A SHIFT IN TIME:

AN INTERACTIVE PAINTING ON A MULTI-VIEW DISPLAY

BY

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ABSTRACT

The goal of my thesis is to boost the interactive potential of flat screen monitors by creating an interactive display that shows distinct and separate moving images to more than one user at the same time. A second goal is to demonstrate the creative power of this display with a responsive digital painting based on the flow of time. Research of past and current attempts to create a multi-view display reveals that merging a standard LCD with lenticular technology is the best method. In designing the interactive painting, I draw inspiration from literature, philosophy, games, and other artworks that explore the nature of time. In the end, I meet both goals of my thesis by presenting a unique multi-view interaction with the past and future of a digital painting. I also consider future research that can develop from the results of this project.

Categories and Subject Descriptors: B.4.2: Input/Output Devices Image Display

Keywords: Multi-view displays, lenticular, LCD, interactive displays

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1. THESIS STATEMENT AND GOALS

We are severely limited in how we interact with our modern flat screen displays. To this day, the public is forced to accept monitors that are restricted to presenting the same set of moving images to everyone watching. The reason for this limitation is simple: the makers of digital displays have grown complacent with a "one to many" design scheme. In other words, they are satisfied with providing us with nothing more than a single visual experience to every individual sharing their display. Meanwhile, we are left with wanting more.

When crowding around a monitor at the bus station or airport terminal, I often wonder why each passenger is forced to view the same information as everyone else. When enjoying a video game on my home television, I often wish I could keep playing when my wife wants to watch a movie. There are times when I'm interacting with a flat screen art installation, and I wonder why everyone around me is forced to see the same visual experience. Why can't we all have a personalized view of what's on the screen?

After years of facing these limitations with a traditional monitor, I'm compelled to answer the question: is it possible to design an interactive display that presents separate and distinct moving images to more than one user at the same time? I claim there does exist a way to achieve this multi-view technology. Proving this fact first involves researching the past and existing methods of those who challenge the "one to many" display approach. The second task is developing a multi-view prototype and demonstrating its interactive potential by using it to host a compelling interactive experience.

1-1. The Importance of "Many to Many"

Interacting with a standard "one to many" display greatly pales in comparison to the interactive potential of what I call a "many to many" display. This refers to a kind of monitor with the ability to project a different moving image to multiple viewers at the same time. A view from one side of the monitor would reveal completely different images if viewed from another angle. By applying this "many to many" principle, the communicative power of digital displays in fields like advertising, entertainment, and education would be significantly increased.

The benefits to the marketing industry would be enormous. New forms of targeted advertisement could be invented. Consider the sci-fi film *Minority Report* in which the hero John Anderton encounters a hallway with futuristic advertisements (2002). By using eye-scanning devices, ads determine his identity and work his name into marketing pitches. While this sci-fi scenario might raise a concern or two (namely invasion of privacy), you can imagine equally powerful but less intrusive ads with a "many to many" display. A separate digital rep could speak to each passerby at the same time. Combine the multi-view display with visual or wireless tracking, and marketing pitches could vary based on walking speed or the brand of wireless devices people are carrying. Brand detection would be extremely helpful, since digital reps could privately pass on important product updates to specific customers. With a multi-view display, only *you* would see information relevant to *you*.

Consider how the "many to many" approach could reshape the video game industry. An innovative breed of multi-player games can be developed specifically for the multi-view display. For example, all players in a strategy game could share the same monitor but experience completely different parts of the game. In this way, the "split screen" mode in countless games could finally reach its full potential, allowing individual players to only see their personal view of the action.

A "many to many" display could greatly enhance the interactivity of games offering different camera angles. For instance, in driving games with a rear-view option, you could simply lean to the side to see the cars behind you rather than push a button. A strategic combat game with night-vision mode could use the same kind of physical interaction.

In addition to marketing and games, teachers in all levels of education could vastly benefit from a "many to many" monitor. Imagine a third grade teacher using this display to present instructional videos in class. The multi-view monitor could be programmed with the position of each student in relation to its own location. As a result, the display could direct customized graphics, text, or other content at specific students, assuring that each child's specific learning needs are met. This kind of personalized education would be incredibly powerful for students of all ages.

For the purposes of this thesis, I explore how "many to many" displays can enrich an artistic

experience. By creating an interactive art installation that uses this multi-view technique, I intend to show how the multi-view display is effective in boosting the interactive potential of digital artworks. If proven correct, then the benefits of this innovative display system will extend to marketing, video games, and educational media.

1-2.   Interactive Simplicity

In addition to the "many to many" approach, a second guiding principle in researching and developing this project is a need for clear and simple user interaction. Whether a monitor is multi-view or standard issue, the user should feel comfortable with controlling what it happening on the display. Since the monitor could be accessed by people of varying computer skills and knowledge, the interface should not be too technical.

Because this thesis is concerned with several people sharing an interactive monitor simultaneously, providing a keyboard and mouse for every potential user would be impractical. Furthermore, these interface tools feel impersonal and often times excessive depending on the nature of the interaction. A common alternative to these devices is a touch-screen system, but due to the shared nature of the monitor, tracking the touch of each user becomes a messy, impractical task. A voice-operated interface also seems unreasonable, since the overlapping voices of simultaneous users could become annoying and possibly difficult for the display to process.

I propose that the user interaction of a "many to many" display involve a gestural or movement-based communication. Since a touch-screen system is ruled out, users will naturally find a comfortable distance away from the screen and each other, nestled in their private viewing zones. A video camera could bridge the gap between user and monitor, tracking the movements of each user and changing screen content accordingly.

Another concern for the interaction with a multi-view screen is how users will control which view they want to see. This must be done delicately so the relationship between viewers and display is comfortable and engaging. For projects involving virtual reality, a popular practice is to equip users with headgear which helps to update the view while moving through virtual scenery. However, as 3-D specialist Raymond Spottiswoode points

out, "given the choice between two systems of equal merit – one with eyewear and one without – the natural preference will be for the system without eyewear" (Lipton, 2002). It's practically impossible to argue this point, since no one wants to carry an extra device to interact with public displays. Therefore, the ideal method for interacting with different view zones in a "many to many" display should not involve eye gear. This means that the full burden falls on the display to provide a clear, easy shift between different views.

1-3.   Image Flips

Guiding my research is a hunch: lenticular imaging will be the key to proving my thesis. This century-old technique used for image flips on trading cards, billboards, and crackerjack prizes seems the only way to realize a multi-view display. To my knowledge, no other method could possibly project several different visual images at different angles from the same shared surface. This technique also meets my second guiding principle of clear, simple interaction. Lenticular art requires no special eye equipment, but instead shifts from image to image based solely on viewing angle.

Thus, I'll begin research with a focus on lenticular imaging, an art regrettably associated with "silly and kitschy images" or deemed "not worthy of any serious research" (Machniewska, 2002). Many are familiar with this art form through gimmicky ad posters and winking portraits of Jesus. Nonetheless, given the sharp clarity of lenticular images in recent years, I predict this technique can rise above its "kitschy" stigma and lead to the design of an effective "many to many" display.

Typically, only printers use lenticular technology to create a dual-image or animated effect. I feel confident, however, that pixels can be used in the same way as print. Pixels are dynamic by nature. So, joining them with the lenticular process is a promising way to present unique moving images to multiple viewers at the same time.

I should clarify that my goal is not a monitor that displays the same scene or object at different angles. Many artworks or public advertisements use lenticular methods in this way to achieve a 3-D effect. While these projects are certainly projecting a series of different pictures, they still show the same object or scene to all observers. Though spatial perspective may vary based on viewing angle, the subject in the piece remains the

same. For this reason, I claim that 3-D examples of lenticular technology take a "one to many" approach of display interaction. This is different from the goal of my thesis which strives to present *distinct* content to all observers.

1-4. Subject Matter

Once the multi-view display is designed and built, an appropriate next step is to develop engaging visual content to demonstrate its potential. As you'll read in section 3-1 of this paper, my interest in the nature of time will guide this process. The subject matter will develop from my deep fascination with the relationship between past, present, and future. I eventually find that a multi-view display is a perfect canvas for playing with the concept of time.

2. RESEARCH OF RELATED PROJECTS

The following research aims to determine the best method of creating a "many to many" interactive display. A secondary research goal is to prove that such a system has not yet been realized. Ultimately, analyzing the research will reveal two important outcomes. The first is that several past and current projects have the capacity for an interactive "many to many" display system but fail to identify this capacity. Thus, the goal of my thesis is unique. A second outcome will be the decision to combine an LCD with lenticular technology.

2-1. Lenticular Technology

Research reveals that the desire to show unique images at different angles is centuries old. In the late 17th century, French painter G. A. Bois-Clair discovers a dimensional effect on his canvas by placing a grid between the viewer and the painting (*History of VariVue*, 2001). Bois-Clair paints two distinct pictures on a planar surface. He fixes a grid of vertical slats to the painting at right angles. By viewing his art from the left, he sees one distinct picture, while the second painting appears
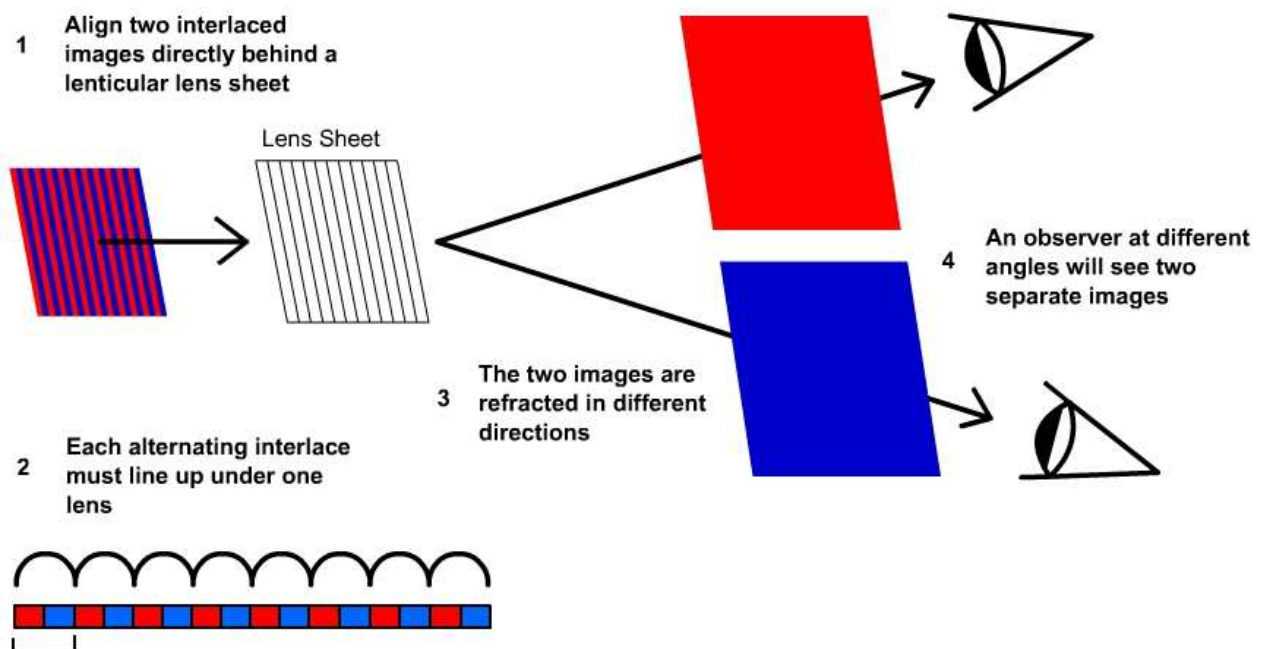
from the right. Staring directly at the piece reveals a blending of the two paintings.

