Kush Patel

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Computer Graphics

Professor Krishnan Seetharaman

Term Paper

First Paper:

- Dynamic Deep Octree for High-resolution Volumetric Painting in Virtual Reality
- Yeojin Kim, Byungmoon Kim, Young J. Kim
- Wiley Online Library / Computer Graphics Forum

Second Paper:

- Designing a Highly Immersive Interactive Environment: The Virtual Mine
- L. P. Soares, F.Pires, R. Varela, R.Bastos, N.Carvalho, F.Gaspar and M.S.Dias
- Wiley Online Library / Computer Graphics Forum

Third Paper:

- Maps and Globes in Virtual Reality
- Yalong Yang, Bernhard Jenny, Tim Dwyer, Kim Marriott, Haohui Chen and Maxime Cordeil
- Wiley Online Library / Computer Graphics Forum

What the Paper is About

The first paper is about creating a volumetric VR painting system. The authors explain about how to transition from 2D pixel canvas to 3D canvas to allow authors synthesize volumetric color fields. They talk about related work, octrees, and their experiment. They talk about updating octrees and its memory. A bunch of the GPU and CPU information is also talked about. Ray traversal is also touched upon and near the end of the paper, they summarize their results from their experiment. The experiment was done by digital artists drawing locations.

The second paper is about creating a simulation of a pyrite mine. A problem of contrasted images was identified and then fixed in the end using various techniques that will be later explained. The authors talk about tracking users, spatial sounds in the cave, and simulation system. On top of this they also talk about the algorithms needed to implement this. In the end, they go over their results from the experiment and future work.

The third paper is about exploring different ways to render a world-wide map in virtual reality. The paper goes over each map in detail and runs the experiment on each on with different variables. The authors also talk about history on maps and related work just like the previous papers. They go over in depth of the user study done with detailed results and ending the paper with future work like usual.

All three papers talk about a separate topic: a painting system, pyrite mine, and a world-wide map. But they do have one thing in general that they all talk about. In general, they talk about algorithms. Since algorithms are needed to accomplish whatever goals that have, all three papers explain about that.

Why the Paper is Important

The first paper is important because they add onto previous work of VR paining systems. It also is important because they were able to accomplish what they had wanted to do. This is backed up by the artists who did the experiments by giving very positive feedback. The authors also want to add more by making it a more 3D volume painting system. Its also important because this new painting system can lead to even more bigger innovations and can help in creating models and more.

The second paper is important because they also add onto previous work. They also were able to do what that had set their goals as. The system has been used for 2 years and still working as expected. Future work is to better fine tune the overlapped features. This paper is also important because this project can help create other virtual environments as well. For example environments in hospitals, new architecture, and other places that you could practice and plan out to get more practice.

The third paper is important because it adds onto previous work just like the other two papers. Its also important they accomplish what they had wanted to do just like the other papers as well. The paper is also important because the authors give detailed results from the experiment with charts and tables. Also, this study can also help in education, development in a country, and similar things like that.

All three papers are important in their own ways: from creating models, practicing in VR environments, to education. That is one thing they share about being important, they want to and could help society with their projects. But they do that one general theme in common. That is that they have future work they would like to add so their project works better.

Describe the Paper

The first paper, just like most research papers, starts off with the abstract of the paper. In the abstract they talk about what the paper is about. In the paper, they talk about generalizing the 2D pixel canvas to a 3D voxel canvas to allow artists to synthesize volumetric color fields. They also develop a octree-based painting and rendering system. They use CPU and GPU where the CPU is used for modeling and GPU for rendering. The authors also will talk about analyzing error propagation in ray casting and will present an error bound.

