Panoramic 360-Degree Video Application Design, Development and Evaluation

1. Research Team

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2. Statement of Project Goals

The acquisition and presentation of high-resolution panoramic video (PV) presents a number of technical difficulties, as well as excellent User Centered Sciences research opportunities. We are using a five-camera 360-degree PV system that acquires high-resolution (>3Kx480) panoramic video images. These images are recorded at 30Hz frame rates and played back for later viewing. During playback, users can wear a head-mounted display (HMD) and a head-tracking device that allows them to turn their heads freely to observe the desired portions of the panoramic scene. Incorporation of immersive audio is anticipated to enhance the usability and sense of presence in these environments and this component has been integrated into investigations with this system. We have made significant advances over the last year in our technical capture and delivery of these Integrated Media Systems (IMS) environments and we continue to explore the issues for creating usable and useful 360 Degree PV environments. The issues that need to be addressed for successful PV application development were detailed in a paper by our lab [1] that was presented at the 2001 International Human Computer Interaction Conference and we recently detailed advances in this work at the 2003 edition of HCI [2] and at the American Psychological Association Convention at the Media Psychology Presidential Symposium [3]. We currently have a number of major application projects that we are investigating in terms of the additive value for PV capture and delivery in the areas of Mental Health, Journalism (User Directed News) and Historical Documentation and in Art and Entertainment. These application areas are currently providing test beds for further investigation into the user centered science issues relevant to immersive IMS, particularly in examining the role of immersion and presence on information processing and emotional arousal.

3. Project Role in Support of IMSC Strategic Plan

The advancement of engineering enabling technologies that underlie the design, development and evaluation of advanced integrated media systems (IMS) with attention to their usability and usefulness by humans is at the core of the IMSC mission. The PV projects have driven research on the enabling technologies required to support efficient and effective system development that will also serve to advance the knowledge base available to other scientists addressing IMS development, implementation and evaluation. Enabling technology advancements in the areas of multimedia programming and display/tracking have allowed us to now be able to deliver our test environments by way of a laptop into a head mounted display (HMD) as well as on traditional flat screen displays. Exploration of the types of environments that 360 PV can deliver, along with a focus on the underlying issues for scene capture/presentation are in line with IMSCs mission to advance the creation, delivery, usability and usefulness of immersive information technology.

4. Discussion of Methodology Used

Field-trials with the PV camera and user testing with acquired content has been conducted across a range of scenarios to explore feasibility issues for using this system with a variety of user applications. The following test scenarios were captured in order to assess the PV system across a range of lighting, external activity, camera movement and conceptual conditions. Informal evaluation of users' responses to these scenarios has been conducted and controlled experiments are currently underway for some of the applications. Our PV scenarios have included:

- An outdoor mall with the camera in a static position in daytime lighting with close background structures and moderate human foot traffic, both close-up and at a distance.
- An outdoor ocean pier with the camera in a static position in extremely intense lighting conditions (direct intense late afternoon sunlight with high reflectance off of the ocean) with both long shots of activity on a beach and close-up activity of human foot traffic and amusement park structures on the pier.
- The interior of an outside facing glass elevator with the camera in a static position and the elevator smoothly rising 15 floors from a low light position (e.g., tree-shielded street level) to more intense lighting as the elevator ascended above the tree line.
- Traveling on a canyon road with the camera mounted in the bed of a pickup truck for 30 minutes at speeds ranging from 0-40 mph under all daylight ranges of lighting (low shaded light to intense direct sun).
- Same as #4, except at night on a busy well lit street (*Sunset Blvd. In Los Angeles),* and on a freeway traveling at speeds from 0-60 mph.
- A USC Football game within the Los Angeles Coliseum from both static and moving positions in daytime lighting, with extreme close-ups of moving people and massive crowd scenes (40-60 thousand people).
- An indoor rock concert in a theatre (*Duran Duran*) from a static position under a variety of extreme lighting conditions in the midst of an active crowd, slightly above average head level.
- Two artistic projects were done in collaboration with the UCLA Digital Media Arts Department and the USC School of Fine Arts. The UCLA project involved the capture of

