Designing for Digital Transformation in a Society of Smartness: Conceptual Cornerstones, Design Implications, and a Road Ahead

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Abstract

Information system (IS) researchers can be seen as key change agents in occasioning positive societal change and playing a role in responding to "grand challenges". In this monograph, we work with and advance literature about digital transformation (DT) towards how IS research can conceptualize and grapple with the design of IS artifacts for responding to such complex issues. We conceptualize DT as transformations of smart service systems (SSSs) due to the widespread use of smart technologies by individuals. We then further develop this literature toward a more sociological understanding of the practices within which individuals interact with smart technologies in their everyday lives. Based on providing these cornerstones, we move toward deriving specific suggestions for IS design of DT at a societal scale and, in doing so, contribute to research about DT, SSS, and IS design, respectively.

Introduction

Advances in computers and communication technology have changed traditional methods for learning and skills training. Today e-learning is becoming an increasing popular alternative to traditional programs. In modern learning and training systems, integrated learning scenarios where e-learning is linked with the world of work, play an important role. Computer-based learning and training techniques are now well established, and provide an environment to create interactive interfaces, and real-time software can monitor every response made by the learner or the system. The use of internet has the advantage that it is not restricted to the time and place. People can study at any time and any place as they wish [1-4].

The system can be implemented as a web service to take advantages of the possibilities of anywhere any time access from any computer connected to the internet. The web technology is very suitable for building an interactive e-lab learning system based on mixed reality environment. An authorized learner can access the server from a personal computer (client) connected to the server. After the web home page has loaded, the learner is guided through a set of pages where the learner can (1) read related teaching materials; (2) set-up the experiment components and parameters, and (3) get help or more related information. These

parts are teaching materials, learners' information, learning activities management and mixed reality environment [5-8].

Drexel University's Engineering Technology program in the School of Technology and Professional Studies has conducted extensive research into enhancing the 3D display system that it had developed in the past years as a tool to improve the quality of learning in the Robotics classes. Two types of 3D technologies, Anaglyph and Polarized, were utilized and compared according to different criteria that are discussed further in the paper. The goal of the project is to achieve online 3D robotics learning experience that can be implemented for on-campus e-lab application. The paper describes the different approaches for creating the smooth and fast online 3D video streaming. This involves finding the way of design and implementation for capturing the digital video stream and the efficient way of streaming it over the internet.

Background

Stereoscopy or creating 3D images has been an area of research for more than a century [9-11]. It is described as the technique for creating the illusion of depth in an image. This is possible by combining a pair of 2D images that have a minor deviation in a way to cheat the eyes and the brain into perceiving each image in a different perspective. The minor difference in the two images allows the viewers' eyes to perceive the incoming images as a single 3D object.

In the early stages, stereoscopy required very expensive tools and mechanisms. The impracticability of these tools rendered the 3D system to be hardly implemented in a theater or public place. Today, stereoscopy has shown the world a new way of looking at 2D objects. Amusement parks, theaters, and even educational institutions are starting to embed this more popular 3D technology in it applications. Thus, the 3D market has been

expanding and the costs of creating stereoscopic effects are decreasing.

Several different techniques of creating 3D visualizations have been developed throughout the years. The most important ones are Polarization, Anaglyph and Eclipse. In this paper, the digital Polarization and Anaglyph 3D visualizations are going to be tackled. The different setups corresponding to the two systems are clearly described in the sections below.

Experimental Setup

To control the robot, the Yamaha VIP+ software was utilized. As for creating the 3D images, in general, the Polarization system requires more tools than the Anaglyph one. The lists of components that were used for the 3D Polarized setup and the Anaglyph setup are described in Tables 1 and 2, respectively.

Table 1. List for the 3D Polarized Setup.

