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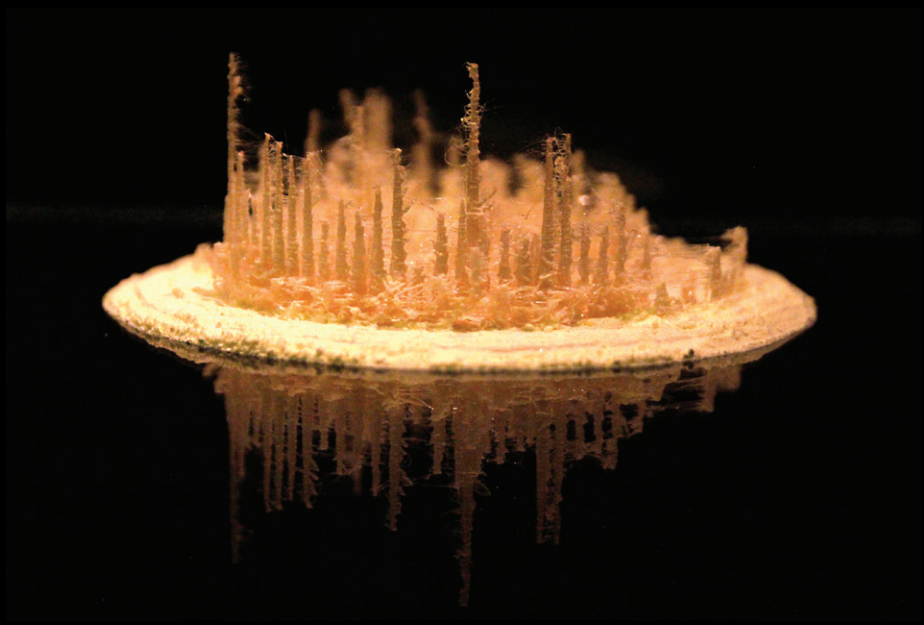

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VOLUME 50 | NUMBER 4 | 2017

LEONARDO SPECIAL ISSUE

SIGGRAPH 2017 Art Papers
and Unsettled Artifacts Art Gallery

ART PAPERS

UNSETTLED ARTIFACTS ART GALLERY

Front Cover
Creature:Dot and the Kangaroo performance, 2015. (A Stalker Theatre & Out of the Box Production. Photographer: Darren Thomas.)

Back Cover
Paul Rosero Contreras, *The Andean Pavilion*, Stornato version I / Someday somehow, A/P, 2015. (© Paul Rosero Contreras / Dos Islas Studio)

ACM SIGGRAPH Distinguished Artist Award for Lifetime Achievement in Digital Art

Ernest A. Edmonds

Ernest A. Edmonds. (Photograph © Linda Candy)

The 2017 ACM SIGGRAPH Distinguished Artist Award for Lifetime Achievement in Digital Art is awarded to Ernest A. Edmonds, who is well known as a major contributor to the development of computational art and has contributed to the broader field of art history from the late 1960s to the present day.

His work represents an important landmark in the field of generative and interactive art. By applying color theory, computational logic, and programmed systems to his work, Edmonds brought together the structural research of Biederman and the Constructivists for the first time and took them to a new, previously unexplored level that encompasses notions of time, color, and structure, as explored in such video constructs such as *Fragment* (1985), *Jasper* (1988), and *Sydney* (1989). His interest in interaction developed even further in recent years, as demonstrated by his *Shaping Forms* series (2007–), a series of generative and computational works where images are constantly generated by a computer program that decides which colors, patterns, and timing the work should display at any given moment. The movement in front of each work is detected by a camera and produces changes in the image, shape and duration, so that the environment, the active spectator, and the work influence each other. Here, interaction is intended as an exploration of long-term influences rather than short-term reactions.

Ernest Edmonds is also an international expert on human–computer interaction specializing in creative technologies for creative uses. His record of achievement in the field of interdisciplinary research is long and distinguished particularly in fostering the development of HCI since 1970: in 1982, he founded the Human Computer Interface Research Unit (HCIRU) at Leicester Polytechnic and later, in 1986, the Loughborough University of Technology Computer Human Interaction (LUTCHI) Research Centre. In 2003, he established the Creativity and Cognition Studios (CCS) at the University of Technology, Sydney, and is now Professor of Computational Art and Director of the Institute of Creative Technologies (IOCT) at De Montfort University, Leicester.

Digital technology has enhanced and stimulated Edmonds's creativity. By writing code to create his art since the 1960s, works such as *Fragment* and *Sydney* illustrate how the constructivist concepts developed through the use of video tape, creating a kind of computer-generated film; other works, such as *Rotterdam A* and *Rotterdam B* (1989), exemplify a kind of digital art that is more aggressively generative in nature, owing to digital technology and the possibility to run a program virtually indefinitely.

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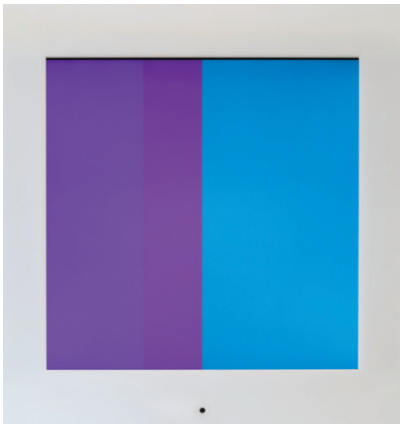

Figure 1. Ernest Edmonds, *Shaping Form 14/5/2007*, 2007. Museum no. E.294-2011. (© Victoria and Albert Museum, London/ Ernest Edmonds)

Figure 2. Ernest Edmonds, *Shaping Space*, installation at Site Gallery, Sheffield, 2012. (© Francesca Franco/Ernest Edmonds)

The "digital" gave generative art new possibilities and brought therefore new thoughts and opportunities to Edmonds's creativity, allowing him to generate a system through which the artwork has a life of its own where color is selected, manipulated, and changed with no restrictions of time. This represents an important step in the generative art field, the consequences of which are still being explored.

The advances in research and education to which Edmonds has contributed from the late 1960s to the present have offered great opportunities for interdisciplinary exchange and ideas that have had a profound impact in the international arena of digital art. They include his work in promoting practice-based research in the interactive arts. These dynamic ways of exploring creativity are a constant stimulus in Edmonds's work both as an artist and as an academic.

He was Editor of Transactions, the fast track section of *Leonardo,* and is an Honorary Editor of the journal. He is a member of the Editorial Board of Digital Creativity and Founding Editor of the international Elsevier journal *Knowledge-Based Systems*. His publications include more than 300 books and papers. Art historian Francesca Franco has recently written a monograph centered on his work, *Generative Systems Art*: *The Work of Ernest Edmonds* (Routledge, 2017).

His latest solo exhibition, Constructs, Colour, Code: Ernest Edmonds 1967–2017, was on view at The Gallery, De Montfort University, Leicester in 2017.

ACM SIGGRAPH is honored to recognize Ernest Edmonds as an important pioneer in generative and interactive art.

Sue Gollifer

CHAIR
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Julieta Aguilera
Planetary Collegium
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Julieta Aguilera studied design at the Architecture School of the Universidad Católica de Valparaíso, Chile. She holds an MFA in graphic design from the University of Notre Dame and an MFA in electronic visualization from the University of Illinois at Chicago. For the past decade she has worked as the Associate Director of the Space Visualization Laboratory at the Adler Planetarium and as faculty at Academy for Creative Media at the University of Hawai'i at Hilo.

Angus Forbes
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Angus Forbes leads the Creative Coding Research Group at the University of Illinois at Chicago. He is an Assistant Professor in the Electronic Visualization Lab within the Department of Computer Science and also has a courtesy appointment in the School of Art and Art History. Forbes's research investigates multidisciplinary topics related to the fields of information visualization, computer graphics, and human-computer interaction; his artwork, performances, and multimedia installations have been shown throughout the world.

Jon McCormack
Professor, Faculty of Information Technology
Monash University, Australia
Jon McCormack is an Australia-based artist and researcher in computing. He is currently full Professor of Computer Science and director of sensiLab at Monash University in Melbourne. His research interests include generative art, design and music, evolutionary systems, computer creativity, visualization, virtual reality, interaction design, physical computing, machine learning, L-systems, and developmental models.

Eitan Mendelowitz
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Department of Computer Science
Mount Holyoke College, U.S.A.
Eitan Mendelowitz's work is situated at the intersection of computer science and the arts. Mendelowitz creates data-driven interactive media art, real-time media for performance, and public art installations. His transdisciplinary practice blends performance, installation, and generative literature, with embodied interaction, physical interfaces, sensing, data science, and artificial intelligence. Mendelowitz has contributed to permanent architectural-scale public artworks and is currently working on the Global Proverbs Project, an aesthetically motivated digital humanities research initiative.

Savannah Niles
Senior Researcher, HCI Lead
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Savannah Niles is a senior researcher at Magic Leap where she leads the Human Computer Interaction group within the User Experience team. She graduated in 2015 from the Viral Spaces group at the MIT Media Lab and has designed interactive experiences for Samsung, Twitter, Walt Disney Imagineering Research and Development, and Bloomberg. Her expertise and interests center on technologies that live quietly and meaningfully between the solid world and a softer one.

Jennifer Parker
Chair, Art Department
Associate Professor, Digital Arts & New Media MFA Program
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University of California, Santa Cruz, U.S.A.
Jennifer Parker is Associate Professor in and Chair of the Art Department at the University of California, Santa Cruz. Parker is the founding Director of UCSC OpenLab Research Center and serves as principal faculty for the Digital Arts & New Media (DANM) MFA program where she directed the Mechatronics collaborative research cohort from 2009–2015, developing research projects that combine art, design, science, and technology. She is the recipient of several grants, awards, and fellowships, including Artworks NEA, Art Matters, the New Forms Regional Grant administered by the Inter-Arts Program of the NEA, the New Jersey State Council on the Arts, and the Kate Neal Kinley Memorial Fellowship.

Ruth West
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Art Papers

Introduction

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Ruth West

SIGGRAPH 2017 Art Papers is the ninth joint publication by ACM SIGGRAPH and Leonardo/ISAST of this special journal issue. This ongoing collaboration fosters a lively dialogue that bridges topics at the heart of SIGGRAPH—the intersection of computer graphics and interactive techniques, with topics central to artists' endeavors at the leading edge of digital culture that provide an additional dimension to artists' voices. Coinciding with the SIGGRAPH conference, and given its accelerated publication timeline, this annual special issue is a unique opportunity for artists to reveal the motivations, thought processes, inspiration, and methodologies behind their work. It reflects the myriad ways in which artists make contributions to their respective genres, build novel communities of practice, and affect the evolution of global culture.

This year's issue contains six papers selected by an international jury of scholars, artists, and developers of immersive technologies from more than 50 submissions from 15 countries. Authors submitted papers to an open call for Art Papers in four categories (project description, theory/criticism, methods, and history) and in response to the theme of artists' contributions to virtual, augmented, and mixed reality. The theme acknowledges the current renaissance of these technologies and their role in emergent digital culture and serves to recognize the role of artists in pioneering these technologies and their use as an expressive medium within the broader context of computation as a cultural force. Topics in this year's Art Papers include storytelling via large-scale mixed-reality interaction; reinterpreting films through machine learning; the impact of generative cinema; redefining lenticular stereography as animation in cylindrical form; mechatronic light field photography; and a media archaeological exploration of the birthplace of the virtual reality CAVE.

A six-member jury working together with 17 tertiary reviewers collectively represents a spectrum of expertise, including digital and interactive art; virtual, augmented, and mixed reality; artificial intelligence; natural language processing; museum and art education; human–computer interaction; performance; data art; mechatronics; sound art; computer graphics; haptics and more. The selected papers are the result of an extensive and rigorous two-round jury and tertiary review process that also included feedback from the *Leonardo* editors. Additionally, 2017 marks two firsts for the Art Papers program: the initiation of a Best Paper Award and the inclusion of a representative selection of art papers to be previewed as part of the Technical Papers Fast Forward session. Participation at the Fast Forward session not only enhances the visibility of the program but also provides recognition of its scholarly contributions. The Art Paper Award recognizes excellence in contributions to the literature on digital arts, computer graphics, and/or interactive techniques.

I'm honored to have served with so many talented and dedicated colleagues who contributed to this year's Art Papers program and special issue. I would like to extend special thanks to the members of the jury—Julieta Aguilera, Angus Forbes, Jon McCormack, Eitan Mendelowitz, Savannah Niles, and Jennifer Parker—and the tertiary reviewers—Hisham Bedri, Jeff Burke, Blanka Domagalska, Vince Dziekan, Angela Ellsworth, Esteban García Bravo, Toby Gifford, Yoon Chung Han, Haru (Hyunkyung) Ji, Jennifer Kanary, Dmitry Kmelnitsky, Hye Yeon Nam, Mitchell Polin, Karen Stolzenberg, Timothy M. Stutts, Daria Tsoupikova, and Graham Wakefield—for their dedication and excellent work in selecting the papers for presentation/publication and shepherding them through the editorial process. Thank you also to my colleagues on the SIGGRAPH 2017 conference committee for their inspiration and the joy they bring to all of the planning and preparations for the conference, the SmithBucklin Conference Administration team, *Leonardo* editors, and the Q LTD design team. Without all of your dedication and tireless efforts, this publication would not be possible. Thank you to all of the contributors to the SIGGRAPH 2017 Art Papers program for sharing your work with the ACM SIGGRAPH and Leonardo communities.

Ruth West is an artist-scientist and creative technologist bridging big data, visualization, sonification, virtual and augmented reality, 3D fabrication, and social and mobile media with domains such as neuroscience, genomics, astronomy, urban ecology, microbiome, live performance, entertainment, and digital remix culture. She creates works with multiple entry points that can exist concurrently as aesthetic experiences and cultural interventions or serve as the basis for artistically impelled scientific inquiry and tools. West is the Chair-elect of LEAF, the Leonardo Education and Art Forum, and is an Associate Professor and Director of the xREZ Art + Science Lab at the University of North Texas where she is cross-appointed in the College of Visual Art and Design, College of Engineering, College of Information, and College of Arts and Sciences. Her work has been presented internationally in museums, festivals, and publications including MONA (Museum of Old and New Art), Los Angeles Municipal Art Gallery, FILE 09 São Paulo, SIGGRAPH, *Wired* magazine's NextFest, Perot Museum of Nature and Science, the Fowler Museum at UCLA, IEEE Visualization, IS&T/SPIE The Engineering Reality of Virtual Reality, *Leonardo*, and the Proceedings of the National Academy of Sciences of the United States of America.

Unsettled Artifacts: Technological Speculations from Latin America Art Gallery

Introduction

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Paula Gaetano Adi

The beauty of artifacts is that they take on themselves the contradictory wishes or needs of humans and non-humans.
—Bruno Latour

Artifacts are the objects that we (humans) make and use. They are products of human activity, yet they continuously shape us. They frame the ways we act in the world, as well as the ways we think about the world. But technological artifacts have another property: they illuminate possible worlds. They not only can describe our "real and constructed" present (and past), but also allow us to speculate about our future, while embodying the anxieties of our own human, nonhuman, and post-human existence. Particularly, when in the hands of artists and designers, technology has been the ultimate ingredient for materializing our deepest utopian and dystopian dreams; it has always been the element that initiated debates and thoughtful reflections about the worlds we might wish to inhabit—or elude.

For the past 35 years, the SIGGRAPH Art Gallery has presented technological and scientific artifacts produced by artists from around the world and has witnessed the evolution of technological development and the transformation of cultural production that it has influenced. Since the early 1980s, SIGGRAPH has been one of the few venues to consistently exhibit speculative artifacts for critical inquiry brought about computer technology. So, one could argue that a historical analysis of the Art Gallery can indeed expose the anticipatory nature of art in helping us to imagine new worlds.

The motivation for the 2017 Art Gallery was, in fact, not only to examine the current state of art, science, and technology, but also to return a sense of "agency" to these technological artifacts and to help us recognize that we all make the choices that create the future. Therefore, convinced of the power of the poetics of technological speculation, and with the intention of mapping the ground on which we can imagine alternative futures, the Art Gallery traveled south in order to exhibit works of art produced outside the traditional centers of industrial and technological development, by artists living and working in Latin America.

Uncertain. Agitated. Discontented. Disobedient. Unstable. Troubled. The Latin American "artifact" has been, above all, an "unsettled" object of study: other, minor, peripheral, mestizo, hybrid, magic, anthropophagic, syncretic, cosmic, postcolonial, decolonial, and so on. It is enough to see its various characterizations in recent decades to prove the impossibility of reducing the Latin American artifact to a single, homogeneous identity—simply because the idea of Latin America as a geohistoric category is in itself an "unsettled" concept [1]. However, and despite the contradictions that the idea of Latin America embodies, it allows us to consider technology-based artistic practices that have been underrepresented, excluded, or ignored in the hegemonic narratives of technological development and to share new knowledge and ideas about how Latin American artists create, adapt, and use technology within a rich cultural context shaped by long histories of imperialism, colonization, and the asymmetries of globalization [2].

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Unsettled Artifacts: Technological Speculations from Latin America is, then, an attempt to recognize the value of a plural world of arts and sciences and to reclaim art's longing for new social narratives, new forms of sociability, and new images of the possible at a time in which the so-called "global" technologies play a central role. Shifting our focus to the non-Western world in the context of the largest international conference on computer graphics and interactive techniques is a way to acknowledge that technology "acts" and "speaks" [3], and that it remains a contested and performative arena used by artists to critically engage our everyday lives.

The works selected for the Art Gallery represent only a small sample of the vast and diverse creative practices developed in Latin America. They do not pretend to be a survey but a focused critical consideration of 10 contemporary artworks using a disparate array of digital technologies and computational media, from bioart and robotics, to software simulation and VR; from performance and screen-based work, to sound installations and 3D-printed sculptures.

Mexican artist Gilberto Esparza has created a hybrid music synthesizer and sound device that cleans polluted water. The *BioSoNot 1.2* makes use of microbial fuel cell technology to produce electricity, generate sound, and improve the quality of water. This bio-instrument is part of Esparza's longstanding trajectory using recycled electronics and microbial life to create symbiotic systems that propose alternative forms of energy while questioning the impact of humans upon the environment. Likewise, *Milpa Polímera*, by Mexican artists Marcela Armas and Arcángelo Constantini, is also a hybrid of sorts; but unlike Esparza's work, this installation presents an artificial and futile crop-growing system in which life will never be able to grow. Part seeding machine, part 3D printer, this work is inspired by the conflicting relationship between the market-driven economy of corn and its deep symbolic and cultural values in Mexico. The installation consists of a tractor that swivels in a closed cycle while repeatedly 3D-printing infertile maize seeds made out of PLA, a thermoplastic derived mostly from genetically modified maize starch. *The Andean Pavilion*, by Ecuadorian artist Paul Rosero Contreras, also uses 3D printing technology to create a series of geologically inspired sculptures that capture the vibrations of four active volcanoes in South America. Working as a field geologist, the artist used custom software and hardware to interpret the immaterial seismic activity of the volcanoes into three-dimensional matter in order to poetically reflect on the vital power of material forms and the ability of natural nonhuman forces to shape the anthropocene.

Blurring the boundaries between human, animal, and machine, the *Echolocalizator*, by Colombian artist Hamilton Mestizo, is a device created to transcend our human modes of perception and to become part of a cybernetic-hybrid system. The *Echolocalizator* is a wearable sonar headset that deprives the users of sight while forcing them to experience a virtualized reality guided by sound waves and echoes. *Octópodos Sisíficos* (*Sisyphean Octopods*), by Argentine artists Mariela Yeregui and Miguel Grassi, is a series of six "futile" robots whose only goal is to carry small screens that reveal their own technological animality. Essentially passive, these robots are not able to detect the environment or to immediately react to it; they merely crawl around the gallery space, calling into question the nature of their existence, and with that, our own expectations of an "intelligent" machine.

Brazilian duo Gisela Motta and Leandro Lima created *Anti-Horário* (*Counterclockwise*), a digital wall clock that attempts to express the anxieties engendered by the experience of time and duration. A disorienting video, the clock's face represents the earth, while its hands are humanized—a child represents the minutes, an adult couple the hour. An endless loop and a philosophical proposition on the passage of time, the cycle of life, and our brief duration on earth.

Cuban artist Rodolfo Peraza takes a similar poetic license to create a paradoxical immersive environment inside different architectures of control. His work *JailHead.com* is an online virtual reality environment in which the viewer is able to navigate the abandoned Cuban Presidio Modelo, constructed as the ultimate panopticon prison for disciplinary surveillance. A tactical intervention using the internet's inherent monitoring technology and videogames' potential to create highly realistic fictional worlds, *JailHead.com* submerges us in a provocative and stifling embodied experience generated by modern artifacts utilized for social control and engineering.

