VR SandScape

Working with Multiple Perspectives in a Hybrid VR/SAR Collaborative Play Space

Kimiko Ryokai
School of Information
University of California, Berkeley
Berkeley, California, USA
kimiko@berkeley.edu

Yong (Leon) Li
School of Information
University of California, Berkeley
Berkeley, California, USA
leon.lee@berkeley.edu

ABSTRACT

We present our informal observations of children and adults playing together with our *VR SandScape*, a hybrid system with a Spatial Augmented Reality (SAR) sandbox and a Virtual Reality (VR) perspective. We discuss our preliminary findings of how the players, with access to multiple shared immersive VR and SAR views, navigate between what they see from their natural viewpoint while considering what other players see, and how the process of such negotiations influences their ongoing play and virtual creation. We argue for the design of a play space that can support sharing and negotiation of diverse perspectives.

CCS CONCEPTS

Human-centered computing~Human computer interaction (HCI); Ubiquitous and mobile computing systems and tools

KEYWORDS

Play, Sandbox, Virtual Reality, Spatial Augmented Reality

ACM Reference format:

Kimiko Ryokai and Yong Li. 2020. VR SandScape: Working with Multiple Perspectives in a Hybrid VR/SAR Collaborative Play Space. *In Extended Abstracts of 2020 ACM Conference (CHI PLAY'20 EA), November 2-4,2020, Virtual Event, Canada*. ACM, New York, NY, USA. 5 pages. https://doi.org/10.1145/3383668.3419892

1 Introduction

With the proliferation of commercially available Virtual Reality (VR) systems and Augmented Reality (AR) technologies, light enough to run on smartphones, players from the young to the elderly are experiencing a variety of VR and AR apps. We envision that in the future, both adult and child players will have more active roles in influencing the design of virtual environments, as opposed to passively consuming pre-made environments. Despite typically being designed for single users, we also envision VR and AR could be used for more collaborative and creative environments of multiple co-located players working together. In particular, we are interested in immersive VR and AR views as a unique opportunity for players to consider an "allocentric" perspective with interest and attention centered on other people and things, in contrast to a more "egocentric" perspective with attention focused on the user themselves [3, 7, 9]. Being able to take multiple perspectives beyond oneself is a beneficial skill for anyone, young and old, but we believe it also contributes to the play itself in a creative and productive way, especially for child players.

To that end, we are studying how players of different ages work together collaboratively to build and experience their 3D creations in a hybrid AR/VR set up. In this paper, we present our informal observations of children and adults playing together with our *VR SandScape*, a system with a Spatial Augmented Reality (SAR) sandbox and VR. Our system generates a real time 3D rendering of the topology of the changing play space via a depth sensing camera installed above the play space. In the VR world, the players could go through the terrain they create as characters who live there (e.g., taking the perspective of a micro creature or a giant). The players may take turns being the creator in the physical world and the creator in the VR world. In the VR world, the player could make it rain, snow, or blow fire, etc. and the physics simulation could be projected on top of the physical terrain so that the players in the physical world can see them. In the physical world, the player could influence the terrain in the VR world as another player experiences it in VR in real time. For example, the player in the VR might suddenly see a gaping canyon

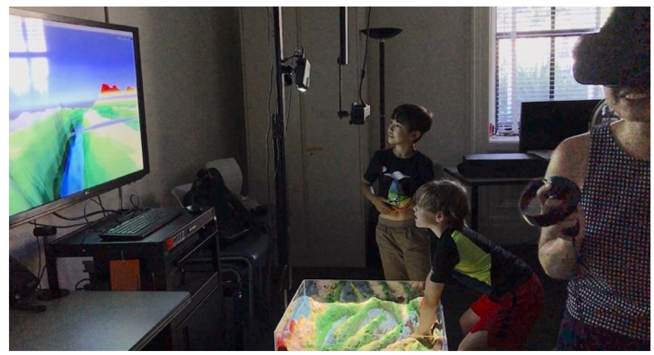

Figure 1: Two children working on a terrain with an augmented sandbox while also looking at their creation from the VR player's perspective.

