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BLENDED REALITY

Yale University and HP have partnered on an applied research program to explore the area of blended reality. The work of faculty and students within this program will blur the lines between the physical and digital worlds, easing the transition of an idea from imagination, to design, to realization. The goal is to democratize 3D design, augmented reality, digital imaging and 3D fabrication technologies, removing the high learning bars that currently exist. This will open new creative outlets for artists, scientists, researchers and designers.

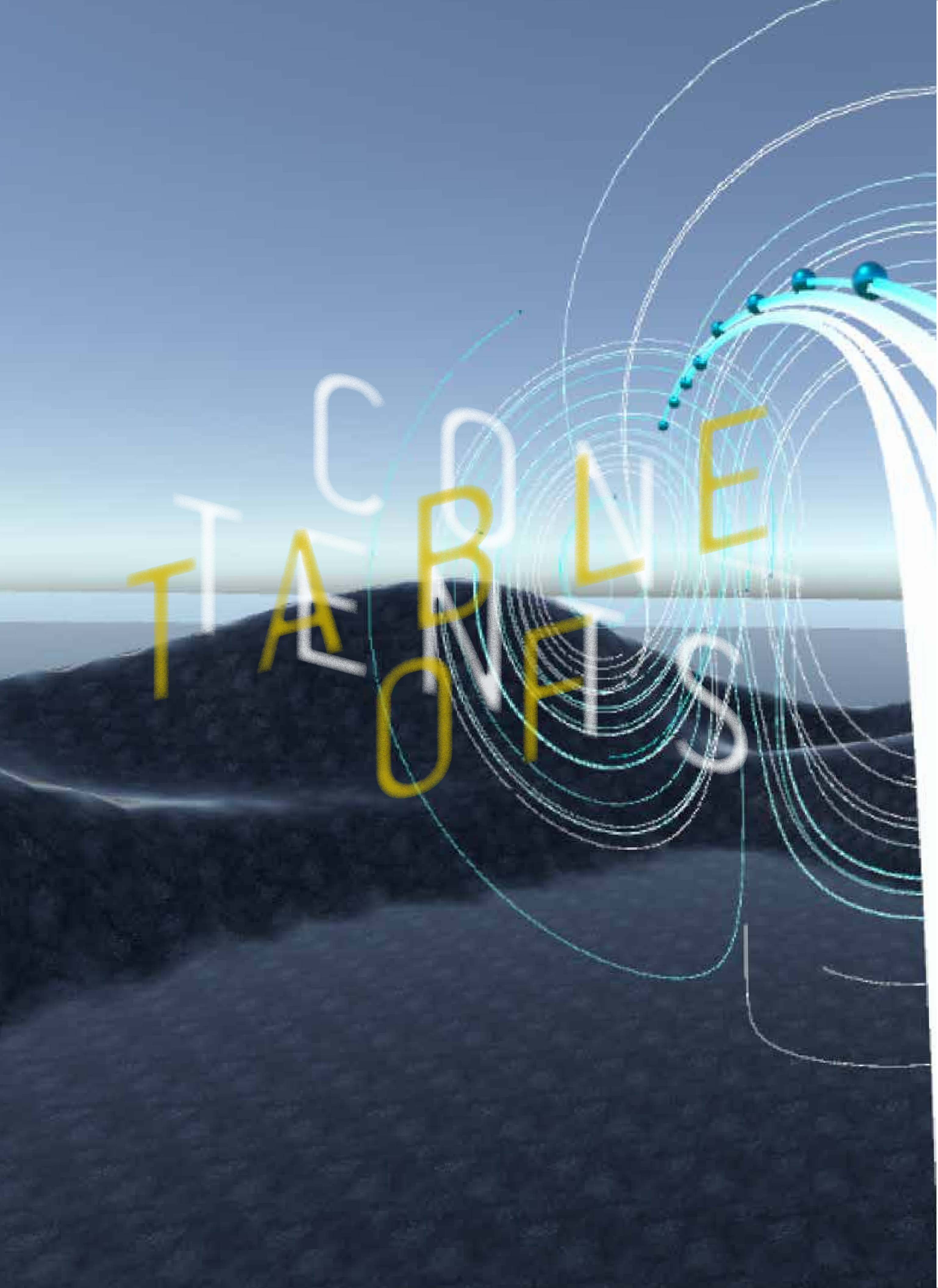
PRINCIPAL INVESTIGATOR

2017–18 ACADEMIC YEAR:
Johannes DeYoung, Director
Center for Collaborative Arts and Media; Senior Critic, Yale School of Art

2016–17 ACADEMIC YEAR:
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

A YALE UNIVERSITY APPLIED RESEARCH PROJECT SPONSORED BY hp



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Letter From The Principal Investigator

Johannes DeYoung

DIRECTOR, CENTER FOR COLLABORATIVE ARTS AND MEDIA
SENIOR CRITIC, YALE SCHOOL OF ART

It has been a great honor to serve the Blended Reality applied research program during its second year at Yale University. From its inception, the program was designed to transcend boundaries of traditional academic inquiry. This year proved especially successful in uniting diverse fields of study under a common initiative, embodied by the fruits of collaborative teamwork. As a result, Blended Reality has become one of the university's most fertile melting pots, a site where scientific and creative inquiries dissolve boundaries of academic discipline and advance new paradigms in interdisciplinary learning, Human Computer Interaction (HCI), and immersive design.

This year our research was organized into four campus centers: the Center for Collaborative Arts and Media; the Center for Engineering, Innovation, and Design; the Center for Teaching and Learning; and the School of Medicine. Our teams met regularly to share work, interests, and goals, and new collaborations were born in the serendipitous intersections that emerged. In the ten years that I have served at Yale, I have not previously witnessed such open collaboration, shared enthusiasm, and collective problem-solving as I have observed in our Blended Reality teams this year. Whether exploring multi-sensory perception or basic human anatomy in virtual reality, expanding the lexicon of the digital humanities through immersive media tools, or exploring models of acoustical material fabrication and HCI in digital music interfaces, our teams continually found new ways to engage each other and blur the lines between arts and science research. While the structural organization of our research plays a small part in the program's success, the real accomplishments lie in the passions, dedication, and collegiality of my inspired colleagues.

I would like to thank my colleagues for their spirited work. In addition to the faculty and students who participated in each of our teams, I would like to thank my partner, Randall Rode, for his superb leadership in bridging connections between academic disciplines throughout campus. I would also like to thank my colleagues Jennifer Glass, Miriam Schroers, and Kati Gegenheimer for their unfailing support, goodwill, and tireless behind-the-scenes efforts to make this program succeed. Blended Reality could not have achieved such a level of accomplishment without their contributions. Additional thanks go to our campus partners Tsai Center for Innovative Thinking at Yale (CITY), the School of Forestry, and Franz Hartl's team at Yale Information Technology Services, who were instrumental in organizing our Mixed Reality Hack-a-thon and other Blended Reality events.

This program was made possible by the generous support of our partners at HP. As our teams tackled questions of breadth and depth in their research, our HP partners provided necessary expertise, insight, and dialogue along the way. Dana Stepp has supported us throughout every step of the process, and Alex Thayer's team at the Immersive Experiences Lab provided a model for creativity and innovation. Alex's generosity to open his lab to our Blended Reality program acted as a catalyst for some truly inspired research at Yale. Finally, I would like to give special thanks to Gus Schmedlen, Vice President of Worldwide Education at HP. It's Gus's vision that actualized Blended Reality and enabled our Campus of the Future to thrive.


BLEND
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Blending Reality In Our New Home Space

The Blended Reality program at Yale, an applied research project supported by HP, is now in its second year. This year, the program has moved, under the direction of principal investigator Johannes DeYoung, to operate within Yale's new Center for Collaborative Arts and Media (CCAM).

CCAM's mission is to bring in Yale students and faculty from across disciplines to collaborate on projects that explore the limits, possibilities, and concerns engendered by new fields of representation, such as augmented and virtual reality. The center provides support for Blended Reality researchers through a range of activities: hosting graduate fellow workshops on virtual reality tools and techniques; sponsoring guest lectures by visiting artists who create work across the mediums of augmented and virtual reality and other 3D technologies; and offering a motion capture lab, media editing suites, equipment loans, technical consulting, and other services required by the Blended Reality research teams. Of particular note was the April 2018 Virtual Reality Showcase that featured work by Blended Reality researchers as well as other students who were introduced to virtual reality techniques through CCAM's teaching outreach.

CCAM faculty are expanding the project beyond Yale's borders. Over the last year, Blended Reality project work appeared in an exhibition organized by faculty member Justin Berry at the New York-based Essex Flowers gallery (August 2018) and at the Frankfurt, Germany, B3 Biennial of the Moving Image (November 2018). In August of 2018 aspects of the Blended Reality research will be presented at the IEEE Games, Entertainment and Media conference in Galway, Ireland.

As the Blended Reality program enters its third year, CCAM faculty are leading research into fundamental challenges and opportunities of blended reality experiences, such as embodied navigation and sound-based linguistic landscapes. Our research builds bridges between the arts and sciences, fostering a cross-disciplinary and collaborative body of work demonstrated by this year's project teams. We count as a major success the number of undergraduate and graduate student thesis projects this year that used blended reality technologies. We also note the growing interest from faculty looking to incorporate these technologies into their classrooms. As we close out our second year and head into the third, we look forward to continued success and growing interest across the Yale community.