Chilean artist Christian Oyarzún creates a different sort of immersive sensorial experience, one shaped by the signal transduction of sound into light. His *drumCircle[]* is a set of eight autonomous machines, each consisting of a den-den pellet drum and an impact floodlight reflector, that trigger an aleatory behavior of loud and rhythmic shadows and sounds. In *Dispersiones (Dispersions)*, Argentine artist Leo Nuñez also uses makeshift technical devices to transform the gallery into an immersive environment comprised of about 400 relays distributed in the space. The work is a sonic interactive matrix that utilizes the simple binary behavior of these electromagnetic switches to generate a complex system activated by the presence of the viewer.

Lastly, the Astrovandalistas transnational collective (Leslie García, Rodrigo Frenk, Thiago Hersen, and Andrés Padilla Domene) will open an office in the Art Gallery where they will engrave "futureglyphs" into rocks and debris collected from the Greater Los Angeles area. In a new iteration of their ongoing project *Imaginario Inverso (Reverse Imaginary)*, the artists will exhibit their disruptive laser machine and collaborate with SIGGRAPH attendees in writing predictions about the future of LA, SIGGRAPH, the geopolitics of technology development, and other speculative micronarratives.

The history of digital and media art in Latin America is as long as that of the United States and Europe. Therefore, as a supplement to this introduction, we have included an essay by art historian and scholar María Fernández, who briefly traces this history, providing some points of entry to better understand the interrelations of Latin American art and modern technologies. In and of itself, *Unsettled Artifacts: Technological Speculations from Latin America* is only a provisional crack in the history of the SIGGRAPH conference. It isn't a comprehensive synthesis or theoretical overview, but an invitation to consider technology as an artifact for critical inquiry. It is an attempt to reconsider the conditions and forms of making beyond the canon; uncover multiple global narratives; analyze other omissions; reimagine possible worlds; and catalyze new and productive conversations across the Americas.

Acknowledgments

It has been extremely gratifying to work on this exhibition, and I extend my sincere appreciation to all of the artists for their vision and inspiring work; to María Fernández for the significant contribution of her essay; to subcommittee member Alejandro Borsani; to the SIGGRAPH 2017 Conference team; and to Jerome Solomon for his continued support and trust. I would also like to thank the teams that made the exhibition and publication possible: SmithBucklin, Freeman, Q LTD, and the *Leonardo* team. The combined collaboration of all of these people has been instrumental in producing this unique edition of the annual SIGGRAPH Art Gallery.

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Creature:Interactions: A Social Mixed-Reality Playspace

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ABSTRACT

This paper discusses *Creature:Interactions* (2015), a large-scale mixed-reality artwork created by the authors that incorporates immersive 360° stereoscopic visuals, interactive technology, and live actor facilitation. The work uses physical simulations to promote an expressive full-bodied interaction as children explore the landscapes and creatures of Ethel C. Pedley's ecologically focused children's novel, *Dot and the Kangaroo*. The immersive visuals provide a social playspace for up to 90 people and have produced "phantom" sensations of temperature and touch in certain participants.

Creature:Interactions (2015) is a large-scale mixed-reality artwork that incorporates immersive visuals, interactive technology, and live actor facilitation to promote full-body movement and social play. The artwork is set in an animated Australian bush landscape that is magically conjured to life by the full-bodied movements of the participants. Participants interact with a range of native Australian animals including koalas, kangaroos, wombats, birds, and lizards represented as giant line-drawn "totem" creatures (Figure 1) and photographic particle clouds that morph and dissolve in response to movement. It features a full 360° interactive visual display that can be presented in 2D or stereoscopic 3D and paired with multichannel audio to create a highly immersive experience that can be enjoyed by audiences of up to 90 people simultaneously. The work transports the audience to a number of Outback locations and simulates environmental events such as bushfires and rainstorms before ascending to the virtual treetops to interact with the moon and night stars.

The work that we created is an interactive companion piece to the *Creature:Dot and the Kangaroo* [1] physical theater show inspired by Ethel C. Pedley's classic Australian children's novel [2] in which a little girl, Dot, is lost in the bush and befriends a mother kangaroo. The kangaroo gives Dot some magical "berries of understanding" that give her the Doolittlian ability to talk with the animals, and she embarks on an ecologically driven journey to understand humanity's negative impact on the natural environment. The interactive installation allows the audience to interact with the creatures and inhabit the digital world presented in the theater show. The experience begins without sound or projections, and as the audience traverses the seemingly empty space, digital particles are created from their movements, and the virtual bushland slowly emerges from the interactive floating particles. The magical shift from a disappointingly empty space to a fully fledged natural landscape through embodied interaction represents the eating of the berries and puts the audience into a state of "understanding" where they can begin their own transformative journey. Mirroring the surreal juxtaposition of real human participants with the surrounding virtual environment, the oversized interactive animals appear to possess a magical presence, simultaneously at one with their animated environment while exuding an almost-alien presence. The embodied interaction with these creatures physically echoes the relationship that human beings have with their own natural environment.

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Figure 1. Participants can manipulate giant bird "totems" with their movement in *Creature:Interactions*. (© Stalker Theatre. Photo: Andrew Bluff.)

The Aesthetics of Interaction

The way that it interacts with the audience is a crucial part of its essence. The core of the art is in the work's behavior more than in any other aspect. —Ernest Edmonds, on interactive art [3]

As its title suggests, *Creature:Interactions* is in essence an interactive artwork. The work features an embodied interaction between the human and the virtual. It also promotes social interaction among the participants as they try to make sense of this mysterious digital world. As a shared mixed-reality playspace, both types of interactions have equal importance, and the "creature" in the title refers to both the virtual interactive characters and the animalistic, social human participants.

Seminal interactive works with a focus on expressive audio-visual interaction include David Rokeby's *Very Nervous System* [4], which translated the movements of a single performer into complex and nuanced sounds. The audio-visual performance work *Messa di Voce* [5] blended vocals and the movement of performers into physics-based projected visuals. The physical nature of the interaction and the generated graphics enabled the creation of rich and complex outputs while keeping the links between performer actions and computer response clear and unambiguous.

More recent works, including *Creature:Interactions*, the similarly themed *Story of the Forest* by teamLabs [6], and *Connected Worlds* by Design I/O [7], feature large immersive environments that allow interactions with large numbers of people simultaneously. In the past, interactive works tended, at least partly for technical reasons, to focus on interaction with only one or two people at a time. The larger size and greater capacity of these recent works have increased the potential for social interactions. We see the increased social aspect as a major opportunity (and also a challenge) for works of this kind.

Digital Interactions

We designed the digital system in *Creature:Interactions* to allow a large freedom of movement and embodied expression from the audience. The focus on free-form expressive movement largely stems from the work's origins in physical theater. The system was originally developed for Stalker Theatre's 2012 production *Encoded* [8] and has since evolved to facilitate the immersive

Creature:Interactions installation and its associated physical theater show, *Creature:Dot and the Kangaroo*. Physical theater artists often explore a wide range of movement including handstands, somersaults, and backflips, often using equipment such as stilts, catapults, and trapeze-like slings at great heights (Figure 2). To capture this wide range of free-form movement, a robust infrared motion-tracking system was developed using optical flow algorithms on a network of cameras. The system picks up any movement and allows the artwork to be used by individuals or crowds. Free from any prescribed movement, the participants have been observed waving, jumping, dancing, kicking, cartwheeling, and performing free-form tai chi as they explore their embodied relationship with the surreal virtual world.

Figure 2. Performers flying through the air on slings in the companion theater show, *Creature:Dot and the Kangaroo.* (© Stalker Theatre. Photo: Darren Thomas.)

To provide the artwork with nuanced and expressive reactions to these free-form movements, the interaction aesthetic was driven by real-world physics simulations. In our design we favored "continuous" gestural interaction where all movements of the participants result in the exertion of virtual forces on simulated physical objects in the virtual world. The intention is that this continuous, physical interaction leads to visual responses that are both complex and intuitively understandable, providing a rich scope for creative expression and discovery. In the field of musical interaction design, the expressive potential of continuous (as opposed to discrete) interaction paradigms and complex, physics-based interactions have been well explored by Hunt [9], Momeni & Henry [10], Wessel & Wright [11], and Cadoz et al. [12]. We draw on these ideas to promote a creative and expressive experience in the visual rather than sonic domain.

The system employs two separate physical systems—a fluid simulation and a rigid-body collision system. The fluid simulation allows star-like particles to gracefully float about the digital night sky in response to audience movements. Movement detected by the camera is fed into a simulation of fluid dynamics, and as the participants move they effectively "stir" this virtual fluid. The particles float on top of this virtual fluid and gracefully flow about the space. Similarly, a multitude of moon balls (3D spheres textured to resemble a full moon) use a rigid-body collision system that lets the objects bang against one another realistically as the audience throws them around in 3D space. The fluid simulation and collision system allow the stars and moons to fly about the space, forming abstract patterns in response to the free-form movement of the audience, creating a more expressive and "conversational" [13] style of interaction where both system and participants are reacting to each other.

To theme the system for the Australian Outback, an attraction system was created to force more literal shapes from the more abstract particle systems. The particles are attracted to the shape of

animal models and rendered as lines to form the giant totemistic animal models that float and warp as the participants stir the virtual fluid. While the line-drawn totems return to their animalistic shapes in the absence of movement, the photographic particle cloud creatures (Figure 3) only appear when movement is detected, disappearing into the virtual ether when stillness prevails. Animated models of birds and butterflies are controlled by the same collision system as the moon balls, but have an added attraction system that flocks around the audience as they move about the space.

The free-form motion tracking, physical simulations, and attraction systems allow a complex but understandable response to movement. The warping of totem creatures, revealing of photographic animals, flocking of birds, throwing of moons, and floating of stars give the audience a range of interaction aesthetics that can be explored through full-bodied, free-form interaction.

Figure 3. Photographic particle clouds emerge from movement in *Creature:Interactions*. (© Stalker Theatre. Photo: Andrew Bluff.)

Human Interactions

In a social mixed-reality environment, the way humans relate with the digital is only half of the story. The participants have a shared experience as they explore the digital environment and often form small groups to throw moon balls at each other or warp the creatures in unique ways. Live facilitators engage with children to suggest different forms of movement as they interact with the system and each other. The facilitators suggest the children "move like a creature from the Australian bush" to expand their palette of movement beyond simple hand-waving. The children hop like kangaroos, flap their arms like kookaburra, jump like frogs, and slither like snakes, which changes the interaction aesthetic and allows them to further connect with the virtual bush environment.

Figure 4. A facilitator working in a group to extinguish the virtual bush fire in *Creature:Interactions*, 2015. (© Stalker Theatre. Video still: Jaina Kalifa.)

The facilitators also form minigroups with the children to work together on tasks such as putting out a bushfire with imaginary buckets of water and hoses (Figure 4), or jumping like frogs in front of the "totem" creatures. The interactive system responds better to combined movement, so grouping together is an effective way to push the graphic response further than what is possible with just one person. As

groups of children work together to move the reactive visuals, they can observe, copy, and improve upon movements that others are using. It is common to hear children excitedly say to each other, "Check out what I just did! Do you want to try it with me?" Many of the children visiting the artwork don't know each other, and the shared experience of embodied exploration has proven to be a powerful icebreaker. When surveyed about the artwork, one of the facilitators responded, "The most interesting interactions were actually amongst kids that didn't know each other working together to move and create shapes with the animals."

Adults also naturally form social groups when experiencing the work. Many adults were observed working together to tie knots in the virtual totem graphics, interacting at either end of a photographic particle creature to reveal the entire image or playing a sort of ad hoc volleyball game with the floating moon balls. Whether the audience members know each other or not, the piece is a shared experience that creates a unique bond between the participants as they figure out how their movements affect the virtual world.

A Shared Immersion

The system running *Creature:Interactions* is scalable, allowing the interactive artwork to be displayed in three different formats. The first features a single wall of interactive 2D projections, while the second uses a continuous 360° display projected onto four walls to create an immersive shared experience. Six infrared motion-tracking cameras, multiple computers, and six high-definition projectors were networked together to create a seamless projection canvas up to five meters high on all four walls and a large interaction zone covering the 18m × 12m space. The third type of installation uses the same 360° canvas, but renders all of the visuals in stereoscopic 3D to provide an even more immersive mixed-reality experience. Members of the audience wear stereoscopic 3D glasses, which expands the depth of the bush landscape and allows the creatures, particles, and moon balls to jump off the walls and float anywhere within the shared space.

While the installation on one single wall is enjoyable, the shift to a 360°, four-wall display represents a surprisingly large jump in terms of immersive effect. Following the two-week season at the Queensland Performing Arts Centre, the artists, directors, and facilitators of the piece were all interviewed to explain how they approached, designed, and received the interactive artwork. All interviewees, alongside many members of the audience, commented on the significant extent to which the 360° display improved the piece.

> I think there's something to be said about it being 360. I think it's just kind of striking on the body and the brain. ...It seems to suit the thing better, you are inside a digital environment, you are inside an animated environment. —Director, *Creature:Interactions*

The large 360° projections were described as "striking," "aesthetically interesting," and "overwhelming," and every single person used the term "immersive" to describe it. Many people observed that the surrounding nature of the system ensured that everyone was interacting with it. Unlike single-wall systems, the 360° setup ensures that no matter where you turn or where you step, you cannot help but participate and interact with the work—there is no escaping it.

Perhaps most importantly, the impressive nature of the interactive visuals actually invited the audience to engage and interact with it.

> The scale of it was incredibly impressive, … when it first came up … it was all the way around them. You could just see the kids going, "Wow. I want to play with this. I want to explore it." —Lead facilitator, *Creature:Interactions*

Figure 5. Facilitator briefs the children inside the large 360° *Creature:Interactions* playspace at the Queensland Performing Arts Centre. (© Stalker Theatre. Video still: Jaina Kalifa.)

Stereoscopic 3D

The stereoscopic 3D version of *Creature:Interactions* has been presented in the University of Technology Sydney's Data Arena, a CAVE-like [14] facility featuring a cylindrical screen. The Creature software was updated with a custom-built "omnistereo" rendering system to ensure that every angle of the cylindrical screen was warp-free and displayed a seamless 3D image no matter where the audience stood [15]. A depth-aware compositing engine was developed to allow the interactive 3D particles to be rendered inside the prerendered 3D bush landscape. Interactive butterflies and birds weave in and out of trees, rocks, and grass, passing in front of or behind these prerendered elements as expected. A 3D tracking system was used to detect motion through the entire space, allowing the participants to throw virtual moon balls into and across the installation space for the night sky finale. A 14-channel sound system was used to attach sounds to virtual 3D animals as they flocked through and around the space.

Participants who experience both versions consistently remark on the added immersion of the stereoscopic 3D system, as it moves the interactive elements off the screen and into the space, around their bodies.

The Phantom Limb Experience

The artwork features a large bushfire scenario that is eventually extinguished by a virtual rainstorm (Figure 6). During the 360° 2D installation, members of the audience reported that they could "feel" the temperature drop during the virtual rain sequence, even though the actual temperature did not change. In addition to this cooling effect, some patrons of the stereoscopic 3D version described a heating effect during the bushfire sequence.

Temperature was not the only phantom sensation activated during the stereoscopic experience. Shortly after the immersive bushscape is conjured into existence at the beginning of the show, one of the participants is given a motion-tracking marker disguised as plastic flowers and told to hold it at arm's length. Controlled by the rigid-body flocking algorithm and rendered seamlessly across all six surrounding projection screens using the omnistereo algorithm, butterflies fly through the space and appear to land on the flowers. When the participant moves, the butterflies scatter and gradually fly back down to the motion-tracking marker held in the outstretched arm.

Many members of the audience remarked upon the impressive illusion of the 3D butterflies during this section and were observed discussing the butterflies long after the experience had finished. On two separate occasions, participants have described physically feeling the butterflies touching the ends of their fingers as they appeared to land on their outstretched hands. This phantom touch sensation is yet another example of the brain activating unengaged senses within the immersive digital environment.

Figure 6. Children playing in digital rain. (© Stalker Theatre. Video still: Jaina Kalifa.)

The phantom temperature and touch effects have never been reported during the one-wall versions. This suggests that the surrounding visuals may trick the brain, empathetically triggering other senses that are known to strongly correlate with the situation at hand. V.S. Ramachandran identified a similar phenomenon in amputees, who report a "phantom" pain or physical sensation in their amputated limb [16]. He was able to elicit feelings of control and sensations of touch in the phantom limb when patients were able to see the limb move via a mirror reflection of their own remaining limb. The phantom limb effect has been studied extensively in the field of neuroscience, but its application to physical theater and immersive installations provides an interesting direction for future investigation.

The Evolution of Interactions

The understandable complexity provided by the fluid simulations and rigid-body collision system promoted a rich palette of full-bodied interactions, while the large-scale 360° display created an immersive and social mixed-reality experience that was further improved by 3D stereoscopic visuals in the Data Arena. We are currently investigating portable dome projection systems to bring the immersive playspace to remote locations, spreading its environmental message. *Creature:Interactions* is a companion piece to a physical theater show and, while successful, future developments may explore a tighter integration of the two pieces with the physical actors performing inside the immersive space to create an interactive physical theater experience. The phantom limb effect will also be explored as a method to create empathy in future works.

The combination of physical interaction, immersive technology, and social participation has made *Creature:Interactions* a unique live experience and heralds a new stream of exploration for the physical theater company.

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The Interactive Image: A Media Archaeology Approach

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ABSTRACT

This paper examines the history of the influential Interactive Image computer graphics showcase, which took place at museum and conference venues from 1987 to 1988. The authors present a preliminary exploration of the historical contexts that led to the creation of this exhibition by the Electronic Visualization Lab (EVL), which included the integrated efforts of both artists and computer scientists. In addition to providing historical details about this event, the authors introduce a media archaeology approach for examining the cultural and technological contexts in which this event is situated.

The Interactive Image featured a collection of computational artworks that encouraged public engagement with interactive graphics in museographic spaces. It was created in 1987 by the Electronic Visualization Laboratory (EVL) at the University of Illinois at Chicago for Chicago's Museum of Science and Industry and was later installed at the 1988 SIGGRAPH conference, the main academic forum for computer graphics research. Although technologically primitive by today's standards of high-resolution images, responsive devices, and immersive environments, The Interactive Image, at the time of its unveiling in October 1987, was an ambitious public presentation of the state-of-the-art in interactive computer graphics and real-time imaging technology. The exhibit was the first of its kind to "use technology to teach technology in a nonthreatening, entertaining setting" [1]. This approach of intersecting arts and sciences in technology proved to be valuable to the history of computational visualization. With the exception of one video created by EVL and available on the lab's website, there is no other publicly available information about this historical exhibit and its impact on interactive visualization. The primary source materials at EVL preserve an untold story of significant activities in computer graphics and computer art. The documents include letters, manuscripts, brochures, drawings, news clippings, and computer code. Unfortunately, this transformative moment in technological history is in danger of being lost and the primary source materials are imperiled due to a lack of archival efforts. No project at present is focused specifically on analyzing, preserving, or making this history available to the public.

Our continuing investigation into The Interactive Image is important for several reasons. Awareness about and promotion of these archives will help to preserve this material and will reintroduce media artists who produced some of the first interactive artworks in the late 1980s. It will also provide insight into this somewhat neglected period in the history of technology and media arts, which is not as thoroughly explored in comparison to the 1960s and 1970s. Moreover, our investigation highlights the diverse activities of EVL, a perennially influential "ArtSci" lab that has successfully integrated artistic and scientific research to develop new technology for over four decades. Our research also analyzes the organization and production of this ambitious interdisciplinary exhibition, which we believe could be useful for designing new events with a similar focus that could inspire the development and applications of new technologies.

Interactive Art Exhibits

The use of the term *interactive art* to describe novel uses of digital technology is somewhat contentious. Artists have always pushed the boundaries of their media to experience art in new ways, but exploration of new technology may not in and of itself constitute artistic practice [2]. Nonetheless, we use *interactive art* to refer to the innovative installations exhibited at The Interactive Image, which encouraged participants with no computing experience to manipulate images through digital means. Since the 1960s, media artists have been intently concerned with the aesthetics of interaction and have focused on designing systems that encourage active participation of the viewer. A further exploration into the history of technology and art can be found in Christiane Paul's *Digital Art* [3].