No.	Device	Make/Model No.
1.	MiniDV Handycam Camcorder	Sony DCR-HC62
2.	MiniDV Handycam Camcorder	Sony DCR-HC62
3.	i-Link Firewire (1394) cables	Sony Co.
4.	Video Card with Dual Output Cables	ATI Radeon HD 2400 Pro
5.	DLP Projector	Mitsubishi XD490UXGA
6.	DLP Projector	Mitsubishi XD490UXGA
7.	Silver Projection Screen	3DimageTek Co.
8.	Twin Sliding Bar(6")	Berezein Co.
9.	Tripod	Sony Co.
10.	Polarized filter	3DimageTek Co.
11.	Adjustable Dual Stacker Unit	3DimageTek Co.
12.	Polarized Glasses	3DimageTek Co.
13.	Webcam XP Pro	Webcam XP Co.

Table 2. List for the 3D Anaglyph Setup.

No.	Device	Make/Model No.
1.	MiniDV Handycam Camcorder	Sony DCR-HC62
2.	MiniDV Handycam Camcorder	Sony DCR-HC62
3.	i-Link Firewire (1394) cables	Sony Co.
4.	Stereoscopic Multiplexer	3dtv.at Co.
5.	Stereoscopic Player	3dtv.at Co.
6.	Twin Sliding Bar(6")	Berezin Co.
7.	Tripod	Sony Co.
8.	Anaglyph Glasses	Berezin Co.

Image Capturing Mechanism

Since the capturing mechanisms for both systems are very similar, they are described within this section. The two camcorders are fixed on the twin camera bar which is then mounted on a tripod. The two cameras are placed in a parallel fashion in such a way that they are both exactly perpendicular to the bar. The zoom level on both cameras must be minimal to ensure that the CCD level is not alternated during recording.

The capturing mechanism is shown in Figure 1. The twin camera bar that was used is designed to allow two cameras to be mounted side by side in a fixed horizontal position. The bar is designed to mount and remove each camera easily using two screw finger Torn Knobs. The bar also includes a bubble level to measure the tilt in the bar. It can easily be mounted on a tripod since it is equipped with a standard mounting hole. In order to guarantee that the quality of the video stream is acceptable, a professional type of tripod is suggested to be used. A portable and expandable tripod was used in this project. It allows capturing pictures and videos at almost all the desired heights and angles. The specifications of the Sony DCR-HC62 camcorder are relevant to the project:

- Focal Distance: 2.5 – 62.5 mm
- CCD Size : 3 mm
- iLink Interface: Yes (DV only)

The two sony camcorders can transfer the data over iLink firewire cables that are sufficiently fast for high quality streaming. The iLink interface also reduces the chances of having any delays in the transfer of the images from the camcorders to the computer. However, a major requirement for this system to work is the ability for the computer to accept two firewire inputs from both cameras. Therefore, the computer should be equipped with a two-port firewire card. The description of the setups applies to both, the Anaglyph and Polarized image capturing mechanisms.
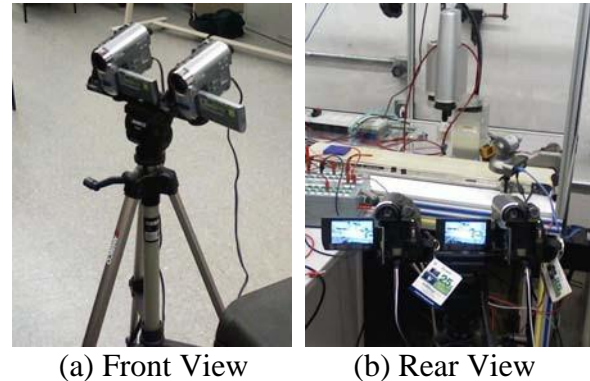

(a) Front View   (b) Rear View

Figure 1: (a) Front View and (b) Rear View of the capturing mechanism.