dancers performing around the 360-degree field of view of the camera. Significant post-production work took place to display the panoramic capture within an immersive theatre that incorporated live dancers in a mixed reality installation. The USC project has now evolved into a full course entitled "Visual Arts and Technology" (FA 336) and represents collaboration between the USC School of Engineering and School of Fine Arts. The first project to come from this collaboration involved building a circular fish tank around the camera with live tropical fish swimming within and a coral reef photo serving as background on the outermost tank wall. The users wore an HMD that helped to create the illusion of being immersed within the swimming fish environment for one minute. Following this sequence, the coral reef photo background was manually removed to reveal the activity in the laboratory where the capture occurred creating a dramatic "breaking of the illusion" effect. This scenario also served as an early test for our continued efforts to create a future project in which the panoramic camera would be placed within a sealed Plexiglas tube and lowered into a very large commercial aquarium exhibit. (We have just learned that we will be able to conduct this shoot within a smaller aquarium maintained by a Redondo Beach Oceanic Conservation Society.) The FA 336 course is now in it's third year and continues to evolve the model of getting art students into the IMSC lab to experiment with concepts for panoramic capture and delivery. The Spring 2003 course was highlighted by a series of panoramic captures from the roof of the Standard Hotel in downtown Los Angeles from a variety of provocative camera positions. These captures lead to an exhibition of student pieces from the course and the creation of the "PanoChamber" which was unveiled at the exhibition (Figure 1).

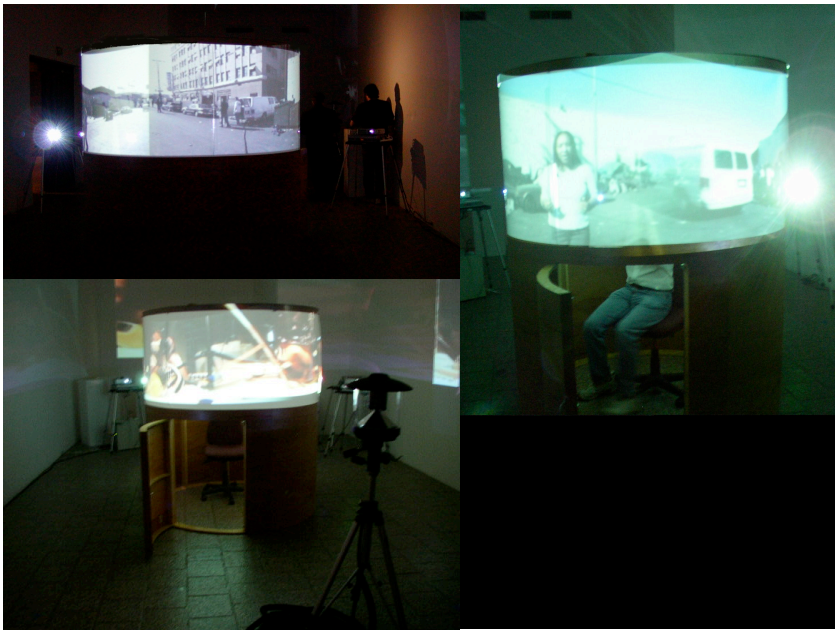

Figure 1. PanoChamber

The PanoChamber was created as a part of a student project and consists of a 360 degree viewing station that users can enter to naturally observe PV content projected from 4 projectors onto a smoked Plexiglas surface. This elegantly simple solution was built for 700$ of materials and serves as a model for future displays that, with use of a better screen surface, could become an option for museum displays of PV content. The PanoChamber is currently being used as a test device for student projects in the FA 336 course.

