Intel 3-D Stereoscopic Viewing System

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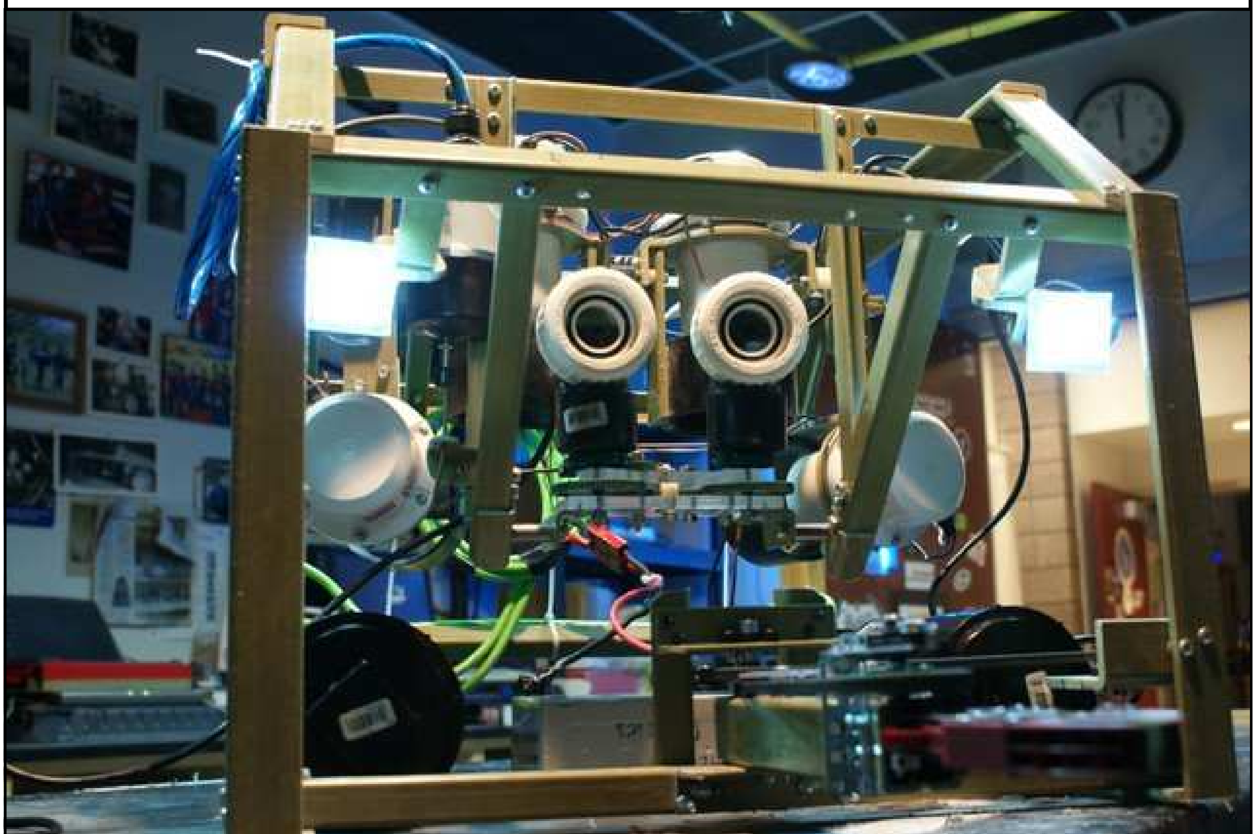
Abstract

In the field of robotics and remotely operated vehicles (ROVs), one element has not lived up to its maximum potential: the vision system of such robots. The operator currently uses a flat screen that projects a two -dimensional version of what the robot sees. Depth of field is non-existent, and the operator must use other visual cues to determine whether or not he can grab or manipulate objects.

The goal of this project is to give the operator something that he or she has never had in tele-operating such robots — three-dimensional (3-D) stereoscopic vision. The operator would be able to determine if the robot can actually grab something or not. It would save the pilot precious time during missions. In this project, my classmates and I, along with our adult mentors , are attempting to provide one of our underwater robots with 3-D stereoscopic vision. We hope to recreate a realistic "vision" of what the robot sees and project it to the pilot of the ROV. The aim is to see if the enhanced vision allows the driver to better pilot the ROV in delicate tasks without ramming or bumping into the objects that the pilot is trying to manipulate.

One of the key technical elements for this project was the ability to process the video and display it in real time. We got access to a cutting-edge computing platform from Intel, which allowed us to bring the project to success. However, some key points became apparent about the differences between human vision and the cameras we used. These differences need to be addressed in future versions of this project to achieve the optimal results we were looking for.