Online 3D Visualization System

Figure 2 shows the Internet-based 3D Robotics educational system. Two client PCs are necessary to run this system. The first PC is used to feed the projectors with the dual video streams. The second PC is used to run the robotic software and perform various robotic operations. As for the video server, it runs a camera management and image streaming software called "WebcamXP Pro". This streaming software functions by capturing continuous images from the camera sources and streaming them to a client. The client keeps rapidly refreshing the streamed pictures in a

web browser allowing it to surpass encoding and decoding delays. This streaming method also cuts down on the buffering delays that are observed at both the sender's and the receiver's sides. Due to the fast Gigabit link between the video server, robot controller, and the two PCs, data can be transferred with little communication delay and the system is able to run in a real-time fashion [12-15].
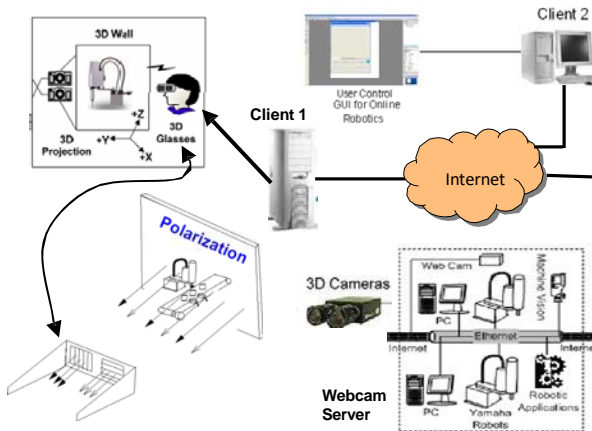

Figure 2: Online 3D visualization system.

As shown in Figure 3, WebcamXP allows a user to share the data coming from the connected camera to the Internet or Intranet users. When this broadcasting feature is enabled, the internal webserver of WebcamXP would be enabled. This allows users who know the server's IP address or Website URL to navigate to a custom-designed page and observe the streaming representation of the cameras that are connected to the server. In order to configure the Webserver, the server's host name and port should be specified. The broadcast is accessed through this name and port. Broadcasting in WebcamXP is performed over HTTP. A user can access the connected cameras through any type of browser (Microsoft Internet Explorer or Mozilla Firefox) that imports from WebcamXP's Webserver. It has to be noted though that authentication can be applied so that the user would be prompted to enter a password whenever he/she tries to connect to any of the cameras. Two video sources can be recognized corresponding to the left and right cameras.

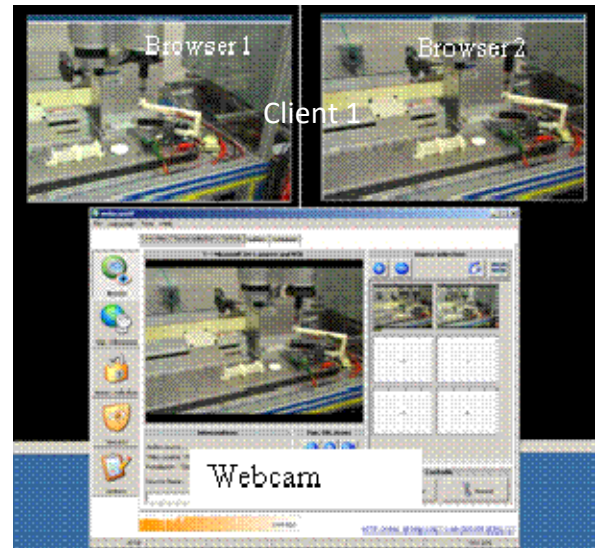After including all the settings, the Webserver can be enabled.

Figure 3: Broadcasting video streams from Webcam Server to Client 1.

Now that WebcamXP is broadcasting the two video streams, it is up to the users to determine how to display those streams. For this reason, it was decided to design a custom website for this type of application. The website would provide the students with some knowledge regarding how the whole system works in addition to accessing the two video streams. Each of the cameras has its own link on the website which can be displayed in a separate browser. Moreover, each of the camera videos can be dragged and dropped over the screen to simplify the procedure of overlapping the video streams for the purposes of creating the 3D effects.