There is a long history of public events that feature the creative use of new technologies to promote new research streams. These events often include various forms of public displays that allow people to interact with these inventions. For example, the Experiments in Art and Technology, or E.A.T., events, which took place in New York during the 1960s, featured groundbreaking visual artists such as Robert Rauschenberg, Frank Stella, and Andy Warhol. E.A.T. provided these artists the opportunity to collaborate with Bell Labs engineer Billy Klüver. *Silver Clouds*, an installation of floating pillows, resulted from Klüver and Warhol's collaboration [4]. Another early example of a public exhibition of interactive technological artworks is the seminal Cybernetic Serendipity, which took place at the Institute of Contemporary Arts in London in 1968 [5]. Throughout the 1970s, EVL faculty and students also showcased newly developed technology at public events, called Electronic Visualization Events (EVEs), in Chicago [6].

In 1987, the most recognized organizations that celebrated digital art at the time were SIGGRAPH in the United States and Ars Electronica in Austria. Other important forums that were established around that time, such as FISEA: the First International Symposium on Electronic Art in 1988 and ArtFutura in 1990, proved that there was worldwide momentum in advocating for digital and electronic art. EVL played a key role in bridging art and technology, while introducing visualization as one of the most important recent scientific tools for the analysis of complex data.

Media Archaeology Approach

Our research utilizes a media archaeology approach to understanding the history of EVL. Media archaeology is an open-ended process that critically examines media-cultural phenomena from a variety of perspectives. Media archaeology has gained traction among social scientists, humanities scholars, and artists, as it provides comprehensive methods with which to make sense of technologies from the past. Rather than focusing solely on technological artifacts, media archaeologists explore the contexts in which these artifacts emerged. In "Media Archaeology: Approaches, Applications and Implications," Jussi Parikka and Erkki Huhtamo explain that:

> On the basis of their discoveries, media archaeologists have begun to construct alternate histories of suppressed, neglected, and forgotten media that do not point teleologically to the present media-cultural condition as their "perfection." [7]

Through a media archaeology approach, we study the complex relationships between events, media, and technology through a preliminary investigation of the forgotten documents at EVL.

Two notable theorists who have utilized the media archeology approach are Huhtamo and Siegfried Zielinski. Huhtamo is interested in connecting the topos, a concept in literary theory, with media archaeology to form the *topoi*. The topoi refers to finding themes or formulas in

media-cultural artifacts. His volume on the history of panoramas, *Illusions in Motion*, develops an extensive and detailed historical study of the origin, uses, and implementation of panoramas as an entertainment system in the 1850s [8].

German scholar Siegfried Zielinski [9] has been able to articulate creative and profoundly diverse historical narratives, a strategy that we could identify as comparative analysis. Zielinski looks for common problems in the historical evolution of media, exploring what he calls the *Deep Time of the Media*. Deep time looks at the layers hidden under the surface of hegemonic history to reveal the past as something new.

Both of these theories (topoi and deep time) have developed a set of methodological tools that have shaped the practice of this transdisciplinary field. In both cases the lesson is clear: there is a need to go back in time, before official history, to more clearly understand media technologies. Moreover, we should pay special attention to the questions that articulate the technological, aesthetic, and social components of media. With the accelerated development of computer graphics over the last 60 years, historical accounts of the early computer art era have just started to emerge. An example of this approach is found in *Peripheral Vision* [10], Patterson's study of the early computer art developments at Bell Labs. Another example is explored in Margit Rosen's *New Tendencies*, which investigates some of the first computer art exhibits in Zagreb in 1968 and beyond [11].

However, most of these historical studies have focused mainly on the first generation of artists who used computers starting in the early 1960s and on the second-generation artists in the 1970s. Less attention has been given to what happened in the following decade, despite the enormous increase in activity in digital art-making in the 1980s. It should be noted that, in general, when we are confronted with the history of computation, there is often an illusion that this history needn't be investigated because the phenomenon took place more recently, over the last 40 years. Roddy Shrock, director of programs at Eyebeam, explains that technological art has been predominantly a future-focused endeavor, "to the detriment of retaining its history." After Hurricane Sandy in 2012, the Eyebeam center reflected on the risks of losing archival materials and made it their mission to look to the past in order to build the future [12].

EVL constitutes one of the "missing links" in the history of digital art, and its study is long overdue. Analyzing these lost documents will address a gap in history and will also make them accessible to the public for the first time since the late 1980s. None of this information has been appropriately catalogued or investigated since that time, and this study is the first to examine this collection. The materials found during our exploration of the EVL archives and The Interactive Image exhibition has shown that the amount of evolution that took place during this time was enormous. However, because some of these materials are disconnected from our present technological environment, the idea of deep time becomes important. The media archaeological approach is essential to understanding what happened at EVL and the early exhibitions, and for shedding light on this era of innovation in interactive art and technology.

Access to the EVL Collection

After establishing contact with Maxine Brown (EVL director), Dana Plepys (EVL associate director) and Angus Forbes (EVL faculty) in the spring of 2016, we were granted access to conduct an initial assessment of the collection. EVL is naturally interested in preserving its past and contributing to this research. Plepys has digitized many videotape recordings of early computer graphics projects from the 1970s and has catalogued many of the time-based visualizations created by EVL students and faculty. Plepys, who graduated with an MFA from

Figure 1. The Interactive Image memorabilia, 1986–1990. (© EVL. Photo: Esteban García Bravo.)

the EVL visualization program, has made these materials available on a YouTube channel, EVLtube [13]. This channel provides excellent video documentation of early video art and performance. Although these videos provide a window into the history of EVL and, more broadly, of computer graphics, many relevant materials are stored in boxes or are stacked on shelves and have not been examined for decades. During a series of visits to the EVL collection, we were able to take samples of manuscripts and photographs to aid understanding of EVL's context. This study is an initial analysis of primary sources at EVL, and many of the materials cited are not publicly available. Figure 1 shows an image of the preliminary data samples taken from EVL. This particular study used a sample gathered during one of our visits. The sample included manuscripts, sketches, press clippings, and correspondence.

Discovering the History of EVL

From the samples collected, we were able to compile a clearer picture of the history and context of EVL. EVL was founded in 1973 as a joint effort by Tom DeFanti and Dan Sandin. Initially named Circle Graphics Habitat, EVL became one of the most relevant places in the world for research in visualization at the early stages of computer graphics. Sandin, trained as a physicist, taught in the art department of the University of Illinois at Chicago. In 1971, Sandin designed and built an image processor that used an analog computer to manipulate video images in real time [14]. The video synthesizer was easily manipulated through knobs and dials in a similar fashion to an oscillator-based musical instrument. Many historic computer animations were created using the Sandin Image Processor, such as Phil Morton's 1974 work *Colorful Colorado* [15].

DeFanti completed his PhD under the supervision of computer arts pioneer Charles Csuri at The Ohio State University. DeFanti's dissertation introduced the GRASS computer framework, intended for artists with little programming experience to create graphics. In addition, EVL faculty, staff, and students helped originate The SIGGRAPH Video Review, or SVR. The SVR was originally created in 1979 by DeFanti as a library of videos to be shown at SIGGRAPH's annual Film & Video Show, which became the Electronic Theater, and is now called the Computer Animation Festival [16].

EVL established "the oldest formal collaboration between engineering and art in the country offering graduate degrees in visualization" [17]. At EVL, artists were able to earn an MFA, while computer scientists earned a Master's of Science. This philosophy of intersecting arts and sciences in technology proved fruitful for the history of computational visualization: "We do not follow the typical production model of operating as a team, but rather expect the artists to learn all the computing they need and the scientists to communicate visually" [18]. Many scientific breakthroughs were first visualized through art-science collaborative efforts. One example of such collaborations is *Astrophysical Jetstreams* by Donna Cox and Michael Norman (1987)

(Figure 2). EVL also played an important role in the establishment of ACM/SIGGRAPH as the world's first and foremost forum for computer graphics, bringing academia, art, and industry together in a yearly conference since 1974.

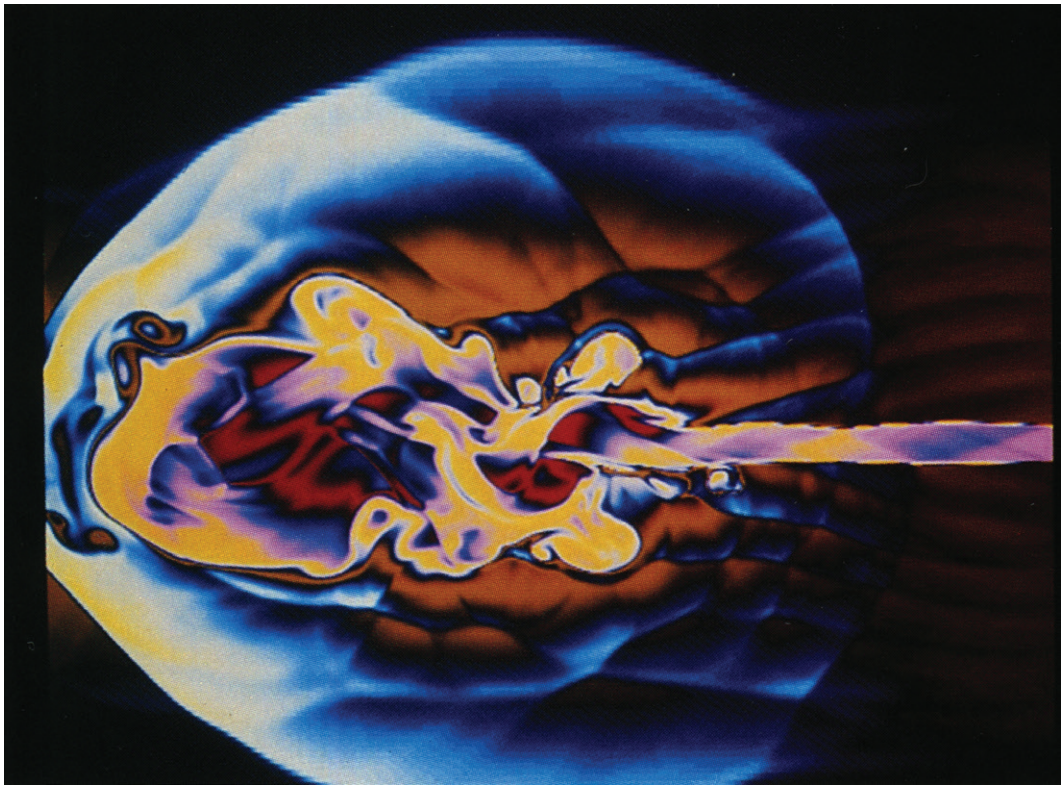

Figure 2. Donna Cox and Michael Norman, *Astrophysical Jetstreams* (fragment), 1987, 8 ½" x 11," color print on paper. (© Donna Cox and Michael Norman)

In late 1986, Maxine Brown was brought in as associate director of EVL to contribute to the design of The Interactive Image for the Museum of Science and Industry in Chicago [19]. Brown furthered EVL's outreach to the scientific community, helping to secure research funds. According to a news report, AT&T donated 1.2 million dollars to EVL in 1988 for the purpose of advancing visualization for scientific imaging. In the same article, Brown explained that "visualization processes are invaluable tools for scientific discovery" [20]. AT&T was just one of many institutions that have sponsored discovery at EVL; others include the National Science Foundation, the U.S. Department of Energy, NASA, the National Institutes of Health, and IBM. Among the most well-known EVL contributions are the ZGRASS language, used for early 3D-animated sequences, including the briefing room scene in *Star Wars* [21]; and the world's first CAVE™ virtual reality theater. Via the CAVE environment, EVL used computer graphics to create visual images that aided in the understanding of complex numerical representations of scientific concepts and results [22].

During the development of The Interactive Image, EVL members also contributed to an NSF committee exploring the use of visualization in supercomputing. The committee was made up of academics, researchers, and industry participants who came together to identify the domain and definitions of Visualization in Scientific Computing (ViSC). This important contribution is documented in a report published by SIGGRAPH in 1987, of which EVL's Maxine Brown and Tom DeFanti were two of the three editors [23]. This discipline (referred to as Scientific

Visualization, or SciVis) was embraced by the general public for its entertainment and exploratory value and by academia as a viable tool for insight and discovery.

The Interactive Image (1987–1989)

The Interactive Image was installed three times: once at the Chicago Museum of Science and Industry, once at SIGGRAPH 88 in Atlanta, and finally in 1989 at the Computer Museum in Boston. In order to understand its significance, we need to understand its context. Today, interactive images are a ubiquitous part of our lives, mainly in the form of smartphones and laptops. In 1987, however, this was a revolutionary concept, as the early raster-based machines and displays that were available barely had the computing power required to present low-resolution pixel images in real time. The Interactive Image pushed the technology forward by making image processing more accessible through creative user interfaces and physical devices. That is, it made computational visualization "interactive" through joysticks, buttons, and trackballs. At that time, these interfaces were not available to the general consumer. It is relevant to highlight that in 1987, image manipulation was also not as easily accessible as it is today—for example, Adobe Photoshop was not officially released until 1990 [24].

The first exhibition of The Interactive Image consisted of both interactive installations and a series of computer graphics animations selected from the SIGGRAPH Video Review. The space layout was designed by one of the art students at EVL. Figure 3 shows an artistic rendering

Figure 3. Interactive Image brochure (fragment), 1987, 7" x 10," color photograph on paper. This is an image included on the exhibit's 1987 brochure. (© EVL)

with a prototype of the show. The seven installations were often referred to as "games," as computational interaction was a new concept in art exhibitions and the collection of pieces resembled a video game arcade more than it did a traditional art exhibition.

The artworks shown in The Interactive Image included the following innovative projects, among others:

- *ERIC: Escher-like Reflective Interactive Computer*: Work by Debra Weisblum Hershmann that included tessellation, kaleidoscope, and animation.
- *Zanimation, Jr.*: An animation software for motion interpolation by Fred Dech.
- *Quark*: A digital image-processing game by Harriet Lurie.
- *Graftals* and *Fractals*: Mathematical techniques for creating complex forms by simple rules. *Graftals* by Sumit Das and Seton Coggeshall, and *Fractals* by Dan Sandin.
- *Exploring Supercomputer Images*: Work by Donna Cox and Michael Norman where visitors interact with selected scientific images such as an astrophysical jetstream or colliding neutron stars (Figure 3).
- *VOILA: Vasarely Inspired Optical Art*: A graphics application by Diane Schwartz.

Other items in the exhibit included the *PHSCologrames* sculptures by the group (art)^n. The PHSCologrames were wood and metal assembled with holograms and barrier-strip autostereograms made using a unique photographic and computer graphics process. The artists described their work as a combination of photography, holography, sculpture, and computer graphics (Interactive Image brochure, 1987). The members of (art)^n included Ellen Sandor, Dan Sandin, Tom DeFanti, Donna Cox, Randy Johnson, and Steven Meyers [25]. Another artifact exhibited at The Interactive Image was the original Sandin Image Processor, referred to at the 1987 show as "The TV Switcher Panel" [26].

Conclusions and Future Work

This study aims to promote the preservation and significance of EVL history. Having played such a significant role in advancing computational art and intersecting the arts and sciences in technology, the artifacts found at the EVL offer deep insight into and understanding of a greater context of work that took place during that time. However, this preliminary research leaves many questions unanswered, and further details about each of the artworks that were exhibited need to be examined in depth. Although we have illustrated some of the activities in which EVL was involved in the 1980s, a complete history of EVL and the media arts landscape will require further study. We argue that the significance of The Interactive Image contrasts greatly with the lack of public documentation available about such a seminal event. The model of exhibiting interactive art proved to be an effective way to encourage collaboration between artists and scientists [27] and provided the public with the opportunity to interact with and experience new technologies, while simultaneously reimagining and expanding the boundaries of original intended use.

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Autoencoding *Blade Runner*: Reconstructing Films with Artificial Neural Networks

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ABSTRACT

In this paper, the authors explain how they created *Blade Runner—Autoencoded,* a film made by training an autoencoder—a type of generative neural network—to recreate frames from the film *Blade Runner*. The autoencoder is made to reinterpret every individual frame, reconstructing it based on its memory of the film. The result is a hazy, dreamlike version of the original film. The authors discuss how the project explores the aesthetic qualities of the disembodied gaze of the neural network and describe how the autoencoder is also capable of reinterpreting films it has not been trained on, transferring the visual style it has learned from watching *Blade Runner* (1982).

Reconstructing videos based on prior visual information has some scientific and artistic precedents. Casey and Grierson [1] present a system for real-time matching of an audio input stream to a database of continuous audio or video, presenting an application called REMIX-TV. Grierson develops on this work with PLUNDERMATICS [2], adding more sophisticated methods for feature extraction, segmentation, and filtering. Mital, Grierson, and Smith [3] extend this approach further to synthesize a target image using a corpus of images. The image is synthesized in fragments that are matched from the database extracted from the corpus based on shape and color similarity. Mital uses this technique to create a series called "YouTube Smash Up" [4], which synthesizes the week's most popular video on YouTube from fragments of other trending videos. Another, somewhat related approach is the research in reconstructing what people are watching while in an MRI scanner, solely from recorded brain scans [5].

During the development of *Blade Runner—Autoencoded*, we were influenced by this earlier research as we pursued the same goal, while taking advantage of the recent advances in deep generative models (detailed in the next section). The film *Blade Runner* (1982) was chosen as the visual material on which to anchor this research, because of its relation to the themes of perception, artificiality, and artificial intelligence.

Technical Background

Research in deep learning, specifically in the field of computer vision, has been accelerating in recent years, particularly since Krizhevsky, Sutskever, and Hinton's [6] breakthrough in the 2011 ImageNet competition, where they used a sole convolutional neural network to place images into 1,000 possible classifications. Prior to this, all competing entries were a combination of carefully engineered visual features, in tandem with more rudimentary machine-learning algorithms to do classification. This was the first successful approach of a system that learned everything end-to-end in this kind of real-world image-classification scenario.

While it was possible to have powerful image-recognition capabilities using a convolutional neural network, it was not thought possible to reverse this kind of system so that it could be used as a generative model for images. As a result, these systems were often referred to as "black box" systems, partially because there was a certain level of skepticism as to whether these kinds of

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systems were seeing things the way humans do. This skepticism was evidenced by the observation that such networks could easily be fooled into incorrectly classifying images that had been subtly manipulated using carefully crafted patterns of noise imperceptible to humans [7]. In response to such observations, there was a drive in the research community towards developing generative models capable of generating realistic natural images, because if a network is capable of generating realistic natural images, it has a greater understanding—or at least we can be more confident it does—of the subject that it is representing.

An autoencoder is one such type of network that can be used as a generative model. It can be thought of as two networks: one that takes input (such as an image) and *encodes* it into a latent (numerical) representation; the other network, which is symmetrical in design, *decodes* the latent representation back into the original data space (reconstructing the image). The network is given images from the dataset to reconstruct and is trained to minimize the loss, which is calculated by the per-pixel difference between the images. An extension to this is the variational autoencoder (VAE) [8,9] that combines this network structure with a variational Bayesian approach to training, which makes strong assumptions concerning the distribution of latent variables (by assuming a Gaussian prior). This forces the autoencoder to use the latent space more efficiently, leading to more robust reconstructions and better generalization.

Generative adversarial networks (GANs) [10] are an altogether different approach to developing a deep generative model. This approach borrows a concept from game theory for the training regime; in this case, two networks are set against each other in a minimax game. One network, the "generator," tries to generate images that fit the distribution of images in the dataset. The second, a "discriminator" network, looks at images (both real and generated) and attempts to maximize the probability of correctly labeling the image as real or generated. Conversely, the generator is trained to try to *fool* the discriminator into thinking it is creating real images. Radford et al. [11] build upon this work by using the same training regime to train deep convolutional neural networks to generate images. This was the first time a convolutional neural network had been effectively inverted and used as a generative model, creating images almost indistinguishable from photographs at low resolutions. (This was accomplished by replacing the traditional structure of the generator network—convolutions alternating with pooling layers—with strided convolutions and fractionally strided backwards convolutions.)

In 2016, Larsen et al. [12] elegantly combined the GAN approach with a variational autoencoder. They used the strided convolution architecture popularized by Radford et al. and combined the training routines of the two approaches. They added a discriminator network to the VAE framework to create a consortium of three networks (encoder, decoder, and discriminator). The discriminator network is used to determine how similar each generated image is to the real image, as opposed to comparing these images on a simple pixel-by-pixel basis. This significantly increases the generative capability of the VAE, optimizing the network to produce images that are perceptually similar, reducing the tendency of the autoencoder framework to generate blurry images. This adversarial-variational autoencoder, trained with a learned similarity metric, was the model used as the basis for this project [13].