Centuries later, the spirit of Bois-Clair's experiment reemerges in the optics lab of Gabriel Lippmann. Lippmann is compelled to capture a series of pictures within a single flat surface. Instead of vertical barriers to separate the images, he uses tightly packed circular lenses to deflect them in different directions. A fellow scientist Herbert Ives later simplifies Lippmann's "fly's eye lens" method by creating a sheet of cylindrical lenses called "lenticules." (Roberts, 2003). *Figure 1* illustrates the basic steps of this process. This lens model becomes the backbone of flip images to come. Soon after, companies like VariVue use lenticular technology to make dual image signs, like the "winkie" billboards of the 1950's.

Guided by this research, I form a conceptual model of how I can build my thesis project. The main idea is to project interlaced moving images onto the back of a rear-projection screen. On the front of the screen, a lenticular lens can cover the interlaced images, thereby refracting them at different angles. Unsure if I can find a standard

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Figure 1   Basic process of a lenticular imaging.

1 Align two interlaced images directly behind a lenticular lens sheet

Lens Sheet

2 Each alternating interlace must line up under one lens

3 The two images are refracted in different directions

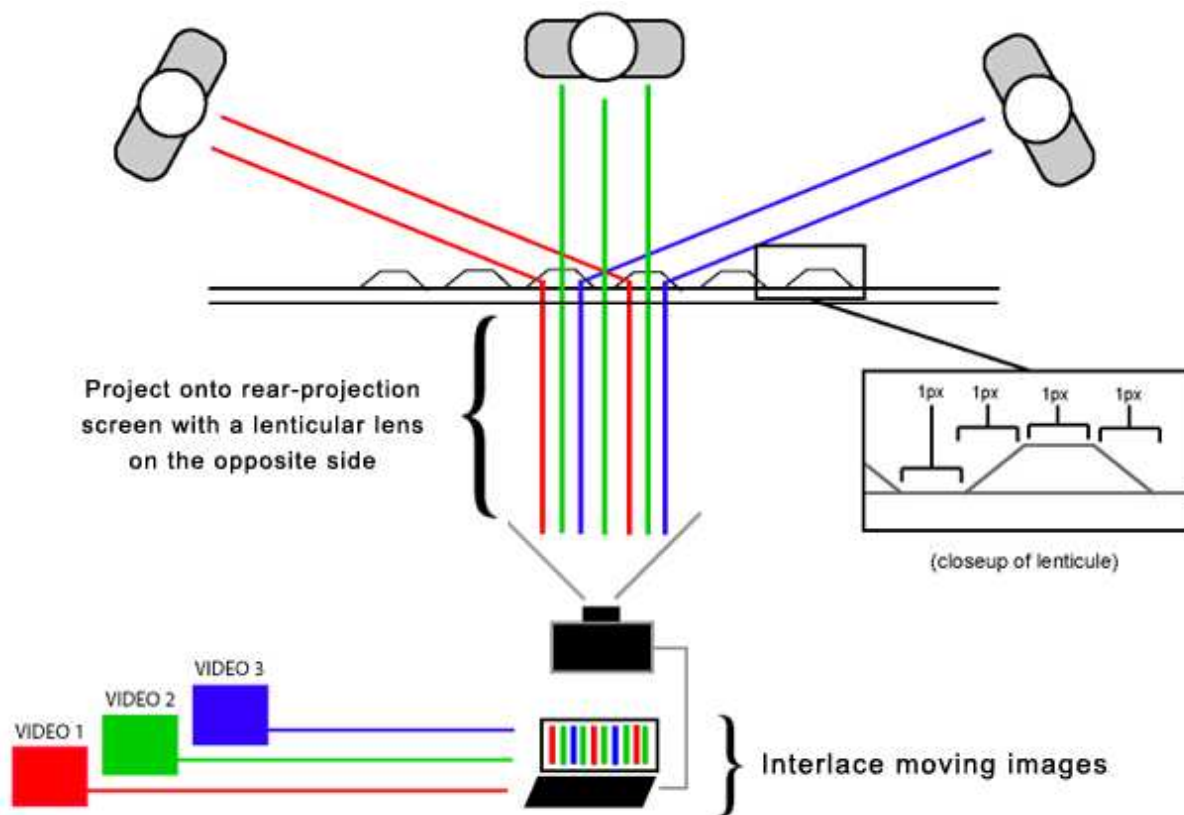4 An observer at different angles will see two separate images

lenticular lens for my project, I plan to make the lens myself. I design it with individual lenses shaped like trapezoids for a three-view "many to many" display. *Figure 2* shows my concept sketch of a multi-view display using lenticular imaging.

About this time, I learn from classmates that it's now possible for specially made speakers to beam sound in a narrowly focused direction. This would be a perfect addition to an interactive "many to

many" display. Equipping a multi-view monitor with "uni-directional sound" would give users a richer, personalized interaction. Every view zone would provide people with a unique audio-visual experience.

Eager and inspired, I seek out companies that specialize in directional sound. My search quickly turns up a company called Holosonics. Founded by MIT graduate Dr. Joseph Pompeii, Holosonics

Figure 2 First concept sketch of multi-view display with lenticular screen.

boasts the ability to beam sound like a spotlight.

My excitement ends quickly with a disappointing find. In 2003, Pompeii and research advisor Barry Vercoe created the first "many to many" digital display: a television featuring directional video and sound (Pompeii, 2003). While not interactive, the project provides "three completely distinct programs to three viewers at the same time." The monitor displays a violinist, a trumpet player, and a vocalist performing a song from *Porgy and Bess*. From one angle you watch and hear the violinist. Take two steps over, and now you see and hear only the trumpet. Sidestep again, and the trumpet player vanishes, replaced by the sight and sound of the vocalist.

Unfortunately, my vision of a multi-view monitor seems to be realized; though, Pompeii's project lacks the interactive element I'm seeking. I e-mail Pompeii to get details. He tells me his invention is "a one-of a kind system" allowing a "full three-way, distinct separate set of video images" (Pompeii, 2005). He further explains that the main component of the television is a special lens that merges lenticular and fresnel lenses with a holographic video screen. Behind the monitor,

three small LCD projectors throw the images onto the lens.

With this information, I realize I have a chance to improve on Pompeii's project. The holographic components can be removed, since I'm not aiming for a 3-D effect. Moreover, the three projectors appear to be excessive with currently available technology.   Pompeii's "three-way" television is three to four years old, so at the time it was probably necessary to split up the job of interlacing three videos into three separate projectors. A current day processor could handle the entire interlacing operation while running at a decent speed. This would whittle three projectors down to one. Then, an epiphany: Why use projectors at all? A simple solution is to eliminate the projector altogether by fixing a lenticular lens directly over a liquid crystal display (LCD). The same method worked for Bois-Clair centuries before, except now I can use monitor and lens versus canvas and slats.

Along with streamlining Pompeii's project, there's also the chance to augment the display with an interactive component. Pompeii merely projects images at his audience. There is no two-way interaction between viewer and screen.

Thankfully, my thesis remains unique. I'm further motivated when I hear from Barry Vercoe, the man who conceived of Pompeii's three-way television, that "there are no plans" to take his project forward (Vercoe, 2005).

Further research into multi-view lenticular projects reveals that Philips is developing a 3-D laptop viewable "without wearing special glasses." Philips promises these new monitors are "a new way of looking at things in medical applications, 3-D gaming and even 3-D TV" ("3-D LCD," 2005). Technically, a slanted lenticular lens covers an LCD screen and achieves up to nine separate images at different angles. The interlaced graphics are calibrated in such a way that a viewer can see the screen content "autostereoscopically." This means the display shows each eye a slightly shifted view of the same object, resulting in the illusion of three dimensions. A useful find in this research is that combining LCD and lenticular technologies is a proven method of producing a multi-view display. There is no longer the need to wrestle with projecting interlaced images onto the back of a lens.
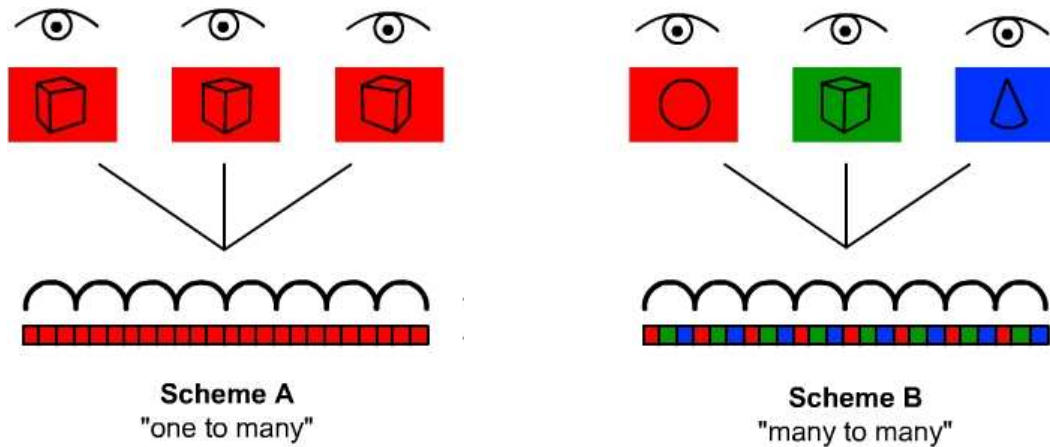
While these Philips 3-D laptops successfully refract images at different angles, they're missing something important: the "many to many" principle that is crucial to my thesis. As stated before, "many to many" means presenting a set of separate and *distinct* images to several viewers. Even with a capacity to show nine different views on the same monitor, the Philips team is focused solely on showing the same image from different perspectives. This qualifies as the "one to many" principle. As a result, their multi-view prototypes fail to acknowledge the increased interactive possibilities that I pursue in my thesis.