ACM ISBN 978-1-4503-7587-0/20/11.
https://doi.org/10.1145/3383668.3419892

appear in front of her because her partner in the physical world just poked the sand with her hands.

We look at this type of real-time collaborative play between co-located players as they design, build, and play together inside and outside of their virtual creations. With access to multiple shared immersive VR and SAR views, how do players navigate between what they see from their natural viewpoint (egocentric perspective) while considering what others see (allocentric perspectives)? And how does the process of negotiating between different perspectives influence their ongoing play and creation? We present our preliminary findings and we argue for design of a play space that can support sharing and negotiation of diverse perspectives.

2 Related Work

A number of augmented sandboxes have been designed and developed since the early 2000's. *SandScape* [4] overlaid computer simulations such as contours, shadows, and drainage on top of changing sand models in real time in order to support landscape architects to collaboratively work on their early designs. A decade later, we started to see *Augmented Reality Sandboxes* in museum settings (e.g., [5, 13]) as well as in experimental classroom settings that invited students to learn about topographic maps and surficial processes in introductory geology labs (e.g., [11]).

More recently, a few projects have introduced VR to augmented sandboxes. For example, *Inner Garden* [10] is a system with a SAR sandbox where a user wears Electroencephalography (EEG) sensor that measures their brain activity, which influences the animation projected on the sandbox. A user could be teleported to the virtual terrain via VR. The system was designed for a single user to support their mindfulness exercises such as breathing and body awareness. The sandbox was an interface to provide a peaceful vantage point, rather than to be messed around vigorously. Most recently, the CHI Play community has seen *VRBox* [2], a system designed for a game designer to build a virtual world with an added benefit of touching sand in a sandbox to help sculpt the world. VRBox uses multiple Kinect depth sensors to enable hand tracking and mid-air gestures over a sandbox. The sandbox itself was not spatially augmented with any animation as it was designed for a single adult game designer who works alone wearing VR goggles.

What these works suggest is a platform where users can initiate the creation of an original VR environment easily by touching and playing around with sand. Trying to design and create an original environment in VR is otherwise a daunting task. Our work builds on these prior works that take advantage of our familiarity with sand and sand as a flexible medium to support the creative process. Yet our work is different as we look specifically at real-time collaboration among multiple players of different ages, and how the diverse spatial perspectives accessed by the players are negotiated and influence their play.

3 VR SandScape: Technical Implementation

We have built our prototype using a Microsoft Kinect [6] as the input sensor (receiving depth image data and color) and building the software using Unity. For the VR output, we are using Oculus Rift [8] for our VR headset. Our custom-made sandbox is 40 x 40 x 8 inches, with a Kinect sensor mounted on top at a distance of 55 inches, and a projector that overlays the real time updated topographic map from Unity to the top of the sandbox.

In Unity, Kinect data is gathered through polling for every frame. We create a terrain object in the Unity Scene and apply the collected depth data to the terrain. During each frame, a delta height value is calculated and applied to the terrain only when the value exceeds a fine-tuned threshold. This is to reduce the sensitivity of the terrain height change and make it more natural for players when they are walking around the virtual terrain with Oculus headset on. With the terrain built in Unity, a world space shader is built to render the terrain with gradient color. The shader is using 14 textures which are rendered according to the height of the terrain to represent elevation color map, topographic contour lines, and simulated water. We also build a first-person character in Unity with the ability to move, jump and navigate in the virtual terrain by binding with Oculus OVRInput. A nearby LCD display shows the first-person VR view in real time.

4 Informal Evaluations

We have observed three different multiplayer groups playing with our VR SandScape system: (a) a grandmother in late 60's with her two grandchildren (age 2 and 8), (b) two 8-year-olds with an adult in late 20's, and (c) three middle-schoolers age 13.