Learning the Distribution of Imagery in *Blade Runner*

The standard practice for evaluating deep generative models is to train them on a standard, widely used set of images (usually all of the same subject matter, e.g. handwritten digits [14] or faces [15]). Using these datasets restricts the complexity of what the model needs to represent and allows a direct visual comparison to be made between the results from different models. Taken as a complete set, the frames from *Blade Runner* contain much more variety in terms of subject

matter and perspective than the sort of datasets commonly used to train and evaluate these generative models. Therefore we were initially concerned the model would not be able to represent such a diverse range of imagery with any great efficacy, but after seeing some initial results (Figure 1) we were reassured by a single model's diverse generative capabilities.

Figure 1. Sample of a 64-frame minibatch of reconstructed samples from the network trained on *Blade Runner* after one epoch at a resolution of 96x64. (© Terence Broad)

Initially the model was only trained at a resolution of 96×64 pixels (64×64 was the standard in research at the time). The size of the model was increased to be able to create a video that was watchable online, with the largest possible model that could be represented on a single GPU being 256×144 (coincidentally the smallest resolution allowed on YouTube). By increasing the size of the model, training became much slower and more precarious, and it was more likely that one of the three networks (they all had to learn in unison) would fail, resulting in a sharp, irrevocable degradation of image quality, forcing the process to be started again from the beginning. It took approximately three days for the model to be trained one time on all the frames of the film. (One complete cycle through the dataset is referred to as one epoch.)

After some trial and error, a set of hyperparameters was found that allowed all three networks to learn in a balanced and sustained manner over a long period of time. As shown in Figure 2, there is a gradual improvement in image fidelity after one, three, and six epochs. One novel technical contribution made to this training procedure was to reduce the amount of noise injected into the latent space over the course of training (by gradually reducing the standard deviation of the Gaussian prior) in order for the model to better differentiate between similar frames. (A more detailed, technical account of this training procedure can be found in the original technical report [16].)

Figure 2. Samples after training the model on frames from *Blade Runner* for one epoch (top row), three epochs (middle row), and six epochs (bottom row) at a resolution of 256x144. (© Terence Broad)

Reconstructing *Blade Runner*, One Frame at a Time

After training, the autoencoder is then made to reinterpret (perform a forward pass) on each frame of the film. The reconstructed frames are then resequenced back into a video. The resulting sequence is very dreamlike, drifting in and out of recognition between static scenes that the model remembers well, to fleeting sequences—usually with a lot of movement—that the model barely comprehends. It is no surprise that static scenes are represented so well, as the model has, in effect, seen those scenes many more than six times. In essence, the model is simply overfitting to the training data (caused mostly by training on a highly skewed dataset), something that machine-learning practitioners normally go to a great deal of effort to avoid. In this case though, the aesthetic result of this overfitting is interesting, especially when viewed in contrast to the parts of the film the model struggles to represent.

The flaws in the reconstruction are in and of themselves aesthetically interesting and revealing with respect to the model. An obvious flaw is that the model has a tendency to collapse long sequences with a fixed background into a single representation, even if there is some movement in the scene (Figure 3). This tendency was rectified somewhat by the novel training procedure of gradually reducing the amount of noise injecting into the latent representation over training, but not completely. Ultimately, this is a consequence of the images being so similar that they share nearly the same point in latent space, therefore they cannot be differentiated by the generator network. Without some training procedure to enforce the difference between frames, this will always be a problem.

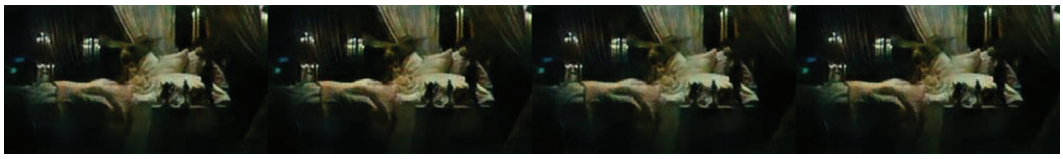

Figure 3. Samples from the reconstruction of *Blade Runner* where the network has collapsed one long sequence with some movement into a single representation. (© Terence Broad)

One curious outcome is the model's inability to represent completely black frames (Figure 4). When asked to recreate a black frame, it instead produces an image with a greenish haze (reminiscent of the phenomenon of seeing colors when one's eyes are closed). This is likely due to the dataset containing very few completely black frames and could certainly be rectified by appending the training dataset with many black images; this was not done, however, as the existing outcome was deemed interesting.

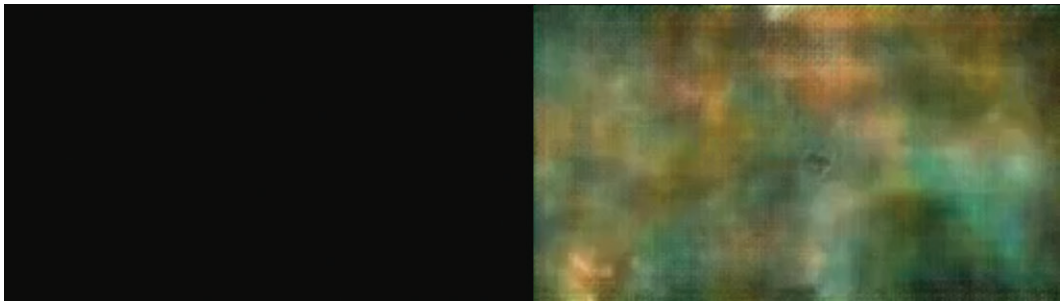

Figure 4. Left: A completely black image. Right: The *Blade Runner*–trained model's interpretation of the completely black image. (© Terence Broad)

Reconstructing Other Films with the *Blade Runner* Model

Once trained, the autoencoder can process frames from any film. The model reinterprets any given set of images based on what it has learned from *Blade Runner*, thus transferring the distinctive "neo-noir" aesthetic onto any video. Figure 5 shows frames from Dziga Vertov's 1929 documentary *Man with a Movie Camera* as reinterpreted by the model. The film is black and white, but the output from the model is in color and is consistent with the visual style of *Blade Runner*.

The reconstructions of other films [17] are aesthetically interesting and unpredictable, but it is difficult to make out what is being represented most of the time. Since this project was carried out, research has been published that uses conditional adversarial networks to translate images from one domain into another [18], providing a more formally defined and effective method to do this kind of image translation.

Figure 5. Top row: Frames from the 1929 film *Man with a Movie Camera*. Bottom row: Frames reinterpreted by the model trained on *Blade Runner*. (Images from *Man with a Movie Camera* are sourced from Wikimedia Commons and are in the public domain.)

Why *Blade Runner*?

The film *Blade Runner* was adapted from Philip K. Dick's novel, *Do Androids Dream of Electric Sheep?* [19]. The story is set in a post-apocalyptic dystopian future where Rick Deckard, the main character, is a bounty hunter who makes a living hunting down and killing replicants—built to be used as slaves on outer-world colonies, but not allowed on Earth. Replicants are so well engineered that they are physically indistinguishable from human beings. Deckard is called back from retirement to hunt down a group of Nexus-6 replicants, the newest model of replicant produced by the Tyrell Corporation.

Because replicants are physically indistinguishable from humans, Deckard has to issue the "Voight-Kampff" test in order to distinguish them. The test is a series of increasingly difficult moral questions about human and animal suffering, with the intention of eliciting an empathic response from humans, but not from androids. With the technological advances of the Nexus-6 replicants, it is increasingly difficult for Deckard to determine who is human and who is not; Deckard feels a growing suspicion that he may not be human himself.

By reinterpreting *Blade Runner* with an artificial neural network's memory of the film, *Blade Runner—Autoencoded* seeks to emphasize the ambiguous boundary in the film between replicant and human, or, in the case of the reconstructed film, between our memory of the film and the neural network's. Some of the flaws in its visual reconstruction are reminiscent of the deficiencies of our own, especially regarding memories of dreams. There is a theory that Dick structured his novel around the work of the great French philosopher René Descartes, with Deckard acting out Descartes's philosophical dilemmas [20]. Descartes emphasized that the senses (our primary source of knowledge) are often prone to error. By examining this imperfect reconstruction of *Blade Runner*—as seen through the gaze of a disembodied machine—it becomes easier to acknowledge the flaws in our own internal representations of the world and easier to imagine the potential of other, substantially different systems that could have their own internal representations.

Outcomes

Blade Runner—Autoencoded and a report on the project were first published online in May 2016 and gained a great deal of attention on social media (with over 200,000 views on YouTube). The project was discussed in several online news articles (most notably by Aja Romano in Vox [21]). After the online publication, the autoencoder was trained for a further 20 epochs to create a second version of the film (Figure 6), which was also upscaled into high resolution to make the work watchable on larger screens. This version of the work was shown at Art Center NABI, Seoul, in the exhibition Why Future Still Needs Us: AI and Humanity, a survey of contemporary artworks (all made in 2016) that incorporate modern machine-learning techniques.

Figure 6. A screenshot from the updated version of *Blade Runner—Autoencoded*, created with the autoencoder trained an additional 20 times on the film. (© Terence Broad)

This work was also featured in, and screened as part of the accompanying film program for, the exhibition Dreamlands: Immersive Cinema and Art, 1905–2016, at The Whitney Museum of American Art in New

York. The exhibition brought together the work of artists articulating the shifts that have taken place as technology has altered the ways in which space and image are constructed and experienced, engaging with the fact that we are now living in an environment more radically transformed by technology than at any other point in human history [22]. For Chrissie Iles, the Anne and Joel Ehrenkranz curator at The Whitney, the work "occupies a unique position, as both a work of science and a work of art," and "belongs to the current moment in which artists are engaging with questions of where the boundary between AI and human perception lies" [23]. Iles relates the work to what Hito Steyerl describes as the "disembodied, post-humanized gaze, outsourced to machines and other objects" [24].

The same autoencoding technique was used in the 2017 film *Geomancer*, made in collaboration with the artist Lawrence Lek [25]. Autoencoding was used in the penultimate dream sequence, to visualize the mental representation of the AI protagonist. In the summer of 2017, *Blade Runner—Autoencoded* will be included in the exhibition Into the Unknown: A Journey Through Science Fiction, at The Barbican in London, and in the exhibition's subsequent international tour.

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Avoid Setup: Insights and Implications of Generative Cinema

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ABSTRACT

Generative artists engage the poetic and expressive potentials of film playfully and efficiently, with explicit or implicit critique of cinema in a broader cultural context. This paper looks at the incentives, insights, and implications of generative cinema, which significantly expands the creative realm for artists working with film, but also incites critical assessment of the business-oriented algorithmic strategies in the film industry. The poetic divergence, technical fluency, and conceptual cogency of generative cinema successfully demonstrate that authorship evolves toward ever more abstract reflection and cognition which equally treat existing creative achievements as inspirations, sources of knowledge, and tools.

This paper is motivated by the observation that there are complex connections between the creativity of cinematography and the procedural fluency which is essential to generative art. These connections have been targeted implicitly or explicitly by the artists of generative cinema but remain virtually untouched in theoretical discourse. Film studies have traditionally been focused on the historical, narrative, formal, aesthetic, and political aspects of the relations among cinema, technology, culture, media, and other art forms. Theoretical studies in new media art primarily address these relations on the conceptual, material, and phenomenological levels, investigating and comparing how the different references of information are captured, stored, manipulated, retrieved, and perceived in film and digital media. In *Cinema and the Code*, Gene Youngblood anticipates the creative potentials of the algorithmic foundation of code-based processing of the formal elements in film, but never explicates them [1].

This paper explores generative cinema by discussing the successful and thought-provoking projects that represent relevant approaches toward cinema in generative art and exemplify the artists' abilities to transcend the conceptual, expressive, and aesthetic limits of code-based art. The theme is observed primarily from the aspect of the artists' creative thinking and critical evaluation, with the aim to show that the cognitive tensions between film and generative art have significant expressive, intellectual, and ethical implications that could benefit both fields. The goal of the paper is also to encourage further theoretical and practical research in generative cinema.

Generative Cinema

The immense poetic and expressive potentials of film have been barely realized within the cinematic cultural legacy, mainly due to industrialization, commercialization, politicization, and consequent adherence to the pop-cultural paradigms [2]. Unrestrained by commercial imperatives, motivated by unconventional views of film, animation, and art in general, generative artists have started to engage these potentials playfully and efficiently, with explicit or implicit critique of cinema in a broader cultural, economic, and political context.

The conceptions of generative art in contemporary discourse vary in inclusiveness [3–8]. In this paper, generative art is perceived broadly, as a heterogeneous realm of artistic approaches

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based upon combining the predefined elements with different factors of unpredictability in conceptualizing, producing, and presenting the artwork, thus formalizing the uncontrollability of the creative process and underlining the contextual nature of art [9,10]. Consequently, generative cinema is understood as the development and application of generative art methodologies in working with film both as a medium and as the source material.

Generative cinema has been an emerging field in digital art for the past 20 years. Before that, generative techniques had seldom been explored in both conventional and experimental film [11–13]. As a logical extension of generative animation [14], generative cinema in digital art became feasible with the introduction of affordable tools for digital recording and editing of video and film. It expanded technically, methodologically, and conceptually with the development of computational techniques for manipulating large numbers of images, audio samples, indexes, and other types of relevant film data. Diversifying beyond purely computation-based generativity—which drew considerable and well-deserved criticism [15]—the production of generative cinema unfolds into a number of practices with different poetics and incentives. Here are some examples.

Supercut

Cristian Marclay's *Telephones* (1995) used supercut as a generative mixer of conventional cinematic situations involving phone calls. Supercut is an edited set of short video and/or film sequences selected and extracted from their sources according to at least one recognizable criterion. Focusing on specific words, phrases, scene blockings, visual compositions, camera dynamics, etc., supercuts often accentuate the repetitiveness of narrative and technical clichés in film and television.

With the explosion of online video sharing, supercut became a pop-cultural genre but remained a potent artistic device, for example in work by Jennifer and Kevin McCoy, Tracey Moffatt, Marco Brambilla, and Kelly Mark. It was charged with political and meta-political critique in R. Luke DuBois's brilliant *Acceptance* projects (2012 and 2016) (Figure 1), the two-channel video installations in which the acceptance speeches given by the two major-party presidential candidates (Obama and Romney in 2012, Clinton and Trump in 2016) are continuously synchronized to the words and phrases each of them speaks, which are 75–80% identical but distributed differently.

The conceptual and technical logic of supercut received a fundamental critical assessment with Sam Lavigne's Python applications *Videogrep* (2014), which generates supercuts by using the semantic analysis of video subtitles to match the segments with selected words, and *Audiogrep* (2015), which transcribes audio files and creates audio supercuts based on the input search phrases.

Statistical

Classification, indexing, and systematic quantification of formal qualities in time-based media allow for building databases that can be handled and manipulated with statistical tools. This enables artists to make alternative visualizations and temporal mappings that reveal the overall visual and structural logic of popular films.

The idea of unconventional editing and presentation of film has been explored in a number of projects. *Soft Cinema: Navigating the Database* (2002–2003), by Lev Manovich and Andreas Kratky, demonstrates Manovich's view of the cinema as a digital (discrete) medium and of the film as a database. The project was based on classifying and tagging a set of stored video clips,

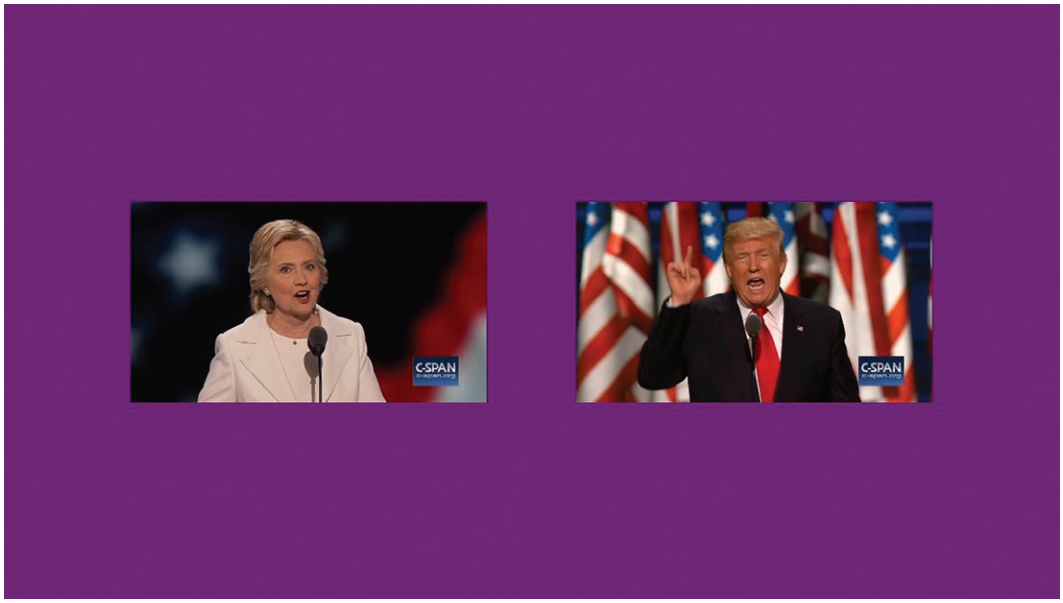

Figure 1. R. Luke DuBois, *Acceptance 2016*, 2016. (© R. Luke DuBois)

algorithmically creating the editing scenarios in real time, and on devising a user interface for arranging, navigating, and playing the material [16].

Programmed manipulation of digitized film also enables artists to statistically process films frame by frame, for example in Ben Fry's *Disgrand* (1998), Ryland Wharton's *Palette Reduction* (2009), and Jim Campbell's *Illuminated Average Series* (2000–2009), which averages and merges all the frames from Orson Welles's *Citizen Kane* (1941) and Hitchcock's *Psycho* (1960) [17].

In *Portrait* (2013) (Figure 2), Shinseungback Kimyonghun used computer vision in the statistical style of Jim Campbell and Jason Salavon. The software detects faces in every 24th frame of a selected movie, averages and blends them into one composite with the dominant facial identity of a movie, stressing the figurative paradigm in mainstream cinema.

The classic conceptual, formal, and experiential form of the infographic processing of film was achieved in Frederic Brodbeck's *Cinemetrics* (2011). Its core is a Python-based online application

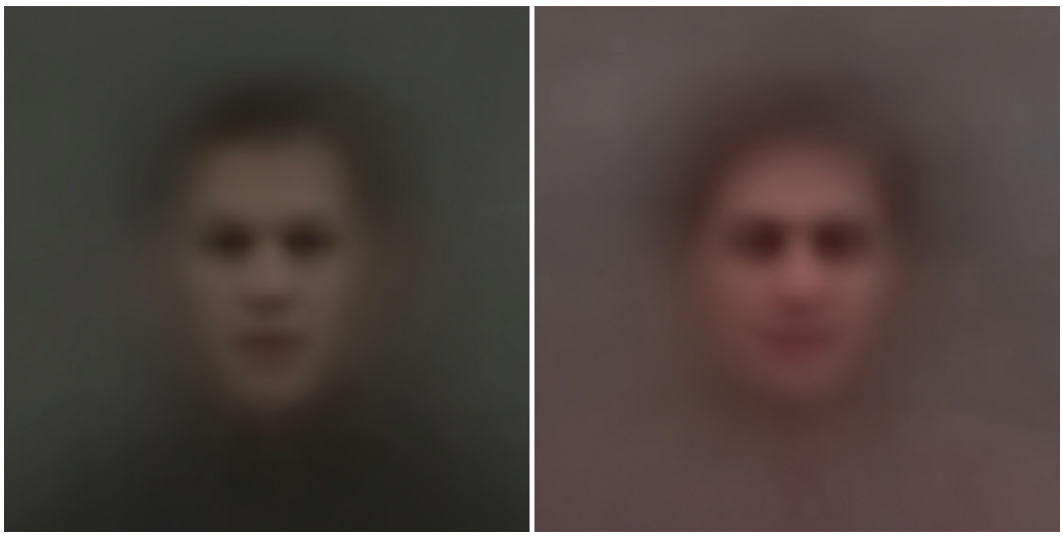

Figure 2. Shinseungback Kimyonghun, *Portrait*, 2013, with images from *Bourne Identity* (2002) and *Taxi Driver* (1975). (© Shinseungback Kimyonghun)

for interactive visualization and analysis of loaded films according to a number of criteria such as duration, average luminance and chromatic values, number of cuts, dynamics of movement in sequences, comparisons between different genres, original film versions vs. remakes, films by the same director, films by different directors, etc. [18].

Crowdsourced

As an old method for outsourcing complex, iterative, or otherwise demanding projects to many participants who are expected to make relatively small contributions, crowdsourcing has significantly evolved with the internet (and has often been skillfully exploited), from the SETI@ home screensaver in the early WWW, to FoldIt, Kickstarter, Wikipedia, CAPTCHA, social networking, and social media platforms.