To better grasp the distinction between the "one to many" Philips laptops and a "many to many" project like Pompeii's "three-way television," refer to *Figure 3*. In this diagram, I show a comparison of the two different lenticular imaging schemes. Notice that *Scheme A* projects the same basic content, while *Scheme B* presents three distinct images.

Digging deeper into the world of 3-D monitors, I find that Sharp is the first to commercially manufacture a 3-D computer monitor ("Sharp's 3-D LCD Technology Now Available for Desktop Computers," 2004). Using a process similar to the lenticular method, Sharp employs a "parallax barrier" technique to achieve an autostereoscopic

Figure 3 Comparison of two primary lenticular multi-view schemes.

Scheme A
"one to many"

Scheme B
"many to many"

effect. This is closely akin to the vertical lathe Bois-Clair used to obscure parts of his painting at certain angles. With the Sharp display, "light from the LCD is divided" by a special screen "so that different patterns reach the viewer's left and right eyes." What Sharp and Philips share is a failure to pursue a "many to many" principle in monitor design. Neither mention of the concept of presenting separate and distinct moving images to several viewers at different angles. In addition, they both neglect a clear, simple user interaction with the multi-view images, aside from the traditional mouse and keyboard combination.

The Fraunhofer Institute of Telecommunications has created the "Free2D 3-D" monitor, a multi-view display that actually succeeds in achieving a

simple, intuitive interaction ("Free2D 3-D Display," 2005). While it uses autostereoscopic methods like Philips, Free2D stands apart by providing a unique gestural interface, a la *Minority Report*. By reaching toward the three-dimensional objects floating on the monitor, you can move them around as if they were real. After debuting at various display conferences in 2003, Free2D has found its way into hospitals as a tool for 3-D surgical simulations.

While this product meets my criteria of "interactive simplicity", the developers at Fraunhofer ignore the tremendous potential in turning the stereoscopic screen into a shared surface of separate and distinct moving images. Imagine if they embraced this potential. They could track the

gestures of not only one but every person using the display. This multi-view, multi-tracking setup would be an ideal experience for a "many to many" interactive display.

2-2.   Persistence of Vision

As I continue research into methods for creating multi-view systems, I find a 360 degree alternative to flat screen lenticular monitors. Several cylindrical displays are now designed to create a panoramic 3-D view of a scene or object. These displays are capitalizing on our brain's tendency to retain images for a brief moment after we see them. An example of this "persistence of vision" occurs when we watch the animation of a spinning zoetrope. Our eyes see the static images that flicker by as a related sequence of events.
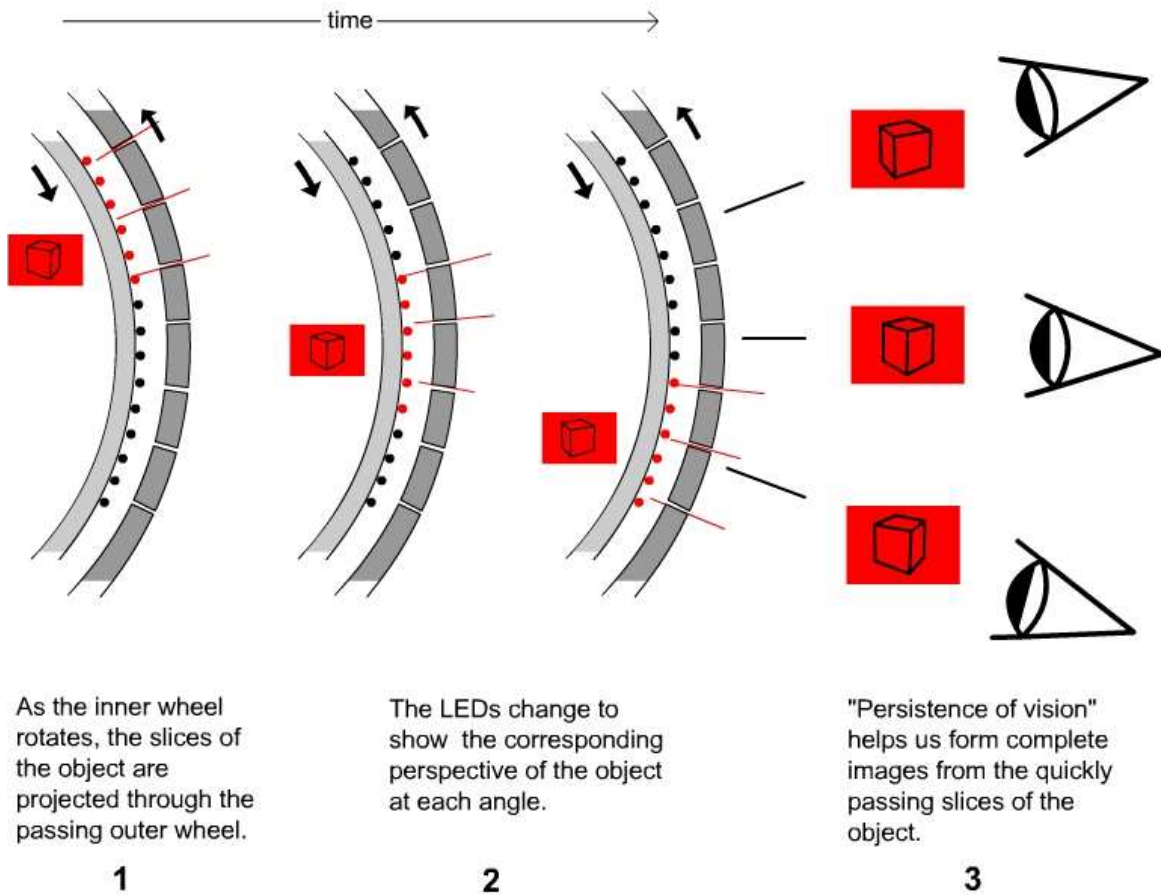
The "SeeLinder" is a perfect case of this new breed of panoramic display (Hardy, 2004). At a SeeLinder demo inside a University of Tokyo lab, creators Susumu Tachi and Tomohiro Endo place a woman in a booth surrounded by cameras. On a nearby cylindrical monitor, the woman suddenly appears in three dimensions. From the front, onlookers see her face, from the side her profile,

and walking to the rear of SeeLinder reveals the back of her head.

To create this effect, an outer wheel with vertical slits revolves clockwise at a fast speed, while an inner wheel vertically lined with LEDs is turning the opposite direction at a slower pace. As vertical slices of the woman's face beam through the passing slits, the many slices merge in the mind's eye to form a complete image. To create the change in perspective at different angles, each vertical row of LEDs switches at precise intervals between the different views of the woman. *Figure 4* presents a diagram of the basic steps of this "LED barrier rotation" process.

The fact that SeeLinder shows different angles of a person to several viewers at the same time makes it extremely relevant to my thesis. Using a cylindrical design, Inventors Tachi and Endo achieve a higher level of viewer accessibility than the previous lenticular examples. However, like the Sharp and Philips 3-D screens, SeeLinder is concerned with a "one to many" principle. The monitor presents multiple perspectives of the *same object*, not unique scenes or objects at different angles. To better understand this distinction, see *Figure 5*. It's important to note that the "LED barrier rotation" method used for

Figure 4 Basic process of "LED barrier rotation" method.

As the inner wheel
rotates, the slices of
the object are
projected through the
passing outer wheel.

1

The LEDs change to
show the corresponding
perspective of the object
at each angle.

2

"Persistence of vision"
helps us form complete
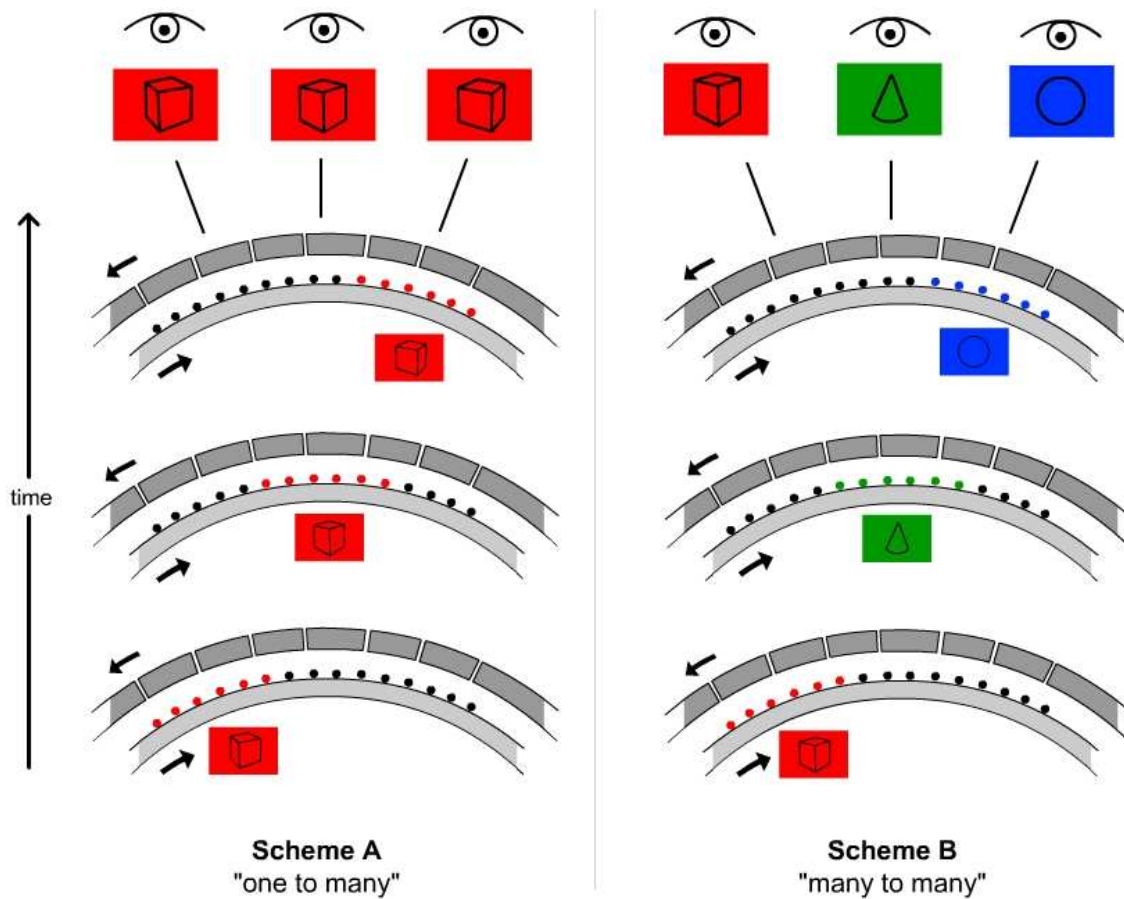images from the quickly
passing slices of the
object.