The website itself was created using Microsoft Frontpage and some custom HTML code. For the pages that include the video streams, additional CSS and Javascript codes are required. The Website has been uploaded to Drexel University's Webserver so that it would be available to all the students. It has been specifically uploaded to the instructor's FTP server space.

For our purposes, to gain online access of the robot, it has to be operated using software that

can be remotely controlled. This objective is primarily accomplished by the use of Yamaha VIP+ programming. Yamaha VIP+ Windows is applied as assistant software for a multi-axis robot controller and robots. To allow remote operation, the Yamaha YK220X Scara robot facilitates the remote robotic control. The Yamaha VIP+ Windows is the software that remotely operates the robot arm as well as runs the robotic programs. It executes instructions via Ethernet connected to the robot controller which facilitates the inputs and outputs for the robotic operations.
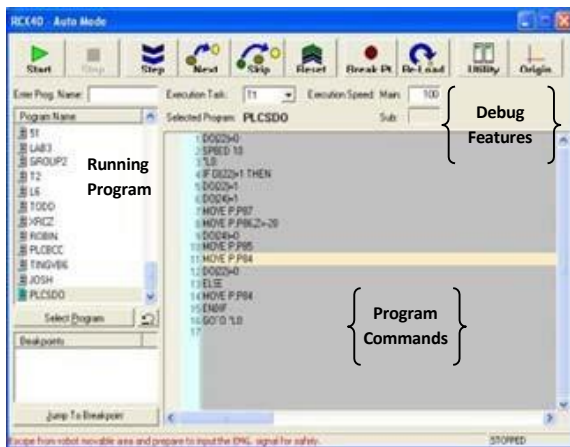

Figure 4: Remote robotic operation by Yamaha VIP+ Windows software in Client 2.

The system integration enables the computer to automatically perform the sequence of tasks outlined by a user when the students start the equipment from a remote site. It can also be used to create and edit programs, teach points, define parameters, and shift and/or run data directory used with robot controller. As shown in Figure 4, the Yamaha VIP+ Windows software for robotic operations enables information exchange between the various levels of the control architecture.

Streaming and Displaying

In this section, the two different types of technologies, Anaglyph and Polarized, are described in details. It has to be noted that the

two systems share common capturing setup features which were described above.

Polarized Implementation Strategy

In the case of a polarized video, the output has to be projected as two images (left and right) on a silver screen. By wearing a pair of polarized eye glasses, the user can see the image in 3D with a proper depth perception.

In order for the dual output concept to work, a dual output video card is required. In this project, the "ATI Radeon HD 2400 Pro" video card was used with a dual output cable. The two cables are connected to two Mitsubishi XD490U XGA DLP ultraportable Projectors that work on 2500:1 contrast ratio and very bright 3000 ANSI lumens. In this case, the ports and cables that are used are DVI ports and cables. The XD490U XGA DLP projectors also feature a color enhancer technology that intelligently produces true colors and smooth images for specific scene settings.

To help align the two projectors, an adjustable stacker unit is used. The stacker unit includes two custom adjustable filter holders for positioning pre-aligned linear polarizers. Polarized filters are installed on the stack unit and in front of each of the projectors to create the polarized 3D effect necessary for the 3D vision. Those filters are essential for creating the 3D image and have to be placed in the correct viewing positions. Another important factor is the use of a silver screen and not any ordinary screen. A silver screen is more reflective and brighter than ordinary screens. It is greatly recommended to be used when projecting polarized 3D images. Figure 5 displays the stacker unit, polarized filters, the silver screen, and two projectors.