Team members:
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Adult Mentors:
Faridodin "Fredi" Lajvardi, Jim Haugen, Greg Harrison,

3-D Stereo Vision System

The Problem

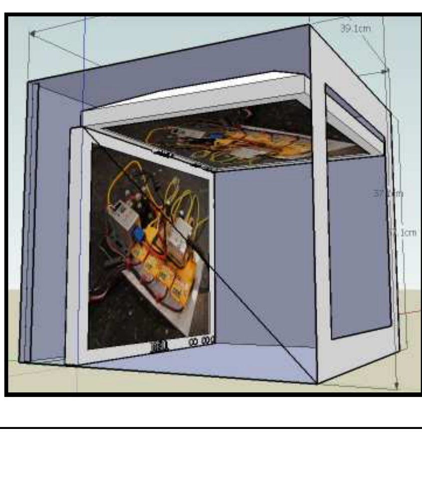
In the years of building, driving and competing in robotics competitions, we noticed one fairly basic flaw in our method of operating the robots. We were driving with one eye! We had no depth perception, and because of this we had a tough time answering the all-important question: “Are we there yet?” For example, when driving our underwater robot, or ROV, with an extended claw, we were forced to run into the object before we could decide if it was really in the claw. This caused a problem because it was not only time-consuming, but it also put us in a tight spot. Some of the things we needed to pick up were most likely set in a sensitive position, and by bumping into an object we would move its position or knock it down completely. The way around this was to use something that we humans use in our everyday life — stereoscopic vision.

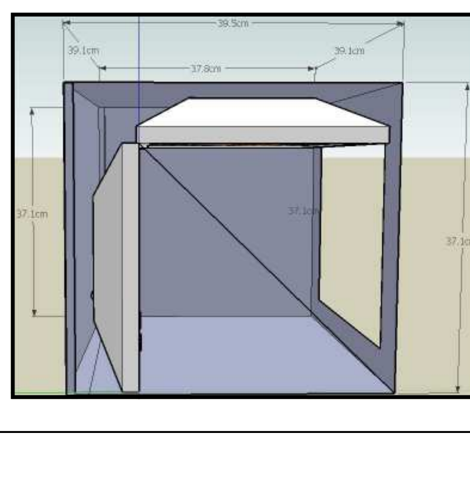
The Solution

We knew that stereoscopic systems were in use and we had vague ideas on how they worked, but we had never seen them used in real time with a live video feed. We realized that doing this in real time would require a system with substantial computing power. We knew all stereoscopic systems work basically the same way, which is by giving each eye an image that’s slightly offset from the other eye. The idea was to duplicate the offset that humans have with their eyes a specific distance apart. One of our options was to use the Red/Cyan method, also called the anaglyph method, but we found that that was very unrealistic because of the color modification. We also looked at using goggles with small LCDs mounted inside them, but that was very expensive and no more than one person could use them at a time. We stumbled upon the perfect design while reading *WIRED* magazine, which had an article about a 3-D system called the Vizard. The creator of the Vizard also posted a video on YouTube that helped us replicate the system.

The Vizard system uses two identical LCD monitors. One monitor is placed on top of the housing and another is placed in the rear. They are positioned so that the tops of the displays are in contact, forming a 90-degree angle. A 50 percent mirror, or teleprompter mirror, is then placed between the two LCD monitors with the reflection side up, bisecting the right angle of the two monitors at a 45-degree angle. The rear monitor’s image penetrates the mirror with its polarity unchanged, and the top monitor’s image is bounced off the mirror, which rotates the polarity 90 degrees. Now you have two images with their polarity perpendicular to each other. When you wear special polarized glasses with the same variance in polarization, your eyes will see separate images. Your brain will then do the rest of the work. The images are separated just as if your eyes were the cameras. This method makes for a very realistic 3-D effect.

To build a real-time 3-D vision system using this method, we knew we’d need a powerful computing platform that could handle the workload. Intel helped us with that part of the solution by providing a quad-core processor that could take the two video signals and send them out independently to the two monitors.