3

SeeLinder clearly has the capacity for a "many to many" approach. This means that a cylindrical monitor design could possibly help me in the development of an interactive multi-view display.

The "Perspecta" display by Actuality Systems is another multi-view project that operates on "persistence of vision;" though, Perspecta works a bit differently from the SeeLinder. First, software chops a 3-D object into 2D slices, like "thin slices of an apple around its core" ("End Flat Screen Thinking," 2004). Next, inside a clear dome a high-speed digital projector beams these slices onto a disc that spins in place at high speed. Like the SeeLinder, this display updates the object's perspective as it changes angles. Persistence of vision helps combine the quickly spinning 2D slices into a full-bodied "colorful 3-D image that can be seen from any angle in the room." Instead of measuring in pixels as you would on a flat screen monitor, Perspecta is divided into "voxels," or volume pixels.

Figure 5 Comparison of two primary LED barrier rotation schemes.

Scheme A
"one to many"

Scheme B
"many to many"

While Perspecta differs from SeeLinder in mechanics, the same effect is achieved: a holographic effect visible from 360 degrees. Unfortunately, like all projects mentioned prior, Perspecta remains a "one to many" system. While the designers can calibrate the display to show unique images or scenes at different angles, they ignore this possibility and cite no plans to achieve this goal. Furthermore, both SeeLinder and Perspecta fail to provide simple and clean user interactions. SeeLinder is geared towards display purposes only, and while Perspecta is described as "interactive," it "attaches to a computer with a standard interface" ("Actuality Systems," 2002).

2-3.   Outcomes

Researching past and existing models of multi-view displays shows two viable design methods: lenticular imaging and a cylindrical design based on "persistence of vision." While all the projects researched have a capacity for an interactive "many to many" system, they fail to identify or explore the potential of such a solution. As a result, the interactive multi-view display I plan to design will be unique. Instead of creating 3-D scenes or images, I plan to offer users the original experience of sharing a monitor while viewing and interacting with separate and distinct content.

Learning the mechanics of these "one to many" projects has been extremely helpful in determining the possible methodology to follow in my thesis. To begin development, I need to choose the best candidate of the two researched multi-view methods. Both practical and financial issues factor into this decision.

While 360 degrees delivers more content to more people, a flat screen lenticular monitor takes up less space. The volume of the cylindrical monitor can crowd tight working quarters or high-traffic public areas. One possible solution would be to develop a much larger cylinder and sink the structure into the wall with only a portion peeking out. In effect, this would create a slightly curved flat screen monitor. This would open up space in the public area, as well as enhance the viewing angle of a standard flat screen display. However, these benefits are not worth the number of materials and hours that can be saved by going with the lenticular option.

Another drawback of "persistence of vision" displays is their reliance on quickly moving parts; whereas, lenticular monitors succeed purely with optics. Having more moving parts can lead to more energy consumed and greater potential for system failure. A further downside is the expense of the materials required to build cylindrical monitors. The parts needed to construct a device like the SeeLinder or Perspecta displays would be far more costly than obtaining a lens and LCD.

Given my current resources and time to complete the project, developing a multi-view monitor with a lenticular lens seems to be the best choice. Combining LCD and lenticular technology is a faster way of getting an interactive "many to many" display up and running. In addition, using a flat screen to develop my multi-view monitor will make

it much easier to apply a successful multi-view prototype to current televisions and computer screens.

3. METHODOLOGY

This section details the development of the technology and content for my thesis project. Throughout this stage, the multi-view display and the screen content are created simultaneously. Along the way, I discover that limitations of the technology shape the possibilities for display content. In the end, art and technology combine to form an engaging art installation based on the flow of time.

3-1.   The Nature of Time

Now that research has proven my idea unique and decided my materials, I begin to brainstorm interactive content to show the creative potential of a multi-view display. The content should be immediately engaging, encouraging viewers to test the different views of the display. In the "Thesis Statement and Goals" chapter, I discuss several settings in which an interactive multi-view display would excel. Classrooms, ad spaces, and the video game industry are just a few. Taking a cue from French painter Bois-Clair, I decide to showcase the multi-view project with an art installation. An artistic experience is immediate and compelling, challenging viewers to discover its

meaning. This is an ideal way to draw people in and to familiarize them with the multi-view monitor.

Searching for artistic inspiration, I consider the project most resembling my thesis, Pompeii's "three-way television." This installation tantalizes users by playing with space, breaking up a scene into its separate components. The television viewers shift back and forth between different areas of space. I realize this interaction is much like shifting through time.

Time, like space, can be divided into pieces. Incorporating a theme of time into the multi-view monitor seems fitting and natural. After all, lenticular images frequently show several consecutive moments of an event as you change angles. On a flip image baseball card, a player grips his bat as a ball approaches. Tilt the card, and the player jumps forward in time, swinging his bat. Tilt it more, and the bat hits the ball. Breaking up the multi-view display into different moments should make users *want* to shift back and forth through time.
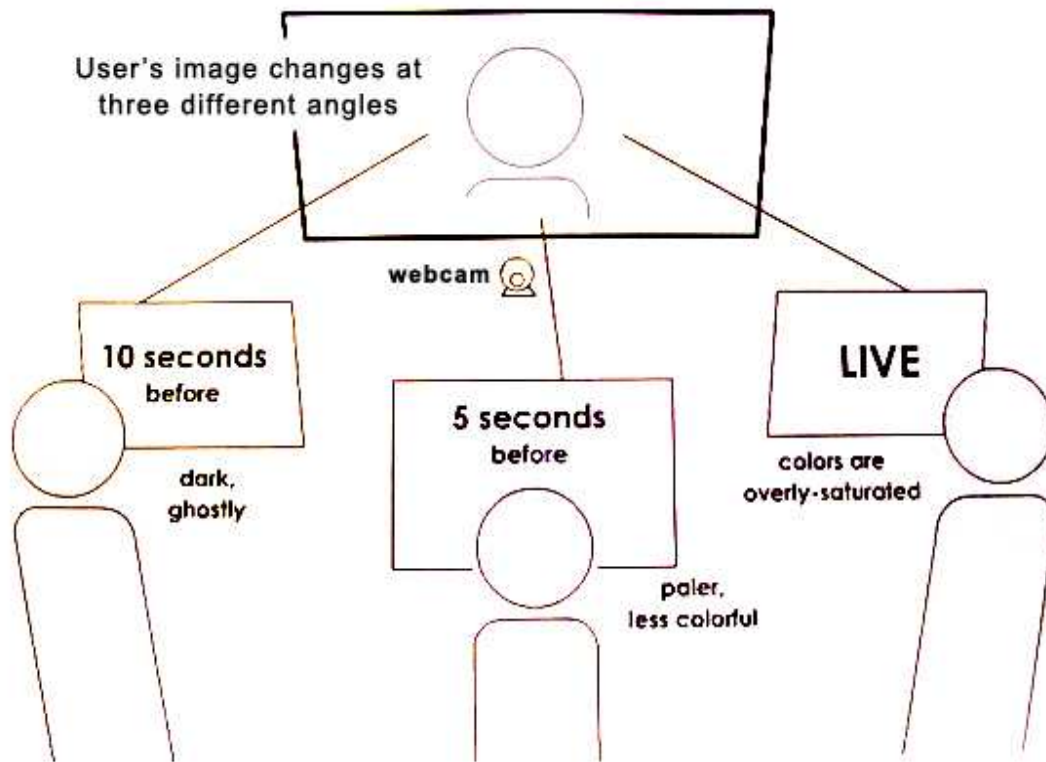
By giving each view of the display its own set of moving images, the interaction with the project should become even more engaging. Each phase

of the shifting screen becomes its own living world. The "three-way" television demonstrates the power of separate moving images sharing the same screen. In that scenario, the three different views are happening at the same time. Violinist, vocalist, and trumpet player occupy the same time and space, but are seen separately in the three viewing zones.

I have a better idea. I'll make the moving images in each viewing zone happen at different times. In this way, the user can shift between living symbols of past, present, and future. With the addition of interaction in each individual view zone, the art installation becomes a completely unique experience. I now dream of ways for users to view and interact with different time periods in the installation.

My first sketch for this idea appears in *Figure 6*. A webcam places the viewer inside his own past, present, and future. From a left angle, he sees his past depicted by a faded live video feed delayed by ten seconds. The middle shows a brighter, less distant past with a five second delay. On the right, the present is represented by live, oversaturated video. This time delay effect is inspired by another installation called *The Crowd in Us* in which time-

Figure 6   First concept sketch of multi-view art installation.

delayed images of the user are projected on the wall before them (Demircioglu, 2004). The different color filters I describe in the concept sketch are intended to give the stages of time specific moods and color.

I ultimately pass on this concept. I feel a need to add more meaningful interactivity to the installation. Several questions begin to surface: What would happen if you interacted with the past of an artwork? How would this affect its future state? These questions directly relate to a

growing trend in video games of allowing players to bend the rules of time. A recently revived game franchise called *Prince of Persia* allows the player to pause, speed up, and rewind the game's timeline (*Prince of Persia: Warrior Within,* 2004). What's ultimately compelling about this experience is the chance to undo a mistake or make a different choice. Fall down a ravine, and you simply rewind time to a point when you are free from harm.

The theme of time travel when used effectively in a game, book, or movie is exciting and thought-provoking. Who hasn't dreamed of the chance to go back in time to change the course of history or simply answer the question "what if?" More than a staple of science-fiction and theoretical physics, time travel is a wonderful starting point to important philosophical questions like "do we have control of the future?"

We often believe we could have *acted differently*, or made a different choice, but clever time travel stories like Terry Gilliam's *12 Monkeys* make us question our free will. In this film, a man travels to the past only to find himself trapped in a cycle of time, unable to change his destiny (*12 Monkeys*, 1995). If time travel becomes possible, this kind of determined existence may be a regular occurrence.