In *Man with a Movie Camera: The Global Remake* (2008), Perry Bard combines online participation with automatic selection of crowdsourced video clips to make a shot-by-shot interpretation of Dziga Vertov's seminal eponymous film, *Man with a Movie Camera* (1929). A similar idea, the surrealist "exquisite corpse" method for sequential collaging of found video clips, is behind João Henrique Wilbert's *Exquisite Clock* (2009), which constructs a digital clock with six screens showing the uploaded users' free-style photographic interpretations of decimal digits.

With *The Pirate Cinema* (2012–2014) (Figure 3) Nicolas Maigret brings real-time robotic sampling of film to the world of peer-to-peer exchange. The installation uses a computer that constantly downloads the 100 most-viewed torrents on a tracker website, intercepts the currently downloading video/audio snippets, projects them on the screen with the information on their origins and destinations, discards them and repeats the process with the next stream in the download queue [19].

The idea of expanding the conventional film structure with crowdsourced, programmatically arranged, and interactively manipulable content was polished up and designed to consequently reflect the logic of online video sharing in Jono Brandell and George Michael Brower's *Life in a Day Touchscreen Gallery* (2011). It is a highly configurable platform for organizing, sorting, and

Figure 3. Nicolas Maigret, *The Pirate Cinema*, 2012–2014. (© Nicolas Maigret)

screening the clip selections of all the 80,000 short video submissions to a traditionally scripted and edited crowdsourcing film, *Life in a Day* (2010), directed by Kevin Macdonald, which used around 10,000 selected video clips. The fact that *Touchscreen Gallery* was a sideshow instead of being central to the *Life in a Day* project reflects the dominant ideology of mainstream cinema.

Deanimated

One of the most impressive critical deconstructions of the structural and audio-visual conventions in cinema was achieved by Martin Arnold with *Deanimated* (2002) (Figure 4). He successively removed both visual and sonic manifestations of the actors in Joseph H. Lewis's B-movie thriller *The Invisible Ghost* (1941), and then consistently retouched the image and sound so that the film's final 15 minutes show only empty spaces accompanied by the crackling of the soundtrack [20].

Figure 4. Martin Arnold, *Deanimated*, 2002, with corresponding stills from *Invisible Ghost* (1941) (left) and *Deanimated* (right). (© Martin Arnold)

Similarly motivated to avoid the figurative and narrative dictates of film tradition, Vladimir Todorović combines generative animations with voiceover narration and ambient soundtrack in *The Snail on the Slope* (2009), *Silica-esc* (2010), and *1985* (2013). *1985* (Figure 5) is an abstract rendition of the fictional activities of the ministries of Peace, Love, Plenty, and Truth that govern Oceania one year after the events in George Orwell's *1984* (1949). Its uncanny ambience relies on sudden changes of sound and image, triggered by the random walk algorithm that was modified with cosine function, accelerated and decelerated.

Documentary narrative structure can also be transcended, for example in Jonathan Minard and James George's computer film *CLOUDS* (2015), which dynamically links real-time generative animations and sound with prerecorded documentary footage.

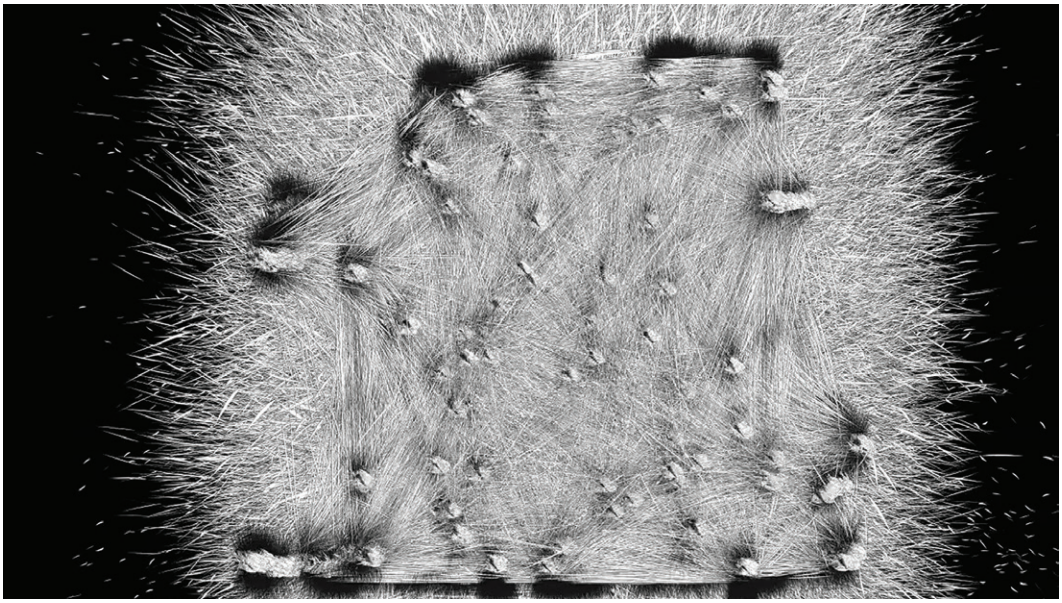

Figure 5. Vladimir Todorović, *1985*, 2013. (© Vladimir Todorović)

Condensed

In *Fast Film* (2003) (Figure 6), Virgil Widrich intelligently expanded the possibilities for reproducing and interpreting film snippets in order to accentuate the fascinations, obsessions, and stereotypes of conventional cinema. *Fast Film* was created by paper-printing the frames from selected film sequences, reshaping, warping, and tearing them up into new animated compositions. In its exciting 14 minutes of runtime, *Fast Film* provides an elegant and engaging critical condensation of key cinematic themes, such as romance, abduction, chase, fight, and deliverance.

Figure 6. Virgil Widrich, *Fast Film*, 2003. (© Virgil Widrich)

Nine years later, György Pálfi exploited this narrative methodology, along with the achievements of supercut art and culture, to produce the feature-length movie *Final Cut: Ladies and Gentlemen* (2012) out of short sequences from 450 popular films and cartoons. Although it proved to be barely watchable in continuity due to the fundamental incompatibility between rapid editing of incoherent imagery and its long running time, film critics praised it as "an ode to cinema" [21].

Synthesized

The concept of real-time procedural audiovisual synthesis from an arbitrary sample pool, in contrast, elevates the film structure by following the essential logic of cinema. This was achieved by Sven König in *sCrAmBlEd?HaCkZ!* (2006), which uses psychoacoustic techniques to calculate the spectrum signatures of the sound snippets from stored video materials and saves them in a multidimensional database that is searched in real time to mimic any input sound by playing the matching audio snippets and their corresponding videos [22]. Perhaps this innovative project was

largely overlooked because König used the *sCrAmBlEd?HaCkZ!* software mainly for VJing rather than for developing complex artworks by establishing the specific relations between the sources of stored and input materials.

Procedural audiovisual synthesis was advanced through the application of neural networking and machine learning by Parag Kumar Mital in *YouTube Smash Up* (Figure 7). Each week, this online software takes the #1 YouTube video of the week and resynthesizes it using an algorithm that collages appropriate fragments of sonic and visual material coming only from the remaining Top 10 YouTube videos [23]. It produces a surreal animated effect, visually resembling Arcimboldo's grotesque pareidolic compositions [24].

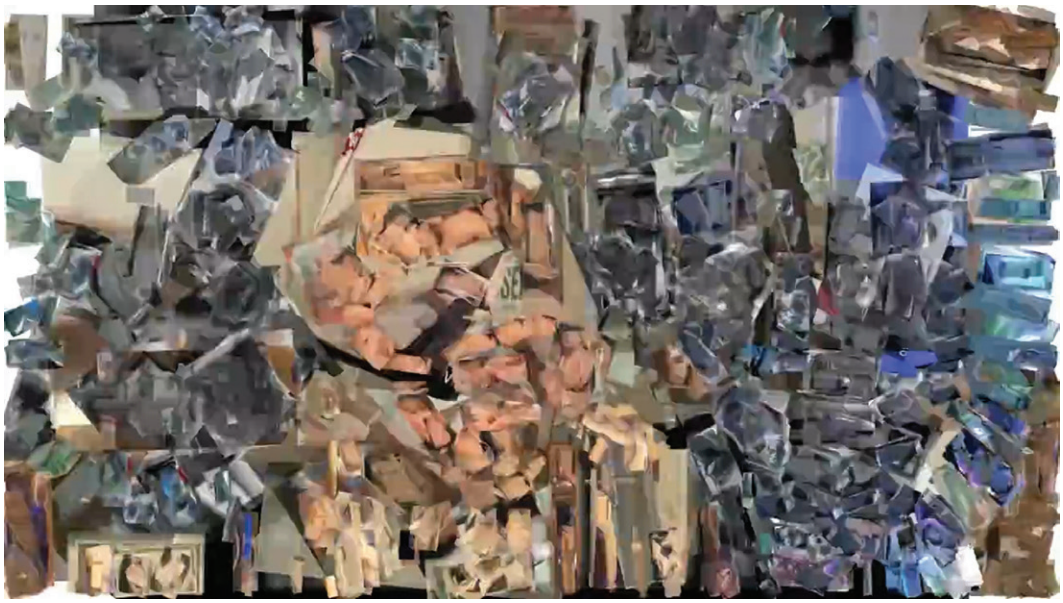

Figure 7. Parag Kumar Mital, *YouTube Smash Up: Emotional Baby! Too Cute!*, 2012. (© Parag Kumar Mital)

The more demanding, machine-based synthesis of coherent film structure and plausible narrative was tackled by Oscar Sharp and Ross Goodwin in *Sunspring* (2016) (Figure 8), which was their entry in the 48-Hour Film Challenge of the Sci-Fi London film festival. Experienced in natural language processing and neural networks, Goodwin programmed a long short-term memory recurrent neural network and, for the learning stage, supplied it with a number of 1980s and 1990s sci-fi movie screenplays found on the internet. The software, which appropriately "named" itself Benjamin, generated the screenplay as well as the screen directions around the given prompts, and Sharp produced *Sunspring* accordingly.

The film brims with awkward lines and plot inconsistencies, but it qualified among the top 10 festival entries and inspired one of the judges to remark, "I'll give them top marks if they promise never to do this again" [25]. *Sunspring* playfully reverses the "Deep Content" technology of the Whatismymovie.com web service, which analyzes transcripts, audiovisual patterns, and any form of data feed that describes the video content itself, and automatically converts it into advanced metadata which is then processed by a machine learning system that matches the metadata with the natural language queries [26].

A Void Setup

All these approaches in generative cinema point to the powerful algorithmic concepts for freely, parametrically, and/or analytically generating cinematic structure, narrative, composition,

Figure 8. Oscar Sharp and Ross Goodwin, *Sunspring*, 2016. (© Oscar Sharp and Ross Goodwin)

editing, presentation, and interaction. One such concept proposes a flexible system for automatic arrangement of manually tagged film clips, or their arrangement according to input parameters [27]. A more complex one would be able to combine computer vision, semantic analysis, and machine learning to recognize various categories and reconstruct plots from a set of arbitrarily collected shots, sequences, or entire films, and to transform and reconfigure these elements according to a wide range of artist-defined criteria that substantially surpass those in conventional film.

The algorithmic tools of generative cinema significantly expand the realm of creative methodologies for artists working with film and animation. They provide artists with new insights into conceptual, formal, and expressive elements of film and animation, which can be enhanced through experimentation. Furthermore, the algorithmic principles of the successful generative cinema artworks, regardless of their technical transparency, can be inferred, repurposed, and developed into new projects with radically different poetic identities and outcomes. These creative capacities also provide a specific context for the critical assessment of conventional film.

Just as it clumsily borrowed or repurposed ideas from the avant-garde, mainstream cinema has been systematically exploiting some aesthetic effects and themes of digital generative art, with little understanding of the intellectual values behind generative methodologies. This superficial exploitation is revealed in goofs spotted by informed viewers. When the commercial film tries to utilize algorithms as creative tools, it does so ineptly and ineffectually, reflecting its rigid ideology, as exemplified by Macdonald's *Life in a Day* and Pálfi's *Final Cut*.

The algorithmic strategies that the film industry applies successfully are those for conceptualization, script evaluation, box-office assessment, and other business-related aspects of production, distribution, and marketing. Major production companies, such as Relativity Media in Hollywood, use statistical processing of screenplay drafts, while consulting services, such as Epagogix, offer their clients the big-data–based predictions of their films' market performance [28–30]. The outcry over the ultimate loss of creativity, provoked by media disclosures on these practices is, however, either naive or cynical because business-related algorithms have always been integral to big-budget filmmaking [31].

Struggling with competitive new media and art forms, the film industry today is unable to transcend and unwilling to hide its reliance on communicating a subset of human universals [32].

Therefore, it runs its business more consciously and rationally, focusing the algorithms on market analysis, target group research, risk assessment, and screenplay design, all the way to the test-screening evaluations corresponding to the debugging procedures in computer coding. While this pragmatic algorithmization seems logical, it is creatively counterproductive. A global mass-market film industry could benefit from generative cinema only if it takes certain commercial risks and opens up to the experimental incentives of its creative talents.

Unrestrained by commercial imperatives, motivated by unconventional views on film, animation, and art in general, generative artists develop new approaches and methodologies that can be advanced and repurposed by other artists, stir our amazement with the moving image, and broaden our critical understanding of the cinema as cultural product. In this regard, the poetic divergence, the technical fluency, and the conceptual cogency of generative cinema successfully demonstrate that authorship evolves toward ever more abstract reflection and cognition that equally treat existing creative achievements as inspirations, sources of knowledge, and tools.

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Lenticular Waterwheels: Simultaneous Kinetic and Embedded Animation

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ABSTRACT

After decades as a novelty, lenticular technology has resurfaced in compelling large-scale projects. Without any required energy, the medium offers stereography without glasses and frame animation without electronics. A kinetic artwork installed in a remote river in the French mountains broke from the technology's previous restrictions of static and flat display, recalculated the print mathematics for a curved surface, and explored narrative structures for a moving image on a moving display. This paper documents how the sculpture used custom steel fabrication, site-specific energy, and revised lens calculation to present a previously unexplored hybrid of animation.

In 2016, I was commissioned to create an outdoor kinetic sculpture for Sancy Horizons Art+Nature, an annual competition in central France in which large-scale artworks are placed throughout the Auvergne volcanic range and visited by hikers and tourists during the summer. The site provided for this work was a river near the village of Égliseneuve-d'Entraigues, about two hours from Clermont-Ferrand, France (latitude: 02°50'12.3" E, longitude: 45°26'31.7" N).

I conceived large-format lenticular prints mounted onto rotating cylinders to be turned by waterwheels dipped into the mountain river's flow. Inside each cylinder, I designed simple lighting systems to use the river's flow as power to light the images and area around the installation. As the river's flow turned the waterwheels, glowing animations of patterns would continuously loop (Figure 1).

While the machines are seemingly simple, the sculpture presented concurrent animation in both content and surface as a result of custom steel fabrication and plastic lens printing. The curvature of the screen's surface required a revised calculation for the visual effect, and the kinesis of the display surface forced a rethinking of narrative structure. The complete system included the steel construction of the player machine, the revised calculations of the surface print, the concept and design of the animation content, and the installation at the site. Together, the components revealed a previously unexplored variation in lenticular technology.

Background

The work was the sixth in a series of kinetic public sculptures that I created under the theme of sustainable cinema. Each sculpture uses natural forces inherent in a site as the energy source to power a simple animation. The forces have included water, wind, tides, pedal-power, and sunlight; the animation has utilized device technologies including zoetropes, praxinoscopes, phenakistoscopes, shadow plays, and lenticulars. By referencing the histories of both film and industrialization, these sculptures are meant to encourage a possible future of more environmentally responsible media by presenting an alternative history of moving image power usage.

Additionally, in being designed for public spaces, they are meant to stimulate general awareness

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Figure 1. A digital painting of the proposed design for *Sustainable Cinema No. 6: Lenticular Waterwheels*, 2016. (© Scott Hessels. Photo: Scott Hessels.)

about alternative clean energy sources. The moving images first entertain and then inform the public about the fundamentals of sustainable design. The sculptures take the abstract principles of renewable energy and makes them tangible and accessible.

Previous sculptures in the series have been presented at the Gerald R. Ford Presidential Museum, Ars Electronica, The Museum of Contemporary Art Taipei, and the Los Angeles Convention Center as part of SIGGRAPH 2012, among others.

Lenticular History

Lenticulars were selected for the commission to promote a less-familiar image trajectory in French history. As early as 1692, French painter Gaspar Antoine de Bois-Clair created optical art that changed when viewed from different angles. His double portrait of Prince Frederik IV and royal sister Sophie Hedevig is a confused amalgam when viewed from the front. However, both subjects become individual when the viewer passes, seeing one image from the right and the other from the left.

The foundation of lenticular printing, a plate of many very small lenses, was first outlined in 1908 by French physicist Gabriel Lippmann (better known for his Nobel Prize in Physics for color photography) [1]. The actual manufacture of this lens was not possible until many years later as molded plastics development moved forward. 3D lenticular photography was greatly advanced by French camera designer, inventor, and photographer Maurice Bonnet. His radical and original imaging techniques are still in use today, and scanning lens cameras are still

referred to as "Bonnet style" [2]. Bonnet is a transdisciplinary icon in image development as someone who developed the technique, the system, and the content. As an academic he advanced knowledge, as a scientist he transformed an industry, and as an artist he produced works of great beauty.

As other imaging technologies for animation and 3D were introduced, lenticular printing became increasingly novelty-based and kitsch. However, the recent artwork *Beyond* at Schiphol Airport by Studio Roosegaarde [3] shows its dramatic potential in large-scale 3D displays, and George Legrady's *Night and Day* [4] series proves the technology also has the potential for a unique metaphoric layering of time and place.

Lenticular Technology

Lenticular printing slices two or more different images that are then spliced back together into a single image and placed behind a sheet of plastic molded with a series of thin lenses. Frames of animation can be interlaced to create a motion effect, off-set images can be used for a 3D effect, or completely different images can be alternated. The lenses must be accurately aligned to the interlaces of the images, which results in light refracting off each slice in a different direction. This slight variation in the direction of light creates a stereoscopic effect when viewed directly but can also create animation if the print or viewer is moved. Stereoscopy is only possible with horizontal, side-to-side movement. Other effects are possible through vertical movement, including motion, morphing, and a range of pseudo camera movements. I designed the waterwheels to take advantage of the range of options available with top-to-bottom movement.

The Player: Animation Powered by Natural Energy

The waterwheels and system to hold the prints were designed and fabricated in a welding shop in Hong Kong. The water's depth was calculated to 15–40cm and a system in the mounts allowed for adjustment for best flow. Most parts were made of stainless steel. Low-speed generators were purchased from a discount website in mainland China and the waterwheel rotation was converted to low-voltage electricity capable of powering a single row of LED lights running along the internal axle. As the lenticulars would be lit from inside, clear plastic tubing was used to support the print to allow light to pass through with minimal shadow (Figure 2). Once tested in Hong Kong, the machines were dismantled, shipped to Clermont-Ferrand, and received by the architecture school there. Students in the school were recruited to assist with the assembly and installation in the river.

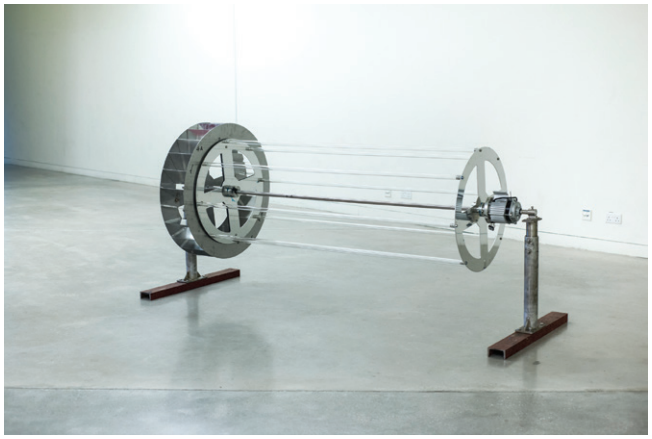

Figure 2. Waterwheel machines without prints. *Sustainable Cinema No. 6: Lenticular Waterwheels*, 2016. (© Scott Hessels. Photo: Scott Hessels.)

The Content: A Gif Riding on a Gif

Depending on river flow, the cylinders would rotate approximately once every five seconds. The image, two plastic prints measuring 180cm × 120cm, would be stitched to form a viewing surface of 180cm × 240cm. The "top" and the "bottom" of the print would line up so that the rotation caused by the river would create a five-second loop of animation. Within the rotation print are five "flips"—five interlaced frames of animation

that are sliced so that each becomes visible when the curved lens moves. The final effect is a moving image looping through five frames of animation that appear and pass by every five seconds of rotation.