Choosing The Right Computer

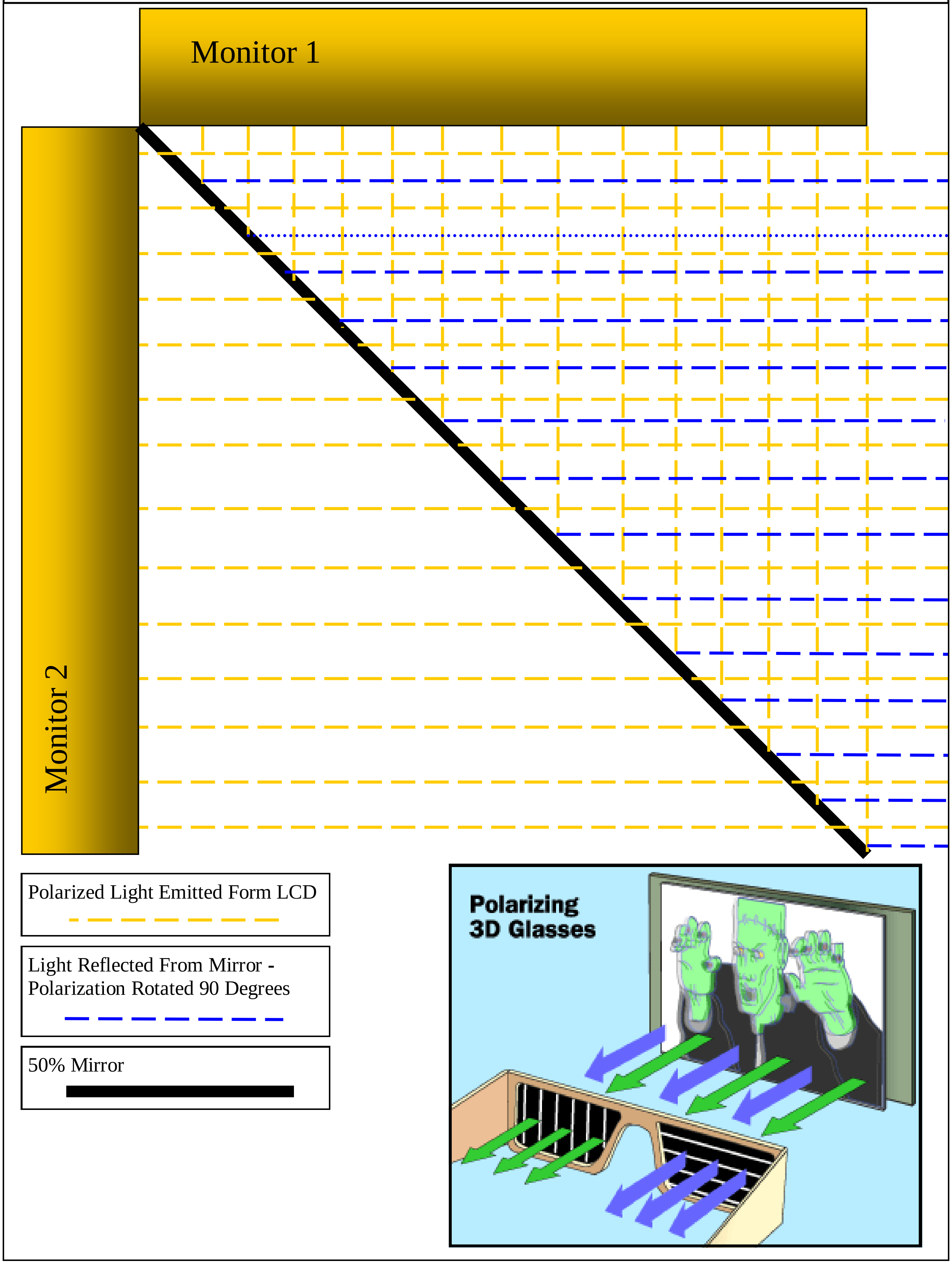
When we were originally trying to prove the concept of the 3-D system, we started off with an old computer, mostly because that was what we had available at the time. This computer had the essential ability to output to dual monitors, but the processor clock speed was so slow that even on standard-definition pre-recorded videos, the picture would stutter and the videos going to each monitor would not stay synchronized. That was not the only problem. This outdated system did not have two FireWire (IEEE 1394) inputs, and when we bought a PCI card with dual FireWire inputs, we found out that you can only have one video signal per card slot. The computer only had two PCI slots. One was being used for the dual output, and the other was being used for a FireWire card. This made it impossible to use this computer for our ultimate goal of real-time 3-D stereoscopic vision.

This is where Intel stepped in and made it possible for us build the machine we have today. Intel provided us with an Intel® Core™2 Quad Processor Q9650 running at a factory-set 3 GHz and equipped with a 12MB L2 cache! That's four cores running at 3 GHz, which means true multitasking! In our 3-D vison system, one core takes care of the video feeds, one core takes care of the recording, the other two cores take care of system processes, and we still have room for growth! This processor is very efficient, with the majority of its 95W (95-watt) power consumption going to actual processing. To top it all off, this chip comes with advanced performance features like Intel Advanced Digital Media Boost and Intel HD Boost, which make video encoding and multimedia effortless. Definitely a processor worthy of praise! It has worked flawlessly for us.