Blending Reality

Putting Virtual Technologies Into Practice

The introduction of the telephone in the 1870s was not greeted with universal enthusiasm; responses ranged from awe and excitement to confusion and terror. A disembodied voice emerging from a wire was spooky, and who knew whether actual ghosts might be lurking in the lines? There was concern that telephones might be dangerous, drawing lightning in thunderstorms, and zapping everyday users and innocent bystanders with electrical shocks. As late as 1933, a *New Yorker* article noted that people were intrigued by the ingeniousness of the devices but "no more thought of getting one of their own than the average man now thinks of getting on an airplane."

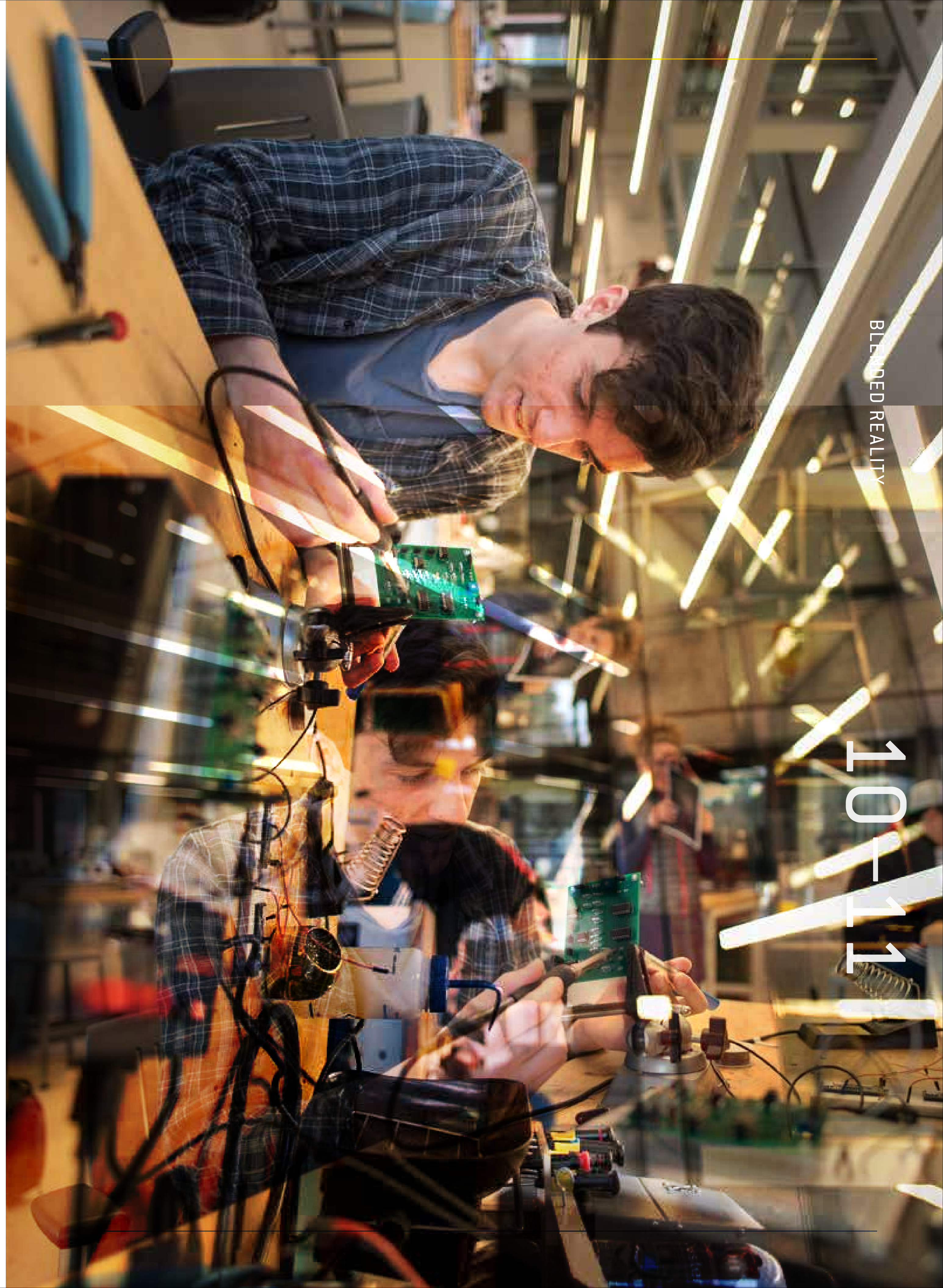
And besides, what was the point of the contraption? A high-ranking official at Western Union, the telegraph company, declared the device "practically worthless," and a 1907 New York Times essay warned that: "The general use of the telephone, instead of promoting civility and courtesy, is the means of the fast dying out of what little we have left."

Nearly a century and a half later, we wrangle with similar concerns about our latest technological innovations. What is this thing? What can it do? What can it not do? What should we do with it? How might it change the ways we live, work, learn, and play? Will it enhance or detract from our lives?

During 2017–18, teams of students and faculty at Yale University applied these questions to mixed, or "blended" reality — applications and experience that explore the intersections of the physical and the virtual environments. With financial and technical support from HP, the teams worked on projects that included integrating virtual reality technologies into the study of anatomy — both botanical and human; exploring the possible applications of immersive technologies to music-making; and rethinking the ways that bodies can function in virtual spaces.

"These are questions that industry—with its focus on 'how'—is not in a position to ask," says Johannes DeYoung, director of Yale's Center for Collaborative Arts and Media. "As a liberal arts institution, we have the resources—and the obligation—to ask what these developments mean and how we understand their place in our culture."

As you will read in the following pages, most of the projects are, by design, in process. Blended reality is not simply a medium, but a field of ongoing and rapid transformation. What is learned from all the projects will offer valuable insights as we continue to embrace, refine, and challenge these technologies.



Virtual reality (VR) is helping medical students deepen their understanding of human body systems; trees yield their structural secrets through the use of VR in courses on plant physiology; VR offers intriguing possibilities for math education; and blended reality tools are used to further students' critical thinking about the internet.

IN THE CLASSROOM

In The Classroom
Internet Cultures

The internet is not a natural habitat. That is a central message of Internet Cultures: Histories, Networks, Practices, a course taught in the spring of 2018 by Marta Figlerowicz, assistant professor of comparative literature and English, and Marijeta Bozovic, assistant professor of Slavic languages and literatures.

“When students interact with the internet,” says Figlerowicz, “they tend to be adept at figuring out how to use it, but also seem to approach it as if it were a fixed entity — a sort of natural habitat that grew up all by itself — and as an inherently democratic space.” Using history, network studies, computer science, and a sampling of cultural studies, the course explored questions ranging from “How did ideologies of the Cold War shape the development of the internet?” to “How misleading and how expedient are the metaphors we use (desktop, pages) for working in virtual spaces?”

The aim, Figlerowicz says, is to help students see the internet in particular and digital and computing technologies in general as entities that grew out of combinations of innovations and environments. The notion of global communication is derived from the much older technologies of the telegraph and telephone. Ideas about super computers are embedded in WW II and efforts to crack the Enigma code. “And the vision of personal computing originated not with libertarian techies,” she says, “but in California with ‘back to nature hippies’ who wanted to have control of their tech tools — just as they wanted to grow their own vegetables.”

Figlerowicz and Bozovic want their students—who come from a variety of disciplines — to understand that the internet is human-made with certain contingent conditions. “When students look back into the past,” Figlerowicz says, “they tend to think teleologically. They think that the early computers naturally led to personal computers, and that personal computers naturally led to the internet, and that certain technologies or products won out because they were ‘the best.’ But once you bring in the history or science, you realize how many other possible paths existed.”

While the focus was not on developing competence in blended reality technologies, students were required to spend time during the last third of the course either experimenting with virtual reality or participating in computer software coding sessions. Blended reality tools were examined in the context of understanding internet history, and developing critical thinking skills about the digital worlds that surrounds us and mediate our experiences.

Interacting directly with those tools, says Figlerowicz, gave students insights into the tools’ workings, capacities, limitations, and possibilities — and frequently challenged their assumptions. “It’s easier to get students to think of older technologies (even print!) as ‘technologies’ as opposed to ‘givens’ if you also introduce them to technologies that feel genuinely new but might be buggy and confusing, like virtual reality. Even though VR is seemingly cutting edge, we are still trying to figure out what its uses can be.”

References and Related Reading:

“New initiative at Yale seeks to answer the question: What is the internet?,” Bess Connolly Martel, *Yale News*, November 29, 2017, https://news.yale.edu/2017/11/29/new-initiative-yale-seeks-answer-question-what-internet

“Crafting the Modern Self,” Rhea Hirshman, October 24, 2017, Blended Reality Project Blog, https://blendedreality.yale.edu/news/crafting-modern-self

In The Classroom
The Secret Lives Of Plants

Plants build themselves out of air, water, light, and the nutrients in the soil. Embedded in the opaque tissues of their roots, leaves, and stems are intricate vascular systems that move water from the soil to the leaves through microscopic vessels smaller than the diameter of a human hair. Hundreds or even thousands of these water conduits can exist inside a stem the thickness of a pencil.