To project the output from the PC as two images, each camera stream has to be projected separately onto the silver screen. Each camera stream will be displayed on an internet
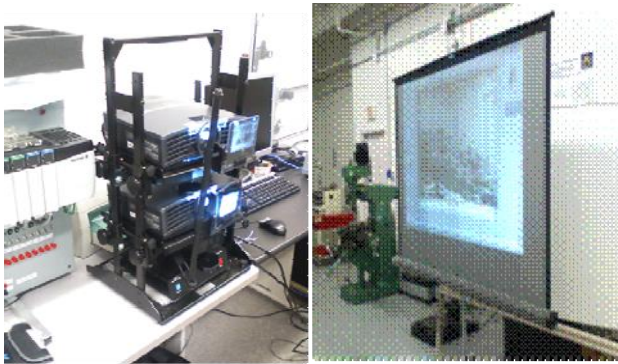
Figure 5: Polarization setup with adjustable dual stacker unit, silver screen, and two projectors.

browser that will be projected on a separate projector. On the screen, the two images have to be overlapping and the adjustments have to be performed manually by tuning the adjustable dual stacker unit and dragging and dropping the two images on the browsers. In this way, the parallax and the separation levels will be adjusted as to obtain the best 3D image quality. After that, a pair of polarized glasses should be worn to see the 3D effects.

Anaglyph Implementation Strategy

Stereoscopic Multiplexer is a Windows driver that allows a user to capture stereoscopic video from two separate cameras. Its main feature is that it combines data that arrives from two different cameras and then encodes them into a single stream in a side-by-side format. It also works on synchronizing both of the streams that are arriving from the two different cameras. This makes it extremely suitable to import the images directly from the miniDV camcorders directly onto a hard disk. This piece of software can also be used to stream live 3D content over the internet by the use of a second piece of software such as Windows Media Encoder. It is a great piece of software to organize the data that is arriving from the two cameras; however, it depends on another software called "Stereoscopic Player" to display 3D video.

Stereoscopic Player is a versatile 3D movie player. It has the ability to import the stream from the stereoscopic multiplexer and create

stereoscopic videos according to the user's choice of stereoscopic format. The software is based on DirectShow and can handle almost any media format from AVI, MPEG, WMV and ASF. Stereoscopic Player works as such:

- Load the stereoscopic movie or stream from Stereoscopic Multiplexer
- Specify to the player the format in which the movie was encoded
- Select the desired viewing method

One of the interesting features that Stereoscopic Player has is that it has the ability to remember the input settings for each stereoscopic movie as long as the movie is in the same video library. Stereoscopic Player can also be controlled by several command line parameters as shown in Figure 6.

Figure 6: Stereoscopic player.

One of the advantages of the anaglyph technology is that it requires only one source of output. In this project, the anaglyph video is displayed on a widescreen LCD monitor. To display the anaglyph video, the so-called Stereoscopic Player software is used. The type of anaglyph that is used is based on the colors Red-Cyan which means that Red-Cyan anaglyph glasses are used to watch the video in 3D. As such, the left lens of the anaglyph class must be the cyan-colored and the right lens must be the red-colored. In order to display the image as Anaglyph, the Stereoscopic Player has to be set so that the viewing mode would be

"Optimized Anaglyph Red-Cyan". The parallax and the separation levels have to be adjusted so that the best 3D image is obtained. After that, a pair of anaglyph glasses should be worn to see the 3D effects as shown in Figure 7.
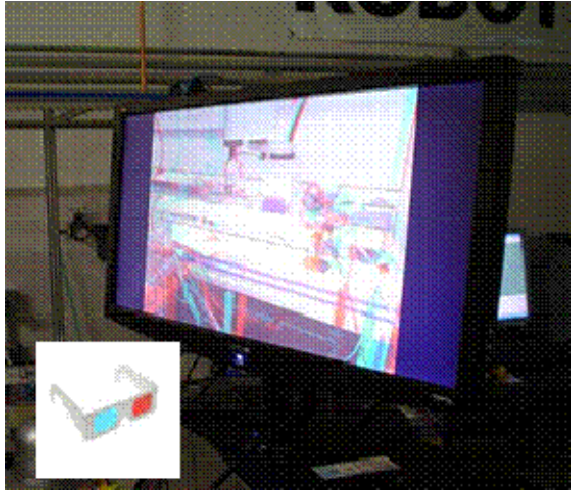

Figure 7: Anaglyph Video.

