



CAMPUS OF THE FUTURE

RESEARCH REPORT
FALL 2017

YALE UNIVERSITY

A YEAR IN THE BLENDER

Practical applications of 3D in virtual, mixed and
printed forms from Yale University's Blended
Reality applied research project





CAMPUS OF THE FUTURE

In partnership with:



Yale University Blended Reality Year One Research Report
Research findings and main text © 2017 Yale University

Published November 1, 2017 on the occasion of the 2017 EDUCAUSE® Annual Meeting
Philadelphia, Pennsylvania
United States of America

Principal photography for this report was taken on location at Yale University in New Haven, CT USA and HP Labs in Palo Alto, CA USA. Front Cover, Back Cover and Page 3-4 photography by Michael Marsland © 2017 Yale University

In accordance with United States and State of Connecticut regulations, identifiable persons and/or their parent or guardians have agreed to the use of their identifiable image for new photography appearing in this document.

Regarding HP products and services:
The information contained herein is subject to change without notice. The only warranties for HP products and services are set forth in the express warranty statements accompanying such products and services. Nothing herein should be construed as constituting an additional warranty. HP shall not be liable for technical or editorial errors or omissions contained herein. Certain methods and processes used in HP Education research are US patent pending (PCT/US2014/039723). All rights reserved.

This is an HP Indigo Digital Print

2017 A YEAR IN THE BLENDER

Practical applications of 3D in virtual, mixed and printed forms from Yale University's Blended Reality applied research project

YALE UNIVERSITY

I. Using multiple realities to improve instruction and research

- 7 Introduction from the Principal Investigator, John Eberhart
- 9 Building the Campus of the Future, Gus Schmedlen (HP, Inc.)
- 10 Mixing It in Blended Reality, Johannes DeYoung

II. The Projects

- 14 Blending Reality: Technology across disciplines
- 16 For Our Feathered Friends: Taxidermy Birds Into 3D Models
- 18 Shifting Dimensions: The 3D Flower Viewer
- 20 Colliding in Mixed Realities: A Different Kind of Disaster
- 22 Game on: Save Our Snax!
- 24 Emerging Technologies Through the Arts: Crossroads
- 26 Re-Visioning the Restroom: Stalled! Blended Reality
- 28 Crafting the Self in a Digital Age: Born Digital
- 30 Think It, Make It: MindDesign

III. Project Director's Summary and Future Research Pathways

- 34 Year One Debrief, Randall Rode

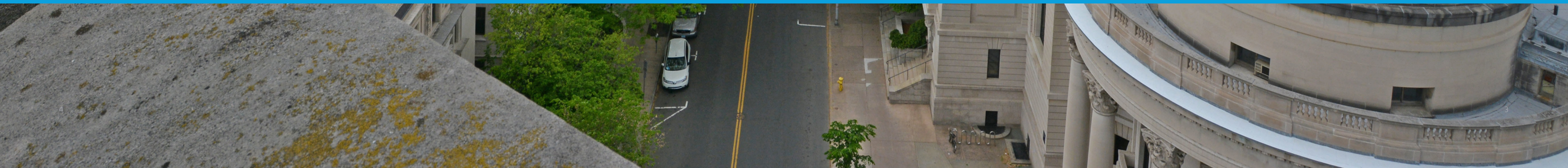
IV. Acknowledgments

Follow Yale's Blended Reality progress at <http://blendedreality.yale.edu>



CAMPUS OF THE FUTURE

INTRODUCTION





Principal Investigator's Introduction

As director of digital media at the School of Architecture I oversaw the digital and fabrication technologies as well as taught courses in fabrications and visualization. When HP, Inc proposed partnering with Yale on the Blended Reality project grant in the summer of 2015, I was torn between being the principal investigator for the grant or submitting my own project proposal in blended reality. However, as I see the wonderful range of project results, I am delighted to have set aside my own research interests to serve as principal investigator, helping to bring resources and expertise to aid the teams in their work.

I am thankful for the work of the steering committee members, who initially helped to spread the word about the grant to the overall Yale community and encouraged people to apply. They cast message broadly, helping to ensure a diverse range of projects. They also aided me in carefully reviewing each proposal, and ensuring a fair and rigorous selection process.

As we moved forward with the grant, committee members mentored individual projects, assisting the progress of the teams, and quickly addressing any issues, concerns, or needs that arose. I was fascinated to see the work develop from initial proposals to full-fledged projects exploring the limits of the blended reality theme.

The *Stalled!* project built a simultaneous exploration of the virtual and the physical in their design of a gender-neutral bathroom, providing a combination of visual, tactile, and audible experiences. The *MindDesign* project turned the act of design on its head by transforming an emotion into a 3D printed object. Some teams discovered new methods that transformed how they do their jobs. Other teams ended up in a very different place than they expected.

All of them were successful in helping us understand the opportunities and possibilities enabled by these rapidly evolving technologies that allow us to blend the physical and digitally created worlds.

Finally, my thanks to HP for creating a unique research opportunity for our faculty and students, which allowed them to learn, explore and push boundaries in new ways.

John C. Eberhart
Critic and Director of Digital Media
Yale School of Architecture
October 2017



Building the Campus of the Future

The fourth industrial revolution is upon us. The rapid pace of innovation is disrupting our campuses, our workplaces and our lives at an unprecedented pace. Automation, artificial intelligence and 3D technologies will profoundly change economies and communities, raising serious questions about the future of employment and social tranquility. Will jobs evaporate, or will *creative destruction* evolve to create new jobs that we haven't thought of yet?

However, the promise of these new technologies can also point to a brighter, more personalized and engaging future. Can universities improve learning outcomes by leveraging alternate realities? Will 3D-printed splints, casts and joints become the norm, revolutionizing ambulatory care? Will VR evolve into a mainstream artistic medium? These are just some of the potential applications of 3D technology in Higher Education.

Over the past year, HP has supported Yale University in its pursuit of instructional, artistic and research innovation through the university's Blended Reality program. Yale's faculty, staff and students awed our team by executing an intensely interesting array of projects across the spectrum of 3D technologies from Virtual Reality to 3D Printing. The results have been delightfully surprising – we did not expect Yale Peabody Preparators to “Reinvent Taxidermy” using Sprout Pro and 3D printing (pg. xx) . We also did not expect School of Architecture Faculty and Students to “Reinvent Public Restrooms” with *Stalled!* (pg. xx) By all accounts, the experimentation and research was successful.

Based on the success of Yale's research, HP will now expand our 3D applied research agenda to other areas on Yale's campus and additional institutions. Using the Year 1 Blended Reality program template, HP and EDUCAUSE have created a global research network aimed at helping institutions conduct pioneering projects in 3D. This new research network is part of a larger set of investments HP is making in Higher Education to create *The Campus of the Future*: a vibrant, secure and sustainable vision for teaching, learning, research and collaboration.

The output of many of Yale's projects required 3D Printing. I would like to personally thank John Kavanagh, President of Dremel, for providing the desktop 3D printers which played a major role in many of the projects.

I'd also like to thank diverse team at HP who supported the research – first and foremost, Dana Stepp, HP's Worldwide Education Channel Manager, without whom this research may never have happened. HP's scientific community also supported the partnership in a big way, including HP Fellow, Keith Moore, and Mirjana Spasojevic and Alex Thayer of HP's Immersive Computing lab. From a headquarters perspective, Doug Warner, Vice President and Global Head of Tech Vision and Strategy, and Todd Gustafson, Vice President and General Manager of Public Sector, both visited campus and engaged directly with the project teams.

Throughout the process, Yale's John Eberhard and Johannes DeYoung were consistent supporters of the research projects and partnership with HP. Their experienced, erudite guidance elevated the academic relevance of the projects and program, overall. Finally, I would like to thank Randy Rode of Yale University, whose tenacity, intelligence and collaborative spirit made the program such an incredible success.

Gus Schmedlen
Vice President, Worldwide Education
HP, Inc.
October 2017

Mixing it in Blended Reality

Today’s conversations about immersive, interactive electronic computer-generated media are much broader than those conversations were thirty years ago, and they include a wide spectrum of applications and experiences collectively referred to as XR, or mixed reality. In our research at Yale University, we refer to this broad spectrum as blended reality.