The authors than go on to the introduction section where they give a bunch of general information about 3D painting. Authors explain how digital painting is being transitioned into 3D volumes and VR-based 3D painting is slowly being accepted by artists. A big reason why artists are excepting it is because it allows them to sketch a scene much faster than the traditional way. Tilt brush and Quill are VR painting systems that make 2D surfaces. Authors than introduce the main topic of the paper: volumetric painting. Volumetric painting is talked about such as being able to depict solid and non-solid shapes. Volumetric painting also supports color mixing and handles semi-transparent strokes and can render using ray casting. The authors believe that volumetric painting system with a large canvas and fine details is a nice promise for new VR art style. Than they go on to talk about elements that are needed for an interactive painting system. Dynamic tree update, constant frame rates, low-latency stroke display, and low memory consumption. To implement these elements CPU and GPU would be needed. CPU would handle the tree, color blending, low latency updates. Essentially, one octree done in CPU for painting and the other for rendering by GPU. In the end of the section, the authors summarize the their contributions, ranging from interactive large octree to 3D painting effects like color pickup and color mix.

The next section they talk about is the related works section in which they mainly talk about previous work about octrees. The first talk about grids which have applied to different problems like field generation and texturing. Explain how octrees are ideal for painting on a large canvas. They also explain how acrylic graphs have rendered scenes in high resolution. Explanations how in the volumetric painting application that dynamic and static parts can't be separated. The authors also state that their work models structures and others with clear and blurry boundaries while coloring them at the same time. In the related works section the authors also talk about ray casting on adaptive grids using GPU.

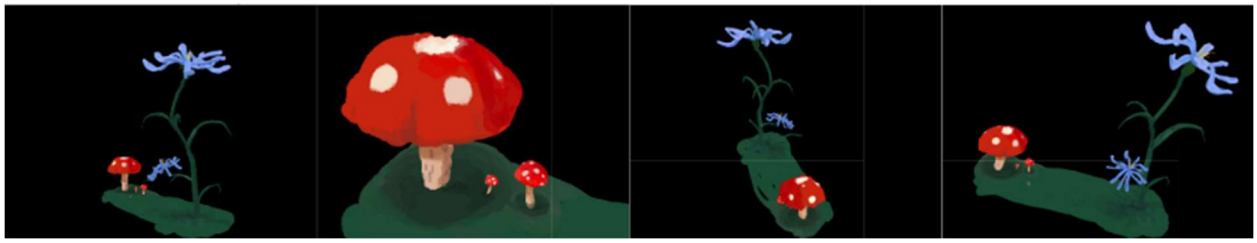
In the system primer section, authors talk more about cpu and gpu again. They also explain about several tasks that are part of volumetric field painting such as processing strokes, adjusting the octree, and a couple more. To support these tasks at the same time, separate octrees are made for cpu and gpu. This allows for better different-flavored buffers, tree adjustment, and more. Than the authors go on to talk about octree representation and memory layouts. The section is split up talking about array, depth, octree representation by cpu and gpu as well.

In the 5th section, the authors talk about octrees. Explain how they can reject cells that don't work well with brush stamps, but octrees are expensive and cause frame rates to fluctuate. Steps needed about a sharp change in depth of cells also is addressed. Updating the blocks is also explained especially how uploading too many times would make the system run slow. The authors also talk about computation rates.

The 6th section is about rays. The paper explains how in a VR environment, the point for the eye can move around causing head positions to move around as well which leads to discomfort. In the analysis they talk about formulas, error is small, and can do ray casting on mobile GPUs. The 7th section of the paper, its about how 2D painting is being transitioned into 3D. Delays are more common in 3D but can be fixed using adaptive brush strokes. Other 2D features like color flow, deposition, and more can be used in 3D.

The 8th section is all about the results and discussion on the experiment/project. They used c++, OpenGL, Nvidia GTX, and other hardware systems as well. In their experiment, they asked digital painting artists to draw three locations with details and different modes. Artists wanted to extend their techniques into 3D and away from 2D. The artists did receive a delay when painting with a large brush. In the conclusion, they did do a quick summary of how they achieved the VR painting system like octrees, cpu/gpu, rays, and more. They would also in the future like to explore other painting models/interfaces.