Streaming the Anaglyph Video

In order to stream the anaglyph video over the internet, Windows Media encoder was used to capture the images from the Stereoscopic Multiplexer and stream it over the internet. In this case, the Windows Media Encoder would act as an HTTP web server that streams the images by buffering them first and then streaming them. On the client side, the user would be using Stereoscopic Player to capture the video stream. The user would specify the URL and port of the web server and Stereoscopic Player would contact the server and request the video stream. At this point, the web server buffers the video stream and sends it to Stereoscopic Player which in turn buffers the stream and then creates the required anaglyph video. This will cause the system to have a lot of delay due to the buffering and transmission delays. According to tests performed on a Local Area Network, the minimum delay that was achieved was about 4 seconds. This might be reasonable enough for some applications. However, in the case of having a real-time 3D video, this result is not acceptable.

Evaluation Between Polariation and Anaglyph

Anaglyph and Polarized Evaluations

As part of the evaluation process, the "Anaglyph" and "Polarized" 3D technologies have to be compared to each other and to a regular 2D technology. In order to accomplish this comparison, a survey was conducted with the help of fourteen students from different classes. The evaluation included the following Questions:

On the scale from 1 to 5, where 1 indicates "strongly disagree" and 5 indicates "strongly agree" please evaluate the following statements:

1. I have observed a significant improvement in the quality of the lab by integrating the 3D technology.
2. I could compare the results from the 3D videos which were played.
3. I will be able to learn about the robot operation more efficiently from an off-campus site if the 3D video is accompanied with this lab.
4. The lab has provided me with the familiarity of different methods including polarized and anaglyph techniques that are used in typical 3D videos.
5. The instructor has provided accurate and easy information to understand the demonstration of the 3D robotic lab.
6. The lab equipment and software were easy to operate.
7. In my opinion, 3D Robotics can have many applications for educational purposes.
8. Please add which one is better (Polarized or Anaglyph) for learning and education and why:

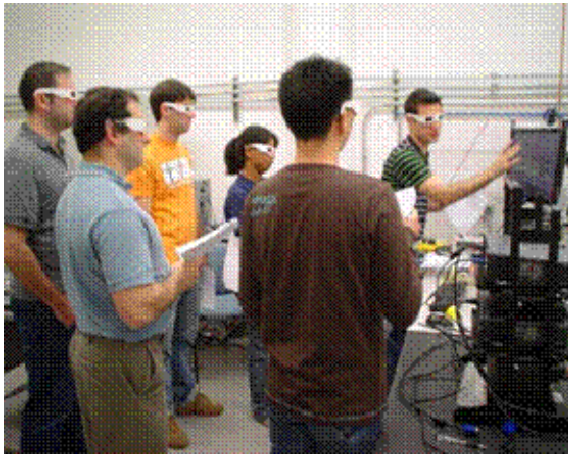Figures 8 and 9 display how the evaluation sessions took place.

Figure 8: Students Using the Anaglyph Technology.

Figure 10: Question Number V.S. Percent Agreement Score.

Figure 9: Students Using the Polarized Technology.

Figure 11: Results to Question 8.

Evaluation Results

The final results of the evaluations are shown in Figure 10. The first seven questions are represented in the histogram. The results for "Question 8" are represented in a pie chart according to the answers that were provided in Figure 11.