Working in the ability to change the past, present, and future of the multi-view display would be a unique and engaging user interaction. The question now becomes: How does interacting with the past of the display affect the future scenes? To answer this, I should consider how time works in the real world. This means imagining what the

future ahead of us looks like as we flow through the present.

If I listen to Aristotle, the future scene in the art installation would be unchanging. Aristotle paints a bleak picture in his famous "sea battle" argument. In a nutshell, he claims that "there will… or will not be a sea battle on 1/1/2010" (Kane, 2002). If the battle happens (or doesn't), then it was always true that it would happen (or not happen). Therefore, there is nothing anyone could have done to prevent it (or cause it). This means that all future events are out of our control. He ends his claim with the wonderfully pessimistic line "Thus, in general fatalism is true."

I believe the future is not written in stone. Even Aristotle soon changes his mind after making his "sea battle" argument, admitting that we can't assign truth to the future. There is something *special* about the future, he thinks. As I see it, our choices and actions in the present result in a future that's always in flux, a future that's always shifting to fit our latest choices. The past is fixed, while the future is alive and fluid.

The novel *Einstein's Dreams* imagines the possible accounts of time the brilliant physicist

might have considered before settling on the Theory of Relativity (Lightman, 2003). In one chapter, time is a stream of water. Occasionally people are pushed into the past by eddies in the flow of history. Such people are "agonized souls" who fear making the slightest change in the past because they "may destroy the future." This chapter conjures imagery of a future that shifts and morphs as we move in the past.

Inspired by the time-shifting concepts in this book and games like *Prince of Persia: Warrior Within*, I form a vision of how users can interact with the different time periods in my art installation. By playing around in the past stage of the scene, the future will change accordingly. In other words, I'll incorporate a kind of "butterfly effect" into the piece. In the same way that followers of chaos theory believe that a small breeze made by butterflies in Tokyo can cause a thunderstorm days later in New York, I'll attempt to express that interacting with the past can have larger, unexpected effects in the future.

3-2.   Lens Experiments

With a solid direction for the content, I begin tests with a lenticular lens. On the web, I find a

company called MicroLens Technologies with high praise and affordable prices for lens sheets. The lenses are made of durayl acrylic and produced with different grades, measured in lenticules per inch (LPI). I order a free sample pack of all their different lens grades to see which lens works the best. With a set of 8'' x 10'' lenses in hand, varying from a coarse 10 LPI sheet to 60 LPI, I devise a way to make an image flip.

In Lipton's paper detailing his lenticular imaging software called Synthagram, he describes a complex interlacing process called "Interzigging" (2002). He and fellow Synthagram creators use this method to weave two images, scale them to fit a lens, and precisely align the interlaced images with the direction of the lenticules. "The Interzig process," states Lipton, "is a complicated floating point algorithm and takes into account the screen optics, lenticular density, tip angle, screen position, and sub-pixel offset distances."

This sounds overly complex for my purposes. I believe I can achieve an image flip by *manually* interlacing images in Flash, placing a lens over my laptop screen, then changing the interlace width to match the lens. Because my test lenses are 8'' x 10,'' they only fit my screen by turning sideways.

Since the lens lines run left to right, then my interlaced images must weave in the same direction. So, I interlace red, green, and blue lines horizontally in Flash. With high hopes, I place the 20 LPI lens sample securely over my laptop screen.

What I get is a magnified view of the underlying interlaced colors. The interlaced pattern is too big to sync with the individual lenses, so I slowly shrink the height of the interlaced field. The bands of color begin growing until I see they are shifting toward a single field of blue. When the entire image beneath the lens turns a solid blue, I know I'm on the right track. Lowering my head, I watch as the blue fades to red. Sitting up, I see the colors morph into solid green. *It's working*, and without a complicated "interzigging" algorithm. There is definitely cross-talk (slight bleeding) between the red, green, and blue, but there's a successful shift between the colors. The experience is similar to the diagram in *Figure 1*.
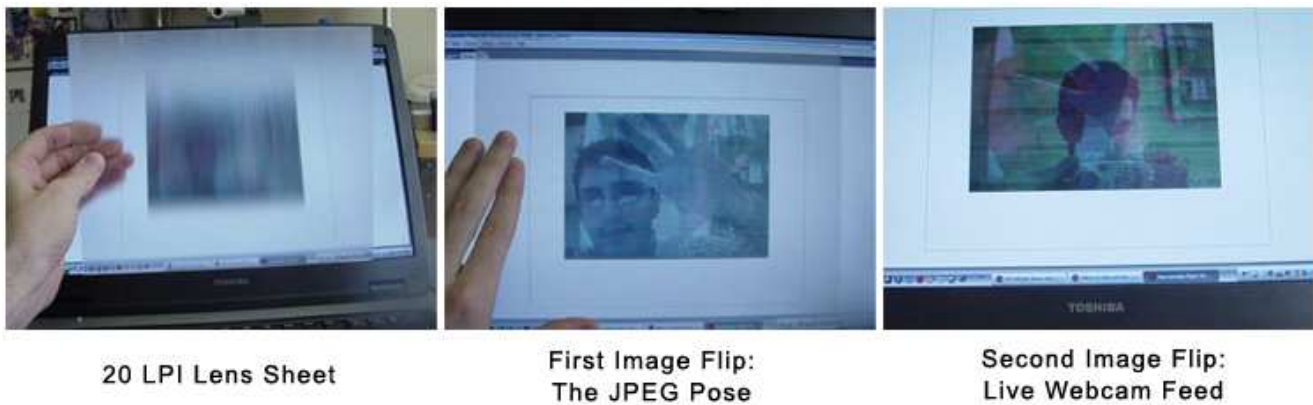
For the next test, I interlace two graphics. I know that eventually I want movement in the several phases of a multi-view monitor. Thus, I make one of the interlaced images a live video feed of me

sitting in front of my laptop. The other is a jpeg screen capture of the same scene. In Flash, I interlace the two by placing the jpeg over the webcam video, cutting strips in the graphic to let the live video show through. Overlaying the lens, I repeat the same height adjustment I performed in the first test. *The images are successfully split into two different directions*. Unfortunately, the cross-talk, or "ghosting," witnessed with the RGB test is more pronounced here. Also, the transition between the two images happens too quickly. The overall multi-view effect is working but needs tweaking. The photos in *Figure 7* summarize the experiment.

3-3.   Setting the Scene

After a promising set of lens experiments, I turn to creating a compelling interactive experience for the multi-view display. Earlier I found that the "butterfly effect" would be a nice mechanism for interacting with the past and future. The next step is designing content that gives the user visual clues that they are looking at past, present, and future scenes.

Figure 7   Lens experiment with interlaced graphic and webcam feed.

20 LPI Lens Sheet   First Image Flip: Second Image Flip:
                           The JPEG Pose   Live Webcam Feed

After brainstorming visuals that symbolize change over time, I have a vision of planting seeds in the past and sidestepping to see them fully grown in the future. Users could make quick movements to generate colorful seeds on the screen at the points of motion. The seeds could fall and form buds at the bottom of the screen. Shifting angles to see future views could show a vivid, fractal-like progression of these plants over time. This might instill the user with a sense of "playing god" by setting life in motion and jumping ahead to see the future results. If the resulting pattern of plant life is undesirable, the user could replant new seeds and watch the "fractal garden" grow differently.

I test this concept by first interlacing a picture of a seed-sprouting person with an image of a fractal-like plant. Soon after applying the lens and shifting views, I realize this is not going to work. There is little connection between the two scenes. I predict the user will lose sight of the "cause and effect" concept when moving between views. There is no anchor to bond the past scene to the future.

My resulting design decision is to forget abstract concepts and develop a more realistic scheme to show change over time. The winning idea comes to me in Central Park. There, I recognize artistic potential in creating a park scene with past and future stages. The trees, buildings, and people in the park could change over time. The anchor between time periods could be the collective scene elements. While everything in the picture can change colors, shapes, and size over time, the overall identity of the scene remains the same. To stay true to my "many to many" principle, the display should project separate and *distinct* scenes at different angles. By separating the

moments within the phases of my display by significant time intervals, I believe the scenes in each view will qualify as *distinct enough*.

After choosing the park setting, I quickly determine the style of the digital painting. The look and feel of the piece is partially guided by the lens. The lens sheet causes slight pixelation of the shapes in the scene. Thus, it's necessary for me to make the underlying images bold, colorful, and distinct.

Another way to counter pixelation is to render the park scene with impressionistic paint strokes. If the images are photorealistic, then pixelation will be more apparent. Scenes with deliberate daubs and bold paint strokes will diffuse the filtered effect of the lens. Unfortunately, this is an example of the technology shaping the nature of the content. Fortunately for me, I love the concept of an impressionistic painting shifting between past, present, and future.

As I design this "digital painting," I gravitate toward the style and layout of Seurat's "Grande Jatte" (1884-86). I liken this piece to a classic, pointillist version of Central Park. All that's missing is a Manhattan skyline in the background. With a visual style firmly in mind, I spend the next few

weeks searching the park for the right scene location. I waver between lawn scenes, rocky terrain, and park sidewalks. Nothing feels right.

Finally, I find inspiration while walking through my neighborhood in Brooklyn. As I pass the usual flock of pigeons on my street corner, I realize these "flying rats" would be a perfect mechanism for the butterfly effect in the installation. The flapping pigeons are similar enough to fluttering butterflies to make my point. Pigeons are also well-established icons of New York City which combined with the park scene will give the art installation a welcome brand of New York life.

Soon after I decide on pigeons, a stereotypical image of a "bird lady" pops into my head – a vision of a lonely woman feeding pigeons in the park. This would give the interactive painting a more personal tone. I can show this sympathetic woman in her past as a young girl, then as an old woman in the future.

The next step is returning to the park to find a setting that suits this new vision. Instead of a woman, I find an aged, bearded man sitting on a bench. I use his photograph to create the image of a "bird man." I take another photo of younger

man who I later scale down to the size of a young boy. To give a virtual flock of feeding pigeons room to maneuver, I settle on a scene depicting a wide bench-lined sidewalk cutting through the park. The photograph in *Figure 8* shows the original park scene.

As I "paint" the future park scene with Adobe Photoshop, I realize that having a center view in the digital painting, or "the present," is an unnecessary step. The lenticular lens, by its very nature, will include a middle stage between the past and future. When a user steps between the two viewing zones, they'll watch as the past and future blend together to form a middle phase in the old man's life. Thus, I decide to paint a before and after park scene, rather than past, present, and future versions. *Figure 9* shows the first set of

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Figure 8   Park scene before adding impressionistic style.

Figure 9   The first before and after paintings.