In studying children's interaction with a play space augmented with VR, it is important to note the age restriction that comes with commercial VR products. Currently, commercially available good quality VR HMDs (such as *Oculus*, *HTC Vive*) are rated for users 13 years or older. This is due to the fact HMDs are originally designed to be worn on an adult user's head. While the HMDs do come with adjustable straps, if the headset does not physically fit well, the display may appear blurry. While the short time exposure (e.g., under 20 minutes) to some blurriness should not be harmful [1], effects from long-term usage is currently unknown. To follow the guidelines, the children under age 13 in our studies did not use HMDs, but participated with adult partners wearing an HMD.

Figure 2: Two children (age 8 and 2) work with their grandmother who explores the children's creation from the VR perspective.

While we are unable to report how young children (under the age of 13) play when wearing VR HMDs directly on themselves at this time, we believe our report here is still valuable as we observed that the sheer presence of another's VR view shown via a nearby LCD monitor seem to influence the children's play (which we will report in the next section). We also imagine that in the near future, there will be HMDs designed specifically for children. When such a future is here, we will be better prepared as design researchers to support creative and collaborative play space involving VR.

All the participants in our study received an introduction to the system. After the introduction, the participants were free to play in any way they liked. All sessions lasted approximately 20 minutes. Participants' names in the following discussions were modified.

4.1 Kai (8), Sara (2), and their Grandma (late 60's)

Kai: [vigorously creates mountains and terrains as he moves chunks of sand around him]
Sara: [busy patting down the sand but sometimes also grabbing and splashing sand]
Grandma: [wearing HMD] I see a rainbow! And a moon!
Kai: [surprised] Where is grandma? What is she looking at?
Kai: [looks at the LCD display that shows Grandma's view]
Kai: Ahh, you are too close to the mountain. Grandma, turn around.
Grandma: [turns around]
Grandma: I see big red mountains and they are moving!
Kai: [looks at the LCD monitor and realizes that it is actually his own hands that are appearing to be the big red moving mountains]
Kai: Rrrrr! A monster has landed! [moves his hands in the terrain]
Sara: [reacts to the red shadow created by Kai's moving hands appearing via projected animation on the physical sandbox and she bangs the sand down to change the terrain]
Grandma: [in the VR world now experiences the flattened terrain by Sara]
Grandma: Now I am at a nice green field!

Each of the three participants added to the play in different capacities and built on each other's actions, and in the process, their play creatively unfolded. Even without wearing the VR headset, Kai observed what his grandma was experiencing in the VR world, and such an allocentric perspective influenced his play as he included a "monster" in his play. The two-year-old may not have completely understood all the perspectives involved in the play, yet she had an equal footing in physically participating in this augmented play space and her physical actions (e.g., patting down or moving sand) influenced the ongoing play. Grandma said that the play space gave her an unexpected thrill of encountering everchanging landscapes, yet it gave her the assurance that the changing landscape was part of her grandchildren (their moving hands, etc.) which felt personal to her.

4.2 Two 8-year-olds and an adult (late 20's)

Two 8-year-olds were invited to play with VR SandScape with a university student who was introduced to them as an additional player in the VR environment. The two kids first created a mountainscape in the sandbox on their own without interacting much with the player in VR. However, as they noticed that the VR player was experiencing every change they made on the terrain in real time, their creation process changed. At the beginning, the terrain had no particularly defined paths, but seeing the player in VR, prompted them to create paths on which the player could travel. Instead of having a clear plan of what the maze might look like (e.g., having a start and an end position), their maze creation developed rather organically around the presence and movement of the VR player trying to navigate their creation in real time. For example, the design of their paths became more defined as they saw that the path needed to be of a certain width for the VR player to feel like a path. Eventually, they made the paths with tall walls on both sides so that the VR player would not be able to climb out. Paths eventually turned into meandering "trenches." Some trenches were deeper and covered with water, while others not, making some paths to be more challenging than others. The two kids enjoyed having an adult player go through a variety of hurdles they created taking both perspectives of egocentric vs. allocentric (attention centered on other people) and incorporated different opportunities to make their terrain more interesting. They eventually evolved the terrain into a complex maze (Figures 1 and 3).