To harness the power of this processor, we mounted the "beast" on a GIGABYTE ATX Intel-based motherboard. This motherboard has 2 oz. of heat-sucking copper, and the BIOS comes preloaded with EasyTune 6 for easy and safe overclocking. The motherboard also has no shortage of PCI and PCI Express slots. The board is equipped with two PCI Express 2.0 slots, three PCI Express slots and two PCI slots. All these slots enable us to use two FireWire PCI Express cards to interface with the Canopus analog-to-digital converters. The benefits don't stop at expansion slots. The motherboard layout easily allows for our massive BFG Tech GeForce GTX 1GB 512-bit PCI Express SLI-ready Video Card. This video card has dual Digital Video Interface (DVI) outputs, which are essential to making a functional 3-D stereoscopic vision system.

With all this new hardware, we can play 1920 x 1080 high-definition videos effortlessly! Nothing bogs down this "beast," which scores a 1950 on the CPU-X benchmarking application. This machine tears through applications that were once thought of as "processor-intensive," starting up Windows Vista in 6 seconds flat. This system is one that commands respect, and at the heart of it all is an Intel chip.

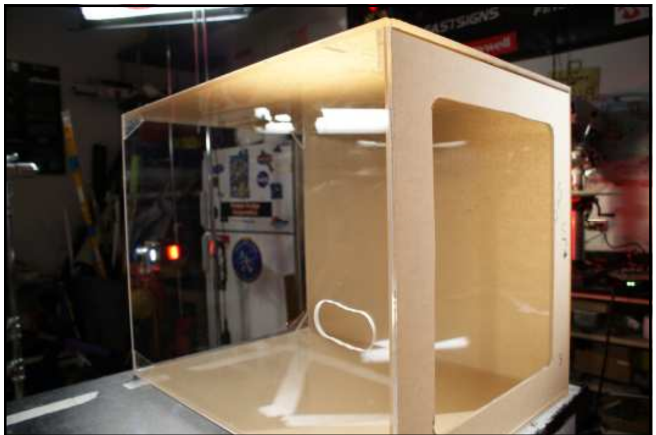
Polarization Patterns of the 3-D Stereoscopic Vision System



Components

Acrylic Housing

We chose 3/8-inch acrylic as our main structural component because it not only has tremendous strength, but also because it looks really cool. We figured the transparency would give the system a futuristic look and allow people to see how it works.



The Frame in it's early stage of construction. It still had it's protective adhesive covering on parts of it.

Another reason we chose acrylic is because it is very easy to bond. We used an acetone- based glue that melts the two surfaces of the acrylic together and makes an extremely strong, permanent bond. On the front panel, we had to use machine screws because we needed the panel to be removable. We simply drilled small pilot holes and then drove the screws in. The acrylic handled the stress of drilling and screwing easily. This made for very sturdy construction.

Cutting the acrylic was the only thing we could not do ourselves. This step required precise accuracy to line up the edges just right, and it was far too much for us to do with a circular saw. So we had to outsource the cutting of the acrylic to a local plastics shop, but all the cut-out holes for the fans and the rear hatch we were able to do ourselves.

You could have the plastics distributor cut the acrylic and ship it. We used Laird Plastics (www.lairdplastics.com).

HID Devices

Our only method of input to the computer is by the mouse and keyboard, which are located behind the small flip-up door. To make the system easy to use, the keyboard and mouse sit on a slider so that you can slide them out just like you would on a typical computer desk. The mouse and keyboard also glow blue. Not only does this look really cool but when we need to use the system in low lighting conditions, it isn't a strain on your eyes.

The Mirror

The mirror is silvered, meaning that a thin layer of aluminum only a "few dozen atoms" thick has been applied to the glass. This allows half of the light that comes in contact with the mirror to be reflected, while the other half passes through it. These mirrors are commonly called teleprompter mirrors. They are most commonly used by television stations to prompt newscasters. We got ours from www.telepromptermirrors.com.

The Monitors

We used two Samsung T260 monitors that measured 25.5 inches diagonally. We picked these for their 20,000:1 contrast ratio as well as their 1920 x 1200 native resolution. The high contrast ratio gives us more of an extreme difference between lights and darks. We chose the high resolution because we hope to someday upgrade our standard-definition cameras to high-definition cameras. Doing so will make the 3-D effect much more lifelike as well. These monitors also have a very fast five-minute response time.