- Thirteen scenarios were created in an indoor office space for an "anger management in the workplace" application. In these scenarios, actors portrayed agitated and insulting co-workers who addressed the camera (and vis a vis, the clinical user wearing the HMD) with provocative and hostile verbal messages (Figure 2). The scenarios were designed to provide role playing environments for patients undergoing psychotherapy for issues relating to anger management in the workplace, or as it is commonly referred to as "Desk Rage" [4]. The patients wearing the HMD in these scenarios have the opportunity to practice appropriate responses to the characters and employ therapeutic strategies for reducing rage responses. Traditional methods of therapy in this area have mainly relied on guided imagery or role-playing with the therapist. It was hypothesized that PV content could serve to create immersive simulations that patients will find more realistic and engaging, and research is currently underway to assess this with clinical users at St. John's University in New York City. This first controlled anger study is comparing physiological and self report data on anger management clients across three conditions: 1. Traditional guided imagery scenarios based on our panoramic monologs. 2. Low immersion flat screen presentation of the single video frame from one camera out of the 5 camera Panoramic array that presents only the antagonistic co-worker without the remaining captured PV. 3. Full panoramic immersion using a HMD containing the complete 360-degree capture of the work setting. This study is currently in progress and is aimed to determine if immersive panoramic content can induce the levels of arousal in these clients needed for therapeutic application beyond what could be induced with simple single camera video capture or by using standard imaginal techniques.
- A Virtual "Mock-Party" with the camera in a static position in the center of an indoor home environment in the midst of an active party with approximately 30 participants (Figure 3). This "scripted" scenario was shot while systematically directing and controlling the gradual introduction of participants into the scene and orchestrating their proximity and "pseudo-interaction" with the camera. The scenario was created for a therapeutic application designed to conduct graded exposure therapy [5] with social phobics. We have also experimented with pasting "blue screen" capture of actors (using a single video camera in the lab) into the panoramic scenes. The actors address the camera with a spectrum of socially challenging questions that provide the clinical user with opportunities to practice social verbal engagement in a psychologically safe environment. The separate capture and pasting of characters will allow the therapist to introduce a progressively more challenging level of social stress to the patient when deemed appropriate based on therapist monitoring of patient self-report and physiological responses. We are currently building the interface controls needed to begin clinical trials with this application at The Virtual Reality Medical Center (VRMC) in San Diego, CA [6].
- We have captured two PV test environments for a journalism project entitled "User Directed News". This project is being conducted in collaboration with USC's Annenberg School for Journalism and involves the PV capture of a news event with an in-the-field news reporter (Figure 4). The research aim of this project involves a comparison of groups of viewers who observe the news story either in the traditional single frame "talking head" newscaster format vs. full user immersion "in the scene" using a HMD. A 3rd condition of flat screen panoramic viewing is also being tested. The project involved the capture of a news story on the situation of the Los Angeles' "homeless" population as part of a study on the usability, head tracking, preference for use and information processing issues related to this potential journalism application. The details of this project will be presented below.

- We also captured an attempt at having the world's largest yoga class admitted into the Guinness Book of Records during The Annual Yoga Exposition at the LA Convention Center, which drew 20,000 visitors to the 4-Day event. While the goal of having 2000 yoga students to beat the existing record was not reached in this attempt, with only 1500 participants, we captured the event as a news story for an extension of the User Directed New project. We placed the camera in the middle of this large mass of people, but were not allowed to have a reporter do a presentation during the class. Instead, to experiment with options for panoramic journalism, we later captured a news reporter delivering the story of the event using the USC School of Cinema's blue screen studio. Using similar pasting techniques as in the social phobia application, we have experimented with inserting the reporter into the yoga class news scene to demonstrate the potential for use of such editing methods that could be applied for creating documentary footage when panoramic scenes are captured without a reporter at the scene.