How do we look at XR in the context of a liberal arts research institution? Foremost, we are not describing a medium, but rather a field of rapid transformation. Drawing upon the theoretical underpinnings of the field, we observe historical precedents for immersive, interactive media throughout human civilization.

The prehistoric painted caves of Lascaux, France are among the earliest examples of immersive simulation and storytelling. These caverns find special resonance in the panoramic cycloramas popularized during the 18th and 19th centuries, in which cylindrical buildings were constructed around painted panoramas that were lit to create representational illusion of real world spaces within a controlled architectural framework. In these venues, viewers would enter the structures through tunnels that traversed the radius of the cylindrical architecture and emerge by way of a central turret within the panorama to a lookout onto theatrically simulated space.

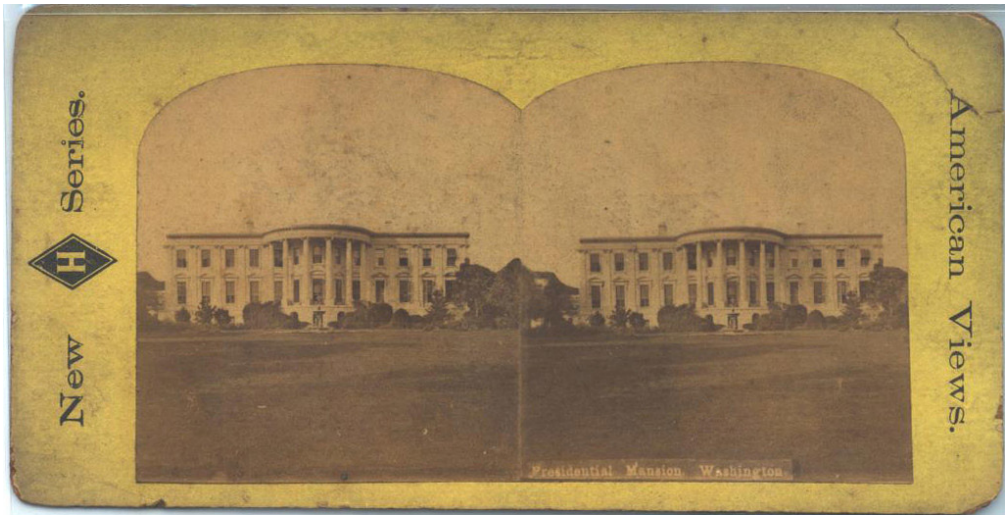
We can also attribute 19th century French phantasmagoric theater with its implementation of variously immersive optical projection instruments, to create popular theatrical venues for entertaining spiritualist encounters with industrialized ghostly illusions — a centennial precursor of Disneyland’s Haunted Mansion theme park.

Other theatrical histories are precursors in the field; among those we find Pepper’s Ghost, a 19th century illusion technique commonly used in stage productions and mechanized in phantasmagoric theater, that continues to find application today. The technique is employed largely in the entertainment industry, wherever seemingly holographic representations of live or posthumous performances are delivered, as it employs arrangements of mirrors and projection instruments to create the illusion of a holographic form.

Moving-image instruments like the zoetrope, praxinoscope, and mutoscope establish the paradigms for modern devices, as do the developments of camera obscura and photographic recording instruments that followed it. If we expand the field of XR to include fabrication by computer-aided design, we might also include the historical precedents of the whole history of mechanized industrialization. And all of these technological innovations might well be served by the fundamental notion of interaction at play, as described by Johan Huizinga in *Homo Ludens* (1938), a theoretical forerunner to contemporary game design.

Framing such an expansive field is challenging, and requires a wide scope of vision. Setting our research within the context of a liberal arts research institution presents unique opportunities. In the first year of our research, eight teams investigated a spectrum of XR applications, with projects ranging from material fabrication of ornithological structures and design generated from brain wave activity, to interactive platforms for immersive experience, media literacy pedagogy, and artistic collaboration.

While the liberal arts framework also presents the challenge of finding common refrain or singular conclusion. A singular finding was not the goal of our research. Rather, countervailing perspectives press the boundaries of the field as it expands, and our inquiries stress the critical relevance of the field within the larger pedagogical frameworks of an institution like Yale.



Stereoview Card: Stereoscopic view of ‘Presidential Mansion, Washington.’
Yale University



Zoetrope Image
Yale University



CAMPUS OF THE
FUTURE

THE PROJECTS

The Projects: Blending Reality

Technology across disciplines

In a small room in the vast basement of the Yale Peabody Museum of Natural History, a 3D printer was putting down layers of material to create a model that would take its place as an exhibit specimen in the museum’s Birds of Connecticut exhibit hall. In a classroom on campus, students in an undergraduate humanities course were reading texts ranging from St. Augustine’s Confessions to The Communist Manifesto — as they also worked with blended reality techniques to explore ideas about “the self” as an historical and modern concept. At the School of Architecture, a professor and his team were employing virtual reality technologies to allow people to enter, experience, and evaluate prototypes for inclusive public restrooms to provide accessible spaces for a broad range of needs and bodies.

During the 2016–2017 academic year, students and faculty from all corners of Yale University developed and participated in these and five other projects that explored the blending of the physical and digital environments. Under the guidance of faculty sponsors and staff associated with the project, and with financial support from HP, Inc., teams participating in Yale’s Blended Reality Applied Research Project worked across disciplines to test hypotheses and investigate the possibilities and limits of hardware and software. Selected by a faculty steering committee from among almost two dozen proposals, the eight projects were chosen with one major criterion in mind: Could the experiences — and, in some instances, the results — of these endeavors point to new ways of thinking and creating for artists, designers, researchers, scholars, and scientists?

Familiarity with the tools of 3D design, augmented reality, digital imaging, and 3D printing was not required for a project to be approved. Instead, says Sarah Stevens-Morling, a steering committee member, vision and imagination were essential. So was the idea of democratizing technology. “We wanted to advance the knowledge about how blended reality technologies could change the ways we perceive and work, and learn what people operating in a variety of fields — arts, architecture, humanities, sciences — need from those technologies.”

As you will read in the following pages, some of the projects had immediate real-world applications. Some participants found new ways of seeing and thinking, while others confronted technology’s limitations. Measured by what was learned, all the projects succeeded in providing lessons that will be invaluable as we continue to explore the challenges, possibilities, and opportunities presented by these new technologies that are permeating the world around us.

CAMPUS OF THE FUTURE

Guide to Projects

- For Our Feathered Friends: Taxidermy Birds Into 3D Models
- Shifting Dimensions: The 3D Flower Viewer
- Colliding in Mixed Realities: A Different Kind of Disaster
- Game on: Save Our Snax!
- Emerging Technologies Through the Arts: Crossroads
- Re-Visioning the Restroom: Stalled! Blended Reality
- Crafting the Self in a Digital Age: Born Digital
- Think It, Make It: MindDesign



For Our Feathered Friends

Reinventing Taxidermy & Museum Displays

Situated on the third floor of Yale’s Peabody Museum of Natural History, the Birds of Connecticut exhibit hall is one of the museum’s most enduring attractions, drawing tens of thousands of visitors each year. Open to the public in 1972, the hall was meant to showcase the more than three hundred bird species that occur regularly in the state — with each species represented by one or more specimens showing sex, age, and seasonal plumage differences. But when Michael Anderson joined the Peabody’s staff in 1988, he inherited an unfinished exhibit, with over a hundred slots unfilled. All of the existing models were taxidermied, and obtaining live specimens of the missing birds was too difficult.

So, a few years ago, Anderson started making the missing birds by hand, a time-consuming process. He describes what was involved: “....a painstaking process of producing a ‘gestural’ clay sculpture of general dimensions, molding it in plaster, and casting in a carving wax. Once the model is cast in wax, I measure wing chords and tail lengths, and delineate feather groups and wing feathers using surgical and dental tools. I make a silicone rubber mold of the wax model and cast it in polyurethane plastic. I fill the hollow cast with urethane foam, add eyes, casts of beaks and legs. The model is finally painted, using ornithological bird skins from Peabody collections (and) field guides (as references.)”

Now, with an immersive scanning workstation and a 3D printer, Anderson has a whole new way of sculpting bird models.