Figure 3: Two children discuss their design by looking at the perspective of a VR user who is exploring their terrain.

4.3 Three Middle Schoolers (age 13)

Three middle schoolers played with the VR SandScape during their after-school program. They took turns being the VR player wearing the HMD and two builders at sandbox. The following is a transcript of a segment where Iris and Pam creates terrain while Mat explores the terrain in VR:

Iris: The cave is right here. Do you see this? [waving her hand to Mat in sandbox]
Iris: [to Mat] Go where my hand is. [wiggles her hand in sandbox]
Mat: Uh... There are two [that seem to represent Iris' hands in VR] So? Uh...
Iris: Ah OK. This one [makes it explicit and waits for Mat to see it in VR]
Iris: Can we pick him up? [moves the terrain near Mat with her hand]
Pam: Oh. What?
Iris: You can move him! [moving a chunk of sand near Mat, which makes him to slide gently in VR]
Mat: Ohhh [feeling the move virtually]
Pam: That's cool.
Iris: [continues to move the sand to influence Mat's position in VR. In the process, Iris' hand comes close to Mat in VR]
Pam: Don't put him on your hand! Because you might fling him!
Mat: Oh! Geez! [experiencing the lift by Iris' hand movement]
Pam: Oh, where did he go?
Iris: He is right here! [seeing the icon representing Mat's position projected on the sandbox]

First, Iris sees Mat wander away from the cave she was trying to show. Iris tries to help Mat by using her hand as a directional device, wiggling her hand in the sandbox to draw attention from Mike ("Go where my hand is"). Mike, who cannot physically see Iris as he is immersed in VR, looks around in VR and sees two moving mountains and communicates what he sees ("Uh…There are two… So?"). Then, Iris is immediately encouraged to consider Mat's perspective, and she changes her gestures in order to better support Mat's view in VR. Next, seeing her moving hands gives Iris an idea, as she says, "Can we pick him up?" Iris moves a chunk of sand next to a projected position of Mat in the sandbox causing Mat to gently glide. This confirms that Iris can move Mat's position in VR. When Iris continues to move the terrain to nudge Mat's position, Iris' hand comes closer contact with Mat's virtual position. Pam who sees Iris' hand almost touching Mat's virtual representation exclaims, "Don't put him on your hand! Because you might fling him!" Pam was initially excited about the possibility of moving Mat in the VR world ("That's cool") but she is concerned about Iris' hand "flinging" him immediately after. Technically, if a player is lifted up in the air, with an upper height boundary, the player will slowly be brought back onto the ground (i.e., the VR player will not crash onto the ground). There is a special opportunity where players are being creative as well as empathetic to the protagonist who is going through it, as they negotiate an allocentric perspecitve. The children collaboratively and inventively coming up with ways to help or challenge each other, while allocentric perspecitve is negotiated among players and driving their play.

Figure 4: Two middle-schoolers work on their terrain while another middle schooler explores it from the VR perspective.

6 Discussion and Future Work

In all three groups, we observed that having to work with multiple immersive views in our VR/SAR setup seemed to encourage the players to consider an allocentric perspective in several ways. First, in the process of physically working with sand, the players' bodies intentionally or accidentally became part of their play space: e.g., their hand became part of the moving mountainscape, which eventually became a "monster" in their play, or a directional device to draw attention from another player, as in "look this way," or a conduit to move or lift up the player virtually in the air, etc. Here, an allocentric perspective taking is encouraged as the players are confronted with their own body transformed into another form in VR. In turn, they are challenged to consider how the new representations of their body appear from other players' perspective, inspired to creatively interpret them, and work them into their ongoing play.

Second, in all three groups, by virtue of having one of the players immersed in the VR world while the world is being created and modified seems to encourage allocentric perspective taking among players, even when players are not directly wearing the VR headset. Access to a real time VR view displayed on a nearby LCD screen gave the players a window into what the world looks like from the person who goes through it directly. This, in turn, gave the players opportunities to collaboratively incorporate a variety of ideas to make the play space richer (e.g., turning paths into meandering trenches that form a complex maze as the VR player goes through it). Allocentrism, with attention given to other people and things rather than to themselves, is a beneficial skill to have for anyone, but especially for kids who are learning to work collaboratively and creatively [12].