Components Continued

Cooling

We knew that with all the high-power components, the computer would produce a lot of heat, especially when pushing the system. On top of that, the computer would be in an enclosed area with limited airflow. We had two options — air cooling or liquid cooling. Liquid cooling was far too high-maintenance and unnecessary, so air cooling was the way to go. Our next step was to install the proper amount of fans to achieve good airflow, and since we really did not know how much heat would be generated, we planned for the worst.

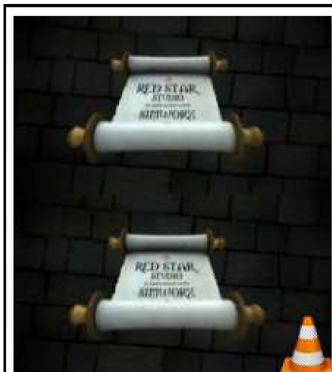
We began with four 80mm fans in the front, two blowing out and two blowing in. These four fans alone were moving 68 cubic feet per minute (CFM). Then we mounted six 120mm fans that blew out, each moving 79 CFM. To top it off, we mounted two 120mm (79 CFM) fans on top of the system accompanied by two massive 2500mm (100 CFM) fans blowing inward. This means we have a total of 800 CFM moving inward and 450 CFM moving outward, and the box has completely cycled air every 40 seconds. Very cool!

Software

The software, which is made for 3-D applications, was purchased from 3dtv.at. It is a very useful application with many abilities. We mainly use this software, called Stereoscopic Player and Stereoscopic Multiplexer, for its video playback and its real-time video encoding capabilities. For playback, the software basically takes the two video signals, which are interlaced together, and outputs them. Using the Extended Desktop feature in Windows, the software displays a video signal on each monitor. The Multiplexer software works in much of the same way, the only difference being that it has support for a real-time video feed.

Prerecorded Videos

We downloaded many different samples of videos from the 3dtv.at site, which hosts Stereoscopic 3-D video content produced by Red Star Productions. Red Star makes both animated and non-animated films. You can download this video content via torrent. Here are two examples of how the video format looks. The picture to the right is in the over-under format and has a resolution of 1440 x 576, and the picture above of the train is a side-by-side format. Either one can be played in our 3-D system. You just have to adjust the settings.



Knights Quest 576p (Wide)

Components Continued

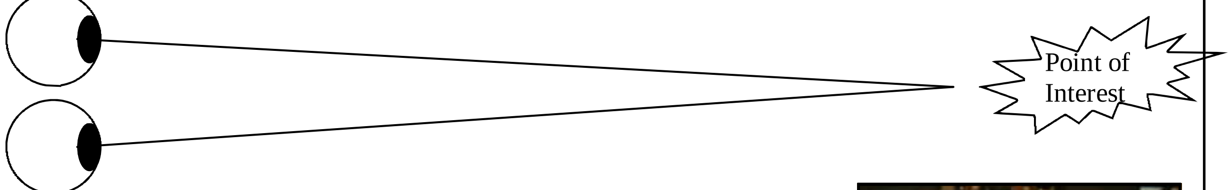
Analog to Digital Video Converters

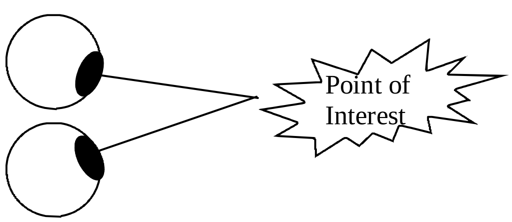
Our cameras output a standard analog video signal (NTSC) like most cameras that use RCA jacks. This is not very computer-friendly since computers like everything in digital signals. To make the analog video into digital video, we needed an analog-to-digital converter (A/D converter). We found what we needed at www.firewire.com. The Canopus ADVC-110 is a nice little box that takes an RCA jack in the front and converts it so you get FireWire output at the other end. It's simple, and it gets the job done.

In an attempt to get around having to use the A/D converters, we tried using USB webcams, but they had a slow frame rate and poor resolution. Also, the USB cable was limited to 16 feet before signal loss, compared to 100 feet with analog video. USB extenders are available, but they require external power and after all, we were going underwater, which complicated things even more. It was much more practical to get the A/D converters and stick to standard video signals.

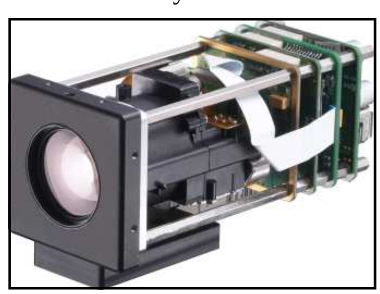
Cameras

To understand how cameras focus on objects, you must first understand how your eyes work. Look up and focus on the farthest object in the room. As you do this, your eyes go from rotated inward (focused on the computer screen/paper) to rotated outward (focused on that faraway object).