"painted" scenes. The man and boy occupy the same spot in the different time periods. The trees grow up over time, and the cab morphs from a classic make to a modern model.

With the style and setting of the painting in place, the next step is determining the interaction. The pigeons are the focus in the past, but how does the user control their movements. Also, what effect will they have on the future?

3-4.   Flash Stays in the Picture

Ready to move beyond prototyping in Flash, I switch to Metrowerks CodeWarrior to test an interlacing program written in C. I quickly find there is no room for precise fitting of interlaced

images to the lens. With Flash, I can adjust the height of the interlaced field by small decimal increments, causing the individual interlace strips to make tiny vector-based adjustments. When coding in C, the x and y pixel positions are by necessity *integers*. While precise lens alignment might be obtained with another program, I no longer have ample time to learn new software. My only choice is to continue with Flash and find a way to overcome the speed limitations.

3-5.   Image Flip Success

I begin testing the image flip on a 15'' CTX flat screen LCD monitor. Because I'm chained to Flash, I try to discover an easier way to interlace two pictures. Weaving them manually would be

painful. With the help of a *setMask()* method in Flash, I develop an alternative interlacing technique. I first create a series of red stripes keeping the width of each stripe equal to the distance between the stripes. By applying this stripe field as a mask over the past scene, the underlying future scene peeks through the subtracted lines. Now, interlacing is instantaneous.

After determining that the 20 LPI lens is the finest lens that succeeds on my personal laptop, I continue with this lens grade on the CTX. The result is impressive. When I look directly at the two individual scenes, the ghosting effect from previous experiments has all but disappeared.

The morphing between past and future is clean and clear. The only noticeable issue is set of dark lines running across the screen. See *Figure 10* for the image flip.

I follow this successful experiment with a quick adjustment to the actionscript in Flash which makes the fitting of interlaced images to the lens (called *phasing registration*) effortless. Arrow keys are programmed to quickly change the height and position of the interlaced field. This allows me to quickly review the image flip between the scenes in the painting.

Figure 10   Image flip of past and future scenes.

Image Flip 1

Image Flip 2

3-6.   Birds and Rain

Returning to the "cause and effect" interaction, I decide to take the butterfly effect concept to heart. I appoint *change in weather* as the variable effect in the future. The pigeons will be the cause, change in weather the effect. To keep the relationship between the two scenes easy to grasp, the weather will become more severe as the pigeons flap around more wildly in the past.

I browse online actionscript examples for ideas on how the pigeons will fly around. Digital artist Jared Tarbell specializes in clean object-oriented Flash design. Browsing his site *www.levitated.net* leads to code that shows a field of white dots rotating in three dimensions (Tarbell, 2003). The look and feel of the animation suggests a smooth flocking motion. I modify the actionscript so I have control over the speed, acceleration, and vertical movement of the dots. I transform the dots into pigeons.

I want a clear, simple way to interact with the birds, so I seek inspiration from Camille Utterback's *Liquid Time* series (2003). These installations allow the user to walk towards and away from a paused video screen to move time on

the screen forward and backward. The user interaction is natural and easy to understand.

I also recall the clean, intuitive interaction in the researched *Free2D 3D* project. This simple gestural interface is perfect for "A Shift in Time," since users must play with the painting from a distance. Thus, I program a way for viewers to interact with the birds by using natural body movements.

Routing a webcam feed into Flash, I attach a method called *activityLevel* to the camera input. Combined with the *Camera.get()* command, this method specifies the amount of motion the camera is detecting. The motion values range from 0 (no motion detected) to 100 (a large amount of motion). To add an extra layer of interactivity, I include a microphone element. The same activityLevel method applies to the sound detection. 0 means no noise, 100 means a very high volume of noise is detected.

I use the movement and sound input to affect the behavior of the birds. When there is no motion or sound, the pigeons are "idle" and peck at the ground. When a user moves or makes noise, the birds circle into the air at a height proportional to

the level of user activity. If the viewer flails around and make loud noises at the same time, the birds reach their highest position in the sky. I make the birds quickly responsive to user interaction. I also keep them locked in their flight pattern for a few seconds after the user calms his interactions. This creates a slight sense of realism, so the birds aren't rising and falling in *exact* accordance to the user's motion and sound. If the user remains motionless and silent, the pigeons quickly return to an idle state, as to invite more play (*Figure 11* shows the different stages of pigeon animation). The intended effect is the feeling of playing a musical instrument with birds.

For weather changes in the future, I create a movie clip with a three-frame loop that cycles through falling rain. To create the feeling of a butterfly effect, the rain movie is completely transparent when the birds are idle (which means the user is still). As the user moves and the birds react, the rain in the future fades in and out proportionally. As the sound and movement input begins to elevate, I fade in two other rain movies. The resulting animation creates a dreary mood in the future scene. This is a perfect contrast to the bright, cheerful past.

Once the past and future animations are set, I run a test of the two scenes interlaced. Immediately, I see significant slowdown in the speed of the Flash movie. This is not a huge surprise. Flash is not

Figure 11   Pigeon animations.

designed to support super-heavy processing speeds. I determine the main culprit of the slowdown to be the mask method I'm using to interlace the scenes. At some point, I need to find a way to maintain the mask while recovering movie speed. For now, my sights are set on finding a larger display for the multi-view painting.

3-7.   Moving to the Wall

I'm given permission by the university to test my project on a 37'' Sharp LCD wall monitor. I immediately order an 18'' x 32'' lenticular lens (20 LPI) to fit the large screen size. Since the LCD hangs horizontally, I request that the lens run vertically, meaning users will flip the images by moving side to side. Once the lens arrives, I test the past and future scenes on the Sharp screen. Unfortunately, I find it difficult to align the LCD pixels with the finely cut 20 LPI lens. This means going with a coarser 10 LPI lens, sacrificing clarity in the graphics. This is yet another example of the technology dictating the visual appearance of the piece.

I obtain a new sheet with wider lenses and place it over the interlaced digital painting. I see an unexpected side effect. Distinct lines of red, blue and green collect near the borders of each lenticule. Disappointed with this effect, I try using a 10 LPI 8'' x 10'' lens sample to see what happens when the lenses run horizontally. The unwanted RGB effect thankfully disappears. I later conclude that the sub-pixels inside each pixel are themselves interlaced in a red, green, blue pattern. When the lens aligns with this interlace, the colors in the sub-pixels are magnified. Turning the lens at a 90 degree angle reduces the effect. I order a new 18'' x 32'' lens sheet to accommodate the LCD pixels.

With the lenses now running horizontally, users would have to move up and down to see a shift. To regain my side to side interaction, I rotate the LCD from landscape to portrait. This also means that my before and after scenes have to adapt to the vertical screen. I take the opportunity to create a brighter, more colorful look for the past, while contrasting the future with drab, faded tones. I also add a bold shadow to the light post. By varying its position in the two scenes, I create a kind of ticking effect to represent the passage of time. *Figure 12* shows the new past and future. I test the new multi-view paintings on the LCD. The two contrasting scenes work wonderfully. The rich contrast makes the image flip dramatic, and

Figure 12
New portrait versions of past and future.

the vertical setup of the piece gives it the look of a framed painting.

3-8.   User Feedback

A criticism I receive about the digital painting is that the boy needs to have a younger appearance. Another critic suggests making the color change in the foliage more prominent. I also consider switching the lamppost in the future to a subway lamp with a green glow. However, a friend notes that keeping the same old-fashioned lamppost in both scenes creates an effective anchor, signaling to the user that this is the same place but different time. I follow all of these suggestions in the final version of the digital painting.

Since the interlaced scenes run slower than expected, I give testers a virtual laptop version of the multi-view display. In this version, I manually change the views as users move side to side. Testers respond immediately to the webcam and microphone, experimenting with the input to see what happens in the two scenes. Based on their response, the pigeon and weather animations work effectively. The users find a comfortable balance of interaction and natural movement in the painting.
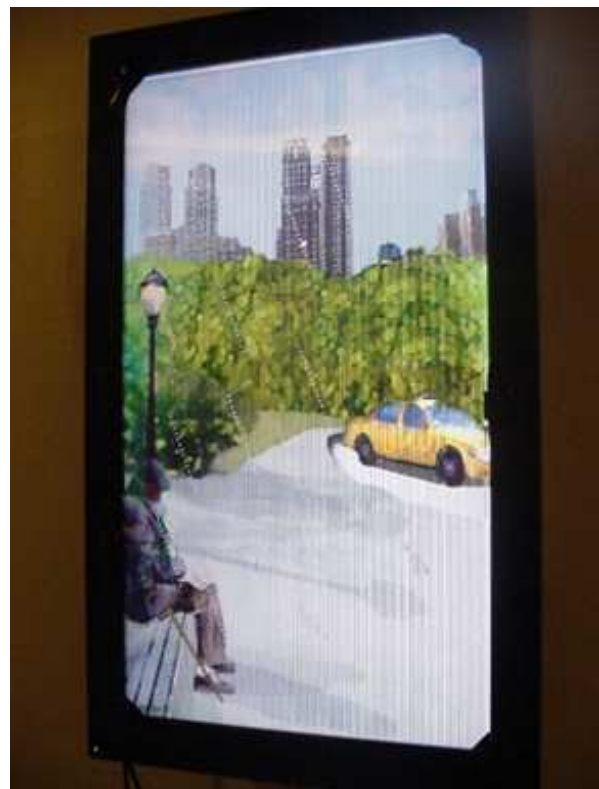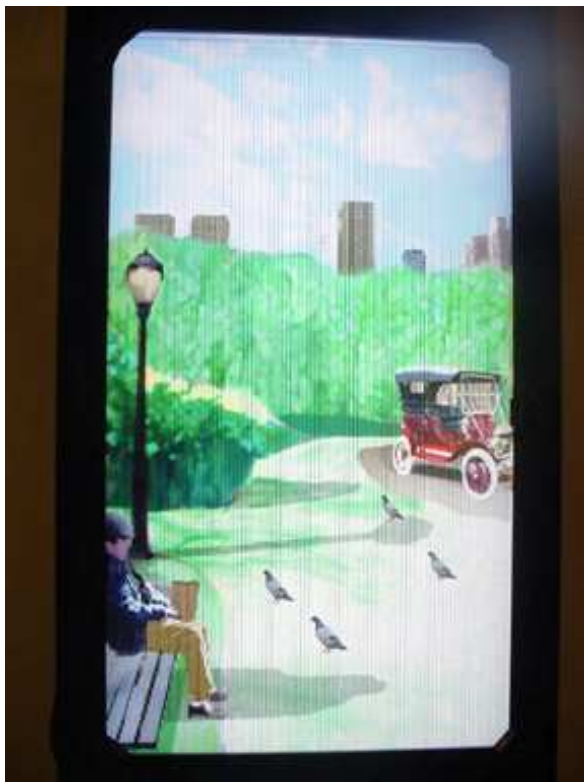
A property of the 10 LPI lens causes the views to alternate approximately five times as you walk past the painting. Past follows the future, then future follows past, and the cycle repeats. The result is poetic, demonstrating the close-knit relationship of past and future. This interlacing effect also provides a practical benefit to viewers. A person on the right side can shift between their own set of past and future scenes, while someone on the right can do the same. Because the piece involves a shift in both time and vision, I decide to call it "A Shift in Time."