Figure 2. "Desk Rage" – PV Therapy for Anger Management in the Workplace

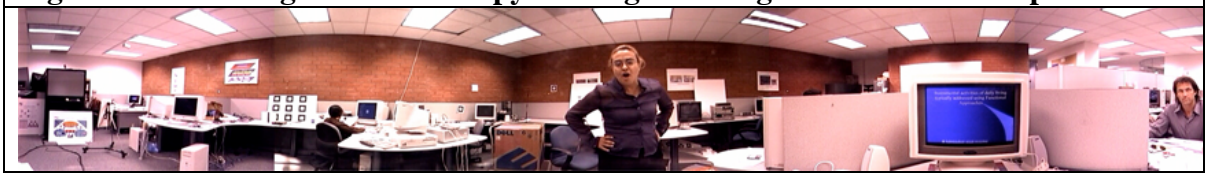

Figure 3. PV "Mock-Party" for Social Phobia Exposure Therapy

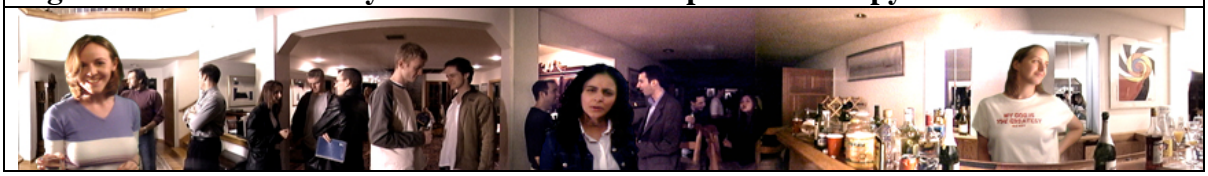

Figure 4. PV/Journalism Project: Traditional Viewing (L) vs. Panoramic Viewing (R)

The capture, production and delivery of PV scenarios presents unique challenges. Application development decisions require informed consideration of pragmatic issues involving the assets/limitations that exist with PV scenarios, the requirements of the application and how these two factors relate to user capabilities and preferences. Based on our initial field-testing experience, we outlined a series of guidelines and recommendations for the creation of PV scenarios that appeared in Rizzo et al. [1]. The areas covered in that paper dealt with pragmatic production issues, determination of suitable PV content, display and user interaction considerations, audio/computer graphic/PV integration issues and hardware options for maximizing accessibility. These recommendations were based on our experience in PV scenario production from a producer/developer standpoint and from user feedback provided by approximately 400-500 individuals at the time. Since then, we have continued to collect user feedback and have used this data to inform the design process in our evolving PV application

research and development program. The following example illustrates the types of methodology that have been employed to study both usability and usefulness for panoramic video applications:

User Directed News Project – The User Directed News project is based on the idea that as journalism moves into the 21st Century, new forms of information technology (IT) stand to revolutionize methods for acquiring, packaging, organizing and delivering newsworthy information content. With these advancements in IT will come both opportunities and challenges for creating systems that humans will find to be usable, useful and preferred options for interacting with newsworthy information content. While some of the basic issues that constrain journalistic methods over the centuries (word of mouth, print, radio, TV, etc.) remain relevant, new issues are emerging for how humans will effectively interact with the deluge of digital content that will continue to expand in both quantity and scope as we move further into the information age. One area where journalism could benefit from the emerging IT revolution is in the use of systems that are capable of capturing and delivering news events within more "immersive" viewing formats. As opposed to traditional "fixed-camera/talking head" capture and delivery of "on-the-scene" reporting of newsworthy events, the potential now exists to produce HMD-delivered 360 PV environments that allow the user to self-select what aspects of the event that they would like to observe and promote a sense of being immersed within the ongoing event. When immersed in this context, the user has the option to actively choose what aspects of the event that they are most interested in or are compelled to view. At the same time, this would not eliminate the need for the news reporter, but rather, would dynamically transform her role into that of a "news-guide", who could stroll freely around the camera and point out aspects of the scene that the user could either chose to view or not. Viewer choice is key here in that current single camera approaches can indeed follow a roving reporter around an event, but do not allow for the user-option to self-select what aspects of the event are most relevant to his interests. This approach may serve to transform the user from simply being a passive observer of "fixed" content, to an active participant in the news acquisition process. The combination of the "immersive" aspect of "being there" along with free choice of viewing may provide a new paradigm for how news is created and consumed. One can imagine many scenarios where use of such a system would be desirable (e.g., observing the activity at a U.N. Security Council meeting, at a national political convention, an inaugural ball, a war zone, a disaster, or at a post Academy Awards party in Hollywood).