Since the introduction of the microscope in the late 17th century, investigating how plants function has meant primarily examining specimens on microscope slides, and traditional teaching methods have presented plants' complex vascular anatomy as flat, two-dimensional images. A challenge in teaching plant physiology, says Craig Brodersen, assistant professor of plant physiological ecology at the Yale School of Forestry and Environmental Studies (FES), is "teaching students the relationships between form and function in structures they cannot see with the naked eye." For several years, Brodersen's lab at FES has been using high-resolution x-ray micro-computed tomography (microCT) — a technique based on the same principles as medical CT scanning but on a much smaller scale — to collect data on complex plant anatomy. Jay Wason, a post-doctoral scientist working with Brodersen, has been using 3D visualization and computer modeling to study how four dominant tree species in the northeastern U.S. might be modifying their interconnected conduits (collectively known as xylem) in response to climate change.

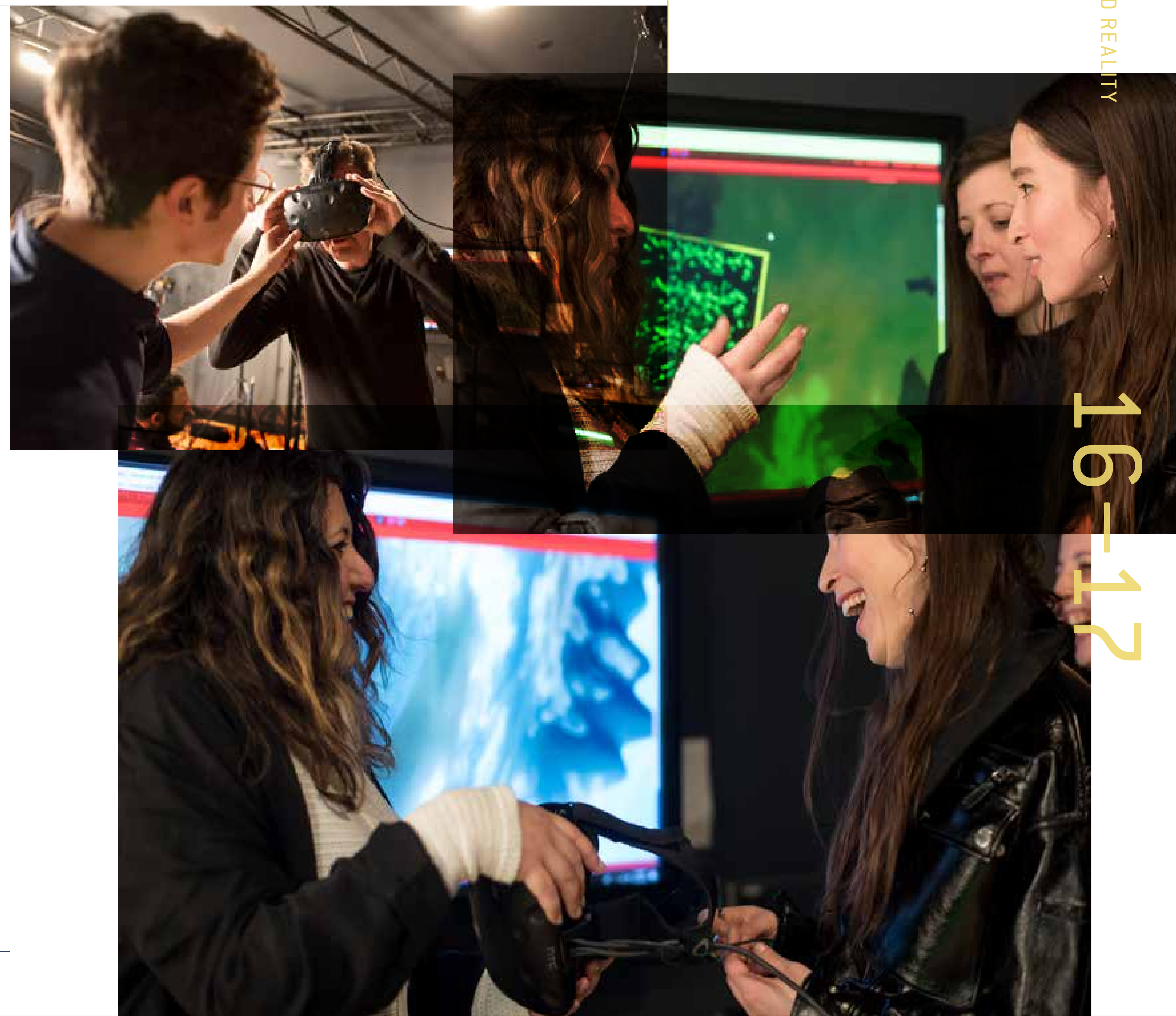
During the fall 2017 semester, Brodersen and Wason tested the use of virtual reality (VR) techniques as a teaching tool in Brodersen's graduate course in plant ecophysiology (the study of interactions between plants and their environments). Using VR headsets, students interacted with xylem models, picking up objects and moving them around in full three-dimensional views. Microscopic tubes and cells became structures the size of rooms that students could walk through while the instructors narrated what students were seeing.

Two questions raised by this pilot program were: (1) whether the methodology could be scaled up from what was done in this relatively small class, in which 15 students used the equipment one at a time; and (2) to what extent 3D immersive teaching techniques enhance student engagement and learning. Currently, several of Brodersen and Wason's interactive xylem models are available on a website that is easily accessed on any device (phones, tablets, computers). While interacting with those models in VR on a large scale is a challenge, Brodersen say that they are planning to use Google Cardboard headsets to scale virtual reality and 3D-movie technologies to larger groups.

As to the second question, Wason says, "The engagement was definitely there! Students loved moving around inside the plants, and we have to make sure that we guide them appropriately." In partnership with Yale's Center for Teaching and Learning, the pair will assess the degree to which their 3D teaching modules are pedagogically effective as compared to traditional 2D teaching. And Brodersen and Wason are in the process of creating lesson plans that will allow other instructors to generate or acquire 3D models, movies, and virtual reality demonstrations that they can use in their own classrooms.

References and related information:

Brodersen Lab, 3d Data Portal, http://campuspress.yale.edu/brodersenlab/3d-data-portal/



In The Classroom The Human Condition

In a rite of passage repeated with every new medical school class, students begin to learn the language of medicine by making their first cuts into cadavers, exposing the intricacies of the human body. But as essential as cadaver dissection is for learning anatomy, relying solely on that process has its limitations.

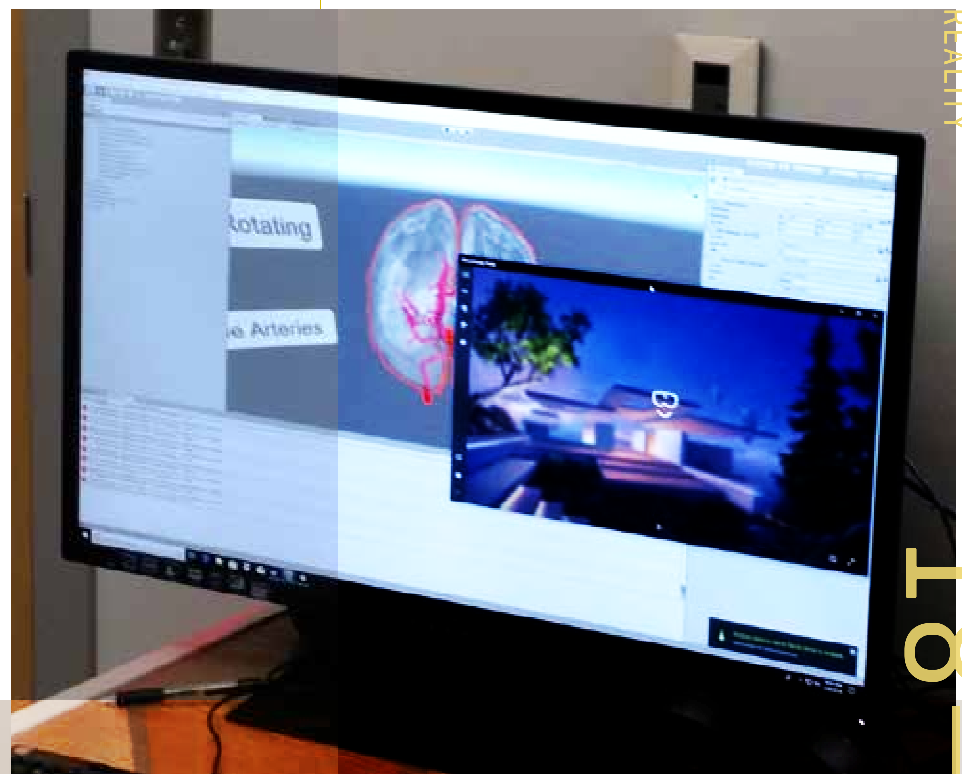
“When students do their cadaver dissections,” says Michael Schwartz, associate professor of neuroscience and associate dean for curriculum at Yale School of Medicine, “they are learning on a model that has changed significantly from its living state.” Working with a cadaver, he says, is essential to sensory-motor learning — the feel of organs and body structures. But the spatial relationships and organization within the body change dramatically after death. The fixatives used to preserve the body cause differential organ shrinkage, organ locations shift, and blood vessels look very different in stasis than they do when blood is flowing through them.

To address these discrepancies, and to accommodate the widest possible range of student learning styles, a team from the medical school, with the guidance of mentors at HP, has been exploring the use of virtual reality (VR) technologies to augment traditional methods of teaching human anatomy. Working with a combination of purchased three-dimensional model sets of brain and vasculature structures, and imaging data generated during diagnostic procedures such as CT and MRI in living patients, Schwartz and his team are creating VR models and experiences. The idea is to give students additional tools for understanding the three-dimensional organization of body and organ systems as they appear in living humans.