3-9.   Summary of User Experience

Barring the final task of speeding up the animation in the multi-view painting, the user experience is complete. A general summary of the user interaction follows:

Approaching the painting, users are first struck by its slightly holographic effect. The interesting double-view property of the monitor piques curiosity*. Figure 13* shows photographs of the digital painting taken at two different angles.
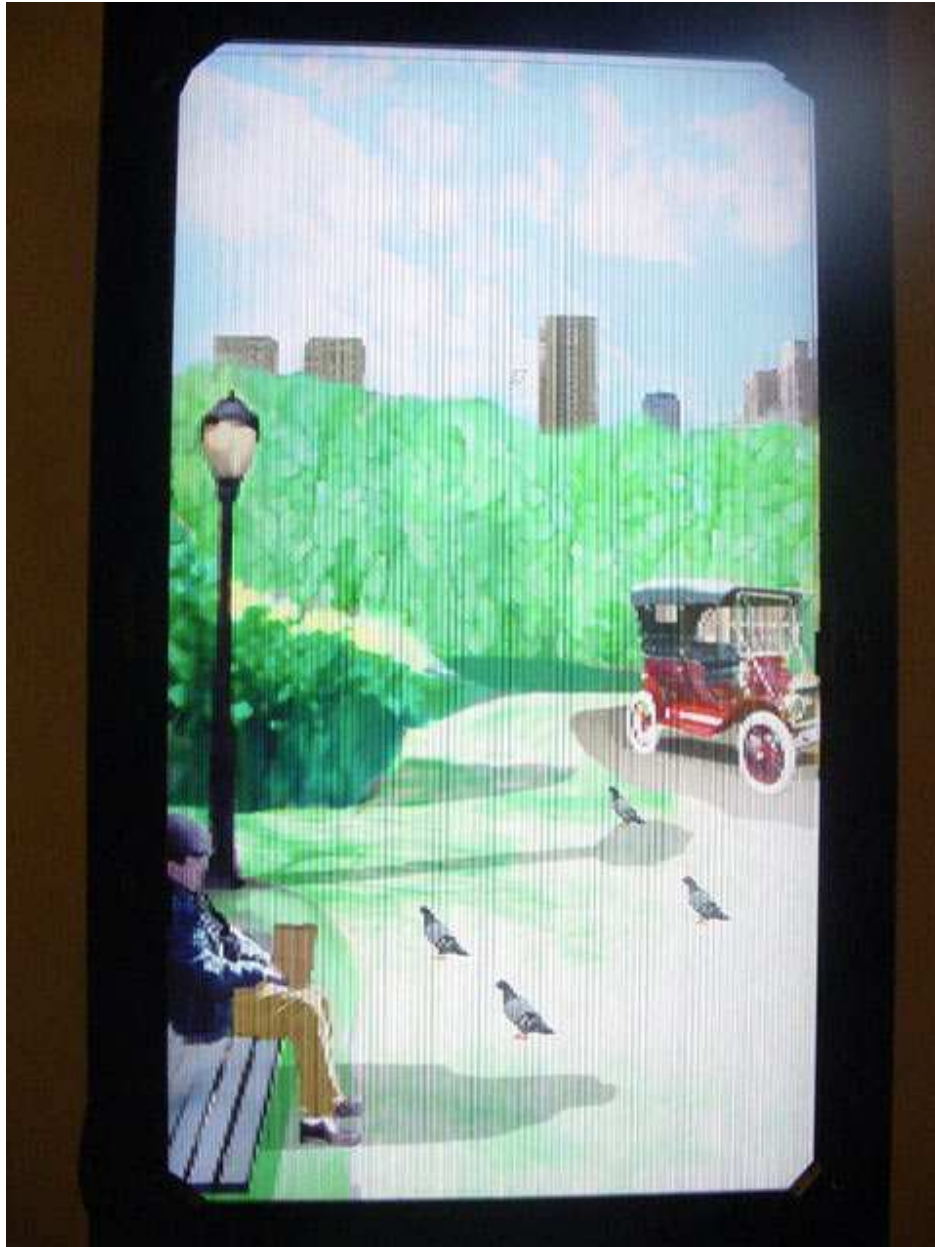
Figure 13   Past and future scenes of the final project.

Figures 14 and 15 provide close-ups. After discovering these two images, viewers move back and forth to find a link between them. About this time, a connection between the users' movements and the animations is noticed. Following are attempts to discover the nature of this interaction.

Figure 14   Close-up of past scene.

The sight of the webcam and microphone inspires experiments to see how these inputs affect the painting. By learning to control the piece, there is a kind of musical experience to the painting. Your movements cause the birds to rise and fall like musical notes. *Figure 16* illustrates this interaction.
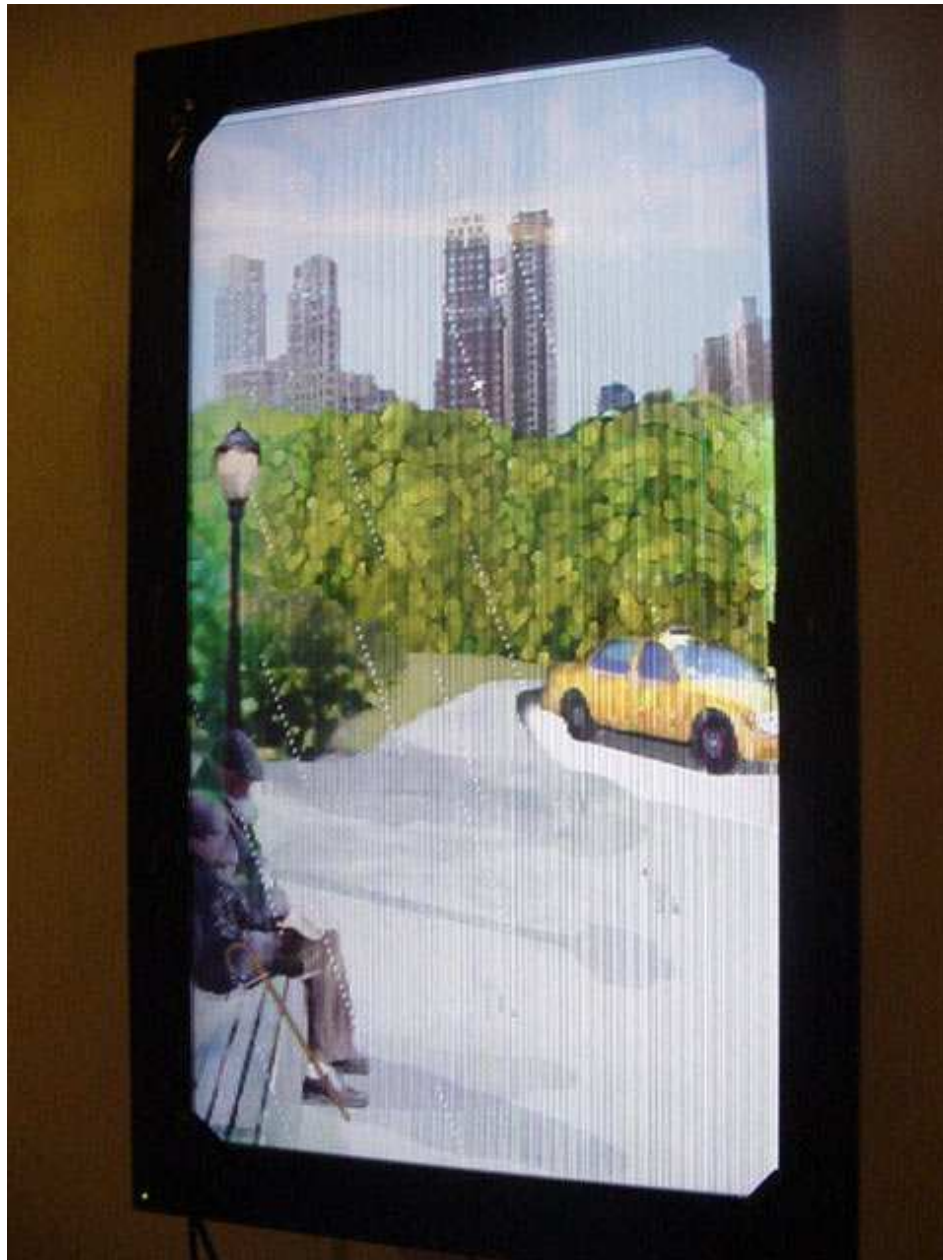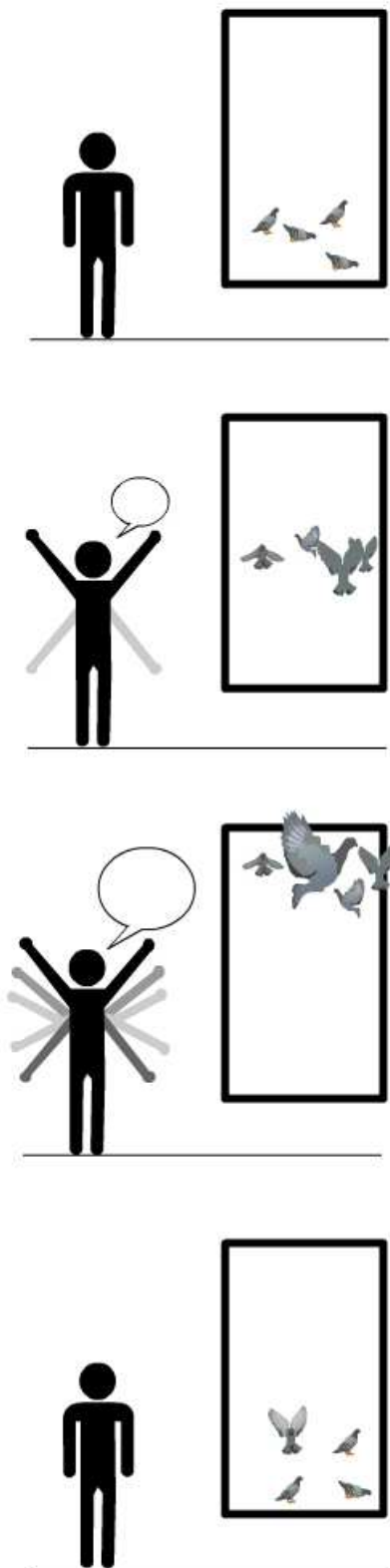
Figure 15   Close-up of future scene.
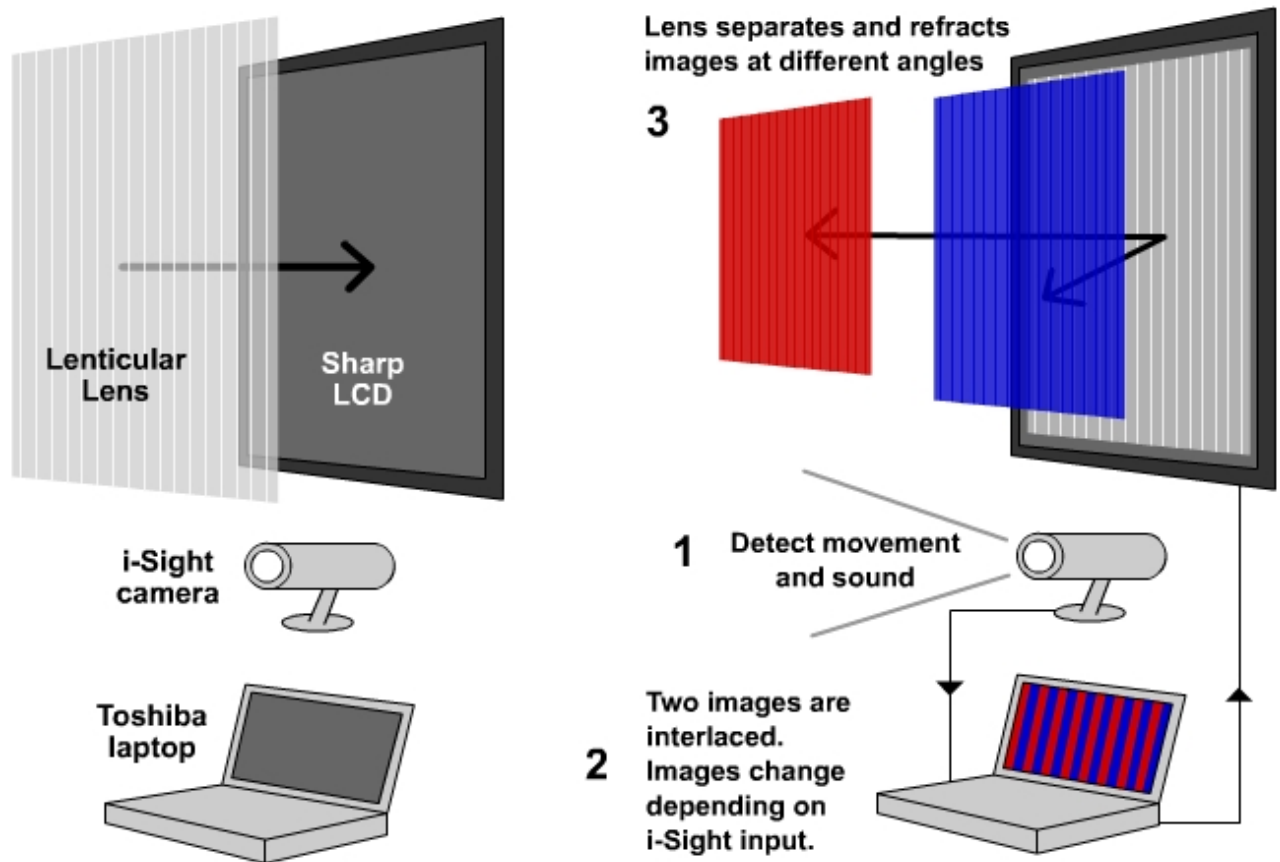
Figure 16   Pigeon response pattern.