This seemingly simple mechanism caused an unexpected problem. Our cameras that have a fixed focal length of 5 inches to infinity cause double imaging. Your eyes can not only rotate inward and outward but they can also change their focal length. You can see this by putting your finger a few inches in front of your face and focusing on it. You will see that everything in the background is blurred beyond recognition. This is called a narrow depth of field. Your eyes do this for a reason. If they did not, you would see double images. This caused a very disorienting 3-D effect. A way around this would be to buy more complex cameras that have an adjustable depth of field. A good example is the DBM 31BF03-Z2,, available from imagesource.com for around $1,000. This is something we may try in the future depending on our budget.



Results

As mentioned earlier, overall our 3-D stereoscopic viewing system works very well, and whatever you focus on appears in 3-D. However, the objects in front of and behind the object that the cameras focus on are still sharp images but double-imaged. The human eye does this as well, but the objects are out of focus, which helps you to ignore them. You have been trained your whole life to ignore things that are not the focus of your attention. Unfortunately, our cameras put all those objects in clear focus, and our pilots had to retrain themselves to ignore what they did not want to pay attention to. Having cameras with a narrow depth of field would solve this problem.

Future Plans

We hope to try using high-definition cameras to see how much more improved and human eye-like the system would be. We would like to see what happens if we use cameras that have a narrow depth of field. We feel that this would more resemble how the human eye works. The model we would like to get is the Sony HXR-MC1 HD Lipstick Camera. We would need two of these.

Sources On Information We Used

Article in Wired magazine online
http://www.wired.com/gadgets/mods/magazine/16-09/pl_screen

Teleprompter Mirrors
http://www.telepromptermirrors.com/

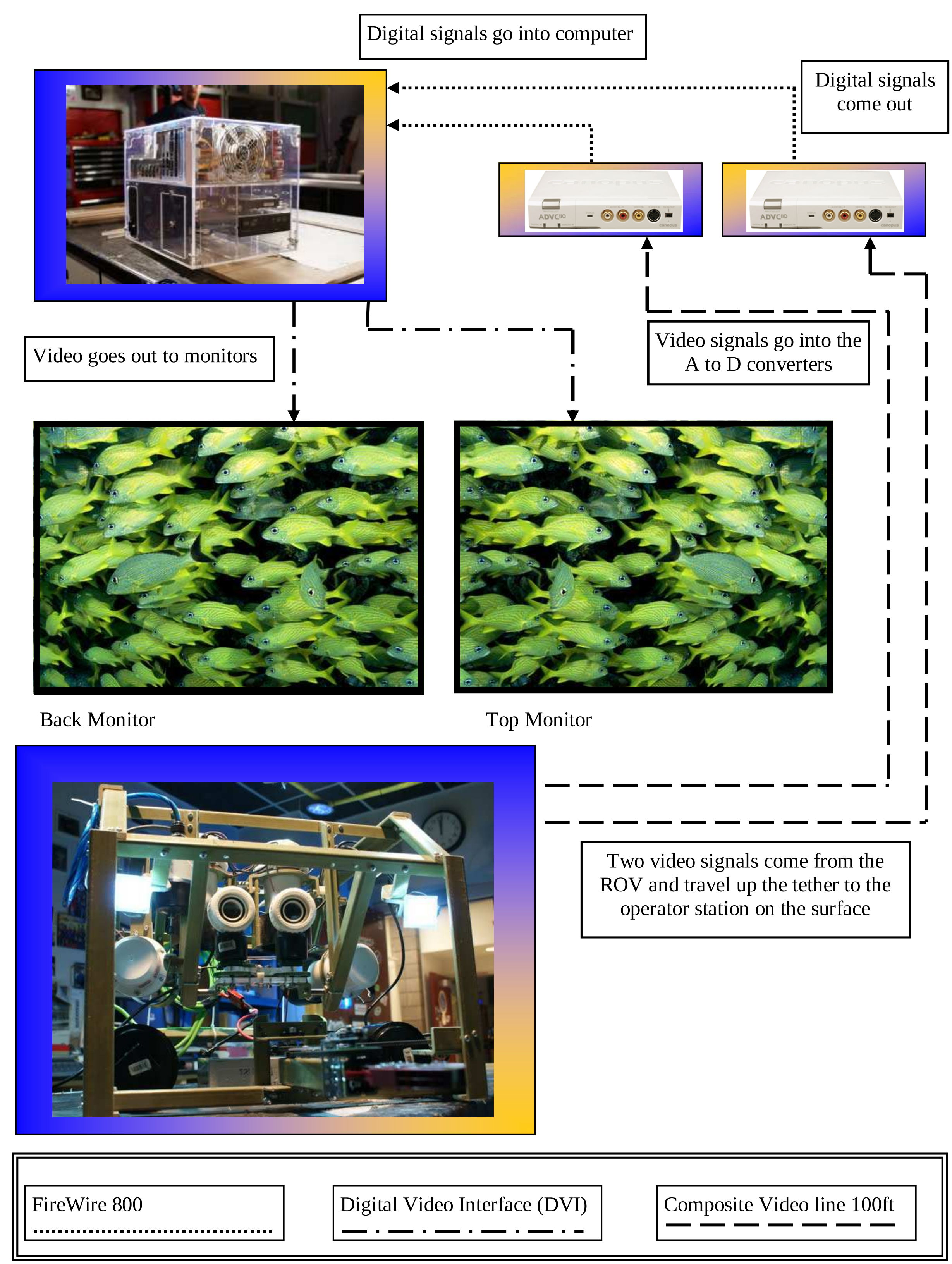
FireWire.com for analog to digital converters
http://www.firewire-1394.com/canopus-advc-110.htm