Figure 13: *"Island" from different view points.*



The second paper starts off with an abstraction of the paper. The authors state that they want to achieve a fill-scale simulation of a pyrite mine. They state a problem, contrasted images, that happen because of head light, narrow paths, and more. Using immersive virtual reality allowed high quality simulations that the authors want to accomplish. The papers hints at infrastructure and systems were developed to do high quality simulations.

The next section is the introduction in which the authors introduce their goal and topics that are about the things they used to make the mine. They claim to use several innovations to make the virtual mine possible. They do a run down of topics they will cover in the paper such as large projection systems, sound simulation, and multi-modal interaction. They also want resolve issues with tracking user position and avoiding motion sickness effects. They developed thi project at a mine in Lousal, Portugal. Lastly, they summarize what each section is about in the paper.

In the related works section the paper talks about VR Juggler. This tools has many tools that can make the development of the application simpler. Section three of the paper is about achieving immersive environments. They talk about the solution they implemented which as a four-sided CAVE-like system. They talk about things used for projection like goggles, filters, and parts of the infrared camera system. Speaking of infrared, an infrared user tracking system

was developed for better user experience. Authors talk about cameras that were used and how they were positioned. They explained mechanical, inertial, electromagnetic, and other tracking techniques. Authors also briefly go over CCD cameras. The authors state that sound is a problem in virtual environments. Special techniques must be implemented to make the sound work properly. To do this, the authors talk about how they used a material to cover the walls to better absorb the sound and remove echo. To drive the solution, a cluster was made. The authors explain about the clusters including how it has six graphic nodes that do different things. The nodes take care of auralization, computing, network access and others.

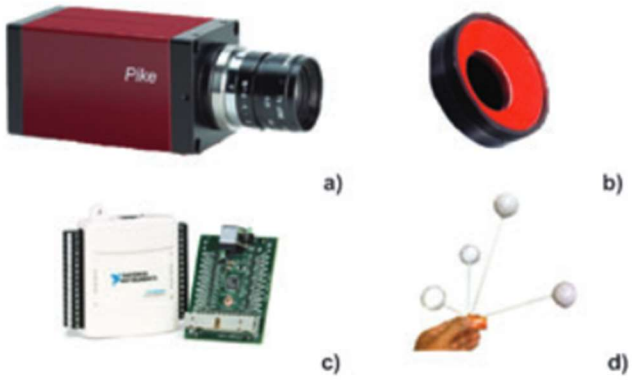


Figure 4: *Hardware components of the Infrared Camera system. (a) Colour camera, (b) infrared LED emitter, (c) shutter controller and (d) artefact.*

Section four is also about how simulation of the mine was done. 12 videos signals was used to drive the 12 projector system. Authors also explain about how they used a master/slave system and a client/server system. In the master/slave way, the application runs the nodes, the master node handles changes. The client/server, the application handles all the input. Authors also state that this way causes a delay but also requires less transmission on data. Than they talk about CaveH Middleware which does many things like produce realistic real-time images, synchronous image generation/frame swapping, and more. The authors explain three phases of the ADE library; refresh, synchronize, and swap. Paper talks about how they added real time rendering of scenes using triangles. Authors talk aboue special effects they implemented like a flashlight, motion blur, lens distortion, fog, rain, and more. As mentioned before, the authors also developed an infrared-based user tracking system. It is used for perspective and pose correction and user interaction. Papers goes over algorithms uses like MECF, HCT, and others. The authors also implemented a Microsoft speech API. You could use your voice to do commands to start/end applications, change gadgets, control navigation, and others as well.

Next section is about content authoring in which they talk about the 3D modeling tools used such as 3ds Max 9 to model the virtual mine. The GtkRadiant was used to create the

simulation scenery. The compiler for the scenery and model is CaveHSpawner. During the compile stage, octree will be made for scenery and handle collision data. The project also capable of handling pre-recorded avatar and player animation. A tool called CaveHFlyEditor is used for this implementation, it records the position of the player and camera movement. Authors also mention the development of 3D character animation.

