuSeeMe was also the only product that met this requirement, as shown by the results of the Dropped Object Test, (this product had a 100% detection rate). CuSeeMe does not archive, however, and must be paired with separate recording software. Archived software must also have acceptable picture quality. The demonstration showed acceptable picture quality for most tasks, but picture quality degraded when the camera was extremely close to the workspace. This occurred when the technician's head was inside the computer while she was removing cables from the hard drive.

The first time the technician performed the demonstration, the camera was rarely focused on the correct area. This discrepancy occurred when the camera was not aimed at the same object as the technician's eyes. The technician reported that within thirty minutes she learned to maneuver in a manner that minimized this problem, incorporating more head movement (as opposed to eye movement alone).

The wireless transmitters were directional, and audio and video were degraded or completely lost depending on the position of the transmitters. For this reason, it may be more practical to tether the technician to a stationary wireless transmitter, rather than leaving the technician completely mobile. Tethering should not be a hindrance if the workspace is of small to moderate size.

Performance of the wireless transmitters was tested under the following five conditions:

- 1) Three feet apart with no obstructions between the transmitters (control scenario). This produced a nearly perfect picture at the receiving end. The best picture was produced when the transmitters were aimed directly at one another.
- 2) Fifty feet apart with no obstructions between the transmitters. The picture was significantly degraded and flickered on-and-off. Directionality was unimportant. This experiment was performed in an eight-foot wide hallway with concrete block walls. Performance may improve in an open area.
- 3) Ten feet apart and through a concrete wall. The picture quality was very close to the control scenario, perhaps slightly degraded. The best picture was produced when the transmitters were aimed directly at one another.
- 4) Ten feet apart and through a metal wall. The picture quality was severely degraded and marred by waves. The best picture was produced when the transmitters were aimed directly at one another.
- 5) Fifty feet apart and through two concrete walls. The picture was significantly degraded and flickered on-and-off. Directionality was unimportant.

The demonstration was performed with both a helmet-mounted camera and a stationary camera. A significant drawback of the stationary camera is its limited field of view. The entire workspace can only be viewed if the camera is significantly far away, which reduces the amount of fine detail that can be seen. When setting up the camera, the technician must choose between a close setting which will allow a detailed view of a small area (useful when performing demonstration tasks that are inside the computer) or a less-detailed view of a large area (useful when performing demonstration tasks that are outside the computer, such as removing cables). The only drawback of the helmet-mounted camera is the discrepancy between that which the camera sees and that which the technician intends it to see. This can be improved with minimal experience.

7.2 Future Work

Future work may involve the investigation of using Internet2 for video transport. Internet2 is a consortium being led by over 190 universities working in partnership with industry and government to develop and deploy advanced network applications and technologies. The primary goals of Internet2 are to create a leading edge network capability for the national research community, enable revolutionary Internet applications, and ensure the rapid transfer of new network services and applications to the broader Internet community [28].