The evaluation results have shown that the polarized 3D technology is significantly preferred over the anaglyph one. As a result, the Polarized 3D technology has been chosen to be tested as part of a lab in the MET 205 Robotics and Mechatronic class. Although the comparison evaluations have strongly recommended the use of the polarized type of technology to display 3D images, the following advantages and disadvantages have to be mentioned:
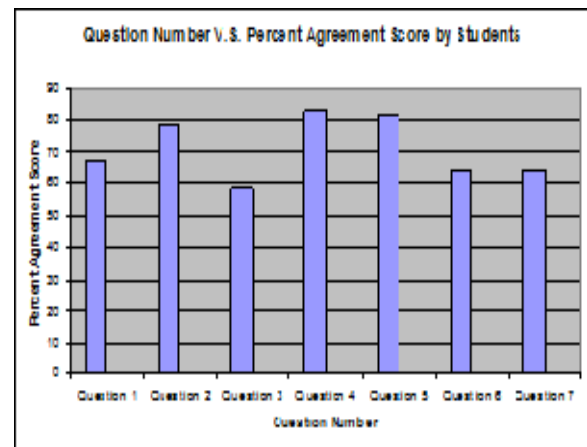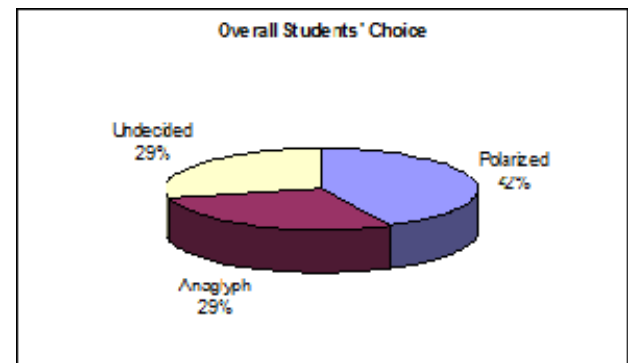
Anaglyph 3D Technology
Advantages
- Compatible with any graphics card
- Compatible with any display system (no need for silver screen)
- Can be implemented at a very cheap cost

Disadvantages
- Fair image quality and comfort
- Low 3D effect
- Large streaming delays

Polarized 3D Technology
Advantages
- Great image quality and comfort
- Advanced 3D effect
- Very small streaming delays

Disadvantages
- Requires special hardware and equipment
- Very high costs of implementation

Online 3D Visualization For E-Lab Experiments

As shown in Figure 12, the new polarized setup was ready to be tested as part of one of the labs for the robotics class offered at Goodwin School of Technology and Professional Studies. The system was setup in one of the School's classrooms and the students were asked to do the following while looking at the 3D video that is streaming from the lab:

- Run and test the motion of the robot on the different axes.
- Each group will teach a set of 4 points by manually jogging the robot.

The 3D video was created utilizing the WebcamXP webserver that was running in the research lab and the website that was especially designed for this lab. The Web pages from the website were browsed separately and overlapped using the projectors. The students used the polarized glasses to see the 3D video that was projected on the silver screen in the classroom. As for controlling the robot, the students used the Yamaha VIP+ software.

Conclusion

A new 3D scheme of viewing the robotic lab has been introduced in addition to the remote controlling of the robots. This new 3D system approach has provided the students with a chance to experience an online robotics lab in a more realistic fashion. An evaluation of the Anaglyph and the Polarized technologies has been performed which has portrayed the students' preference of the Polarized technology. As a result, the Polarized 3D technology had been tested as part of a lab in the MET 205 Robotics and Mechatronics class and the evaluations have displayed positive results. This type of research has introduced a new level of realism and visual communications to online

robotic learning in the Applied Engineering Technology program.

Figure 12: Students listening to the Lab lecture, visualizing, and controlling robot in 3D.

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Biographical Information

Dr. Richard Chiou's background is in mechanical engineering with an emphasis on manufacturing. Dr. Chiou is currently an associate professor in the Goodwin School of Technology and Professional Studies at Drexel University. His areas of research include machining, mechatronics, and internet based robotics and automation. He has secured many research and education grants from the NSF, the SME Education Foundation, and industries.

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