The next section the authors talk about is results. The authors talk about the algorithm they used to calibrate color and brightness improved the quality of the image. The scenes are handled by CaveH Middleware. Paper state some of its states like 9.3 MPixels at 60 hertz and 3 – 10 million triangles. The author for 3D scene is able to position models, enhance behaviors, sensors, and a bunch more actions using a tool. Than authors talk about the precision of the artifact of how close it retrieved from the original place. They also shows charts of the deviation from this. Then they go on to talk about the results of the user interaction. The cost of it was low. The tracking system was also good because of its good results of accuracy and precision. The user uses a Nintendo Wiimote to interact with the system by using it for navigation and actions in the simulation. They authors concluded that the CaveH system is better than desktop but not in terms of color perception.

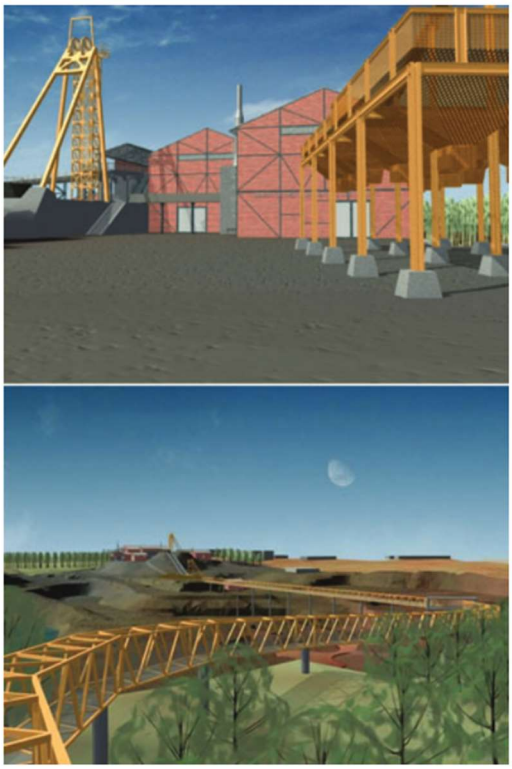


Figure 18: *Simulation of the exterior landscape of the old pirite mine at Lousal.*

Lastly, the authors talk about the conclusion section. The authors talk about how they overcame many challenges and they eventually realize that they can still put new developments into the simulation to make more real and better performance. The simulation has worked so well that it has used for two years. As explained in the paper and this essay, the authors had to

develop tools for some content. Authors used game industry level tools to make the simulation but they believe they can do even better so they will continue researching on it. They also state they found major errors of overlapped features with the HCT algorithm. But this error only accounts for 0.8% of the experiments ran. Authors also want to do one specific future research. Specifically, they want to research the Minimum Enclosing Circle Fitting which improved the overlapped features error.

The third paper just like the previous two papers starts off with the abstract. In the section they give a quick overview about the paper about different styles of rendering a map it. 3D exocentric map, flat, egocentric globe, and a curved map are the ways they will do this project. Talk about what each map is better for, exocentric is better for distance. Flat and curved maps take less time for area comparison. Exocentric is also better for direction. They also talk about the results of the study, the participants preferred the exocentric map over the others.

In the introduction section, the authors talk about maps, the purpose of them, and the history around them. Geovisualization is also mentioned, it is used to understand social and physical data. Specifically analyzing census data, urban transportation policies, and others. Ancient Greeks and the Renaissance are mentioned in their connection with maps. The question the authors want to answer is whether virtual globes are the best way to show global… in immersive environments…. Authors than go on to introduce two contributions; producing the four maps/visualizations and the study where participants use them. One approach to this is to have the user stand outside the globe and another is "inside". For all maps, the user can move any location to the center and can user the tracking system on their head to change viewpoints by just moving their heads. In the study contribution, they investigate user preference and efficacy. They also analyzed distance, orientation between two locations, and physical movement. The authors lightly go over the results, exocentric was best overall. Even though it have its fair share of problem with distortion. Flat and curved maps did do better in some parts of the study. The results from the study motivated the authors to make an interaction that transition from exocentric globe to flat map.