A moving image on a moving screen has become culturally commonplace as mobile phones are now common display systems for cinema. Dual-image kinesis is often discussed as a hybrid of moving images, a post-cinema development created by digitization [5]. The static, fixed viewing position of cinema has expanded and kinetic screens, whether intentionally designed as such or simply transported in one's pocket, are all around. Screen mobility has affected cinema's form by favoring shorter duration [6]. Despite the apparently low-tech design of the waterwheels, the systems offered an opportunity to explore the use of retrograde technologies to reconsider both shorter form and also narrative structure.

Narrative Structures for Kinetic Sculpture

The original design called for animated patterns due to the complexity of simultaneous movements. However, I explored the challenge of dual animation, both image and surface, further when I received the commission. I developed two different stories, each in the form of five large animation panels with the understanding that the focused viewing area would be approximately 60cm × 180cm when moving down the panel horizontally.

One story idea, "Country Noir," was to place the five cylinders in the river to form a larger tableau. The most distant machine depicted a night sky flashing with lightning; the next machine contained animations of gothic-style tangles of trees and crows; the next machine showed bats in flight; and finally the cylinder nearest the viewer was an animation of a woman holding a torch continuously running down a dark stone staircase. When viewed together from a bridge over the river, the five animations would combine the character animation in five-frame loops with background animation rotating past to form one giant "image" of a haunted night in the highlands.

However, designing and working in Hong Kong for a site in the French mountains presented so many unknowns that a compromise between pattern and photorealism was more prudent. The materials and forces within the site and the sculpture's construction in China provided the inspiration to visualize *Wu Xing*, the traditional Chinese belief in the five forces of nature—water, earth, plants, fire, and metal—which must be kept in balance. The philosophy is not concerned with the elements themselves, but with the relationships between them. Five-frame images of stones falling, flowers opening, gears turning, fire burning, and water bubbling were created with the top and bottom lining up to make the loop seamless during rotation (Figure 3).

Site Experience

The work was installed in June 2016. The waterwheels were placed downstream from a small wooden bridge that allowed for viewing all five simultaneously. A small path along the river's edge made it possible for visitors to walk alongside the installation, while the depth of the river made closer inspection also possible (Figure 4). The combined display surface and distribution throughout the river made the artwork one of the largest lenticular displays in the history of the medium.

The river is a high-altitude mountain stream flowing through a valley between two volcanic ranges. Two days prior to the exhibition opening, a violent mountain storm passed through the region, raising water levels as much as 50cm in high force. The plastic rods supporting the lenticular prints snapped and the sheets were ripped from the machines, mangling the steel

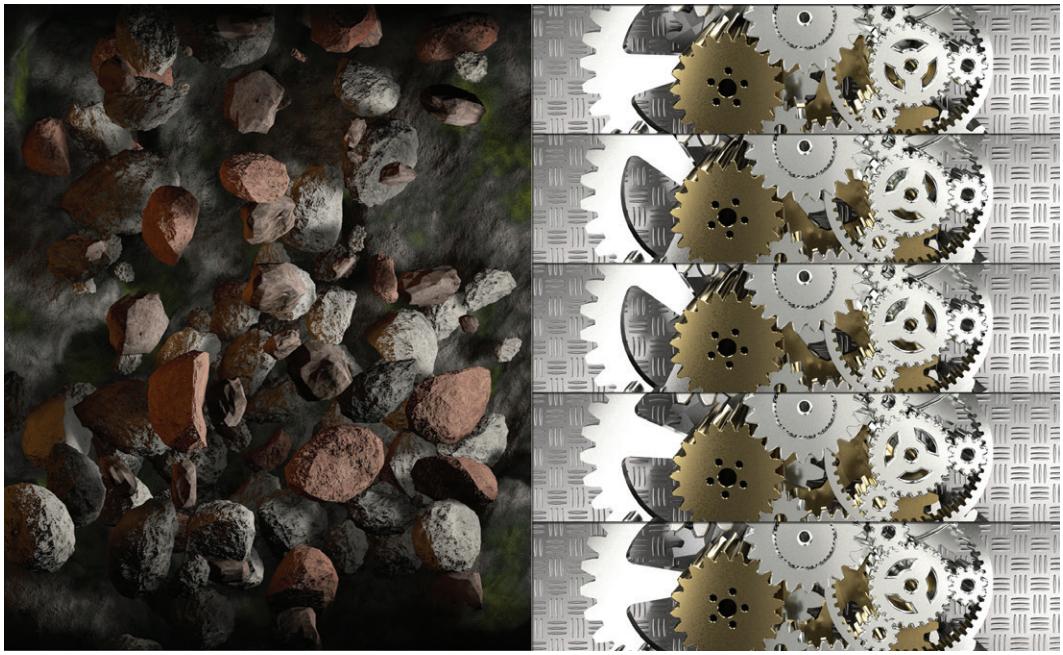

Figure 3. Single frame of earth animation, 180cm x 240cm, and sliced frame of metal animation representing five frames. *Sustainable Cinema No. 6: Lenticular Waterwheels*, 2016. (© Scott Hessels. Photo: Scott Hessels.)

Figure 4. Installation of *Sustainable Cinema No. 6: Lenticular Waterwheels*, 2016, in Auvergne, France. (© Scott Hessels. Photo: Scott Hessels.)

support wheels. All loose metal and rod fragments were recovered, although, strangely, no fragments of plastic from the lenticular sheets could be found. It was hypothesized that they had been stolen after breaking loose. However, the evening prior to the opening they were found intact under 50cm of mud at the base of a large waterfall downstream. The lenticulars were recovered from the icy water and carried upstream. For the opening, the machines with reattached lenticular prints were displayed along the riverside, allowing guests to rotate the machines themselves and view the resulting animation.

New supporting rods to hold the lenticulars were fabricated from steel and the machines were returned to the river. However, violent weather conditions continued to damage the systems through the duration of the exhibition. The electrical systems never recovered from the initial storm and a heavy hailstorm, with ice as large as 5cm in diameter, pounded the structures in early July. Direct sunlight softened and deformed one of the sheets when its rotation was stalled by a tree branch caught in the current. Evidence of direct hits from lightning were present in two of the prints in early August. The five machines were hobbled together until their removal from the site at the end of the exhibition in mid-September. They have since returned to Hong Kong and mechanical repairs and new animation are occurring for a revised presentation of the systems in another, less-difficult context.

Conclusion

When the difficulties regarding the site and subsequent damages to the artwork were relayed to colleagues in Hong Kong, there was a discussion regarding Wu Xing. Each force in Wu Xing can overpower another if the equilibrium is not correct. The philosophy posits that the five energies—fire, metal, earth, water, and wood—are of equal power and only imbalance can cause one to overcome the other. The artwork had proven one of the philosophy's core phases—water breaking metal. I had miscalculated not the flow of the river nor the strength of the steel, but simply the balance of the energies present.

The rapid development of moving image technologies and displays can make it difficult to understand the shifting ontology inherent in new forms. The sculpture simplified the complex relationship between movement and moving image and, due to the site, demonstrated the volatility of the relationship as well.

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Transforming the Commonplace through Machine Perception: Light Field Synthesis and Audio Feature Extraction in the *Rover* Project

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ABSTRACT

***Rover* is a mechatronic imaging device inserted into quotidian space, transforming the sights and sounds of the everyday through its peculiar modes of machine perception. Using computational light field photography and machine listening, it creates a kind of cinema following the logic of dreams: suspended but mobile, familiar yet infinitely variable in detail. *Rover* draws on diverse traditions of robotic exploration, landscape and still-life depiction, and audio field recording to create a hybrid form between photography and cinema. This paper describes the mechatronic, machine perception, and audio-visual synthesis techniques developed for the piece.**

Rover synthesizes three areas of emergent technology: computational light field photography, machine listening, and low-cost embedded motion control. The project engages these techniques to create a hybrid, variable representation of place. *Rover*'s method is similar to that of the landscape painter, travelogue writer, or field recording artist: traveling to a variety of locations gathering audio and visual documentation of its experience. However, rather than producing fixed representations, it captures dense sets of data to be computationally explored, refocusing through scenes in an endless process of machine reflection. Figure 1 shows an example of this searching focus within a scene.

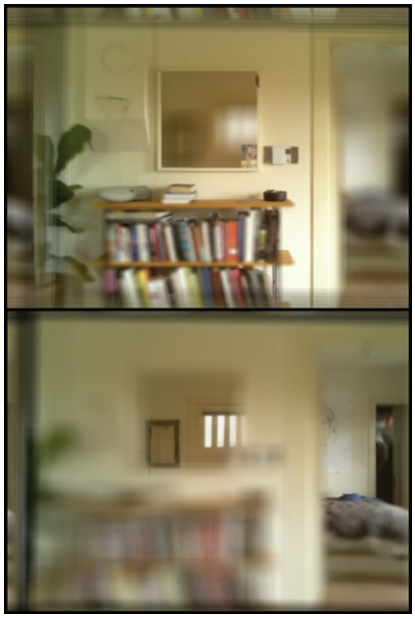

Figure 1. Refocusing a domestic scene to shift the focal plane from near (top) to far (bottom). (© Robert Twomey and Michael McCrea)

Rover has three main components: a mechatronic imaging apparatus, an analysis back-end, and synthesis front-end (Figure 2). The imaging apparatus is a single camera with a computer-controlled positioning system. Hundreds of images are gathered in a structured way, recording light from multiple vantage points within a scene. Sound is also recorded for the duration of the image sampling.

Upon completion of this on-site engagement, the audio and visual samples are processed to extract salient features. Multiview geometry techniques are used to recover camera positions, producing a light field data set. In a parallel process, sonic moments are identified with machine-listening techniques and classified for later use.

Finally, a real-time synthesis engine takes the products of these analyses—light field data and classified audio—and creates a 30-minute audio-visual composition. In a single cycle of the piece, viewers are taken on a journey

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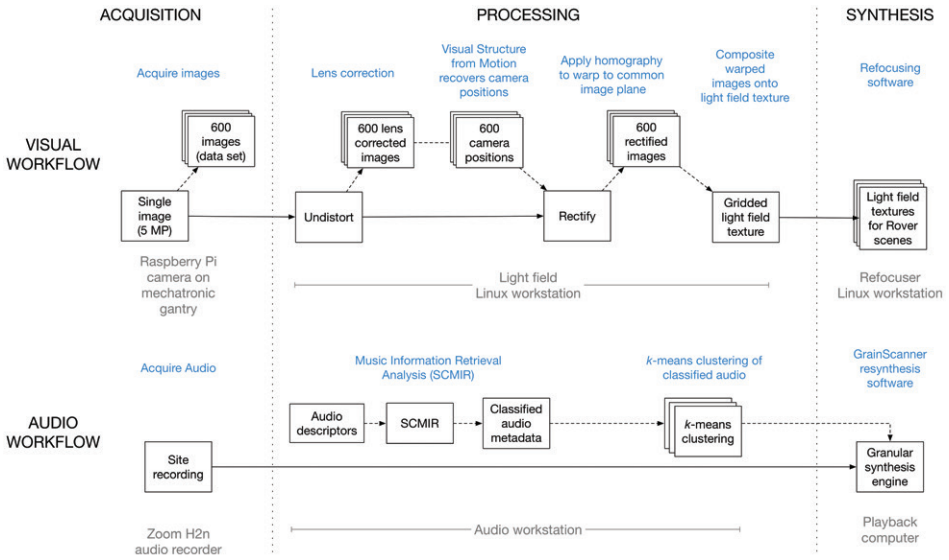

Figure 2. Audio and visual processing workflow. (© Robert Twomey and Michael McCrea)

through the sites *Rover* has visited. The viewer peers through a dreamlike vantage onto spaces that emerge and dissolve as *Rover* churns through recorded images, varying its synthesis parameters to manipulate its own perception. Sounds are similarly revisited and reshaped until they are no longer commonplace.

The result is a hybrid between photography and video, a kind of cinema that follows the logic of dreams: suspended but mobile, familiar yet constantly shifting in detail. Indeed, the places visited through *Rover*'s motility are the kinds of places found in dreams: cliffside, seaside, bedside, trapped in the corners of homes, or adrift and unable to return home.

Background: Light Field Imaging

In traditional photography, the camera captures an image from a single vantage point, losing all information about the directionality of light rays through the scene. In light field imaging, a camera or imaging device samples a scene from multiple views, capturing both positional and directional information about incident light. The additional information in a light field image allows for the synthesis of new views of the scene, well beyond the physical limitations of traditional lenses, resulting in ex post facto control over rendered depth of field, vantage point, and focal plane [1].

Light field imaging has existed in theory and practice for more than a century. Nobel Laureate Gabriel Lippmann described and created a multilens plenoptic camera in 1911, shooting 12 coplanar images on photographic film using 12 lenses [2]. In the past 20 years, advances in digital image sensors and computing capabilities have enabled breakthroughs in light field techniques: dynamic light field–based rendering [3], light field acquisition with custom camera arrays [4], moving gantries [5], hand-held light field cameras [6], and even consumer products [7].

Light field synthesis, when augmented by programmable robotic movement, computer vision and machine listening techniques, exists somewhere between photography, photogrammetry, and cinema. Mature, open-source computer vision libraries, cheap imaging hardware, and affordable motion control systems have put light field techniques within the reach of independent artists and researchers.

Formal Strategies

This work draws on the literary tradition of the travelogue, documenting a subjective journey through unfamiliar places. The sites *Rover* visits are familiar to us: homes, forests, bedsides. At the same time, *Rover*'s gaze is mechanical and exacting—that of a robotic explorer. This intersection of the travelogue form with a nonhuman gaze creates an aesthetic situation wherein the viewer sees the commonplace transformed—familiar scenes observed through an alien subjectivity.

The compositional structure for *Rover* produces a looping orbit through multiple interior and exterior sites, inspired by W.G. Sebald's *The Rings of Saturn* [8]. *Rover* evokes the digressive and at times bizarre aspects of Sebald's peripatetic journey: captivation in quotidian details found in photographic artifacts and encountered throughout the landscape. The narrative is one of constant departure; each scene, upon persistent observation, grows increasingly remote.

Rover's unique modality is born of a technology modeled after our own vision—the camera. While artists have developed a stable understanding of the photograph as form, its reinvention as a shifting, manipulable image through light field photography complicates its identity as fixed media. *Rover*'s dynamic reworking of photographic space invites the viewer along as it actively manufactures synthetic images. Moment to moment, *Rover* ultimately produces hybrid photographs, maintaining the grip on nostalgia and affective communication advanced in Roland Barthes' *Camera Lucida* [9], but they reveal their own contingent instability. Viewers' understandings of apparently inert moments or places are given new dimension through *Rover*'s computational search. In one scene, a wooden frame hangs above a bookshelf, holding a floating, dimensionless volume of light. In the next moment, as focus shifts, the volume resolves into an image of *Rover* seeing itself. The frame, however, has disintegrated and the optical play is revealed to be the inverted space of a mirror.

In contrast to *Rover*'s continuous motion, moments of rest in the image resynthesis acquire an unexpected stillness and distance. We find resonance and inspiration for this in the cinematography of Andrei Tarkovsky, enveloped in the effects of light, depth, and stilled time. In particular, his personal polaroids [10] pique longing and nostalgia through their traces of inhabitation yet lack of human presence. *Rover*'s interiors are saturated with signs of inhabitation, though in cyclically revisiting these places, those signs become fleeting. A floral centerpiece on a dining table, for example, is rendered ephemeral as *Rover*'s focus wanders away, dissipating the object.

Rover departs from domestic interiors into expansive exteriors—seaside, cliffside, and pastoral trails. Viewers witness the dissolution of the photographic eye as light fields are shaped to reveal and obscure features of the landscape: the trunk of a tree dissolves to reveal the surrounding forest, only to further dissolve, giving way to the distant sea. Through the perception of the viewer this selective attention is attributed with subjective intent, akin to the controlled focus and erasure in Gerhard Richter's paintings of reappropriated landscape photographs [11].

While the refocusing system can perform "strict" light field synthesis towards synthetic photography, the parameters for resynthesis can also push the process into abstraction (Figure 3). For example, wildflowers on a cliffside, when faithfully rendered, serve as a pointillistic texture surrounding an empty pathway leading into the distance. When the synthesis bounds are intentionally crossed, these yellow flowers fragment into a color field that merges with evening light caught by the clouds in the background.

Figure 3. Refocusing parameters can push the image synthesis into abstraction. (© Robert Twomey and Michael McCrea)

Figure 4. The CNC cable-driven camera gantry, shooting an exterior scene (top) and an interior scene (bottom). (© Robert Twomey and Michael McCrea)

This abstraction violates the presumed fidelity of machine perception. In moments of abstraction—when *Rover* appears lost, when depth and sense are seemingly destroyed and *Rover* fails to spatially resolve its light data—its vision, while imperfect, is no less "true." *Rover*'s inability to faithfully recount its travels paradoxically finds resonance with our own imperfect—or impressionistic, one might even say creative—memory.

The various degrees of plasticity in the light field synthesis technique highlighted here hold great appeal to artists seeking to recruit the photographic image back in both time and space.

Image Acquisition

Light field photography requires dense sets of spatially rectified images. For each of the 15 scenes included in the initial iteration of the *Rover* project, approximately 600 images were acquired on-site. To achieve this structured sampling, we developed a computer-controlled positioning system with a single camera moving within a two-dimensional plane (Figure 4). This apparatus is a cable-driven computer numeric control (CNC) system, suspending an embedded processor (Raspberry Pi) with image sensor (pi camera) on spectra line between two portable C-Stands. Camera movements are directed by an external computer sending GCODE commands and interpreted by an Arduino stepper motor controller running GRBL, an open-source, embedded GCODE-parser [12].

This single moving camera approach offers several advantages. It is economical and portable, a key constraint given the exploratory, site-based nature of the project. With a cable-based configuration, the synthetic aperture can be expanded or condensed to match the desired spatial resolution: an outdoor scene may require a large aperture with a deep focal plane (Figure 5), while an indoor scene may be better suited to a smaller aperture and denser image set (Figure 1). In the present configuration,

Rover's imaging plane can span 40 feet. Finally, the quantity and positioning of images within the capture sequence can be modified on-site.

Figure 5. Outdoor scenes are well-suited for a large synthetic aperture, accommodated by the configurable capture system. (© Robert Twomey and Michael McCrea)

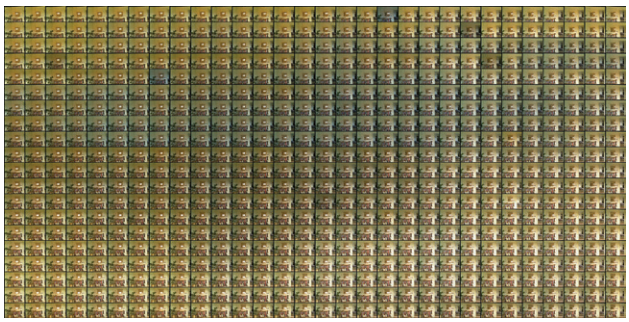

Figure 6. Temporal effects in the light field data: sunlight in the room shifts between the upper left and lower right of this image set. This dataset "contact sheet" is used to synthesize Figure 1. (© Robert Twomey and Michael McCrea)

Temporal parameters offer control over how *Rover* records the passage of time. For example, shifts in natural light are recorded into the light field data during a long-duration scene capture (Figure 6). This temporal dimension can be navigated in a nonlinear way during scene reconstruction. Furthermore, image acquisition can be ordered spatially in anticipation of particular moments or events witnessed by the system. For instance, in one scene of the final work, a subset of images was selected to emphasize the passage of a train through the landscape.

Visual Analysis

Once captured, image processing is a multistep workflow. Images are 1) corrected for lens distortion, 2) located in space using structure from motion algorithms, 3) rectified to a common virtual imaging plane, and 4) arranged in gridded textures to be sampled for resynthesis.

Lens distortion is corrected using a chessboard calibration procedure with Python/OpenCV [13]. Intrinsic and extrinsic lens parameters are applied with Python code to undistort the raw images. Since the Raspberry Pi Camera is a fixed-focus device, chessboard calibration is only done once and can be applied for all subsequent image sets.

Next, the undistorted images are used to recover camera positions with Visual Structure From Motion (VSFM), a comprehensive multiview geometry software [14]. Visual features are recognized within images [15]. Pairwise feature matches are created between images, used for a sparse scene reconstruction, and camera locations are refined through multicore bundle adjustment [16]. This results in 3D positions and rotations for all cameras relative to the visual scene (Figure 7).