References

- [1] "Discovery crew performs well first 24 hours of mission", October 30, 1998. URL: <http://www.cnn.com/TECH/space/9810/30/shuttle.03/#3>
- [2] "Latest Discovery delay could stretch beyond Sunday", December 9, 1999. URL: <http://www.flatoday.com/space/explore/stories/1999b/120999e.htm>
- [3] E. Kibble, "Now goal umpires put viewers in the picture", *The Advertiser*, April 25, 2001.
- [4] E. Iwata, "Silicon Valley techies suit up Army with sleeker gear", *USA TODAY*, February 7, 2002.
- [5] S. Mann personal WWW page, 2000. URL: <http://wearcomp.org/mann.html>.
- [6] MIT Wearable Computing Page, 2000. URL: <http://mevard.www.media.mit.edu/projects/wearables/>.
- [7] GT Wearables, 2000. URL: <http://wearables.gatech.edu/>.
- [8] S. Mann, "Wearable Computing: A First Step Toward Personal Imaging," *IEEE Computer*, Vol. 30, No. 2, pp. 25 - 32, February 1997.
- [9] H. Fendich, "Notes: Newfangled NFL coming to a TV near you," Total Sports Network, August 31, 2000. URL: <http://aol.totalsports.net/news/20000831/fbo/000831.0426.html>.
- [10] R. Ross, "Wearable computers a ringing success", *The Ottawa Citizen*, August 7, 2001.
- [11] N. Blackburn, "Does that computer really go with your outfit?" *The Jerusalem Post*, January 20, 2002.
- [12] Xybernaut, 2002. URL: http://www.xybernautonline.com/eCommerce/Poma/Plac_Poma.htm
- [13] "Troops Outfitted with technology", *Tampa Tribune*, August 28, 2001.
- [14] Erwin, Sandra, "Foot-Soldier Modernization Effort Regaining Credibility". URL: <http://www.nationaldefensemagazine.org/article.cfm?Id=498>
- [15] B. Osinski, "Norcross firm markets 'camera-in-a-pill' system", *The Atlanta Journal and Constitution*, November 18, 2001.
- [16] Given Imaging, 2002. URL: <http://www.givenimaging.com/usa/default.asp>
- [17] D. Chapin, "PenCam mightier than the word in verification of autographs", *The San Francisco Chronicle*, January 19, 2002.
- [18] "Ooh, Ah, Groan: Now Follow Footy With Ball-cam", *Sun Herald (Sydney)*, November 25, 2001.
- [19] C. Goldman, "Moving Pictures", *Wireless Review*, May 01, 2001.
- [20] M. Grotticelli, "Tandberg's TV-pack", *Broadcasting and Cable*, October 01, 2001.
- [21] A. Gordon, "Pocket PCs - Pocket rockets.; Packing a processing punch that belies their small size, the latest", *What PC*, February 13, 2002.
- [22] ISEE, 2001. URL: <http://www.i-see.org/eyecharts.html>
- [23] Expansys, 2002. URL: http://www.expansys.com/product.asp?code=TOSHI_E570
- [24] Microsoft, 2002. URL: <http://www.microsoft.com/windows/netmeeting/default.asp>
- [25] Microsoft, 2002. URL: <http://www.microsoft.com/windows/windowsmedia/wm7/encoder.asp>
- [26] CuSeeMe, 2002. URL: <http://www.cuseemeworld.com/>
- [27] ICUII, 2002. URL: <http://www.icuii.com/>
- [28] Electronic City, 2002. URL: <http://www.electroniccity.com/brands/8.asp>
- [29] D-Link, 2002. URL: <http://www.dlink.com/products/usb/dsbv100/>
- [30] Electronic City, 2002. URL: <http://www.electroniccity.com/shopping/pricelist.asp?prid=160>
- [31] Internet2, 2002. URL: <http://www.internet2.edu/>

Appendix A – Snellen Eye Chart

F

B C

P T E O

B Z F E D

O F C L T B

T E P O L F D Z

L P C T Z D B F E O

Z O E C F L D P B T

E T O L E B Z E F D C

B O I C P T E B L I B E Z C O P E

Appendix B - Formal Procedure for Replacing a Hard Drive in a PC

Purpose: Replace hard drive in a Dell Dimension PC

Parts and tools:

- 1) Cup to hold loose screws during procedure
- 2) Tray to hold loose cable during procedure
- 3) Phillips head screwdriver

Procedure:

- 1) Verify tools and parts.
- 2) Disconnect power cord from the computer
- 3) Disconnect all peripheral cabling from the computer and place in holding tray.
- 4) Remove outer cabinet housing from computer.
- 5) Remove power cable connector from hard drive.
- 6) Remove IDE 40-pin data cable from hard drive.
- 7) Remove screws from hard drive bay and place them in cup. The cup should now have 5 screws.
- 8) Remove hard drive from hard drive bay and verbally acknowledge.
- 9) Reinsert hard drive into hard drive bay.
- 10) Retrieve screws from cup and reattach the hard drive bay.
- 11) Reconnect the IDE 40-pin data cable, making sure of proper alignment.
- 12) Reconnect the power supply to the computer.
- 13) Reattach the outer cabinet casing of the computer.
- 14) Reattach all peripheral cables to the computer.
- 15) Reattach the power cord to the computer.
- 16) Touch and verbally acknowledge that the screw cup is empty.
- 17) Touch and verbally acknowledge that the holding tray is empty of cables.