These are preliminary findings with a small number of participants. We are currently preparing to conduct a formal study with children over the age of 13 so that we could more systematically look at how kids take turns sharing their immersive views in VR/AR, negotiate differences between their perspectives, and incorporate them into their play. As for future implementation work, we are currently working on a tool to record the ongoing story/adventure the children create to be able to play it back in multiple perspectives.

7 Conclusion

We presented our ongoing work to study how multiple players collaborate over our VR SandScape system, a play space where players are invited to take active roles in influencing the design of virtual environments. With access to multiple immersive views to evaluate their ongoing creations, the players are also encouraged to actively shift their perspectives, which seems to help evolve their creation in an organic and creative way. With more mixed reality games and apps being developed today for a variety of ages, we argue that it is important to consider an augmented play space where players could share and negotiate diverse perspectives and build on each other's ideas.

ACKNOWLEDGMENTS

We thank our participants, Leah Rosenbaum, Julia Park, and Google for funding part of this project.

REFERENCES

[1] Bailey, J., & Bailenson, J. (2017). Considering virtual reality in children's lives. Journal of Children and Media, 11(1), 107-113.
[2] Fröhlich, T. Alexandrovsky, T., Stabbert, T., Döring, T. & Malaka, R. 2018. VRBox: A Virtual Reality Augmented Sandbox for Immersive Playfulness, Creativity and Exploration. In Proceedings of CHI PLAY'18. ACM, NY.
[3] Hu, Q., Yang, Y., Huang, Z., Shao, Y. Children and Adults Prefer the Egocentric Representation to the Allocentric Representation. Frontiers in Psychology, 17 Aug 2018.
[4] H. Ishii, C. Ratti, B. Piper, Y. Wang, A. Biderman, and E. Ben-Joseph. 2004. Bringing Clay and Sand into Digital Design – Continuous Tangible user Interfaces. BT Technology Journal 22, 4 (October 2004), 287-299.
[5] Lawrence Hall of Science. 2015. Lawrence Hall of Science, UC Berkeley. Retrieved July 15, 2020 from http://www.lawrencehallofscience.org/

[6] Microsoft. 2014. Kinect for Windows SDK 2.0: Retrieved July 15, 2020 https://docs.microsoft.com/en-us/previous-versions/windows/kinect/dn782025(v%3dieb.10)

[7] Mou, W., McNamara, T. P., Valiquette, C. M., and Rump, B. (2004). Allocentric and egocentric updating of spatial memories. Journal of Experimental Psychology: Learning, Memory, and Cognition 30, 142-157.

[8] Oculus Rift. Retrieved July 15, 2020 from https://www.oculus.com/rift/

[9] Piaget, J., and Inhelder, B. (1967). The Child' s Conception of Space. New York, NY: W. W. Norton.

[10] Joan Sol Roo, Renaud Gervais, Jeremy Frey, and Martin Hachet. 2017. Inner Garden: Connecting Inner States to a Mixed Reality Sandbox for Mindfulness. ACM Press, 1459-1470.

[11] Terri L. Woods, Sarah Reed, Sherry Hsi, John A. Woods & Michael R. Woods (2016) Pilot Study Using the Augmented Reality Sandbox to Teach Topographic Maps and Surficial Processes in Introductory Geology Labs, Journal of Geoscience Education, 64:3, 199-214.

[12] Tummolini, L. Making our ends meet: shared intention, goal adoption and the third-person perspective. Phenomenology and the Cognitive Sciences 13, (2014).

[13] W.M. Keck Center for Active Visualization in the Earth Sciences (KeckCAVES). 2015. KeckCAVES, UC Davis. Retrieved July 15, 2020 from http://keckcaves.org