To create a model for a missing bird closely related to one they already have, Anderson and his assistant, Collin Moret, scan either an existing taxidermied bird or a study skin (a hollowed out bird body stuffed with cotton to create a bird lying on its back with its wings folded), and adjust the measurements. If neither a study skin nor a model is available (as with extinct birds), they work with models or study skins of similar species, using the technology to adjust the size, colors, and markings.

After the bird is printed from the scan, it is sanded, and skimmed with a thin layer of wax that allows for the addition of fine details. Sometimes the 3D prints themselves have to be further manipulated (for instance, by repositioning a head or tail) to get the precise gesturing. Then the bird gets glass eyes, a beak, and legs before being painted. This digitally enhanced workflow reduces the building process from months to a couple of weeks for each bird model. In February of 2017, Anderson and Moret installed the first digitally-created bird model into the Birds of Connecticut exhibit hall — a non-breeding Baird’s Sandpiper.

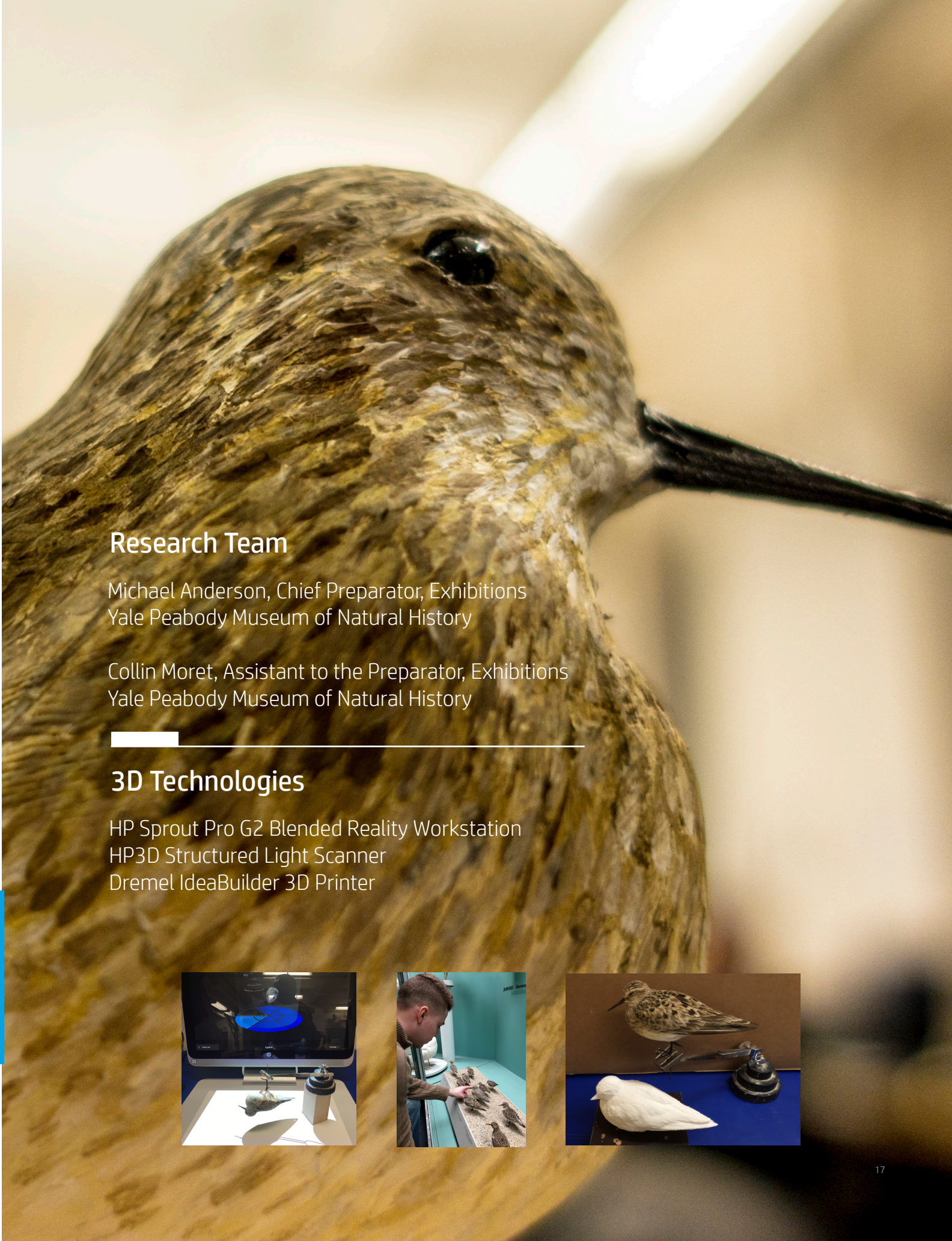
The following month, they added three other sandpiper species. As spring progressed, they added several other birds. When they are done over the next several months, twenty of these models will join their taxidermied relations in the hall’s exhibit cases, each model reviewed by the museum’s ornithologists to ensure accuracy of markings, measurements, and coloring. Models of four extinct birds — the passenger pigeon, the heath hen, and male and female Labrador ducks — are among the twenty.

Anderson and Moret have made more progress towards the goal of a completed Birds of Connecticut exhibit over the past several months than they had made over the previous years using traditional modeling methods. And completion is now in sight. Anderson and Moret had a lot to learn about the technology in order to produce the results they wanted. Now, seeing those results, elated by what the technology has allowed him to do, and with time freed up from fabricating casts and molds, Anderson can envision how these technologies can be applied to other museum projects, some of which he has already undertaken.

“I had a feeling that this grant would change my life,” he says. “And it has.”

Taxidermy Birds Into 3D Models: Research Questions

Four sandpipers are missing from the Birds of Connecticut exhibit hall. We will scan one of the small taxidermied sandpipers to create four models to fill in the blank spots. Rather than kill live birds or have to painstakingly sculpt accurate bird models, *can 3D models scanned from taxidermy mounts work in the exhibit hall?* *Does the process save time?* *Are the models scientifically accurate?*



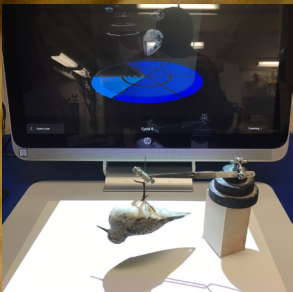
Research Team

Michael Anderson, Chief Preparator, Exhibitions
Yale Peabody Museum of Natural History

Collin Moret, Assistant to the Preparator, Exhibitions
Yale Peabody Museum of Natural History

3D Technologies

HP Sprout Pro G2 Blended Reality Workstation
HP3D Structured Light Scanner
Dremel IdeaBuilder 3D Printer





Research Team

Bek Anderson

Yale School of Art, '17 (Photography)

3D Technologies

Bespoke holographic projection device
High definition digital projector

Shifting Dimensions

The 3D Flower Viewer

Photographer Bek Andersen carries with her a pocket-sized hologram viewer — it works with an iPhone. It is a fitting accessory for someone who has been thinking deeply about how to push our experience of the medium beyond its usual two dimensions or, as she puts it, “to get the photographic image off the wall.” For the past few years, she has been exploring the relationship between screen-based and projected images while studying the history of photography and how the art form relates illusion and materiality.

Inspired by sources as varied as the Princess Leia hologram in the original Star Wars movie, and the work of light artist Thomas Wilfred, Andersen used the opportunity provided by the Blended Reality project to work on creating a 3D viewing experience that would combine photography with projection. Holograms and variations of the idea, Andersen notes, have been used mostly onstage, but she was searching for a technique that could provide a more intimate and more “real” experience — a true blended reality. “I wanted the result to be fully immersive without requiring that viewers enter the virtual reality space,” she says. “No one wants to live inside a box. I wanted to make it an object that could exist in the world and be viewed communally.”

In the course of her work, Andersen studied modalities ranging from traditional theater techniques such as the Pepper’s Ghost effect commonly used in 19th century stage productions, and the technology behind the camera obscura dating back to at least the 16th century, to current high definition video projection systems. She examined a variety of solutions that could combine traditional with current and developing technologies to accomplish a 3D hologram without having the experience overwhelmed by the viewing apparatus.