The related works section talks about previous work on the immersive technology and maps tasks. Authors explain how analyzing geospatial data in VR is a fit for immersive analytics because most of it is in 3D. VR is used in so many fields like architecture and environmental planning. Though exocentric globes can only show one hemisphere, they were still the preferred map style. Authors talk about map perception tasks for user studies in which they find out that map edges don't have a positive impact on the perception. Than the authors talk about map projections and distortion in which they state that all maps have some level of distortion.

The third section is about showing the earth in VR. The authors compare different visualization they made in terms of amount of distortion. All of the maps used Unity3D engine to be compatible with the headset. The headset is HTC Vive which provides linear perspective, texture gradient, and shadows. The authors then go on to individually talk about the four maps. The exocentric globe has no distortion in the center but has angular and areal distortion at the edges of the hemisphere. For the flat map, authors use the hammer projection because it doesn't distort relative size of the areas but has angular distortion. But you can also view the entire earth

in the map. For the egocentric globe, participants said the field of view was limited at the center and many also reported motion sickness. To fix the motion sickness issue, the authors added static rings, which essentially ends a fake horizon. The curved map has a more immersive experience than flat maps. They used two transformations, one in which the hammer projection is linearly placed on the sphere. But then, the size of the areas are not relative. The authors also talk about the interaction of the four maps. The VR system is one place and viewers can move around it. They can also adjust center so bring the desired place to them while reducing distortion.

The fourth section is the user study where the authors go over the details and statistics of the study. They evaluated three tasks distance comparison, area, and directional estimation. These comparisons are related to real life. One example is that area comparison can used to analyze forest cover. The authors used fake distances and areas so that previous knowledge of the system doesn't influence. For the distance comparison task, the two factors that can effect user performance are is variation of the distance and geographic distance of the points. Just like the distance comparison task, in area comparison task, the user performance can be affected by variation of the distance and geographic distance of the points. For the direction estimation task, only geographic distance between the locations can affect the user performance. Authors also explained about the response time, accuracy, and interaction. They used aggregated changes in positions and rotations between records to analyze user interaction. In the experimental setup subsection, the papers talks about the head and pc information. It talks about how the user will interact with map and also mention the website where map is from. Participant information is also mentioned; their vision, age, and VR experience. Authors also explain the design of the experiment. 3,456 questions get answers and each person spends about an hour. There were also repetitions done as well. For the procedure, participants were introduced to the project and were given two types of training. In interaction training, the maps were introduced to the participants and shown how to interact with them. In task training, participants were told do to tasks. They has to do this with all four maps. At the of the procedure, they were asked to answer a questionnaire on feedback.

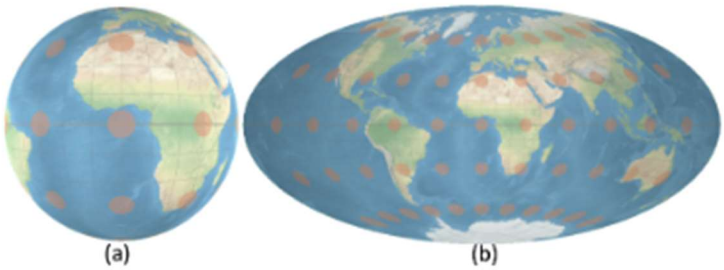
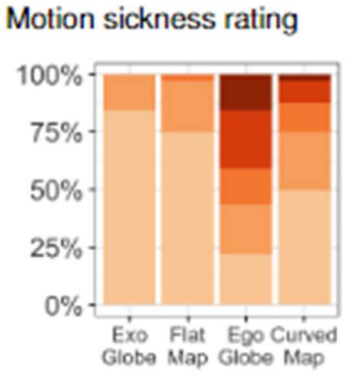