To produce a light field dataset for each scene, these hundreds of camera views are rectified to a common virtual image plane. Figure 8 shows an input image, single projected image, and stack of aligned, rectified images. This rectification also compensates for slight error in the physical capture position. Finally, rectified images are stored as a maximum resolution "contact sheet" (as in Figure 6) to serve as the texture data for refocusing software. In this texture, subimage location corresponds to position in the acquisition grid. This texture is selectively

sampled for synthetic aperture manipulation and resynthesis effects as described below.

Audio Analysis

One goal for the audio synthesis was to use computational listening techniques to explore how a machine narrator might identify sonic qualities or moments of interest in a scene to then reimagine for the viewer. This process begins at the site of light field capture, where stereo field recordings are made over the approximate duration of the capture sessions. The recordings were continuous and unscripted, capturing many small events and shifts in environmental sound. This material presents a challenge that is familiar to artists working with durational recordings or, more generally, with large datasets: to distill large amounts of information into an experience that conveys the variety and scope of the source material, while also providing emphasis and interpretation.

To this end, we developed a framework of computational synthesis that begins with audio feature extraction. This stage translates the recordings from single-dimensional (temporal) material into a multidimensional space that is organized by perceptual, spectral, or temporal characteristics. This task was performed in SuperCollider, using the SCMIR library by Nick Collins [17]. After analysis, the multidimensional data is further ordered into *k*-means clusters, ordered by self-similarity. This creates a nonlinear structure that can be navigated algorithmically upon resynthesis.

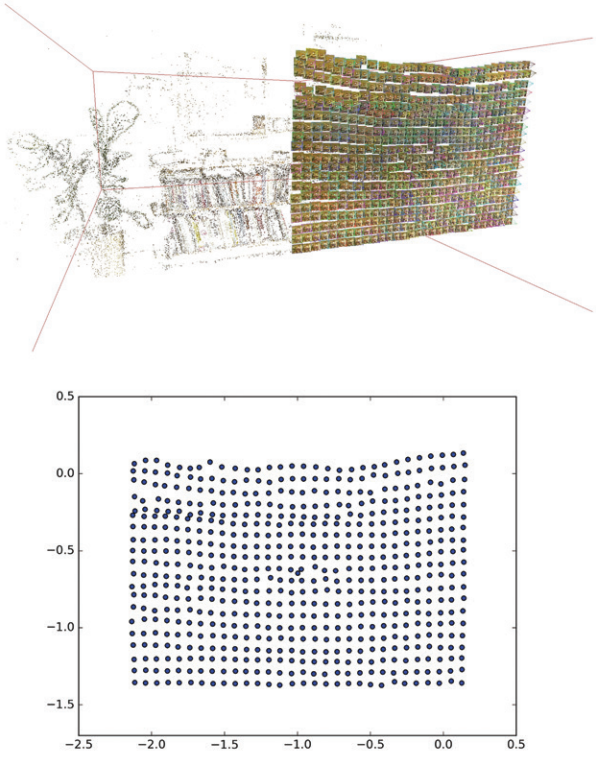

Figure 7. Recovered camera positions and rotations relative to a scene (top). Same cameras plotted on virtual image plane (bottom). Note the slight irregularity in the sampling grid due to the nonrigid acquisition platform. (© Robert Twomey and Michael McCrea)

Figure 8. A test image (top left) projected onto an image plane (top right) and aligned with other rectified images (bottom). (© Robert Twomey and Michael McCrea)

Resynthesis

The front end of *Rover* is a live synthesis system. It has two parts: an audio synthesis engine written in SuperCollider, and a light field refocusing engine written in openFrameworks and OpenGL Shading Language (GLSL). These systems are controlled in real time with Open Sound Control (OSC) messages generated from a unified compositional control system written in SuperCollider.

The scale of our light field data requires a high-performance program for resynthesis. Initially written in C++, the refocusing algorithm has been ported to GLSL and optimized to run on a high-end GPU (NVIDIA Titan X), employing its full compute capability and usable memory (12GB of pixel data). It loads high-resolution, uncompressed light field textures and enacts a broad range of transformations inherent to synthetic aperture rendering of light fields. OSC signals modulate the depth of field, parallax, focus, crops, pans, zooms, contrast, brightness, and hue shifts.

The texture is comprised of many rectified images, forming a "contact sheet" as described in the previous section. Pixel data from all, or only a subset, of the images are sampled to generate the projected scene. The positions of the subimages used determine the particular vantage point of the synthesized view. Therefore, the perspective of the viewer can be made to traverse the image plane by dynamically sampling different regions of the contact sheet.

For the audio synthesis, a compositional process brings clustered audio feature data back into a temporal dimension for each scene. We wrote a software instrument in SuperCollider that allows high-level parametric control over granular synthesis—a process wherein fragments of sound are arranged in time with varying duration, amplitude, pitch, and density. The instrument, GrainScanner, uses *k*-means clusters as stochastic anchors, scanning each cluster for sounds of high similarity in the center and more anomalous sounds toward the outer radius. Figure 9 shows examples of clustered audio data points and the synthesis control GUI.

The GrainScanner offers a wide degree of control over the perception of synthesized sound as diegetic (a faithful reproduction of the original) or purely gestural (by stretching, freezing, layering, cycling, or phasing moments in time). This diversity of sonic character serves many ends: reinforcing the sense of place shown on screen, enhancing the motility of the machine narrator as it navigates the space of the image, and augmenting the memorious quality of the visual system by recounting, echoing, and realigning sounds in real time.

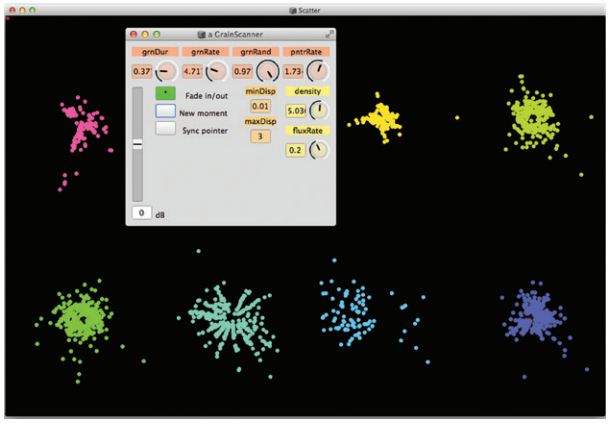

Figure 9. Clusters of feature-classified audio samples based on site recordings with an instance of a GrainScanner GUI.

This framework of "generative computational synthesis"—the aggregate of offline analysis and real-time synthesis—used for both sound and image, is analogous. This allows the algorithmic controls for sound synthesis to be composed in concert with those used for visual synthesis. For example, the drifting focus of an image is accompanied by a modulation in granular density of the sound field, obscuring or revealing the source material in concert with the shifting clarity of the image.

Presentation

Rover premiered at the Black Box 2.0 Festival in Seattle, Washington in 2015 [18]. It was installed in a 20-foot shipping container as a single-channel video projection with four-channel audio (Figure 10). A rectangular projection screen was suspended toward the rear of the container. Two speakers were installed behind the screen and two speakers hung just inside the container doors, behind a viewer that had entered the viewing space. Installed in this long box and lit only by the floating image plane, *Rover* echoes both its own imaging process and the form of the *camera obscura*, its artistic and technical antecedent, creating the impression for the viewer of stepping into a large imaging device.

Figure 10. *Rover* installed at the Black Box 2.0 Festival. (© Robert Twomey and Michael McCrea)

Conclusion and Future Directions

Over the course of development, we have identified a number of improvements and new directions for *Rover*. Technically, the GLSL shader code can be optimized to work with full-resolution light field datasets beyond the memory limits of the graphics card, using dynamic texture loading as is typical in the game industry. The image and audio analysis pipeline can be ported to cloud infrastructure [19]. Variations on the image acquisition apparatus, for instance a rigid Cartesian CoreXY gantry [20], have been developed to enable new capture geometries.

There are also a number of desirable additions to *Rover*'s operation; for instance, dynamically updating the light field data to include new images acquired during the course of an installation or exhibition. The resynthesis engine can be integrated into other responsive or immersive (AR/VR) display paradigms. Nonuniform refocusing parameters can be implemented using control masks, for instance varying focus across regions of an image. The mechatronic capture process itself has a performative quality that could be used for performance-based project iterations.

Most importantly, as the project is iterative by nature, we continue to develop content for the *Rover* system, experimenting with new subject matter and seeking new sites for *Rover* to visit.

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María Fernández

For the first time in its history, SIGGRAPH focuses on Latin American artists working with digital technologies. This is momentous, as this subject has seldom been explored—neither in the history of new media art nor in the entire history of art—despite the tremendous growth of these fields in the last 20 years. The insufficiency of study in this area has to do in part with the historical tension between digital art and the art world, and with totalizing stereotypes of Latin American underdevelopment that perpetuate the marginalization of the region from modernity [1]. While the SIGGRAPH 2017 Art Gallery critically advances these histories, a multiplicity of inventive engagements of Latin American artists with a variety of modern technologies precedes it. Hence the exhibition is both unique and in conversation with a long tradition.

European technological media, such as books and printed images, have been integrated into Latin American art and society through the processes of colonization, Christianization, and exchange since the 16th century. Prints were used to train artists in the techniques of European representation and were particularly effective for disseminating ideas among those who could not read. In some territories, such as Peru and Bolivia, as well as in 16th-century Mexico, the confluence and convergence of indigenous and European imagery generated distinctive regional visual cultures. In the 19th century, and more frequently in the 20th, some artists employed modern technologies in their work while others used traditional media to depict visions involving technologies real and imaginary. Many artists traveled abroad and actively participated in international networks, which makes it difficult to disassociate Latin American art from international artistic developments.

In 1920s Mexico, the *estridentistas*, recognized as Latin America's first vanguard movement, were presciently conscious of the changes that modern technologies presented to society. Estridentista visual and literary works bustle with the images and sounds of streets, shops, corners, advertisements, radiators, airplanes, cinema, jazz, radio, telegraphs, automobiles, locomotives, factories, and strikes. Their work was partially a response to the irreversible technological and social changes that Mexico underwent during the period of reconstruction that followed the devastation of the Mexican revolution [2].

Subsequently, renowned Mexican muralists Diego Rivera, David Alfaro Siqueiros, and José Clemente Orozco painted images of technologies including electric light, airplanes, microscopes, telescopes, x-ray machines, and fictional cyborgian creatures to communicate hopes, fears, and imaginations for the future [3]. Such images include Rivera's famous—and now destroyed—1933 mural in Rockefeller Center in New York City; *Portrait of the Bourgeoisie* at the Electrician's Syndicate in Mexico City, by Siqueiros, Josep Renau, and the Team of Plastic Artists (1939–1940); and Orozco's murals at the Instituto Cultural Cabañas in Guadalajara (1928–1939).

During the 1940s and 1950s, Latin American artists began to investigate new media. In Argentina, Gyulia Kocise and Lucio Fontana created neon sculptures that preceded the development of neon art in the United States [4]. In Brazil, Abraham Palatnik exhibited his first kinechromatic work at the São Paulo Biennial in 1951. It consisted of a backlit plastic screen onto which colors and forms were projected using lights of varying voltages, colored electric wires,

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electronically controlled rotating cylinders, time switches, special lenses, and a prism. The result was a "painting" of light in continuous transformation [5]. Later in France, Nicholas Schöffer of Hungary and Frank Malina from the United States would independently create backlit devices with similar purposes.

After the Second World War, the art world witnessed a surge of artistic production using new media and technology. In the 1950s and 1960s, a number of Paris-based Latin American artists, including Argentines Julio Le Parc and Martha Boto, created innovative kinetic and electronic participatory sculptures and installations. Le Parc, along with compatriot Horacio García-Rossi, was a member of GRAV (Groupe de Recherche d'Art Visuel), an influential group of artists that challenged the traditional model of the artist as genius by adopting a model of collective, and even anonymous, authorship based on scientific research. GRAV drew inspiration from cybernetics and information theory, and sought to incorporate the audience's responses into the work of art. They did not embrace technology blindly, however; GRAV frequently interrogated the notion of technology's infallibility and emphasized the instability of phenomena such as vision and meaning [6].

Meanwhile, in New York, Chilean artist Juan Downey, in collaboration with the engineer Fred Pitts, was creating interactive electronic audio-kinetic sculptures using electromagnets, radio, photocells, a Geiger counter, and tape recorders, among other technologies. Downey was fascinated by people's experiences with technology. Regarding the motivation for these sculptures, he said, "They imitate aspects of movement in life. Art is more concerned with thinking about what people experience than with producing objects" [7].

In Argentina, the Instituto Torcuato Di Tella financed artistic explorations of television, telex, radio, and audio recording from 1966 to 1970. Artist Marta Minujín experimented with mass media technologies in Buenos Aires concurrently with Nam June Paik's innovations using television in Germany and New York. *Simultaneity in Simultaneity*, a collaboration with Allan Kaprow in New York and Wolf Vostell in Berlin, was intended to consist of simultaneously occurring events broadcast via satellite. The first part, *Invasión Instantánea* (*Instantaneous Invasion*), was planned as a transmission via radio, television, and telegraph reporting Minujín's "invasion" of the homes of 120 people; simultaneously, Kaprow and Vostell were to have executed their own "Happenings" in New York and Berlin. In the second phase of the project, *Simultaneidad Envolvente* (*Enveloping Simultaneity*), 60 members of Argentina's cultural elite were photographed, filmed, and recorded. The same people later attended an event at the Instituto, dressed exactly the same as in the recordings, where they were seated to watch themselves on individual television sets and in projected slides while listening to their own voices on the radio. Ultimately, the satellite connection did not work and the "Happenings" abroad did not occur [8]. The multimedia event that did take place, even if only a fragment of that originally proposed, was nevertheless impressive for its ambition.

Brazilian artist Waldemar Cordeiro is believed to be the first producer, in collaboration with physicist Giorgio Moscati, of computer art in Latin America. In 1968 they used an IBM 360/44 in the University of São Paulo's physics department to create digital prints addressing various subjects. Predominantly these works were portraits featuring the human face [9]. In order to make a print, Cordeiro manually digitized a selected image and entered the information with punch cards. He divided the image into 9,600 points, 80 points per line, and assigned to each point a number from zero to six to indicate its degree of darkness. Then Moscati wrote a program in FORTRAN to process the image [10]. The resulting print had a pixelated appearance. In some images the pixels were ASCII characters layered to create gradations of

light and shadow in conjunction with randomly placed dark dots [11]. In addition to his artistic work, in 1971 Cordeiro authored "Arteônica," an essay in which he stressed the importance of electronic media for mass communications and for the development of novel, international, and interdisciplinary art forms. Given the limited availability of computers worldwide at that time, these projections were visionary [12].

The work discussed above is but a fraction of Latin American art involving technology. I have not discussed cinema or video, which have been significant fields of Latin American cultural production; nor have I discussed the important work of artists at the turn of the millennium, such as Regina Célia Pinto and Giselle Beiguelman in Brazil; Ivan Abreu, Ximena Cuevas, Fran Ilich, Carmen González, and Leslie García in Mexico; Andrés Burbano in Colombia; and Brian Mackern in Uruguay. Latin American artists have been especially active in recent years, as is evident in the most prominent exhibition venues for new media art, such as ISEA International and Ars Electronica, where Latin American artists including Rafael Lozano-Hemmer, Ivan Abreu, and Tania Candiani from Mexico and Eduardo Kac from Brazil have received high recognition [13]. Latin American new media art of the last century is at once the product of specific locales and inseparable from international trends—and this is clearly evident in the SIGGRAPH 2017 Art Gallery.

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13. In 2013, Nicholas Warchausky (Argentina), Kuai Shen (Ecuador/Germany), Gilberto Esparza (Mexico), and Tania Candiani (Mexico) received honorable mention at Ars Electronica, arguably the most prestigious competition in the field of Electronic Arts. Candiani represented Mexico in the 2015 Venice Biennale.

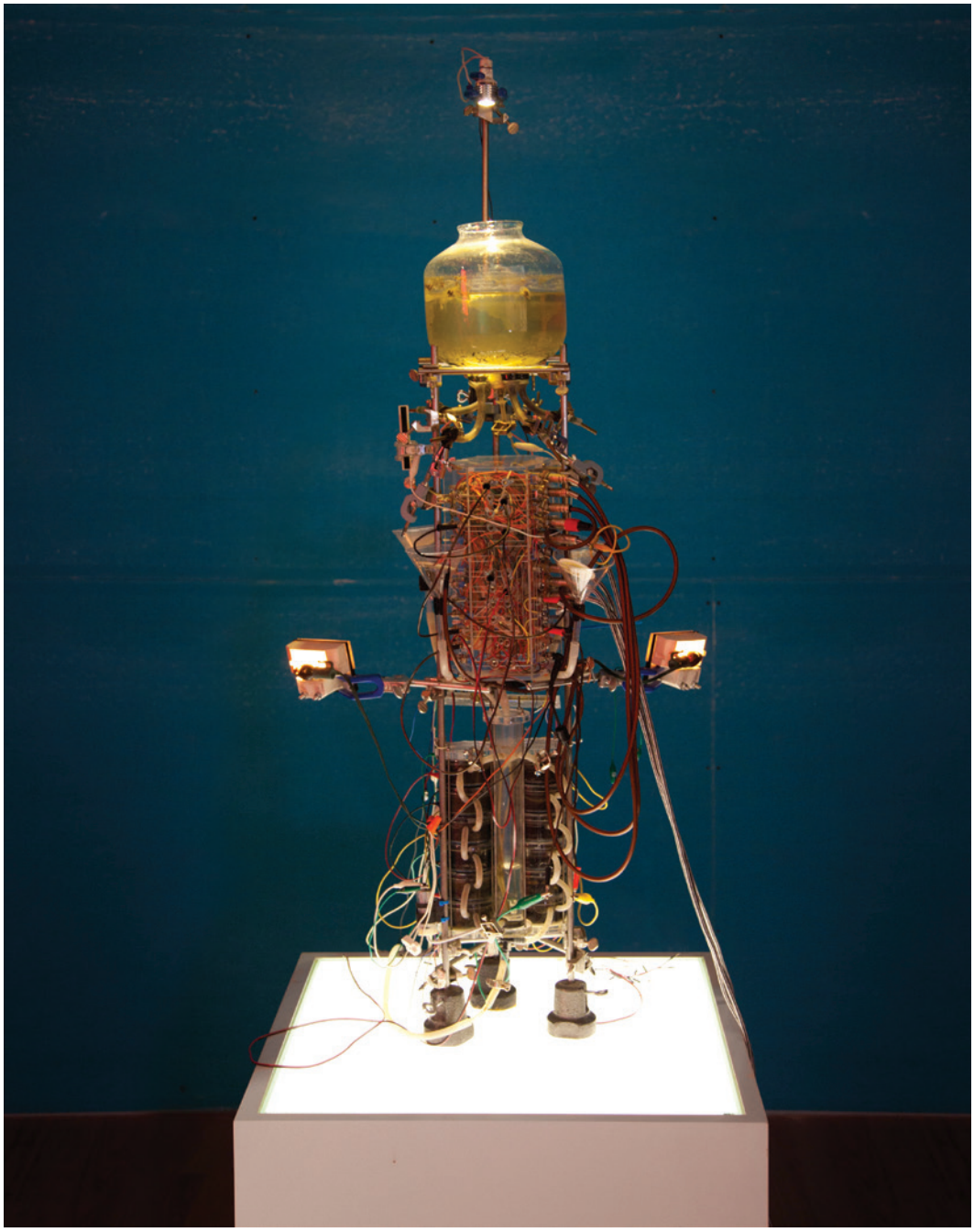
María Fernández is Associate Professor in the Department of History of Art and Visual Studies at Cornell University. Her research interests include the history and theory of digital art, postcolonial and gender studies, Latin American art and architecture, and the intersections of these fields. She is the author of *Cosmopolitanism in Mexican Visual Culture* (Texas University Press, 2014), which received the Arvey Book Award by the Association for Latin American Art in 2015.

BioSoNot 1.2

Gilberto Esparza
Mexico
http://gilbertoesparza.net/

See <www.mitpressjournals.org/toc/leon/50/4> for supplemental files associated with this issue.

Gilberto Esparza



BioSoNot 1.2. (© Gilberto Esparza)

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BioSoNot 1.2. (© Gilberto Esparza)

BioSoNot 1.2 (2014–2016) is a musical synthesizer that translates biological activity into sound while cleaning contaminated water samples. A hybrid bio-sound instrument, this sonic device generates music and noise from the biological activity of different living microorganisms.