For her image, Andersen chose a flower. “I wanted to project something organic and contemplative,” she says, “since so much of what has been happening in the VR world has been geared toward action.” The installation of the 3D flower image was mounted for one day in December of 2016 in Yale’s Dwight Hall chapel — a perfect venue, Andersen says, for highlighting the meditative aspect of the viewing experience.

To subvert the usual requirement for hologram viewing – that it be done in a dark room – Andersen projected the stop motion video of the flower onto a clear Plexiglas surface with a digital projector, using the Pepper’s Ghost technique. In the context of the chapel, the structure supporting the apparatus became an altar that was faintly illuminated by the chapel’s ambient light, while the projection glowed in the center. Guests were invited to kneel or sit in front of the altar, while the projection played in an endless loop.

That installation was a prototype, and Andersen continues to explore the outer limits of her medium. As she does so, she will be looking to collaborate with those from other disciplines who can help with some of the technical challenges she encountered — such as how to scale images without distorting them, and how to achieve the lighting effects she wants.

“The most important point I learned,” she says, “is that the fundamental principles of light don’t change, whether you are working with a digital projector or directing sunlight through a glass. Honoring the material tradition of photography is important to me. At the same time, virtual reality is now part of our expanding universe. What I value about blended reality is that it doesn’t deny our temporal existence, but builds on it for a richer exploration.”

3D Flower Viewer: Research Questions

I am combining traditional photographic and projection technologies with current and developing technologies to generate a 3D hologram without a viewing apparatus overwhelming the experience. *Can I incorporate a lens to achieve this? What would happen if I start with an image captured in virtual reality and then project it into 3D?*

Colliding in Mixed Realities

A Different Kind of Disaster

What is the meaning of a collision? What is gained and what is lost when objects try to inhabit the same space?

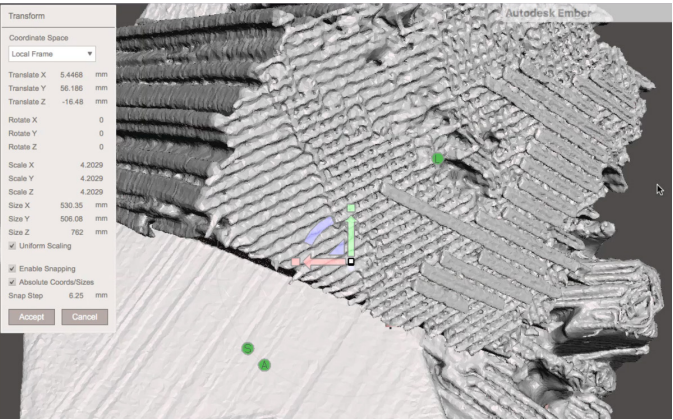
To explore these questions, Christie DeNizio and Stephanie Gonzalez-Turner created *A Different Kind of Disaster*, a material project that moved back and forth between the digital and real worlds — and that referenced disciplines from astrophysics to engineering to game design - with the goal of creating “a series of mixed reality sculptures.”

Their project began with a material collision simulated in Unity (a software used to develop video games and simulations for computers, consoles and mobile devices), generating artifacts that were 3D printed to fix in physical form all aspects of the hypothetical impact. They then 3D scanned the resulting objects back into the program to run a successive simulation, introducing new variables to the virtual process and creating a generative loop between digital, ideal, and real spaces.

Noting the importance of modeling to a range of disciplines, Gonzalez-Turner says, “How could we capture artifacts of a digitally-simulated collision and re-integrate them into subsequent iterations? How would the translation between the virtual and physical manifestation of objects create both information loss and accumulation?”

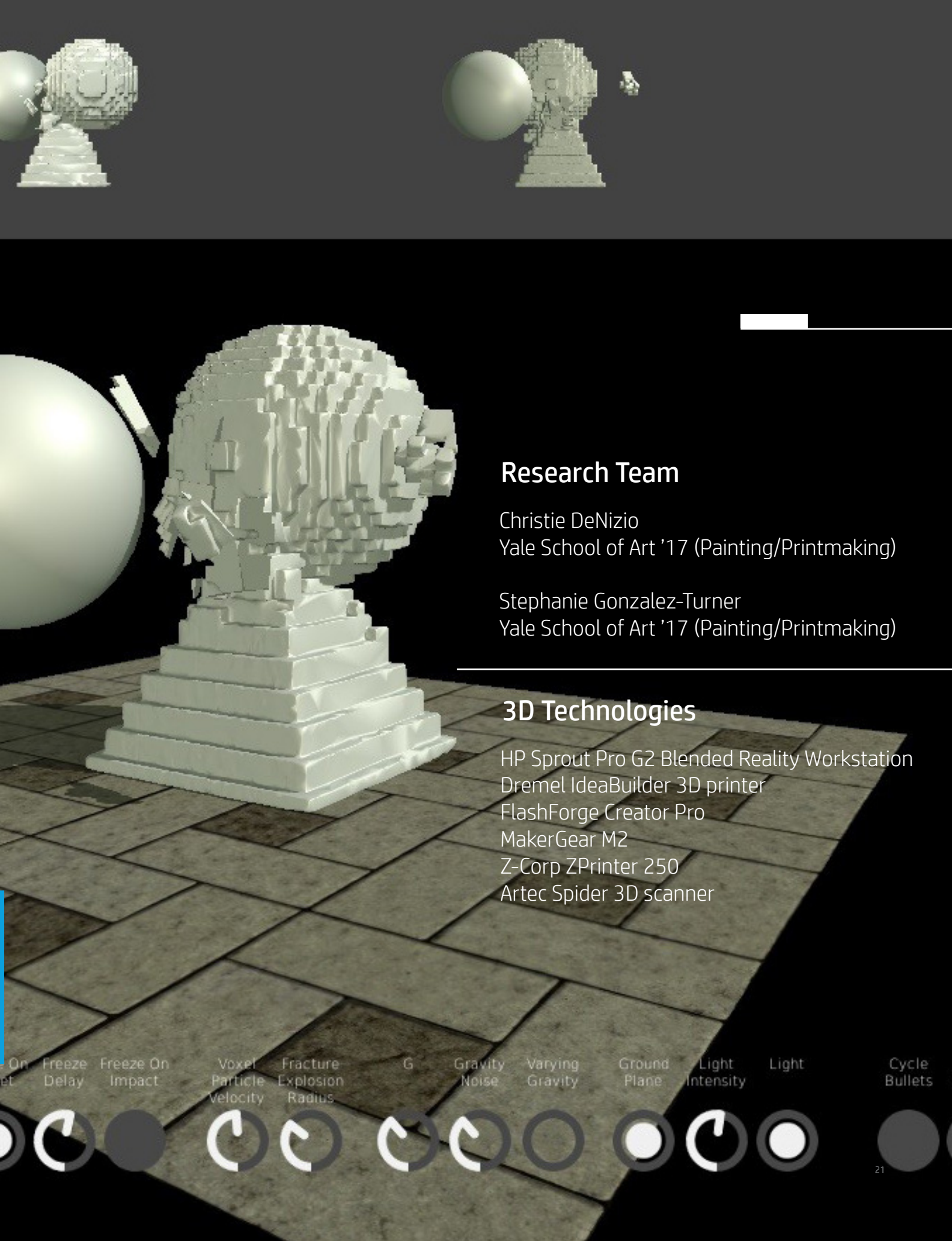
As an analogy DeNizio uses the idea of a meteor, which holds in its form the history of material encounters. On one hand, a meteor collision can be seen as a kind of disaster. “On the other,” she says, “it is also a generative process. The matter from the meteor combines with what strikes it - or what it strikes - that then creates a composite material that is introduced to the galaxy.”

As the project moved forward and the pair learned more about both the capacities and limitations of the technologies, they had to be flexible and problem solve for both efficiency and aesthetic considerations. As of this writing, they are working with a 3D printing company to create the final nylon sculpture, which will be printed in several segments, reassembled, dyed, and suspended from a concrete armature. Other artifacts of the process — including scale models printed for each round of the recursion — will be included when the sculpture is exhibited at the Yale Center for Collaborative Arts and Media in the fall of 2017.



Collision: Research Vision

Our intention was to create a generative recursion between a digital, ideal space and real space to create a mixed reality sculpture. Starting with a virtual object, a material collision is simulated in a virtual 3D environment. The results of the virtual impacts are 3D printed and then re-imported into the 3D space to simulate further collisions. As a final step we generate a physical sculpture of the end results.