"A Shift in Time" also provides a unique chance to explore the relationship between past and future. By seeing the fluctuating weather in the future, users are given a special ability to "paint" in time. The interaction in the past becomes a brush, while the future becomes a canvas. Since past and future occupy the same screen, viewers truly feel they are shifting between two time periods. Only a multi-view monitor can make this kind of interactive experience possible.

In the end, "A Shift in Time" is a novel invention and compelling art installation that can be enjoyed by one or many. Hopefully, it will mark a new trend in "many to many" displays, and inspire others to think of new and exciting uses for such a monitor. I also hope it encourages viewers see the close-knit relationship between past and future in a new light.

3-10.   Summary of Technical Setup

The diagram in *Figure 17* summarizes the final technical setup for "A Shift in Time." The i-Sight camera can be replaced by a video-only webcam and a standalone microphone. The interlacing and animation of images takes place on a laptop in Flash, but Flash can be replaced by any software capable of precise image alignment with the lenticular lens.

Figure 17 Final technical setup.

The lens size used in the final project is 18'' x 32'' with a grade of 10 lenticules per inch. Ordered from MicroLens Technologies, the lens costs $69.99, trimmed down from a 32'' x 42'' sheet. The lens thickness is just below ¼ inch. On the backside of the lens, the plastic is smooth and flat. The lens is gingerly attached to the monitor with metal clips and electrical tape.

The display is a Sharp LC-M3700 Professional LCD monitor. The Sharp receives input from the laptop via a DVI connector. The screen resolution is 768 x 1366 pixels. As LCD technology improves, the number of pixels on each screen will increase. This means finer grades of lenticular lenses can be used to create multi-view displays like "A Shift in Time." Thus, the individual view zones of multi-view monitors will continue to improve in resolution.

4. CONCLUSIONS

Three major conclusions can be drawn from this thesis project:

- This is the first known case of combining lenticular technology with an LCD to create an *interactive*, "many to many" experience

- "A Shift in Time" effectively demonstrates the power of a "many to many" display

- There are current limitations in developing content for this kind of system

4-1. Proof of Concept

I've achieved what I set out to accomplish. I successfully created a multi-view display system that presents separate and distinct moving images depending on viewing angle. The combination of the LCD and lenticular technology is successful, achieving a clear, sharp image flip with minimal ghosting. The clarity and independence of the two dynamic images prove that the display system used in this art installation would be just as effective in other fields like gaming, marketing, and educational media.

The digital painting effectively demonstrates the interactive potential of the multi-view monitor. The painting draws in viewers with its unique double-image appearance. The interactive input system of the web camera and microphone is clear and simple, allowing the users to explore the potential of communicating with the separate images within the viewing zones. Moreover, the "butterfly effect" theme is a compelling mechanism for demonstrating the power of using multiple views on the same screen.

4-2. Originality

Research of related projects proves that "A Shift in Time" is the first instance of a display system that accomplishes all of the following:

- Combination of lenticular lens and LCD

- User interaction with a camera and microphone

- "Many to many" principle of a digital display

4-3. Current Limitations

The current pixel size of large LCD wall monitors dictates coarseness in the lenticular lens grade. The 10 LPI pixelates the interlaced content, removing the clarity and power of the original images. From the current trend in shrinking pixel

per inch property of LCD screens, one can conclude that within the next decade LCD screens will reach a resolution suitable for the finest of lenticular lenses. This will help to assure the original appearance of the underlying images.

Speed is obviously an issue with Flash. However, working in OpenGL or another lower level programming language should allow me to reach the processing speeds I need. Faster processing speeds are essential in order for "many to many" displays to reach full potential.

A final limitation worth mentioning is the unwanted appearance of dark "mask lines" between lenticules. However, this issue seems to have been solved by other researchers. Van Berkel, for example, suggests slanting the pixels in relation to the lens (1996). This is the same strategy followed by the Philips engineers in designing 3-D laptops. According to Philips, the masking effect can be almost totally removed by slanting the pixels of the LCD at a specific angle. This same solution can be applied to eliminate the magnified RGB effect I encountered when first testing the Sharp LCD. This would allow the lenses to run both horizontally and vertically, depending on the need.

5. FUTURE RESEARCH

Speeding up the animations in the different view zones is a major priority in future research. A possible solution for recovering processing speed in Flash is to drop the setMask method and manually interlace the two scenes. A more obvious answer is to interlace with a faster processing program. A fellow student suggests attaching interlaced images to the surface of a 3-D cube in Open GL. Carefully moving the cube forward and backward along the z-axis could achieve the precise alignment of interlace to lens.

With increased processing speed, I can attempt exciting multi-view projects like interlacing two computer displays to test the collaborative potential of the "many to many" monitor. Equally compelling is the potential to create multi-view games. I'd like to develop a game specifically for this "many to many" system where multiple players can compete while viewing separate and distinct images from different angles.

Perhaps platforms like the Sharp LL-151-3D monitor and the forthcoming Philips 3-D laptop will be good testing grounds for "many to many" applications. These "one to many" machines have

the capacity for displaying distinct images at different angles. According to Sharp, their 3-D notebook "can be switched between 2D and 3D display modes with the touch of a button" ("Sharp's 3-D LCD Technology Now Available for Desktop Computers," 2004). By activating the 3-D mode, one might be able to experiment with custom interlaced video and graphics.

Further multi-view experiments should include uni-directional sound like Pompeii's "Audio Spotlight." This was used to great effect in the "three-way television" project. Adding uni-directional sound to a "many to many" system would only deepen the personal experience of each user.

In addition, I'd like to incorporate more targeted motion tracking with a webcam in conjunction with a lenticular lens. By tracking the movement in each individual viewing field, I can provide a separate and distinct interactive zone, so each viewer can carry out a personalized activity. This would create what can be called a *personalized interactive viewspace* for each user. This new kind of interactive system, like "A Shift in Time," would help us break away from the "one to many" limitations that plague our traditional displays.

Ultimately, I believe all multi-view experiments should be moving towards a display that can switch views vertically as well as horizontally. Currently, all multi-view projects allow view shifts in *only two directions*. None have explored the possibility of *omni-directional* view zones. One potential way to achieve such an omni-view display is by testing alternative lens types. A "fish eye" lens, like the one Lippmann designed, might be helpful. Another possible method would be combining lenticular and "persistence of vision" methods. For example, one might try adding a horizontal lenticular lens to the spinning cylindrical shell of projects like the SeeLinder. This would result in both a vertical and horizontal shift.

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