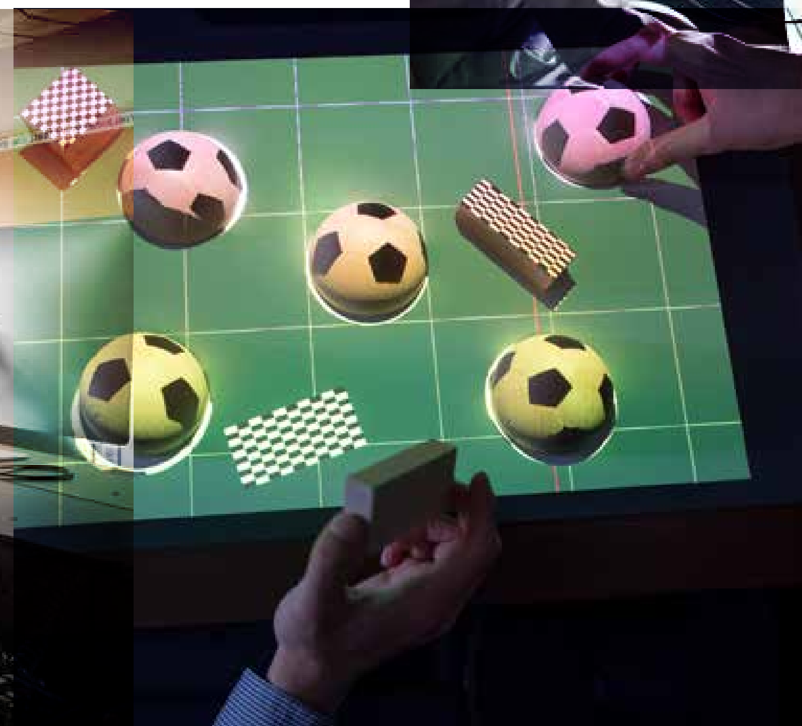
An important element of this team is the medical school imaging group that provides DICOM (digital imaging and communications in medicine) data sets that form the basis of the VR models. The available data sets include not only data stacks for every anatomical system, but also for many of the pathologies that affect these systems.

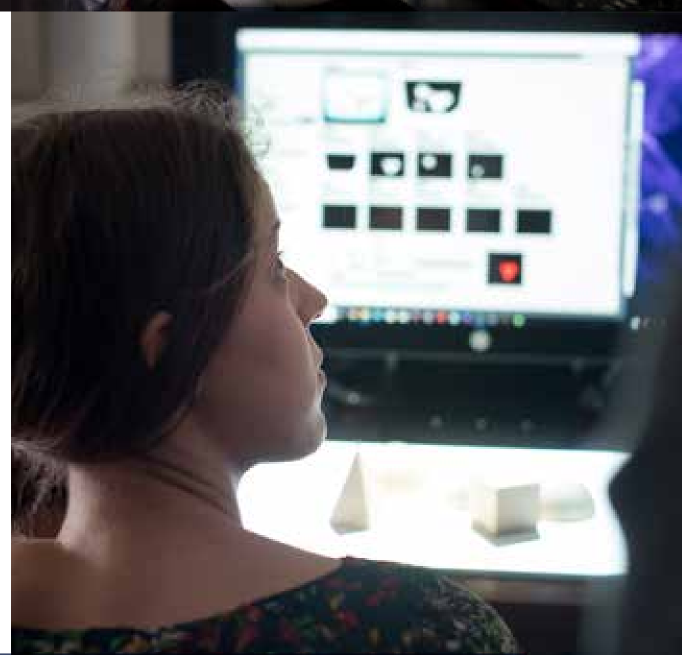
Since members of the initial team work primarily in neurology and the neurosciences, they are currently focused on applying these technologies to teaching about the nervous system. But the idea, says Gary Leydon, associate director for technology services, Yale Medical School Teaching and Learning Center, is that whatever is learned would be applicable to any other body system. “We are just beginning to explore the possibilities of VR space for teaching anatomy,” Leydon says. “Maybe we could create a VR model that would allow students to tunnel through the chambers of the heart.”

Both formative and summative assessment capabilities are being built into the VR models for use in the classroom and for self-study. “Will using VR to manipulate and interact with anatomical structures generated from MRIs, CT scans, and other imaging modalities enhance the ability of students to acquire a spatial understanding of these structures in health and disease?” Schwartz asks. “We think these technologies provide an enormous opportunity, but we’ll know more as this work continues over the next year or two.”



In The Classroom
Making Music Move





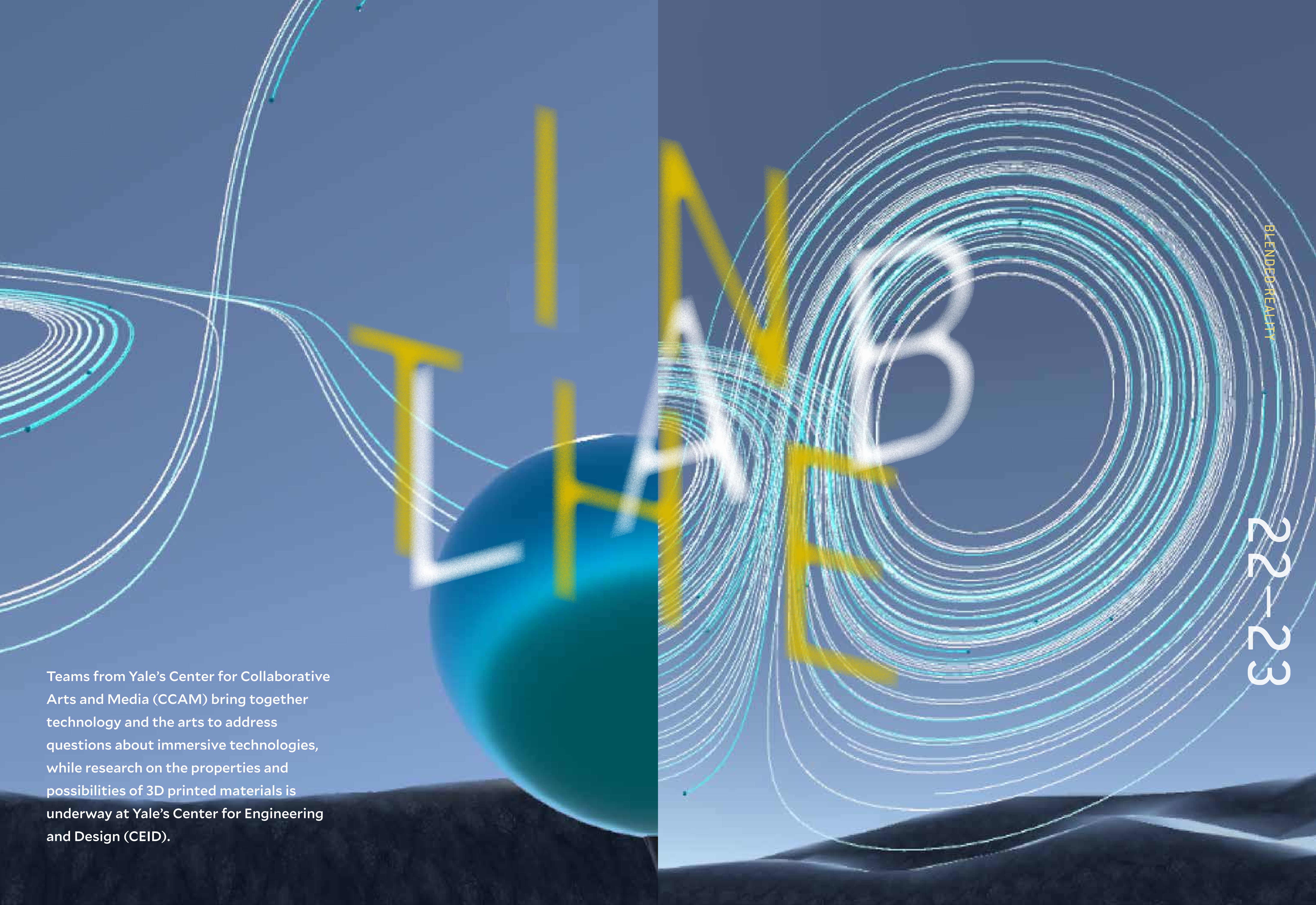
Musical instruments have come a long way since the Upper Paleolithic period — about 40,000 years ago — when the first modern humans blew into flutes crafted from bird bones. Today's music-makers have a vast array of woodwinds, brass, percussion, and strings that can be bowed, blown, struck, plucked, or shaken to create anything from jazz riffs to symphonies.

And they can also make interesting musical sounds by moving little wooden blocks across a visual field. This past year, Yale College students worked with Konrad Kaczmarek, assistant professor of music, in Yale's Music Technology Lab to experiment with ways to use technology for music making. "The question we were exploring," says Kaczmarek, "was how do we integrate tools associated with immersive technology — technology that blurs the line between the physical world and digital or simulated world — into music production, sound synthesis, and collaborative performance."

Using the HP Sprout immersive computing system, one group of students developed a way to make wooden blocks of various shapes trigger musical sounds, acting as a type of virtual music box. With the blocks placed on the Sprout's projection surface, the downward-facing camera read the blocks' positions, orientations, and shapes. The project was led by students Soledad Tejada (Yale College '20) and Tomaso Mukai (Yale College '19), with assistance from Nikola Kamcev (Yale College '19).