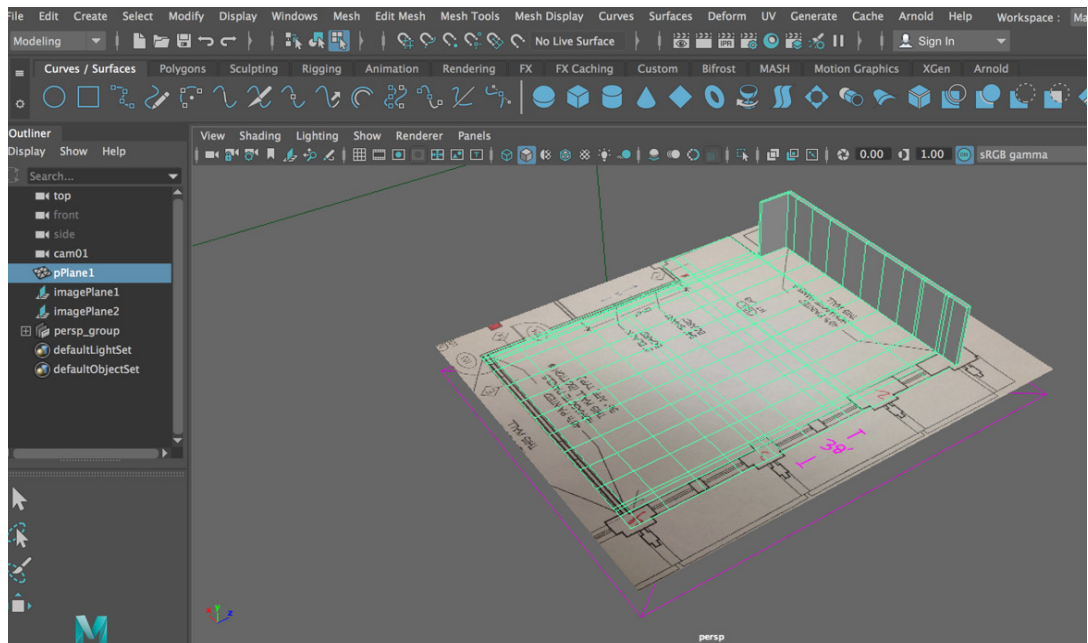
Research Team

Christie DeNizio
Yale School of Art '17 (Painting/Printmaking)

Stephanie Gonzalez-Turner
Yale School of Art '17 (Painting/Printmaking)

3D Technologies

- HP Sprout Pro G2 Blended Reality Workstation
- Dremel IdeaBuilder 3D printer
- FlashForge Creator Pro
- MakerGear M2
- Z-Corp ZPrinter 250
- Artec Spider 3D scanner



Research Team

Sheiran Phu
Yale College '19

Adam Moftah
Yale College '19

Elia Taffa
Yale College '20

3D Technologies

HP Z Workstations
Unity® 3D Game Engine



Game On!

Save our Snax

You are hanging out in your room, anticipating digging into some tasty fruit after dinner. Suddenly, the door is pushed open by a posse of raccoons charging straight for the fruit bowl. You manage to repel some of them, but others are scurrying in through the windows and even through the heat vents. And your only weapon is your smart phone.

Will you be able to save your snacks?

Save Our Snax! team member Sheiran Phu explains, “With Save Our Snax! we wanted to create an immersive video gaming experience that would employ virtual reality technology to create a navigable fantasy world.” The challenge that the participants initially set for themselves was to break traditional gaming barriers with a game — to be played on a mobile device — that would overlay a template for that world onto the real surroundings of the viewer.

“The team had an intriguing idea, but little practical game design experience,” notes steering committee advisor Johannes DeYoung. Although Phu and Moftah had done some work with computer game design (Taffa had no previous game design experience), the learning curve for this project as originally conceived was steep, involving becoming familiar with the operations and limitations of complex hardware and software that the team had not worked with before.

Aware of the experience gap and educational opportunities at hand, faculty advisors connected the team with affiliate faculty members to help guide the project. The team consulted Elena Bertozzi, a game designer and Gates Foundation grant recipient, to develop an official game design document. They also consulted Andrew Schartmann, a composer and music theorist, to develop sound design strategies for the immersive experience.

By the May 2017 end date of the project, the team realized they would not to bring to completion the final product they had envisioned. “The research and skill-building part of the project was more time-intensive than we anticipated,” Moftah notes. Still, team members individually and collectively became more proficient in technical modalities including 3D technologies and game design — modalities that will be increasingly integrated into our everyday lives, whether we play video games or not.

Phu says that she can imagine that virtual technologies might be used for learning languages, or for creating visual guidebooks for travels — and she and her teammates are eager to see what horizons their enhanced skills will open.

“This is a clear instance of where the virtue lay in the process rather than the product,” DeYoung says. “With their deeper understanding of the game design process, the team members will use their experiences for years to come.”

Save our Snax! Research Vision

We hoped to create a more immersive gaming experience by using 3D technologies, specifically augmented reality (AR). By combining the visual aspects of AR with the auditory elements created by sound design, we believe that our game can break traditional gaming barriers.

Crossroads

Emerging Technologies and the Arts

Human beings are story tellers, and the arts are the vehicles through which our stories are told, heard, and remembered. For centuries, we told stories through painting and sculpture, through song, dance and theater. The printing press, the camera, and film – each revolutionary in its time – opened vast new possibilities; those possibilities expanded again when radio and television came on the scene.

With digital technologies both enabling and requiring new ways of thinking, seeing and communicating, the Crossroads project team took as its challenge the creation of augmented and virtual reality (AR and VR) experiences using interactive and immersive media technologies. “Our goals,” says faculty member Justin Berry, “were to enable interdisciplinary research with emergent technologies in the arts areas at Yale, and foster interdisciplinary dialogues among the arts.”

He notes that they also wanted to establish a platform for sharing knowledge and research with the broader Yale community in the areas of AR/VR, using mixed reality tools. To these ends, the team of five graduate students from the School of Art and the School of Drama, led by Berry, conducted research that pushed boundaries of interaction and immersion through a series of projects that created AR/VR experiences.

The individual and collaborative research conducted by team members, who participated in weekly meetings, resulted in a dozen free workshops offered to the entire Yale community throughout the spring 2017 semester. Thematically, the workshops explored topics including psycho-spatial interaction, gaming and social interaction, animation, and the psychological affects of kinetic perception. Workshop participants — who did not need any prior knowledge of the technology for most of the sessions — could learn how to perform 3D scans, build a mixed reality musical instrument, capture live performance using a 360 degree camera, or interact with their computers using tiny virtual hands.

Student projects included animating virtual versions of traditional sculptures, augmented reality experiences that engaged acts of discovery in public spaces, interactive multimedia installation, and immersive animated video.

In addition, members of the Crossroads team and Blended Reality workshop participants organized an exhibition of VR works at Essex Flowers Gallery in downtown Manhattan. The exhibition, entitled The Sands, paid homage to one of Las Vegas Boulevard’s original hotel/casino complexes, with all the hyper-real qualities for which The Strip is famous. Curated by members of the Crossroads team, fifteen works by sixteen participating artists offered virtual creations that visitors explored and interacted with as they walked around the empty real-life gallery space. The virtual gallery space was mapped at one-to-one scale with the physical gallery, creating landmark references that traversed both environments.

Artworks were programmed to randomly enter and exit the gallery, creating a dynamic experience that ensured no two experiences in the virtual space would be exactly identical. Half of the show’s artists were participants in the Crossroads team’s spring workshops, including both Yale graduate students and faculty.

Looking back on a successful semester, Berry reflects on the larger significance of the team’s work. **“We as a culture do not yet have a critical language to describe what it might mean to occupy two different kinds of reality,”** he says. “I am proud that we wound up with a really good product, and that the work we did was so well-received. But even if we had not had such success, I would have been glad to create the context for dialogue and engagement. There is real, necessary, and practical value in having artists take apart these media, as artists do, to help all of us understand them better.”