3-D Stereoscopic viewing software
http://3dtv.at/Index_en.aspx

3-D Stereo video demos
http://www.redstar3d.com/index_001.asp

Info on Stereoscopic vision process
http://en.wikipedia.org/wiki/Stereoscopy

Video Flowchart



The Computer

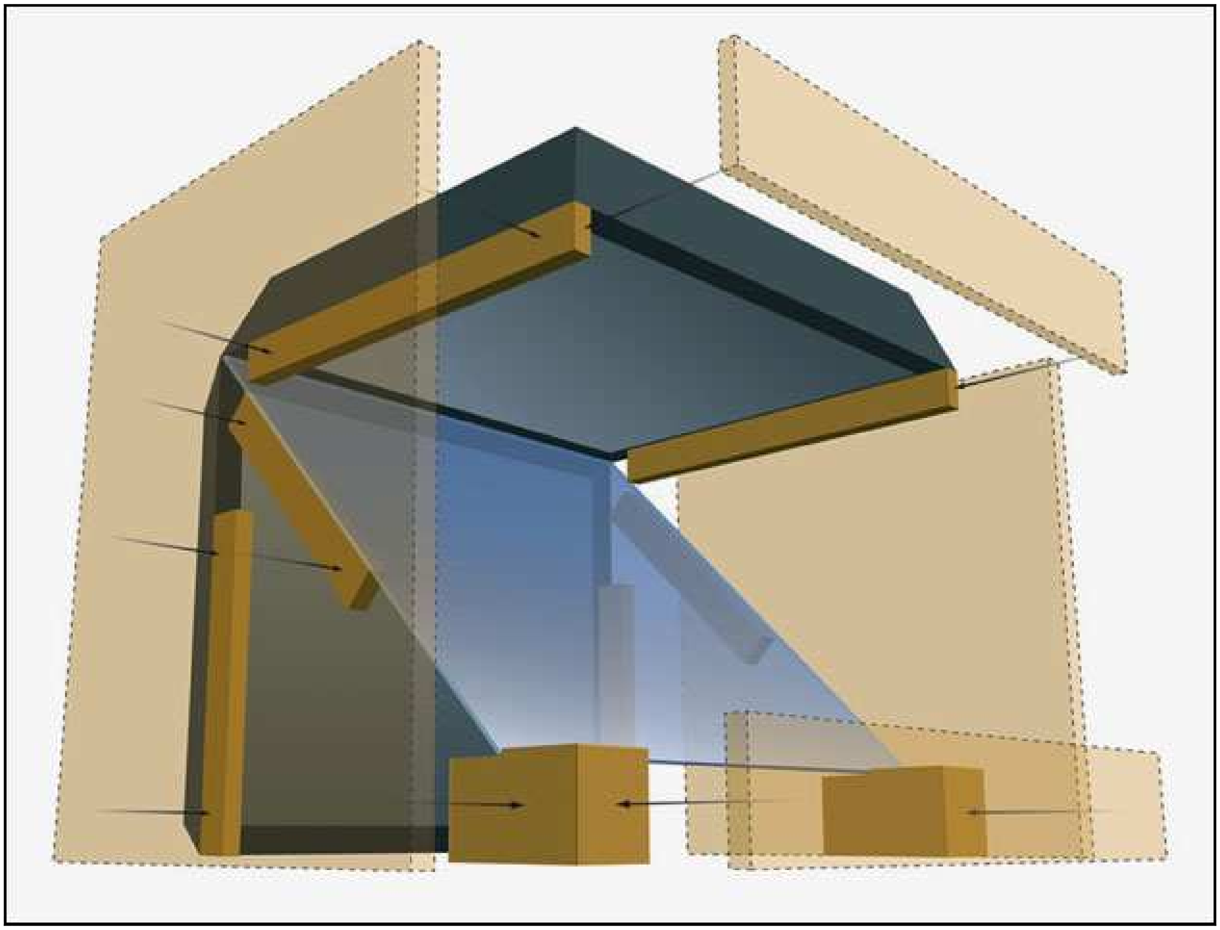
The main concern that we had while selecting the parts for the computer was performance. Since we where using the 3-D system to drive robots in real time we could not tolerate any lag. So we went with the highest specs possible that our budget would allow. If you are planning on using your system only for prerecorded video you can get by with lower performance parts.