To enhance the visual appeal of the experience, the students used projection mapping — having the Sprout's projector overlay moving images on the blocks (for instance, making the semi-spherical ones resemble turning soccer balls). The controller, programmed in MAX (a visual programming language for music and multimedia), contains a moving electronic bar that acts as a timeline and sweeps across the objects, triggering musical sounds as it reads the location, shape and orientation of the blocks. The visuals projected onto the blocks also changed with the timing of the music. Because the visuals are stimulating the sound, the musicians compose by moving the blocks around the Sprout's projection surface.

Kaczmarek is particularly interested in the interface between the aural and the visual. Outside of his work under the Blended Reality research program, he recently guided a senior composition students Jack Lawrence, in using the MAX program to create an immersive visual landscape composition featuring guitar, singers, piano, trumpet, and cello. Kaczmarek is interested also in how immersive technologies can be used to augment or contribute to collaborative music-making — for instance, a group working together remotely on the same musical project. Another focus is gesture-based music creation — using one's full physical presence as a way of controlling various aspects of sound. "These technologies are becoming part of our everyday lives," Kaczmarek says, "I'm glad to have enthusiastic students who want to test their possibilities for music creation."



Teams from Yale's Center for Collaborative Arts and Media (CCAM) bring together technology and the arts to address questions about immersive technologies, while research on the properties and possibilities of 3D printed materials is underway at Yale's Center for Engineering and Design (CEID).

In The Lab
Real Bodies In Virtual Spaces

reality," noted science fiction writer Philip K. Dick, "is that which, when you stop believing in it, doesn't go away." If everything that we know about what we call "reality" comes to us through our senses, how do we understand what happens when we enter virtual spaces, in which our sensory inputs are overtaken by digital interfaces? Furthermore, how do we make virtual reality (VR) spaces — which have been defined thus far primarily by the needs and interests of gamers — accommodating and accessible to a wide range of bodies and backgrounds? And how do we test the limits and possibilities of VR in order to bring critical faculties to bear as we test its possibilities and limitations?

Get artists and computer scientists working together. "By encouraging artists, designers, and others in creative fields to work with this technology," says Justin Berry, critic at the Yale School of Art and a core faculty member at Yale's Center for Collaborative Arts and Media (CCAM), "we are discovering its possibilities, edges and limitations as well as the cultural complications of using it."

In this year's iteration of Yale's Blended Reality Applied Research Project, two related endeavors are considering these issues. The Embodied Navigation team, headed by Johannes DeYoung, director of Yale's Center for Collaborative Arts and Media, focuses on creating a framework for developing alternative ways to navigate virtual spaces. The Multi-Sensory Perception team, headed by Berry, is exploring how our senses — specifically sight, hearing, and proprioception — interact with VR. In addition, students from a variety of disciplines (e.g., drama, sculpture, painting, computing in the arts) developed projects examining the meanings of representing the body in virtual reality While virtual reality technologies have become more accessible and affordable, the navigation mechanisms in virtual environments have been limited primarily to handheld input devices similar to game controllers.

That kind of model for navigating virtual space, while the industry standard, is also problematic, says Stephanie Riggs, virtual reality pioneer, founder of Sunchaser Entertainment, and a consultant to the projects. "One issue," she says, "is cognitive load – the number of elements used in working memory during a task. In immersive mediums, the process of entering an unfamiliar medium, navigating it through unintuitive mechanisms, and interacting with foreign controllers creates a heavy cognitive load." Another concern, says Berry, is that "in many ways, the controller, with its 'point and shoot' construction, is a gendered form of engagement that may not be welcoming or intuitive to a broad range of bodies, ages, and experiences."

For those not familiar with or comfortable with standard gaming input, VR navigation devices are not intuitively mapped to real world forms of locomotion and can be frustrating and disorienting. Currently, the industry lacks an intuitive, inexpensive navigation method that can be easily learned and accessed by those who are not oriented toward video games. The Embodied Navigation project involved building a simple mode of embodied navigation — using the body itself rather than traditional controller mechanisms — for VR in the Unity 3D game engine. The participant can engage in natural motions such as leaning forward and back to propel the body, stopping, and picking up objects. "Our research," says DeYoung, "is asking whether embodied navigation allows more intuitive user interaction in virtual environments, thus easier access and greater engagement."

While some research has been done on controllerless navigation through other devices such as boards and chairs, Riggs notes that most investigators tend to instruct users on how to navigate — thus skipping a key factor in effective human-computer interaction. "Learnability, or the ease with which a user learns a system, plays a major role in how user-friendly the system is," she says. "By prompting the users in advance, researchers missed the opportunity to learn whether the navigation methods are truly intuitive. We want to understand what happens naturally when someone enters an embodied navigation environment." Given the growing presence of VR in our lives — for example, the increasing use of virtual modeling in fields as diverse as architecture, medicine, meteorology, and military training — this kind of research has the potential for wide application.

Additionally, says Berry, "As we live in increasingly virtual environments, we need to develop a robust vocabulary for articulating what is real, what is not, and examine how we occupy both of those kinds of spaces and the spaces in between." In exploring how sight, sound (focused on immersive language learning) and proprioception interact with VR, the students involved in Multi-Sensory Perception created a series of artworks that examined physiological and psychological effects through a range of blended reality experiences.

The following is a selection of representative team projects:

EMBODIED MOTION

Jack Wesson (Yale College '19) and **Lance Chantiles** (Yale College '19) with **Johannes DeYoung**, **Justin Berry**, and **Stephanie Riggs**

Embodied Navigation research compares existing modes of VR navigation (game controller based) with a mode of controller-less embodied navigation, developed by the Embodied Navigation team at Yale. Results were tested within communities of self-identified gamers and non-gamers, evaluating navigation modes designed for joystick control pads, trigger-based teleportation, and controller-less embodied navigation. This research inquires whether embodied navigation allows virtual environments to function in more intuitive manners that allow easier access and engagement for non-gamers (inexperienced, less comfortable or experience). The results of this work are published in a white paper, "Evaluating Embodied Navigation in Virtual Reality Environments," for the 2018 IEEE Games, Entertainment, and Media conference in Galway, Ireland.

ARCHIVE

Valentina Zamfirescu (Yale School of Art '18)

Zamfirescu created a large sculptural object populated with avatars of herself. These representations are engaged in various activities, from the jocular to the somber. The viewer is moved through the space along with another character who is only partially visible and acts as the viewer's companion. Other sculptural objects also populate the space. The work investigates the relationship of a viewer to her/his portrayal in VR as well as to how the female form is represented in virtual worlds.

LINGUISTIC LANDSCAPE

Michael Costagliola (Yale School of Drama '18) with **Justin Berry**

This is part of a research project that seeks better ways for people to engage in immersive audio landscapes for the purpose of learning new languages. By replicating how we experience language in the real world, distributed through space and in a non-linear format, the project looks to help users gain an emotional and contextual understanding of a foreign language. Using embodied motion and a system that generates spatial audio, with visual cues to the location of sound, the project focuses on the auditory experience of virtual spaces rather than the more common visual experiences.

SEVENTY-FOUR LETTERS FROM HER

Yong Eun Ryou (Yale School of Art '18)

Seventy-Four Letters from Her is an anthology of letters between Yo-E and her alter egos. This virtual reality project begins with looking at the act of correspondence: writing a letter is a paradoxical experience in which your imagination creates a fictional presence of the person who is not there, and interacts with the tension between a void and trying to fill this void. Yo-E created an audiovisual landscape of the letters by adapting the soundscape set up by Justin Berry and Michael Costagliola to create a space where letters written by her alter egos are read aloud. Short videos float in the air and, as viewers go to investigate them, they are able to hear the poetic letters, recorded using binaural audio — a type of audio that replicates the way we hear sounds through the lens of our ears.

WHALE

Ilana Savdie (Yale School of Art '18) and **Antonia Robins Kuo** (Yale School of Art '18)

Ilana Savdie and Antonia Kuo created a heavy sculptural apparatus that attaches to a VR headset. To navigate the world, users must lift the unwieldy object and are able to move only in relationship to it. Inside the VR experience a whale-like creature moves as the participant moves, generating the feeling of moving a heavy, enormous character along with oneself. This work brings the tactile feelings of weight and gravity into the simulation, emphasizing the participant's cumbersome dependency on the VR apparatus.

GHOSTS

Bobby Berry (Yale College '18)

Berry's work begins in an entirely empty white world. Whenever the player moves through the space, a character is created based on the player's location. Over time the world becomes filled with bodies that act as a legacy or memory of everywhere the viewer has been, or multiple viewers have been. The experience is about building a world based entirely on one's own movement through it. The work is also about how virtual worlds and digital systems track movement and position — without asking permission — in ways in which we may not even be aware.

LIVING INSTRUMENT

Michael Costagliola (Yale School of Drama '18)

Costagliola set up a motion capture system to track the position of a series of baseball caps. By knowing where the hats are located in space, and using that information to control audio, users in the space become living instruments and can make music by moving around the room. Users control a single sound source, and by coordinating their movements they can spontaneously compose music together. This is a lot of fun! It is also the framework for a larger composition that Costagliola will present as his thesis project for his MFA in sound design.