Vision for “Crossroads”

An interdisciplinary group of graduate students met weekly to research the possibilities, both technical and conceptual, of bended reality, with a focus on AR and VR. Aspects of their research were made accessible to the broader Yale community through participant-led workshops and, ultimately, a public exhibition in New York City. By generating work and dialogue about AR and VR, and opening their research to the public, they created a platform for experimentation and exploration of blended reality.

Research Team

Justin Berry,
Critic, Yale School of Art

Michael Commendatore
Yale School of Drama ’17 (Projection)

Young Joo Lee
Yale School of Art ’17 (Sculpture)

Teddy Mathias
Yale School of Art ’17 (Graphic Design)

Will Wheeler
Yale School of Art ’17 (Sculpture)

Wladmiro Woyno Rodriguez
Yale School of Drama ’18 (Projection)

3D Technologies

HTC® Vive™ Head-Mounted Display
Unity® 3D Game Engine



Research Team

Joel Sanders
Professor Adjunct, Yale School of Architecture

David Langdon
Yale School of Architecture '18

Francesca Carney
Yale School of Architecture '18

Edward Wang
Yale College '16

Catherine Shih
Yale College '15

3D Technologies

HTC® Vive™ Head-Mounted Display
Rhinoceros® 5.0
Chaos V-Ray™ 2.0
Viar360™

Stalled!

Reinventing the Restroom with Virtual Reality

From public transportation to furniture, the designs of everyday architectural spaces and items have historically used ergonomic standards derived from “averages” that are based most frequently on the measurements, needs, and expectations of able-bodied white males.

Joel Sanders, principal of the firm Joel Sanders Architect and a faculty member at Yale’s School of Architecture, has been interested for a number of years in the social justice implications of architectural design. “Public restroom design in particular,” he says, “can trigger personal and often uncomfortable feelings about the nature of embodied experience that tap into deep seated issues about privacy, gender, sexuality, hygiene, and disability.”

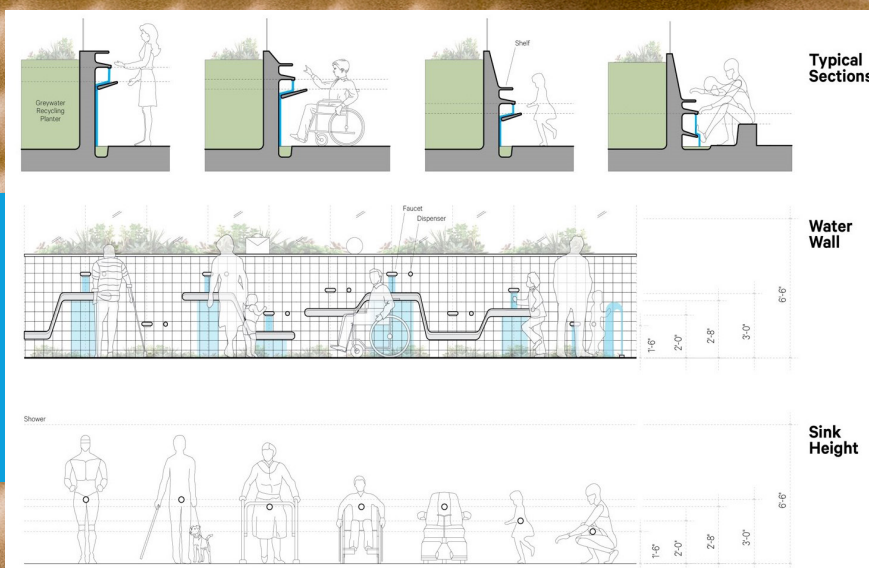
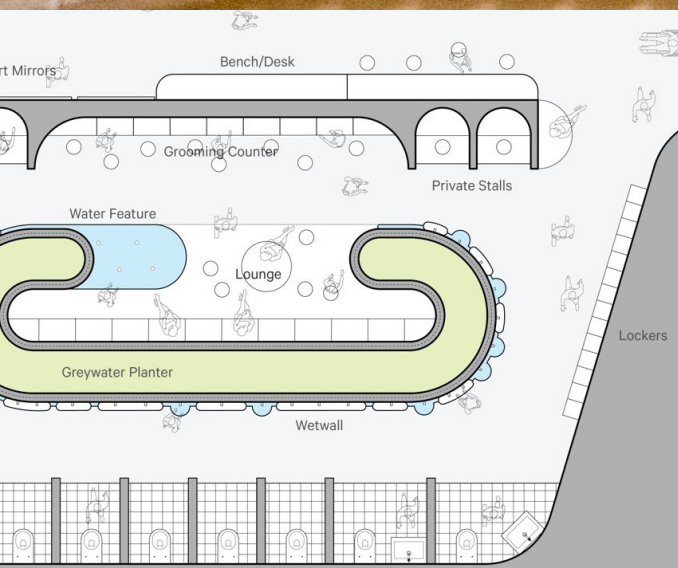
Sanders points out that architects tend to think of their discipline as a visual art. “Too often,” he says, “we neglect to think about the biological bodies - bodies that see, hear, smell and touch - who will be inhabiting the spaces we design.” Those sensory impacts and user needs, Sanders notes, cannot be explored easily or effectively using the conventional design tools of blueprints, floor plans, and scaled models.

So, to translate their ideas, and incorporate the needs of a broad range of differently embodied people of all ages, genders, religions and physical capacities, the Stalled! Blended Reality team developed an approach called **Diversity Design**.

Their process involved identifying a representative sample of user groups, researching the design consequences of their functional and psychological needs, and then finding common creative design solutions that could be shared among them. Working with this information, the Stalled! Blended Reality team applied the research to the design of a prototypical public restroom for an airport terminal. They employed virtual reality as a design and representational tool to generate a model that would allow users to experience the visual and acoustic qualities of a multi-unit, all-gender bathroom.

The larger conceptual framework is based on European style floor-to-ceiling stalls that afford complete privacy. The underlying idea, Sanders says, is the creation of spaces that are both inclusive and respectful of individuals’ privacy needs and requirements. While the project began with the intent of creating the airport prototype, the team is also now working with an actual client — Gallaudet University (the world’s only higher education institution in which all programs and services are designed to accommodate those who are deaf and hard of hearing). The airport project involves the creation of a prototype for a generic facility, to be built from the ground up, that would accommodate a high volume of diverse users.

The Gallaudet project, on the other hand, explores how to retrofit two existing gendered restrooms into the multi-stalled, all-gender model. “In the process of generating design solutions geared to rest rooms,” Sanders says, “we will likely discover other ideas that can be broadly applied to improve the quality of life for the wide range of human bodies interacting in public space.”



A Blended Reality Prototype for an all-gender public restroom

This project will employed virtual reality technologies to develop design prototypes for safe and inclusive public restrooms that addresses the needs of diverse bodies of different genders, ages, and disabilities. We used virtual reality technologies as a design and representational tool to generate a model to allow users to experience the visual and acoustic qualities of a multi-unit, all-gender bathroom.

Born Digital

Crafting the Self in the Digital Age

An ancient Greek maxim holds that knowing oneself is the beginning of wisdom. But what do we mean when we say “the self?” How do we construct our identities as private individuals, as members of given or chosen groups (families, friends), and as parts of larger communities? Are we always the same “self” — and, if not, what are the meanings of the interplay among our various selves? How are ideas about “the self” shaped by time and place?

With a grant from the Blended Reality project, Yale professors Ayesha Ramachandran and Marta Figlerowicz created Born Digital, which provided blended reality tools to help students explore such questions in their course entitled: Modernities: Selfhood, Race, Class and Gender. The idea: to have students use those tools to reflect on ways in which the sense of self is mediated by technologies and media.

Designed as a critical history of the self in the West from antiquity to the present, the course, taught in the spring of 2017, intended to provoke students to think more deeply about the categories that structure their sense of self, identity and community. The range of texts was broad across time and genre. Sources included Plato, Descartes and Shakespeare; Marx and Freud; the Kama Sutra, Judith Butler, Frantz Fanon, and Bollywood movies.

Adding the technology, Ramachandran says, “gave us the opportunity to turn our classroom into a blended space - both physical classroom and virtual sandbox - where students could encounter the texts, ideas and objects we discussed from multiple perspectives.”

Figlerowicz and Ramachandran encouraged students to explore creating 3D images and prints of objects of various kinds, and to analyze their experience with this emerging medium alongside better known forms such as poems, novels, plays, film, memoirs, and philosophical treatises.