However, a number of pragmatic and user-centered questions need to be addressed scientifically before a determination of the value of this system can be made. Some of these basic questions include: Will users generally prefer to have news delivered in this format? Does immersion and self-selection compel the user to prefer this method of being "involved" in the story? Will reporters be able to adapt to this more "free form" method of reporting and what challenges will this produce for reporters in delivering "stories" to users who may not chose to follow the information flow in a traditional fixed "linear" manner? Will choice of viewing interfere with the acquisition of the logical story line in a news report? Will users be able to recall key points of the reported event in a meaningful manner? What types of news events would this system is best suited for in terms of user preference and information processing issues and what are the key elements of newsworthy events that might predict successful outcomes for use of the system? Will users naturally explore the 360 environment and choose to use this option?

Research Design Summary - Research is currently underway to address some of these issues by way of a very basic analog "news event" user preference and information processing comparison study. The current study is based on the production of a panoramic news story on issues regarding the "homeless" in Los Angeles, which puts viewers in the midst of some of the harshest living conditions imaginable within a modern society. Within this environment, the camera was strategically positioned in the middle of a street that was lined with people, an array of tents and makeshift living quarters on the sidewalk. The reporter stood in a fixed position within the field of view of one of the five cameras and reported a 2-minute story, as is typical of on-the-scene reporting. With this content, three user groups are currently being compared:
Condition 1 (C1) subjects view a 2-minute news story in a "traditional" single-frame viewing format on a computer monitor. This group of users has access to a field of view containing the news reporter's standing delivery of the story, as is common practice in a traditional on-the-scene reporting approach and is typical of what the subject would see on standard television news broadcast.
Condition 2 (C2) subjects have access to view the complete 360-degree arc of the environment from where the C1 news story was reported. These subjects may view the 360-degree arc on a flat screen computer monitor using a 3-degree of freedom inertial tracker mounted on a swivel device that we built, to freely navigate around the panoramic arc. C2 subjects also hear the *exact same verbal delivery from the reporter as presented in C1, in addition to having access to the full panoramic 360-degree arc* since the C1 story is actually a flat panel extracted from the full panoramic used in C2.
Condition 3 (C3) subjects view the exact same 360-degree arc of the news story environment that is available to the C2 group, but from within a movement tracked Virtual Reality head mounted display. This system updates the video image in the display in real time as the subject turns their head. This allows the subject to get the sense of what it would be like to be at the site of the news story and to have free choice to observe the panoramic scene from any perspective within the 360-degree arc using head turning movements as they would under normal real world viewing conditions.

Following exposure to the 2-minute story, users in all three groups are tested on multiple measures of memory for the information presented in the story (Free recall, Cued recall and Recognition) and on user preference for use of the system. Memory for the content of the news story is also being tested one week later. This allows us to compare groups on immediate acquisition/retention of content and on long-term recall/recognition retrieval. As well, scanning of the news scene using the inertial tracker in both C2 and C3 groups is being quantified to produce a metric of exploratory behavior within the 360 degree PV scene. We hypothesize that the sense of "being there" or "presence" will be enhanced in C3 by way of using an immersive HMD, and that this added engagement will increase recall by providing better contextual retrieval cues that leverage episodic memory processes. While the groups may not differ on measures of immediate memory, due to competing distraction effects nullifying immersion based gains in the HMD condition, we predict that when subjects are tested one week later, the contextual, episodic memory and presence effects will operate to produce much better recall/recognition retrieval. Thirty-seven of the 90 subjects needed for this experiment have been tested at the time of this writing with the estimated completion date being June 2004.

5. Short Description of Achievements in Previous Years

In addition to the technical challenges that have been addressed in the capture and playback of these scenarios, we have captured an impressive range of scenarios (as detailed in Section 4) and conducted initial informal heuristic evaluations of the scenarios. We have now had more than 1000 users try our various scenarios and have used their input to target ways to improve the total system.