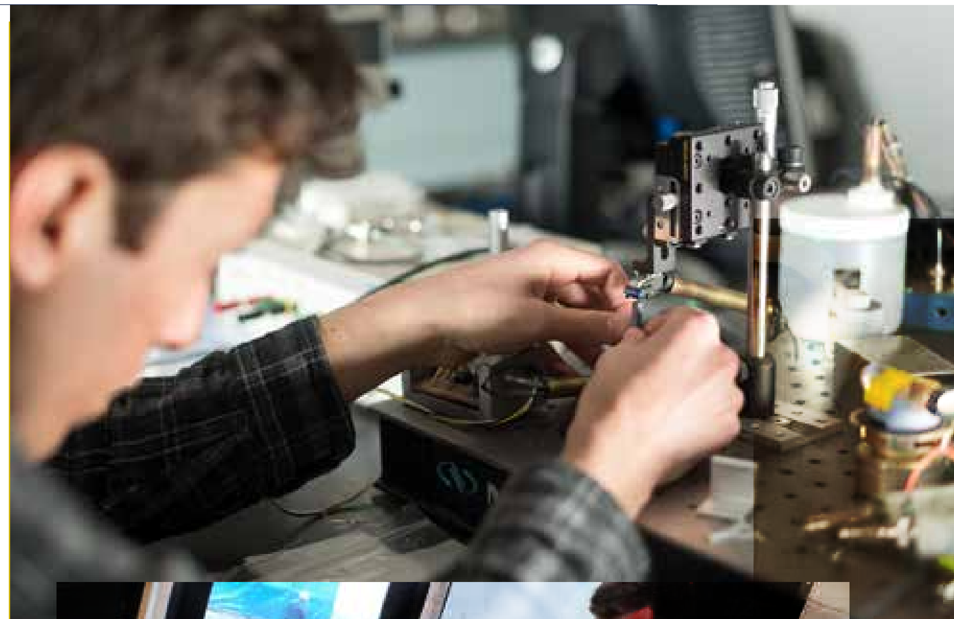
PALANTIR

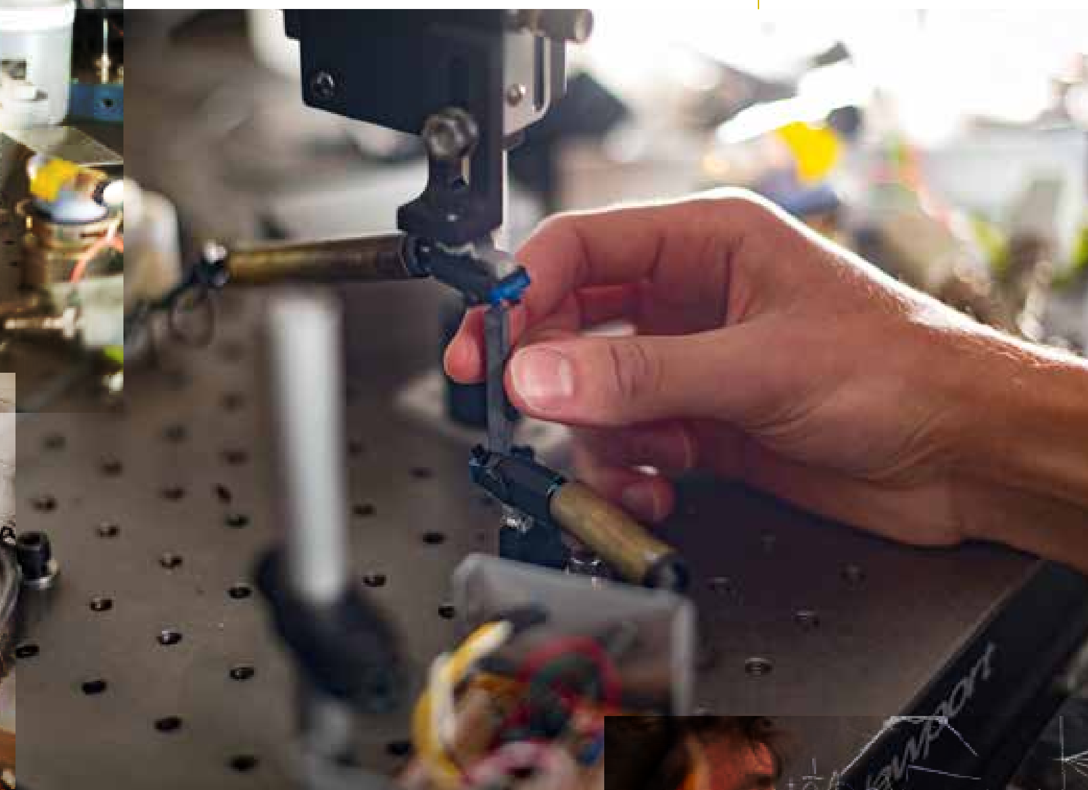
Jack Wesson (Yale College '19)

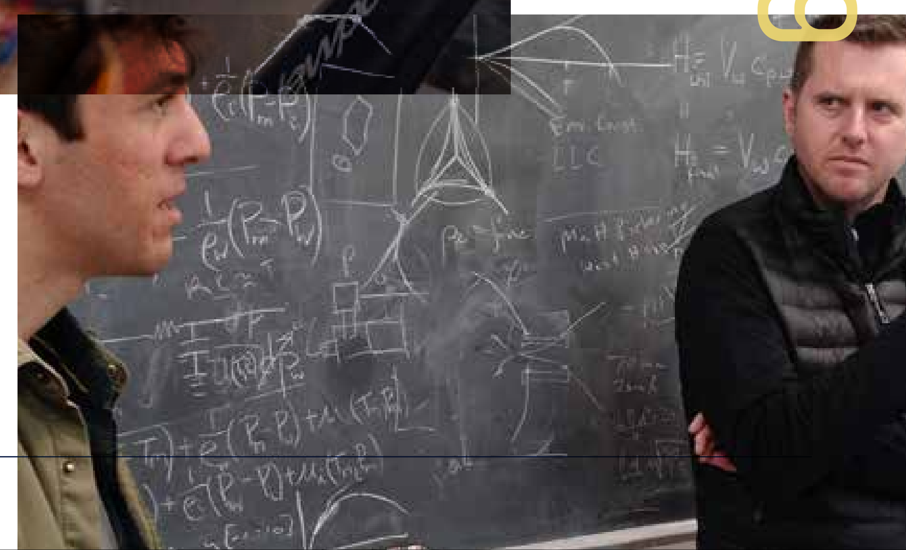
Wesson has created a way for viewers to have more empathetic VR experiences. Users begin in a blank work populated by a single character. A larger world is visible, but only by looking at/through the character, as if the character were a living screen. If users place their head inside the head of that character they can see the entire world as seen by that character. By discovering new people and matching their movements with one's own, and seeing through their eyes, the participant can see a world whose features and qualities are different depending on whose eyes provide the window. A child might see the world filled with color and movement, while a parent might see it as more subdued and static. The goal is to make users identify and connect with the people populating the virtual world in a more emotional way.

In The Lab

Good Vibrations







The 3D printer has come a long way since the introduction in the mid 1980s of the first devices that could print real physical objects using instructions provided by digital files. Today's models can create anything from toys and common household items to aerospace components and body parts, using materials that include epoxy resins, titanium, steel, wax, wood fibers, polycarbonate, nylon, and a wide range of plastics.

In a project called "Tuning Acoustic Resonance in 3D Printed Components," Larry Wilen, senior research scientist at the Yale School of Engineering and Applied Science, developed a method for exploring the mechanical properties—such as elasticity and density—of certain materials used in 3D-printing processes. Wilen, who teaches a course in acoustics and musical instrument design jointly with the Department of Music's Konrad Kaczmarek, explains that materials possess natural frequencies corresponding to motions such as bending, twisting, and compressing. Resonant ultrasound spectroscopy is an experimental technique used to measure these frequencies. "The measurements we took," he says, "could provide information about whether a given material would be suitable for various applications. For instance, if the material is used for making musical instruments or instrument parts—like a guitar bridge or a xylophone bar—the measurements would give information critical to tuning the instruments."

Existing acoustic techniques for measuring resonant frequencies tend to be inaccurate at the lower frequencies and therefore unsuited for the types of materials Wilen was testing. His process, which offers greater accuracy, uses inexpensive magnetic stereo phonograph needles to send sound through the material samples and then measure the mechanical responses.

While Wilen and Kaczmarek can use the musical applications of this technique in teaching their course, Wilen emphasizes that the information gleaned from resonant ultrasound spectroscopy also has significant engineering applications in fields such as aviation and construction. When companies such as New York's Mass Transit Authority explore 3D printing to meet their replacement parts needs, test protocols to verify material quality are an important consideration. The types of measurement work Wilen is pursuing will help build a basis to ensure crucial 3D-printed components meet their designed strength and quality parameters.