Hardware	***Why We Chose It...***
GIGABYTE LGA 775 Intel P45 ATX Intel Motherboard	Bullet-proof cooling, super fast bus speeds, plenty of Express PCI slots for firewire cards and video card.
Intel Core 2 Quad Q9650 3.0GHz	High clock speed would minimize lag and the quad core would enable us to use threading.
GeForce GTX 280 1GB PCI Express 2.0 x16 Video Card	The dual output is a necessity for stereoscopic viewing system.
XIGMATEK 750W ATX12V Ver.2.2 Power Supply	We needed to give the processor all the power it needed as well as power for all the fans the would cool not only the computer components but as the monitors as well .
Patriot Viper 4GB (2 x 2GB) 240-Pin DDR2 SDRAM DDR2 1066 Memory	We got 4GB of RAM that would allow us to run the stereoscopic multiplexer while also using anther application for recording the incoming video.
Seagate 1.5 TB Serial ATA/300, 32MB Buffer Hard Drive	We needed the high capacity for recording our long missions and because we were planning on upgrading our standard definition cameras with high definition. We also needed the high RPM model for fast transfer rates.
BYTECC 2-Port 1394B FireWire 800 PCI Express Card Model	We chose this card because its fast at 800 Mbit/sec and we wanted no lag in the video

Bill Of materials

Part Name	*Price*	*Total*	*Amount*
Samsung 25.5" LCD (1920 x 1200, 20,000:1, 5ms)	**$ 400.00**	**$ 800.00**	**2**
PlexiGlass 3/8" by 4' by 8'	**$ 211.00**	**$ 633.00**	**3**
$25 FOR 6 CUTS	**$ 25.00**	**$ 75.00**	**3**
Mounting Hardware	**$ 200.00**	**$ 200.00**	**1**
Teleprompter Mirror 24" by 24"	**$ 240.00**	**$ 240.00**	**1**
Power Strip	**$ 29.99**	**$ 59.98**	**2**
Firewire card	**$ 40.00**	**$ 80.00**	**2**
Dual Output Video Cards	**$ 315.00**	**$ 315.00**	**1**
Processor	**$ 324.99**	**$ 324.99**	**1**
Mother Board	**$ 134.99**	**$ 134.99**	**1**
Power Supply	**$ 124.99**	**$ 124.99**	**1**
RAM	**$ 70.00**	**$ 140.00**	**2**
Cooling Fans Green 150cm	**$ 15.00**	**$ 75.00**	**5**
Cooling Fans Blue 150cm	**$ 15.00**	**$ 75.00**	**5**
Cooling fan 250cm	**$ 18.00**	**$ 36.00**	**2**
UV Light	**$ 4.00**	**$ 20.00**	**5**
Key Board	**$ 50.00**	**$ 50.00**	**1**
Mouse	**$ 40.00**	**$ 40.00**	**1**
Steriosocpic Player	**$ 50.00**	**$ 50.00**	**1**
Steriosocpic Mutiplexier	**$ 76.00**	**$ 76.00**	**1**
Cooling Fan 150cm UV Glow	**$ 10.00**	**$ 50.00**	**5**
Hard Drive 7200rpm	**$ 120.00**	**$ 120.00**	**1**
Case	**$ 80.00**	**$ 80.00**	**1**
A to D Converters	**$ 250.00**	**$ 500.00**	**2**
Grand Total		**$ 4,299.95**	

Supplemental Information



Here is the construction schematic from Sean Hellfritsch and Isaiah Saxon of Encyclopedia Pictura , the original creators of this method.
Contact info: mail.encyclopediapictura.com