Students were asked to analyze their own Facebook® profiles as if they were assigned texts. The instructors also had students develop independent projects collating and discussing their own virtual archives. One student used 3D scanning to create a model of her face, employing a split screen to show herself applying makeup as a way to reflect on the meaning of her Asian ethnicity in a white, western world. Several students experimented with activities that explored the interface between lived and represented experience.

“Part of working with blended reality,” Figlerowicz says, “is thinking about how material objects embody meaning in our lives. That direction was fruitful, she says, for considering how current technology fits in with other kinds of media. “It’s not that the book is old and passé and now we have this cool 3D scanner,” she says. “The students were able to think holistically how all these creations fit into the longer history of technology, and have raised similar questions across time.”

Having incorporated blended reality into their course on an experimental basis — “We didn’t know going in exactly what would happen when we asked students to work with the 3D scanners,” Figlerowicz says — they are eager to continue using it in the next iteration of the course in the fall of 2017.

Ramachandran adds: “This was a unique opportunity to get undergraduates, who live in media-rich environments, to incorporate those experiences into thinking about questions of selfhood and identities. We wanted to bring more traditional humanities questions into conversation with this broader social, technological world that our students inhabit, and that is shaping them.”

Research Team

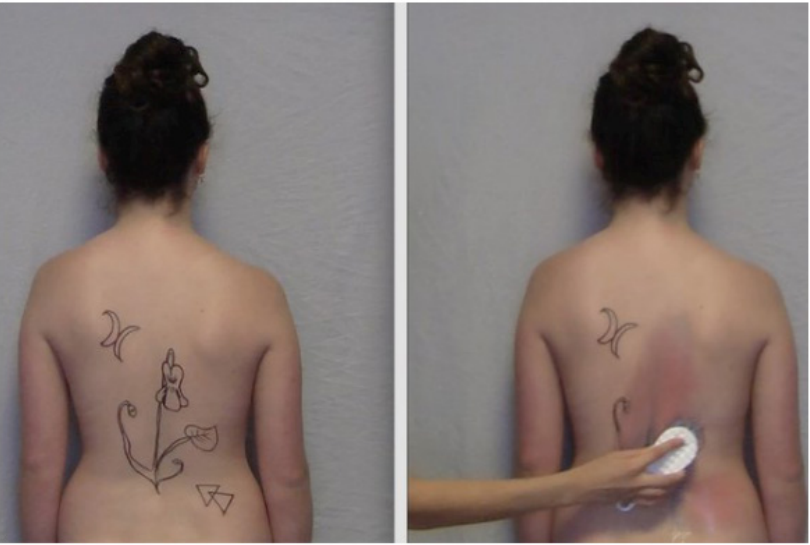
Ayesha Ramachandran
Assistant Professor, Department of Comparative Literature
Department of English, Yale University

Marta Figlerowicz
Assistant Professor, Department of Comparative Literature
Department of English, Yale University



3D Technologies

HP Sprout Pro G2 Blended Reality Workstation
Dremel IdeaBuilder 3D printer

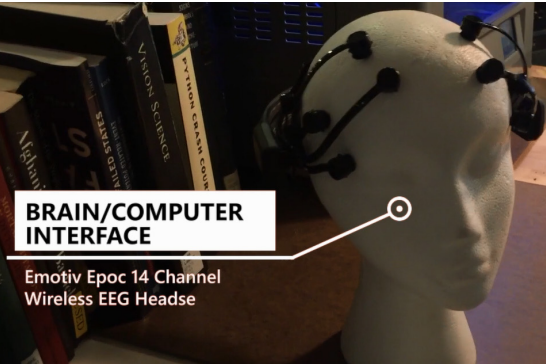


What does it mean to be “born digital?”

Our spring seminar on the categories that structure self, identity and community used blended reality tools to explore how race, class and gender emerge from and challenge boundaries between the virtual and the physical, the imagined and the real. Students will engage creatively with the notion of selfhood, both in its history and in how it applies to their everyday lives, by creating blended reality archives that capture traces of their selves.

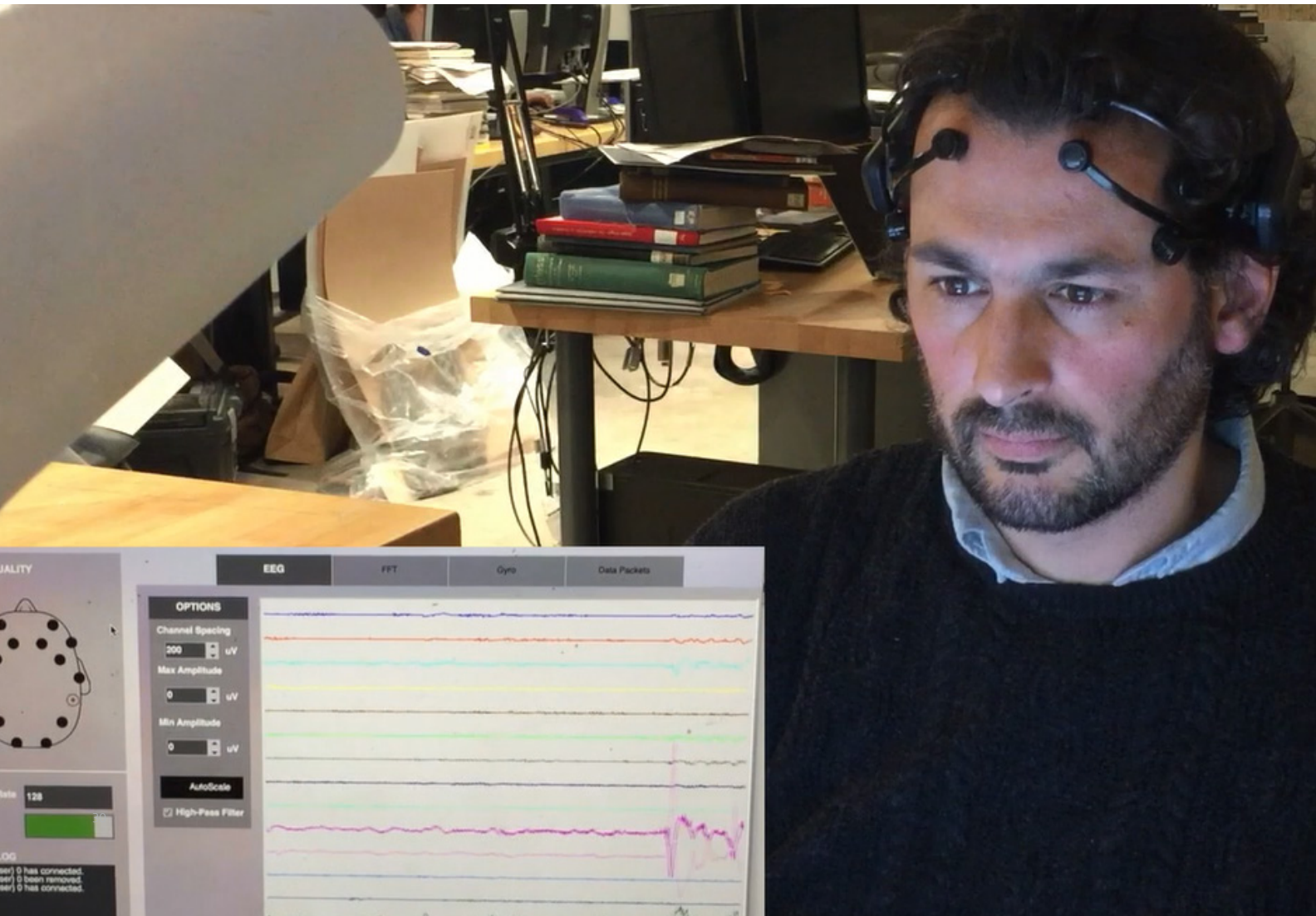
Research Team

Summer Sutton
Yale School of Architecture '21 (PhD)



3D Technologies

HP Sprout Pro G2 Blended Reality Workstation
Dremel IdeaBuilder 3D printer
EMOTIV Systems EPOC+ Multi-Channel EEG System



Think it, Make it MindDesign

How does what we imagine become what we create? Anyone who has ever seen a tree in the world can see a tree in the mind’s eye. But not everyone can take that imagined tree and draw, paint or sculpt that image into a form that resembles what the mind envisions.