In The Lab

Visualizing Math

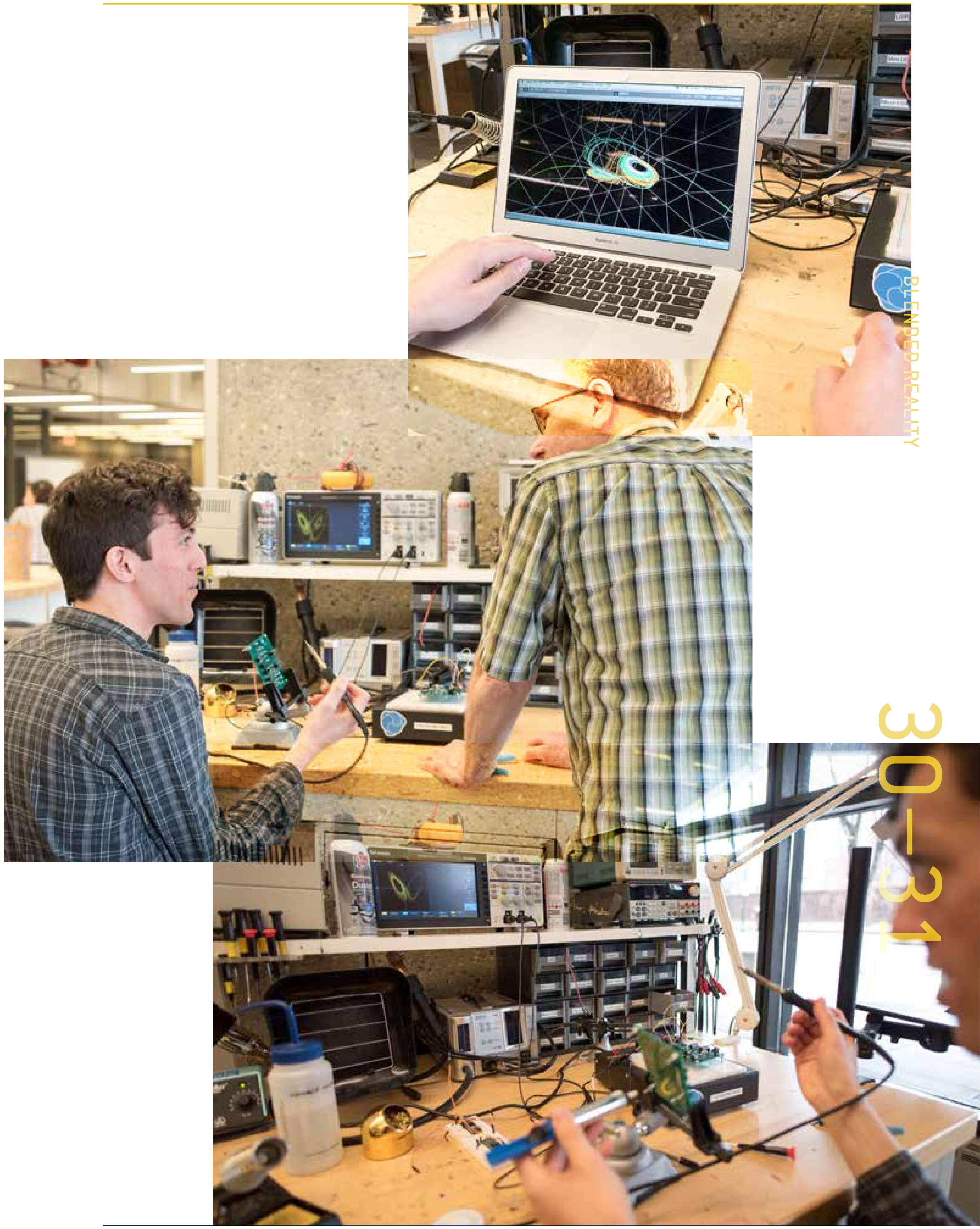
While searching for an equation that could provide a model for the unpredictable behavior of the weather, mathematician Edward Lorenz came up with the concept of the "butterfly effect"— the notion that an action as small as the flap of a butterfly's wing can dramatically influence future events. Lorenz found that, no matter how close to each other the initial meteorological conditions were, the model predictions would diverge at an exponential rate. His discovery led to the development of chaos theory — the branch of mathematics that deals with complex systems whose behaviors are highly sensitive to slight changes.

Recent Yale College graduate Scott Weady, whose field is applied mathematics, wondered about the possibilities of using virtual reality (VR) to tell the story of chaos in the Lorenz system of equations.

"The Lorenz equations are a great tool for studying how the states of systems change over time," Weady says. Using mathematical models of atmospheric temperature variations (atmospheric convection), Weady rendered the equation solutions in VR, using Unity, the most common software for virtual reality development. The rendering produced an intricate structure known as a "strange attractor." Virtual reality allows users to interact with this mathematical structure in an intuitive way, exploring the geometric space and various phenomena common to the study of dynamical systems such as bifurcations (sudden qualitative changes in a system's behavior), instabilities, and sensitivity to initial conditions. "What I want to do with VR," Weady says, "is develop models that will allow someone to see the differential equations in action by sharing a three-dimensional space with the strange attractor and seeing how it responds to variations in parameters and initial conditions."

Weady thinks that VR has significant pedagogical potential to illustrate complex mathematical concepts in an intuitive and interactive way, and that the same techniques could be used to explore other mathematical models in areas including climate science, neuroscience, and fluid mechanics. "You don't need to know any math to be intrigued by these VR models," he says. "They illustrate the overall concepts and are just cool in themselves!"

Currently, Weady is working on developing the educational possibilities of the VR application, with the goals of making applied mathematics concepts accessible to those without formal training, and getting younger students excited about pursuing advanced mathematics.



IN THE WORLD

By forming partnerships with others exploring immersive technologies, Yale students and faculty enhance their own research and contribute to the field's ongoing and rapid transformation.

In The World
Building Connections
Beyond The
Campus

Spring break offers students an opportunity to decompress from the stress of mid-term exams and other academic deadlines. An especially cold and snowy winter in the northeast had many Yale students dreaming of an escape to warmer climates. This year's 2018 research trip to HP Labs in Palo Alto, California, offered that opportunity and a lot more to one administrator, three faculty, and three students involved in the Yale - HP Blended Reality research project.

HP Labs' Alex Thayer played host, helping the group connect with Silicon Valley product teams at Google Daydream and Intel RealSense, as well as arranging a full day of conversations with the HP Labs Immersive Experiences team. The trip agenda included a full day at Stanford University, sharing research insights at the Virtual Human Interaction Lab with teams at Stanford Medicine anatomy, instructional technology, and simulation lab areas. The goals of the trip were to expose the Yale faculty and student researchers to commercial development approaches; introduce them to the latest advances and successful applications of blended reality technologies; and, most important, help them build relationships and partnerships with other research/product development groups. By every measure, the trip was a roaring success.

The Yale team landed in San Jose at noon on March 19 and headed right off to meet with Intel's RealSense team. Our hosts, Brian Pruitt and Anders Grunnet-Jepsen, demonstrated the capabilities of the stereo depth cameras that are supported by a rich software development kit (SDK). Visual input is a technical challenge across the Yale teams. For instance, Yale Department of Music faculty member Konrad Kaczmarek often has students use hand gestures to control electronic music performances. At each of the stops, the Yale group shared highlights of their own work, helping Pruitt and Grunnet-Jepsen better understand the needs and opportunities within a higher education environment. To further the Yale team's research, Intel provided three of the RealSense D435 stereo depth cameras; the cameras were used by teams working over the summer on a range of experiments.

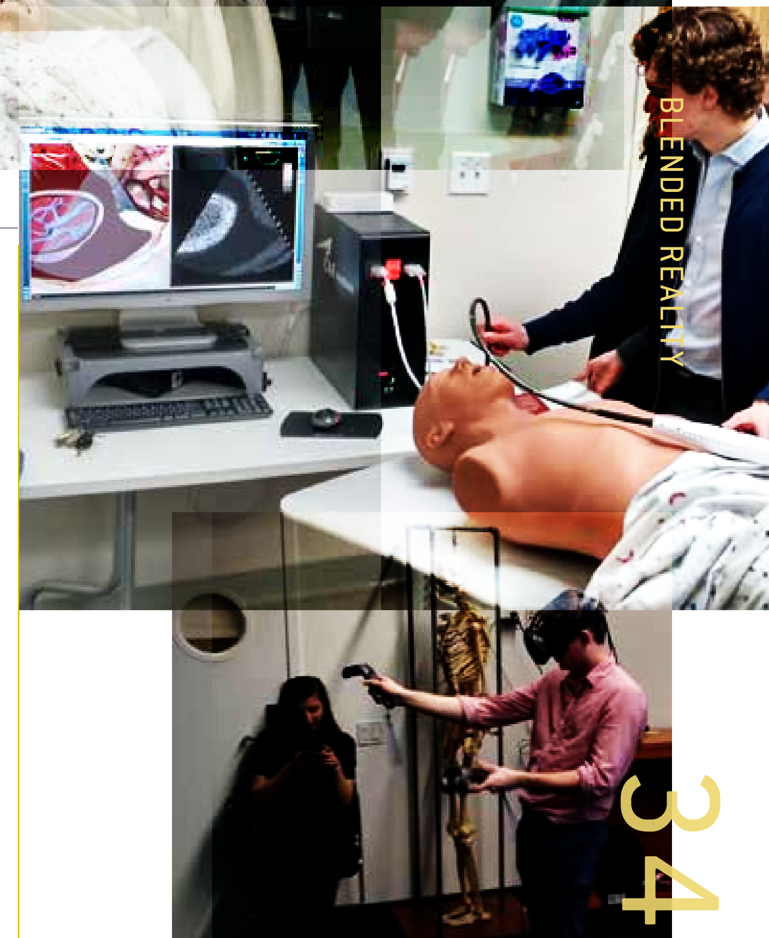
After a good night's rest, day two started at HP Labs. Alex Thayer, director and chief experience architect of the HP Immersive Experiences Lab, was joined by his colleagues Tico Ballagas, Alex Ju, Ji Won Jun, Hiroshi Horii, and Kevin Smathers. The Yale team included Justin Berry, Johannes DeYoung, Konrad Kaczmarek, and Randall Rode and students Lance Chantilly, Jack Wesson, and Valentina Zamfirescu. One of the research areas the Yale Blended Reality teams have explored this year focused on ways to make the user interface of virtual reality environments more intuitive and natural. Movement and interface within virtual environments typically requires the use of hand-held controllers, with little standardization across programs and apps; each app can require its own learning curve.