5a. Detail of Accomplishments During the Past Year

Following the previous year's technical accomplishments in the creation of a system for capturing PV and in the building of a media player that allows the scenarios to be delivered on a standard PC or laptop, we have now redesigned our media player system. This was based on the experience we garnered with intensive use of the initial system and the limitations that were discovered. In addition to this ongoing iterative redesign process, we have commenced the process of conducting user evaluation studies that allow for both assessment of immersion and usability issues while concurrently addressing important clinical and societal issues. This can be seen in our collaborations with St. John's University and the VRMC for the anger management and social phobia scenarios. In this work, we have successfully experimented with blue screen single camera capture of persons to be pasted into our panoramic scenarios (as described above) in order to foster a higher degree of controllable "pseudointeraction" for users. We are currently building a system that allows clinicians to paste in these characters "on the fly" as would be valuable in most clinical applications of this technology. We have also developed ongoing partnerships with both the USC School of Fine Arts and the USC Annenberg Schools for Communication and Journalism to foster multidisciplinary development of PV scenarios. The Annenberg collaboration is illustrated in our description of the User Directed News project above. During this year, we also held a symposium at USC for the Associated Press Television and Radio Association on the future of Panoramic Journalism and set up a display of the PanoChamber at their annual Convention in Anaheim. The School of Fine Arts project has evolved into Dr. Rizzo serving as a co-instructor in the "Visual Arts and Technology" School of Fine Arts course that IMSC has collaborated on over the last three years. Over the last two years we have put together two competitions whereby student groups in the Art/Tech course submit a proposal for how to create an art installation using the PV system. The best projects were selected by a jury of IMSC and Art faculty with the winner having the opportunity to produce their piece using the system as described in the FishTank and Standard Hotel applications above. The course has now evolved an exclusive focus on panoramic capture and content manipulation, with 7 separate student group projects anticipated during the Spring 2004 semester. This Engineering/Art School collaboration is expected to continue with further integration of other IMSC technologies being planned for next year.

6. Other Relevant Work Being Conducted and How this Project is Different

Although panoramic capture and display is becoming more popular in recent years, we are unaware of any other group that is systematically researching the issues of immersion and exploration of PV for the applications that we are addressing in the areas of art, psychology and journalism. Nor are we aware of any full-scale controlled experiments (such as seen with the

Anger Management and User Directed News projects) being done by others that address the issues of PV immersion and it's impact on information processing and emotional arousal within the context of this level of functional application.

7. Plan for the Next Year

Over the next year, we expect to both advance the technical processing issues for the creation of PV scenarios with the Panoramic system and aim to better specify the issues for usable and useful creation of PV scenarios that target a range of application areas. Specific targets are listed in the next section.

8. Expected Milestones and Deliverables

We plan to continue our system development in this area by:

- Completing the initial User Directed News experiment and based on the results begin to explore new event captures while evaluating usability with a wider range of user groups.
- Complete and publish findings on the Anger Management, Social Phobia and User Directed News projects.
- Experiment with and expand our bluescreen capture/PV pasting process.
- Explore options for using more compact higher resolution cameras.
- Further integration of Immersidata capture and analysis with collaboration with Cyrus Shahabi's lab. This will be a standard tool for analyzing tracker data as a measure of exploration in these environments.
- Explore development of branching PV formats and broadband internet delivery.

9. Member Company Benefits

If found to be usable and useful, PV offers a method for creating immersive environments which capture real world events and could be of value for IMSC corporate sponsors. For example, we consulted with USC partner, Korean Airlines (KAL) on the redesign of their panoramic "Circle-Vision" Theatre on JeJu Island. Dr. Rizzo inspected the current film-based "Iwerks" facility and made recommendations for upgrading the theatre to Hi Definition Digital projection. A test shoot of stitched panoramic content was captured using a variety of Hi Def camera types and displayed across different projectors for a demonstration at the USC Bing Theatre for the owner and board members of KAL. The results of the Hi Def capture and projection was successful enough to warrant negotiations with an outside vender to deliver and install a full system at the theatre.

10. References

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