Figure 3: *Tissot indicatrices on the Natural Earth raster map with a graticule, (a) on an exocentric globe, (b) on a flat map.*

Next, the authors talked about the results of the study. According to the histograms and Q-Q plots they made, the error rate distribution was not normal. Since the authors were getting

unbalanced answers, the authors use LME and ANOVA to check for significance. They also used the Friedman and WNMT test for user preference and motion sickness. They did LME and ANOVA on all four maps with different variations like easy, small variation, far distance. The results for distance comparison shows that exocentric was more accurate than ego and the flat map. Authors also explained the accuracies and response times for all of the variations. Participants also had their own ways of interaction with the maps. For the flat and curved maps, people moved the pairs around the center symmetrically. For the exocentric map, they used the top of the hemisphere as a reference to place a point and memorizing the other point, to make sure they were aligned vertically. For the area comparison, accuracy of the egocentric was lower than the other visualizations but the exocentric performed faster than the egocentric. For direction estimation, the exocentric had a higher accuracy score than all the other four. Participants had three main ways for estimation, mentally imaging a marble following a arrow, moving the mid-point of the points, and moving the start of the arrow to the center. Authors also talk about data of the user interactions. The authors uses a scale for rating the motion sickness causes by the maps. People got more motion sickness with egocentric and curved map. Exocentric had best visual design and readability according to the participants. Participants found the exocentric intuitive an easy to use. But the perceptual distortion was a problem and some even suggested a solution for it by synchronizing the rotations. Flat map was known by many people but they had a hard time using it and also found it boring to use in VR. Egocentric was novel and immersive, some people liked to look around and not use their hand. Motion sickness as well complained about with this map. Participants found the curved map like the flat map but it was more distorted compared to the flat map. Motion sickness was also reported with this map.



The next section of the paper is the discussion. The authors discuss each maps and user interaction on what each is good and bad about. Starting off with the exocentric globe first, this map presents the geographic information without distortion and has the best accuracy. The response time was good as well so meaning it was best overall for all three of the tasks. But the area comparison was slower than the flat and curved maps. The flat map was efficient for distance and area comparison because the entire map is viewable. But the projection and perceptual distortion creates bad accuracy for the other variations of tasks. The egocentric globe

was the most immersive visualization. Though it had the most stable accuracy across the tasks it also had the worst performance overall. Participants also had motion sickness despite the fake horizon lines added explain in the paper earlier on. The curved map was better than the flat map but it also still had motion sickness problems. For user interaction, the participants interacted with the egocentric the most. Authors also said that the participants didn't like to move themselves especially for exocentric, this could be due to them not being familiar with the VR system.

Lastly, the papers talks goes to the conclusion and future work section. As mentioned before the authors find out that the exocentric was best for VR visualization even though less of the earth was visible and the most perceptual distortion. The curved map was better than the flat map but also had the most motion sickness. Egocentric was the worst visualization. The authors also talk about the headset used and that it was best to combine the exocentric with a flat map. So they created a prototype that allows the user to transition between those two maps. In the future the authors want to implement zooming, use different types of maps, they also still believe that the curved map has potential.

All three of these papers are about virtual reality. The first paper is about a painting system, second is on a mine, and the third is on maps/globes. All three talk about algorithms since all three projects need them. All three papers are also important because they want their projects to contribute to society. For the first paper, the painters of the experiment want to extend their techniques into 3D and the authors want to do future work on other models. The project of the second paper was done so well that it was used was two years. In the third paper, the exocentric was the best overall and also had have the curved map in future work because they still believe in it. The three papers have their own topics, similar importance, and had successful experiments in what they each wanted to do.