For her Blended Reality project, Summer Sutton explored how thoughts and emotions might be converted into 3D representations. She created the MindDesign tool, which she describes as “a design tool for generating physical objects from cognitive activity.”

Using an EEG (electroencephalogram) brain scanner and an immersive scanning workstation, the MindDesign tool operates both as a computer assisted design (CAD) software plug in and a physically interactive creation interface that allows users to fabricate design ideas directly from their imaginations. The tool links a user’s neural activity from emotive stimuli, using EEG sensor headsets with an algorithmic digital manipulation of a 3D scanned object.

As the person wearing the headset sees emotive stimuli on a computer screen, each of the fourteen sensors in the headset reports neural activity in a different region of the brain. Points and lines that make up base forms are manipulated on X, Y, and Z axes (three dimensions) based on the data coming from the sensors and visible on the computer screen. The user can also stimulate neurological activity that will in turn be picked up by the sensors. All of the data manipulate points on a 3D form that is being modeled via CAD in real time. **The user can then print a physical 3D model of the emotions, memories or thoughts that were generated during the process.**

“The MindDesign tool,” Sutton says, “widens design possibilities while also bridging the translational gap between conceptual ideas and physical reality.” She gives as an example a boyfriend who wants to create a unique piece of jewelry for his girlfriend. A brain scan while he thinks loving thoughts about her could be translated into a gift that represents their relationship.

While Sutton is still working on fully automating the process, she notes that the forms created with the MindDesign tool will truly be the product of blended physical and digital realities: the physical world (original scanned object and final fabricated object); augmented reality (visualizing the effects of live neurological activity); 3D design (CAD software plug-in); and computer graphic and fabrication tools.

In addition, she says, “I see this tool as a way to create meaningful and unique objects that are not automatically generated from culturally or socially learned aesthetics, and to open up the practice of design to those for whom reliance on fine motor skills inhibits design potential.”

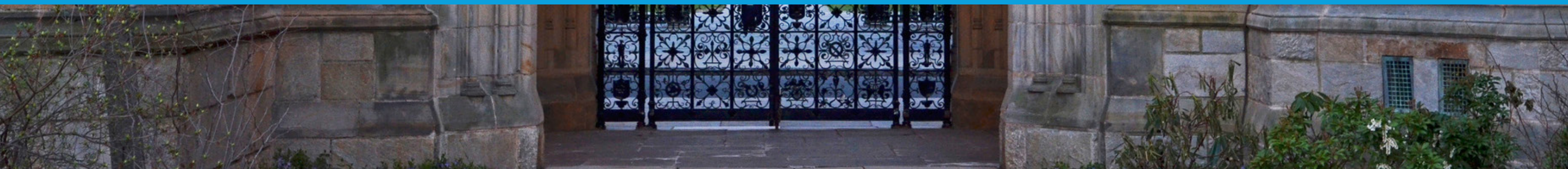
3D Printing Physical Representations of Human Emotion

The MindDesign tool jointly operates as a CAD digital plug-in and a physically interactive creation interface allowing users to *fabricate design ideas directly from their imagination*. It reads a user’s neural activity from emotive stimuli, using a commercially available EEG sensor headset to lower the technological skill barriers of object design and fabrication. Beyond basic functionality, the platform of communication between neurological activity and object design allows the user to identify a personal syntax of neurological stimuli for shaping forms.



CAMPUS OF THE
FUTURE

CONCLUSIONS



Looking Back, Looking Forward

A key goal in the Blended Reality project is to build a cross-disciplinary community of faculty and students to explore the boundaries of technology-enhanced and generated realities. Rather than creating isolated, custom, one-off projects, the aim is to produce examples and lessons that build the overall knowledge base, and generate templates and techniques that are repeatable and reusable in other projects. At the beginning of year one, we were not sure how best to accomplish these aims. While much of what we did worked well, we also learned key lessons to put into practice for year two.



What we did right (and will repeat in year two):

Strong Faculty Leadership

The Blended Reality project falls under Yale's sponsored project directives, an important component of which is the requirement that a faculty member serve as the principal investigator (PI). That person's responsibilities include monitoring the financial health of the project and ensuring that project work aligns with the sponsor's intent. This structure helped in connecting other faculty and students with the project, and ensured a strong alignment with Yale's teaching and research missions. The year one PI, John Eberhart, director of digital media at the Yale School of Architecture, strengthened faculty engagement by creating an advisory committee. That group not only selected the final slate of project teams, but served as a cohort of mentors for the teams throughout the year.

No requirement for Past 3D Experience

Applicants were invited to submit "a clear description of the project, goals and how access to 3D design, augmented reality, digital imaging or 3D printing/fabrication technologies will support and enhance the project goals." We made clear that prior technical experience was not required, opening participation to faculty and students across the disciplines. The advisory committee's selection criteria were for intriguing, well articulated projects that would employ the technologies in innovative ways.

We built community

A requirement for the project teams was that they participate in three group meetings during the year to report on their progress and provide feedback to each other. Our original idea was that these meetings would add default project milestones for each team, and enforce informal project management. That plan did not work out quite as well as we hoped (see below). What did emerge was a wonderful level of sharing — such as group training sessions — and peer support among teams.

What we learned (and will add in year two):

Technology mentorship

Given that none of the teams was experienced with 3D technologies, they made remarkable progress towards their goals. Still, a lack of mentorship and support to help them over the technical hurdles was a limiting factor for all of the teams. For instance, when a student finds themselves needing to spend weeks learning Maya (the feature-rich and expert-level computer animation software package) before starting work on their project, there is an increased likelihood that their project progress will stall. In the second year HP is providing technical mentors for each team, and we are establishing a core set of Yale technical support resources for the project teams to draw upon.

Project management

We learned that running the Blended Reality project involves a substantial amount of planning, coordination and communication. In year one we made the mistake of underestimating the amount of project administration work required. Those administrative duties fell to members of the steering committee to juggle alongside their regular work loads. While we avoided complete disasters, the entire project will benefit from a dedicated project manager, a position we will include in our second year staffing.

Leveraging Yale support resources

Yale faculty and staff have disciplinary support centers available to assist with their projects. Several of the first-year teams found their way to one of these resource centers to seek assistance. However, the center staffs would have been better prepared to respond having advance notice of the types of assistance teams might require. In the second year, each of the project teams is aligned up front with a relevant support center. These are the Center for Teaching and Learning; Center for Collaborative Arts and Media; Center for Engineering Design and Innovation; and the Yale School of Medicine Teaching and Learning Center.



Credits

Yale University

Principle Investigator

John C. Eberhart
Critic and Director of Digital Media
Yale School of Architecture

Project Director

Randall Rode
Director of Campus IT Partner Development
Yale University Information Technology Services

Business Office Specialist

Lillian Smith
Financial Administrator
Yale School of Architecture

Writing (unless otherwise noted) and editing:
Rhea Hirshman

External Collaborators

HP, Inc.

Gus Schmedlen
Vice President, Worldwide Education

Todd Gustafson
Vice President and General Manager, U.S. Public Sector

Doug Warner
Vice President of Technology Vision and Strategy

Dana Stepp
Worldwide Education Channel Manager

Mirjana Spasojevic, Ph.D.
Head of HP Immersive Computing Lab

Alex Thayer, Ph.D.
Senior Manager, HP Immersive Computing Lab

Dremel

John Kavanaugh
President, Dremel (Robert Bosch Tool Company)

Andrew Ortman
Manager, Dremel Education

Yale Blended Reality Steering Committee

Johannes DeYoung
Senior Critic
Yale School of Art
Director, Center for Collaborative Arts and Media

John C. Eberhart
Critic and Director of Digital Media
Yale School of Architecture

Laurel German
Program Manager, Student Technology Collaborative
Yale University Information Technology Services

Randall Rode
Director of Campus IT Partner Development
Yale University Information Technology Services

Sarah Stevens-Morling
Critic and Assistant Dean for Communications and Digital Media
Yale School of Art

Lucas Swineford
Executive Director of Digital Learning
Yale University Center for Teaching and Learning







CAMPUS OF THE
FUTURE

www.hp.com/hied