The Yale teams envision a future with standardized interfaces for virtual reality experiences, with a greater reliance on physical body movements rather than clicks of a controller.

Through the day's discussions we learned the HP teams have similar interests. A day of productive and informative conversations about these ideas ensued — conversations that will be continued over the coming year in a planned series of check-ins to share research findings.

Stanford University was our host for the final day's research visits. At the Human Virtual Interface Lab we viewed a range of their VR projects, including walking over a chasm on a virtual plank, feeling an earthquake's rumble in an emergency planning application, and having an embodied experience to empathize with the challenges of homelessness. Through several labs within Stanford Medicine the group discussed challenges in producing medical simulations, the delivery of virtual anatomy models within a classroom, and supporting online delivery of 3D teaching assets. Once again, the Yale team shared examples of their work, leading to engaging discussions with our Stanford peers and revealing a number of possibilities for new collaborations.

A college campus can be insular with everyone's head down in the day-to-day demands of the academic schedule. This Blended Reality team research trip offered an opportunity for team members to take a step out of the daily routine and gain a broader



understanding of the range of use cases and techniques being employed across the virtual, augmented, and 3D reality technology fields. New partnership opportunities were formed, and existing relationships were strengthened. What we learned on this trip is already influencing project outcomes and will continue to invigorate the research and project work over the coming year.

In The World
A Dive Into The Deep End

The Reality Of Global Climate Change

think back to your first junior high school dance: a lot of kids standing around looking at each other as the band plays. You want to dance, but are not sure how, don't want to look stupid in front of everyone, and really wish someone else would be the first one to step out onto the dance floor. A college campus can feel a lot like that junior high dance when faculty and students are curious about virtual, augmented, and 3D technologies, and intrigued by the possibilities, but unsure how to get started.

Our solution? Hackathon!

Hackathons are events where participants build technology projects—apps, programs, websites, etc.—to solve challenge problems within a set time limit. The final outcomes are judged, and prizes are awarded. Success often comes to cross-disciplinary teams with a range of skill sets. The events are intense, engaging, and a lot of fun.

The challenge of effectively communicating the impact of global climate change is a good fit for the types of immersive experiences possible in virtual and augmented reality. And that topic would prove to be a draw for student and faculty, environmental scientists, data engineers, creative writers, visual artists, media producers, and others. For our first time planning a hackathon, we figured that attracting 20–30 participants would be considered a success. But as our speakers took the stage of February 9, 2018, at the opening meeting of the hackathon weekend, over 60 people sat in the audience, ready to create mixed reality experiences from climate change data: an overwhelming response to what would end up being a fantastic event.

A broad range of partners came forward to help with the hackathon. Providing expertise on climate change were people from Yale organizations—Center for Climate Change Communication, Data Driven Yale, and the Center for Business and the Environment. Staff from Climate Watch were also on hand to help teams and provide data sets. Technical expertise came from Yale's Information Technology Services and Center for Collaborative Arts and Media. Technical staff from local New Haven software developer Spheregen and Microsoft's mixed reality team were also on hand. Logistical and financial support came from Yale TSAI CITY, Connection.com, and Microsoft. Much of the hackathon's success is owed to these contributors.

Ten teams of students and faculty formed during the Friday evening kickoff. They started work on selecting a climate change challenge/dataset and planning their approaches. Most teams used the Unity game engine as their development platform, rendering the project to play within a Vive or Hololens headset. A few participants attended a quick start Unity boot camp on the Friday afternoon preceding the hackathon. Others relied on guidance from the roaming technical mentors. As breakfast was served on Saturday morning, teams began creating their projects, working through the day until judging started at 5:00 pm.

The main goals of the event were to get Yale faculty and students excited about the possibilities of mixed reality technologies and to experience how these technologies could be used to communicate ideas. As the hackathon teams gave their final presentations on Saturday evening, we knew we had achieved those goals. Every












team had impressive 3D experiences to demonstrate, with every member of each team engaged in the creation process.

One example: the winning team created an experience called “Climb-it” (pun intended). The “Climb-it” virtual reality environment was set inside a giant water tower. At the start, water was flowing from pipes in the ceiling, each pipe representing one of five countries, at rates proportional to the level of annual greenhouse gas emissions from each country. The player would staunch the flow of water from each pipe by selecting a map of the country from the ground, climbing up the side of the tower, and stuffing the country map into the corresponding pipe. While climbing the player heard a narrative of climate change impacts from that country drawn from current news reports. The judges felt the overall experience put the audience inside the climate change data in a playful and engaging way, using the immersive qualities of mixed reality to build a memorable user experience.

The best indicator of the success of this type of activity is whether you would do it again. The overwhelming response from our support team, sponsors, and participants was not if, but when. Planning is already underway for a repeat experience next year.



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PROJECT MANAGEMENT
Miriam Schroers, Information Technology Services

PROGRAMS MANAGER
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Stephanie Riggs, Virtual Reality Pioneer, Founder of Sunchaser Entertainment
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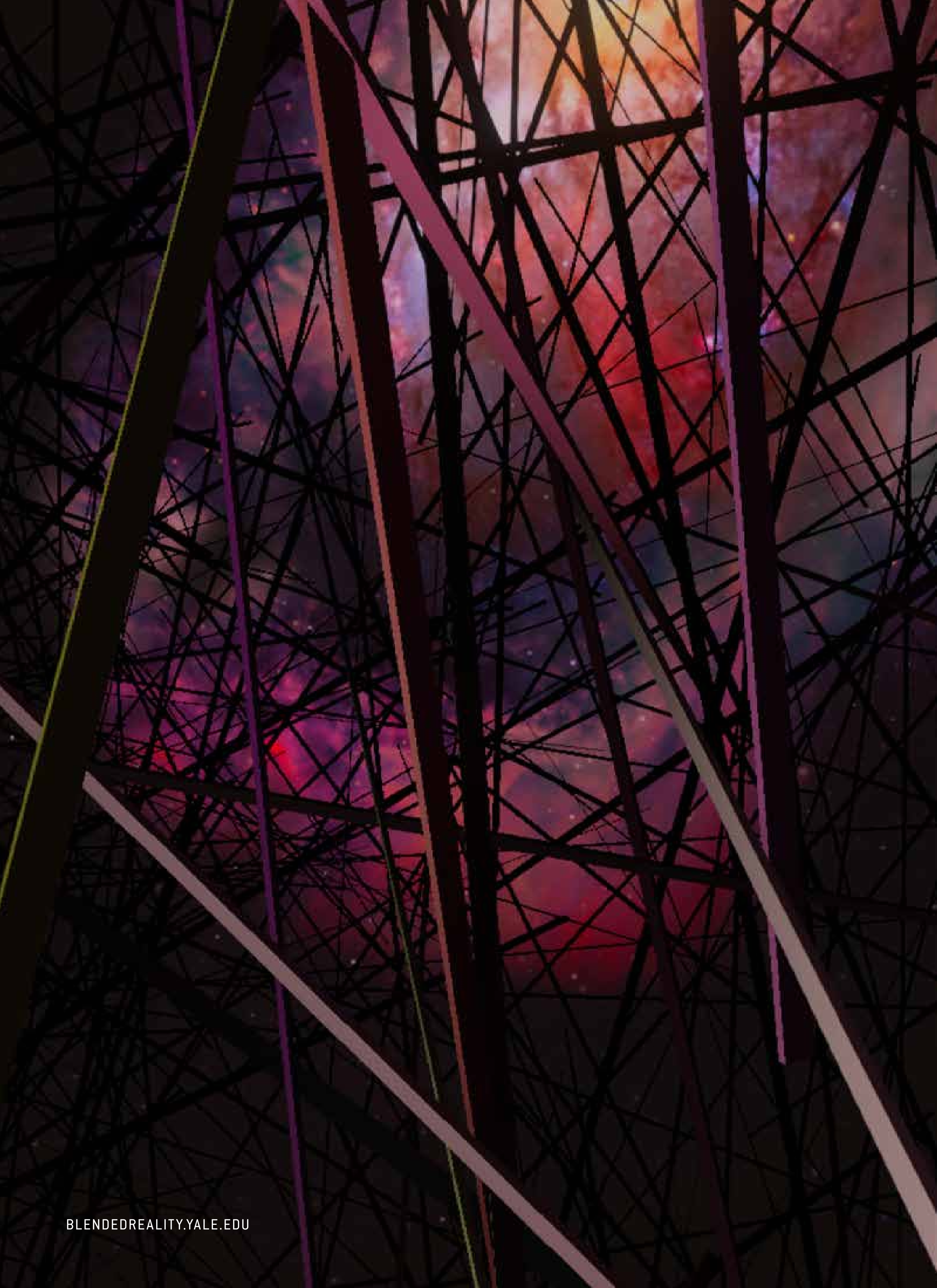
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