BioSoNot 1.2 consists of a series of custom-made microbial fuel cells that work as biosensors, capturing the electrons produced by the metabolic processes of the bacteria living in polluted rivers and urban municipal waters, such as Geobacters, commonly found in decomposing organic waste. This bio-electrical information is harvested and fired as energy into an oscillator that expresses the information as sound, generating an organic symphony of bacterial life.

Part machine, part organic system, *BioSoNot 1.2* is a product of the artist's longstanding interest in creating symbiotic systems that reimagine the management of contaminated waters and the recycling of urban waste.

Gilberto Esparza's work uses electronic and robotic means to investigate the impact of technology on everyday life, social relationships, the environment, and urban structures. His current projects explore alternative energies, consumer technology recycling, and biotechnology. Esparza graduated from the School of Fine Arts at the University of Guanajuato in Mexico and also studied at the School of Fine Arts of San Carlos in Valencia, Spain. His work has appeared in solo and group exhibitions around the world. He received the award for Latin American Production at VIDA 9.0, and second prize at VIDA 13.0 by the Fundación Telefónica of Spain. He was also given Honorary Mention at the Prix Ars Electronica, and the 2015 Ars Electronica's Golden Nica in Hybrid Art. He is currently a member of the National System of Art Creators in Mexico.

Milpa Polímera

Marcela Armas
Mexico
http://www.marcelaarmas.net/

Arcángelo Constantini
Mexico
http://www.arc-data.net/

Marcela Armas and Arcángelo Constantini

Milpa Polímera. (© Marcela Armas and Arcángelo Constantini)

Milpa Polímera (*Polymer Cornfield*) (2013) is a 3D open-source printer modified to function as a tractor that plows seeds made out of polylactic acid (PLA), a thermoplastic biopolymer made from corn. The printer-tractor is fixed by an axis to a closed cycle in which the machine is only able to perform a single repetitive and absurd task: print artificial corn seeds and sow them into the soil.

Like the never-ending loop in which this tractor-printer operates, the work is a manifestation of a series of contradictory relations between the natural and the artificial, as well as other conflicting narratives of patents, open-source technologies, and free knowledge.

The machine was constructed using the first generation of MakerBot, an open-code 3D printer developed by a community of enthusiasts who selflessly supported the advancement of this technology. Nevertheless, soon after it achieved enormous success, MakerBot Industries terminated its open-code printer production and entered the patent market. At the same time,

the PLA used as the machine's main production material is a thermoplastic obtained from cornstarch, processed by a genetically modified bacteria. The corn used to produce this polymer is itself transgenic patented, which paradoxically contradicts the very origins of corn: a seed domesticated about 10,000 years ago by a collective civilization whose cosmogony and culture saw it as a shared source of life.

The *Milpa Polímera* tractor is trapped inside a perverse cycle whose logic is strictly economic and market-driven, planting infertile seeds that are unable to germinate. Thus it exposes the system behind the control of life and knowledge, which radically negates the origins of corn and the original *milpa* crop-growing system.

Acknowledgment
Milpa Polímera was originally conceived for Sin Origen/Sin Semilla, curated and directed by María Antonia González Valerio and Liliana Quintero as part of the research group BIOS Ex MachinA. English translations of texts by Tere Carter.

Marcela Armas's work seeks to articulate disciplines, techniques, processes, and research to address the relationship between matter, energy, space, time, and their relation to society and history. Her work has been shown in North and South America, Europe, and Asia, and has been exhibited recently at the Eleventh Biennial of Havana. Armas's work has been supported by FONCA (the Mexican National Endowment for the Arts), the CENART (National Center of the Arts, Mexico), and the program Arte Actual by Bancomer–MACG. She has received awards including the ARCO/BEEP Award at ARCO Madrid 2012 and the VIDA 16.0 prize of the Telefónica Foundation in Spain. She currently co-organizes the Meditatio Sonus series with Arcángelo Constantini and is a member of FONCA's National System of Art Creators.

Arcángelo Constantini is an artistic inventor, technological hacker, and existential speculator. His work is characterized by a deep scientific, philosophical, and perceptual investigation of the processes of nature through technology. He was the new media curator at the Tamayo Museum of Contemporary Art; the 1/4 project; the 2005 and 2009 Transitio MX Electronic Art Biennial at CNA/CONACULTA; and director of FACTO 2014 and 2015. Constantini currently co-organizes, with Marcela Armas, the Meditatio Sonus series. He obtained the Rockefeller/MacArthur Fellowship, the VIDA award from the Telefónica Foundation in Madrid, and the CNART PAPIAM. He is a member of FONCA's National System of Art Creators.

The Andean Pavilion

Paul Rosero Contreras (Dos Islas Studio)
Ecuador
http://paulrosero.com/

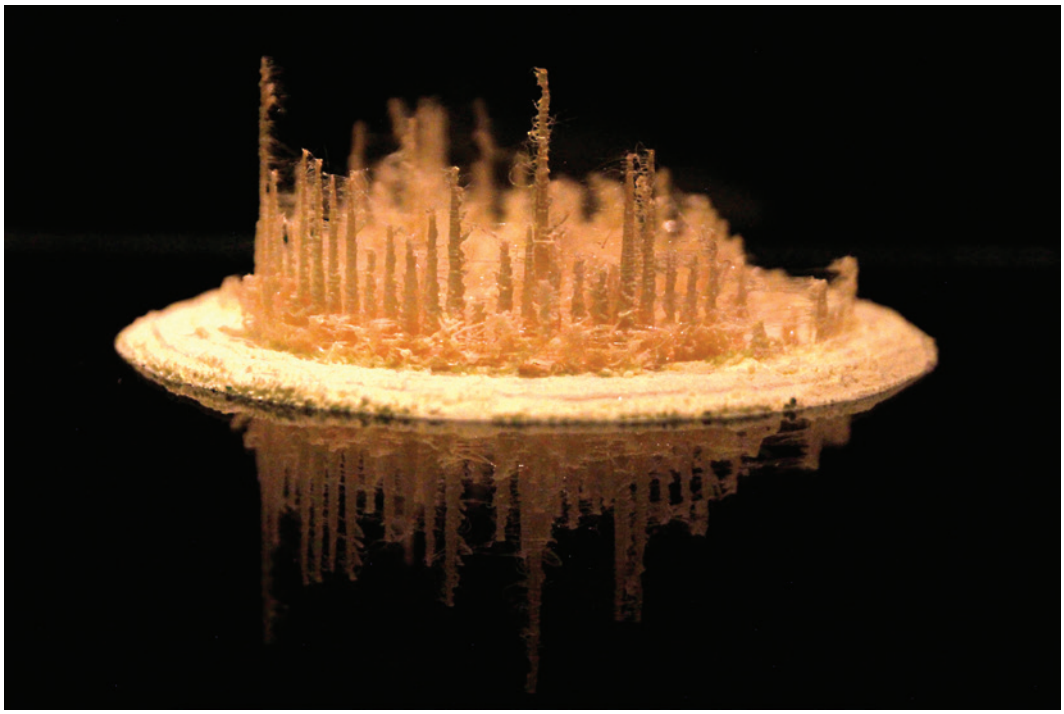
Paul Rosero Contreras

The Andean Pavilion / Someday somehow, A/P. (© Paul Rosero Contreras / Dos Islas Studio. Photo: Leonardo Arrata.)

The Andean Pavilion (2015/2017) is a video installation composed of a series of fictional videos and 3D-printed sculptures, which are the material outcome of the seismic activity in four active volcanoes in the highlands of Ecuador and the Galápagos Islands. This project is part of an experimental inquiry speculating on the possibility of emergent relations between the environment, humans, and technology in settings that are heavily defined by natural phenomena.

By means of vibration sensors, volcanic activity was recorded with sound devices and converted into computational 3D models using custom software. The result is a series of hybrid objects created at the intersection of different worlds: geologically inspired artifacts that not only complicate the relations between life and matter, but also expand the notion of in-situ intervention and translation of natural forces into physical matter.

In the Andean highlands of Ecuador, three active volcanoes have been registered: the Cotopaxi, during its first eruption after 138 years of inactivity; the Tungurahua, which has been continually ejecting ash for 17 years; and the Cayambe, recently active after 230 dormant years. In the Galápagos Islands, the Sierra Negra volcano on Isabela Island was recorded at the site of a fumarolic sulfur mine. *The Andean Pavilion* is, therefore, the reenactment of a momentary encounter between a volcano, a human, and a machine—an encounter that seeks to open up



The Andean Pavilion, Stornato version I / Someday somehow, A/P, 2015. (© Paul Rosero Contreras / Dos Islas Studio)

possibilities of interaction and understanding of our surroundings by exposing situations where the human-environmental dynamics are constantly redefined.

Acknowledgment

This project was developed with the support of Ecuador's Nuevo Mariano Aguilera award and the sponsorship of Voxeljet.

Paul Rosero Contreras works in the interstice between scientific data, speculative realism, and fictional narratives. His body of work explores topics related to geopolitics, environmental issues, and the relationship between humans and their living surroundings. Rosero received a Master's degree in Cognitive Systems and Interactive Media from Universitat Pompeu Fabra in Barcelona, as well as an MFA in Art and Technology from the California Institute of the Arts. His crossdisciplinary interests include photography, experimental sound, post-humanist philosophy, and A/V performance. His work has been displayed at the Moscow Biennale for Young Art; the Musée du quai Branly, Paris; the Instituto Cervantes, Rome; the Museo Centro de Historia, Zaragoza, Spain; the Cuenca Biennial, Ecuador; the first Antarctic Biennale, the Antarctic Pavilion at the 57th Venice Biennale; and at Import Projects, Berlin, among other venues.

Echolocalizator

Hamilton Mestizo
Colombia
http://librepensante.org/

Hamilton Mestizo

Echolocalizator (2015) is a wearable device that aims to change or augment our human way of interacting with the environment. Using "sound spatialization," this technological helmet simulates the echolocation sonar used by animals like bats and dolphins, highlighting the essential role of technology in the coevolution of humans and animals.

Echolocalizator is, in fact, a perception-bending, environment-transforming portal to a world that simultaneously exists and does not exist. The work proposes a "virtualized reality" where visible phenomena are reinterpreted into synthesized sounds that generate new cognitive associations and perceptive experiences.

The helmet is a cybernetic hybrid computer that recreates physical reality within a biofeedback system and executes a computer algorithm in real time, translating sensory stimuli into a new language for human interpretation. Using ultrasonic sensors placed to the left and right of the forehead and a microcontroller that translates incoming signals into centimeters, this leather wearable device is able to produce a binaural sound atmosphere created in the mind of the user with sounds that correspond to their movements and the positions of objects in their vicinity.

Acknowledgment
Echolocalizator was a collaborative effort that began in 2015 at the Festival de la Imagen in Manizales, Colombia, and continued in the design laboratories of the University of Caldas.

Hamilton Mestizo earned a degree in fine arts in 2006 in Bogotá, Colombia. His work primarily explores the interfaces of science and technology and their critical, ecological, and sociopolitical implications. In the last decade, Mestizo has combined his artistic practice with education and research focused on hardware development, DIY-DIWO culture, and biotechnology. Mestizo has participated in several exhibitions and festivals around the world, including Interactivos? at the Medialab-Prado, ISEA, Pixelache Festival, Balance-Unbalance, and GOSH (Gathering of Open Science Hardware).

Echolocalizator. (© Hamilton Mestizo)

Octópodos Sisíficos

Mariela Yeregui
Argentina
https://yereguimariela.wordpress.com/

Mariela Yeregui and Miguel Grassi

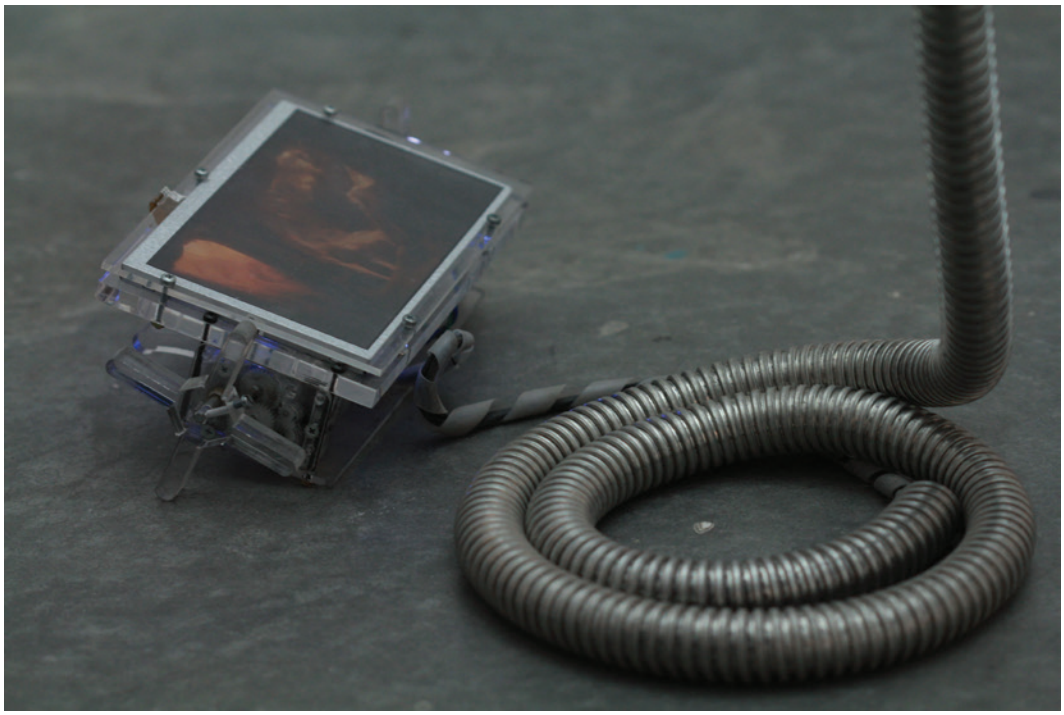
Octópodos Sisíficos. (© Mariela Yeregui / UNTREF Grupo de Artes Electrónicas)

Developed by the Artes Electrónicas group at the Universidad Nacional de Tres de Febrero in Argentina, directed by Mariela Yeregui, *Octópodos Sisíficos* (*Sisyphean Octopods*) (2010) is an installation comprised of six mobile robots that carry LCD screens displaying endoscopic videos with images that resemble internal body organs.

The robots move erratically, without any purpose but to reveal their own technological animality; they display a corporeal behavior that is both artificial and organic, material and phenomenological, exposing their own absurd existence as "living" artificial objects. Forced to repeatedly carry their own physical and virtual bodies, the robots' task might be considered a useless effort; or, on the contrary, in transporting themselves, perhaps their labor grants the machines an ontological dimension by humanizing them. Like Sisyphus, condemned to perform a laborious and futile task ad eternum, these mytho-technological beings were created to carry an image of themselves and, with that, to define their own fate and identity.

Credits
Direction: Mariela Yeregui
Robotic Design: Miguel Grassi
Production: Cipriano González, Mariana Pierantoni, Ernesto Romeo, Alejandro Schianchi, Santiago Villa
Video Editing: Marcelo Terreni

Mariela Yeregui is a visual artist, educator, and scholar. Her work includes installations, net.art, interventions in public spaces, video-sculptures, and robotics that have been exhibited in numerous museums and art festivals across Latin America, the United States, and Europe. Yeregui was artist-in-residence at the HyperMedia Studio at the University of California, Los Angeles; the Banff Centre for Arts and Creativity in Alberta, Canada; the Media Centre d'Art i Disseny in Barcelona; and the Stiftung Künstlerdorf Schöppingen in Germany. She has received prestigious awards such as the First Prize at BEEP_Art, Barcelona; First Prize at the Argentine National Salon of Visual Arts, 2005; Third Prize at the Transitio_MX Festival; the MAMBA / Telefónica Foundation award in 2004; and the First Prize from the Argentine Academy of Fine Arts in 2014. Founder and current director of the Master of Technology and Aesthetics of Electronic Arts at the National University de Tres de Febrero in Buenos Aires, Yeregui holds a BA in art history from the University of Buenos Aires, a Master's degree in literature from the National University of the Ivory Coast, and a PhD in media and communication from the European Graduate School.



Octópodos Sisíficos. (© Mariela Yeregui / UNTREF Grupo de Artes Electrónicas)

Anti-Horário

MOTTA & LIMA
Brazil
http://www.aagua.net/

Gisela Motta and Leandro Lima

Anti-Horário. (© Gisela Motta and Leandro Lima)

Anti-Horário (*Counterclockwise*) (2011) is a video installation, and a "wall-clock," that addresses the cyclical movement of human existence and the poetics of duration and perception. *Anti-Horário* combines several layered elements (the earth, a child, an adult couple, and the sky) moving at distinct cadences, registered from the same point of view that results in a disorienting analogic clock. While the child covers a circular movement like the clock's second hand, the adults represent the minute hand. With each revolution, the child causes the couple to move foward, representing the passage of time as well as the cycle of life.

Anti-Horário. (© Gisela Motta and Leandro Lima. Photo: Leandro Lima.)

The "clock" uncannily proceeds at a unified pace, as if reordered by the latent narrative of time itself. Unlike the classical narrative of film, *Anti-Horário* is a looped montage that continues Motta and Lima's recurring explorations of temporality and the suspension of time. For the artists, their task is not to replicate or simulate reality, but to produce concrete systems of phenomena and artificial images that make evident that the perception of the real is partially constructed.

Gisela Motta and Leandro Lima's partnership began in the late 1990s. They have since used various media and modalities, including video, object, light, and interactive technologies to create highly constructed situations that emulate organic behavior, synthesize natural phenomena, and provoke ambiguity despite their apparent objectivity. Solo exhibitions include venues such as the Galeria Vermelho and Sesc Santo Amaro in São Paulo; HIAP in Helsinki; Centro Cultural Banco do Brasil in Rio de Janeiro; Maman No Pátio in Recife; and others. Motta and Lima's recent group exhibitions include the 10th Havana Biennale; We Used to Be Painters at Plan 9, Bristol; I/Legítimo at MIS, São Paulo; and Aktuelle Videokunst aus Brasilien at KW Institute for Contemporary Art in Berlin. Awards include the prestigious Marcantônio Vilaça prize; a commission from the Cisneros Fontanals Art Foundation, Miami; and the Incentive bursary of the Sergio Motta Art & Technology Awards.

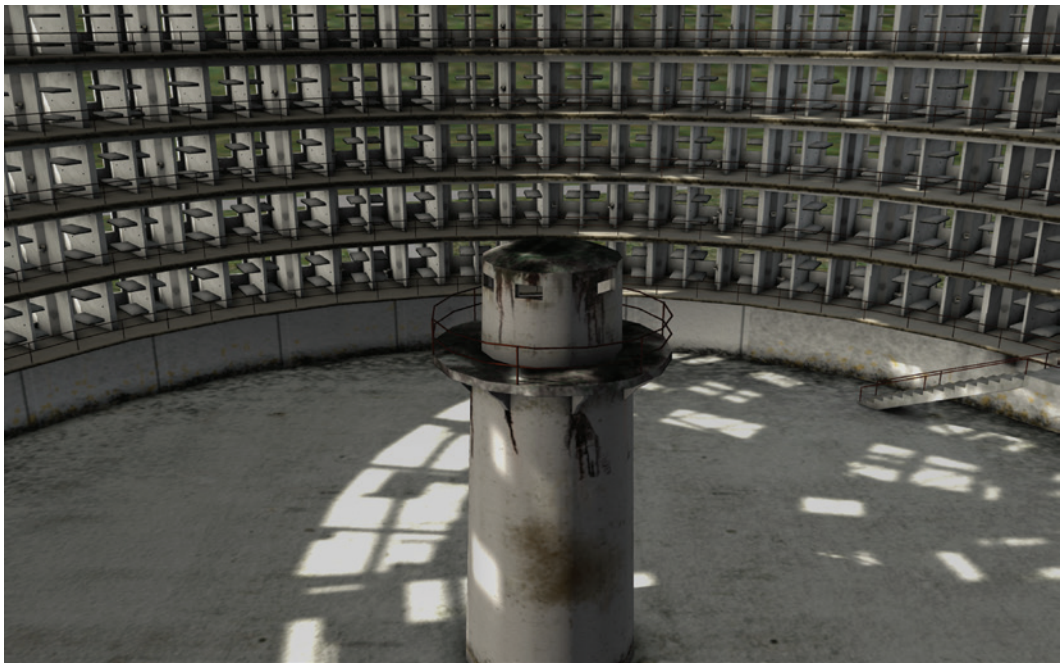
JailHead.com

Rodolfo Peraza
Cuba
http://fanguitoestudio.com/

Rodolfo Peraza

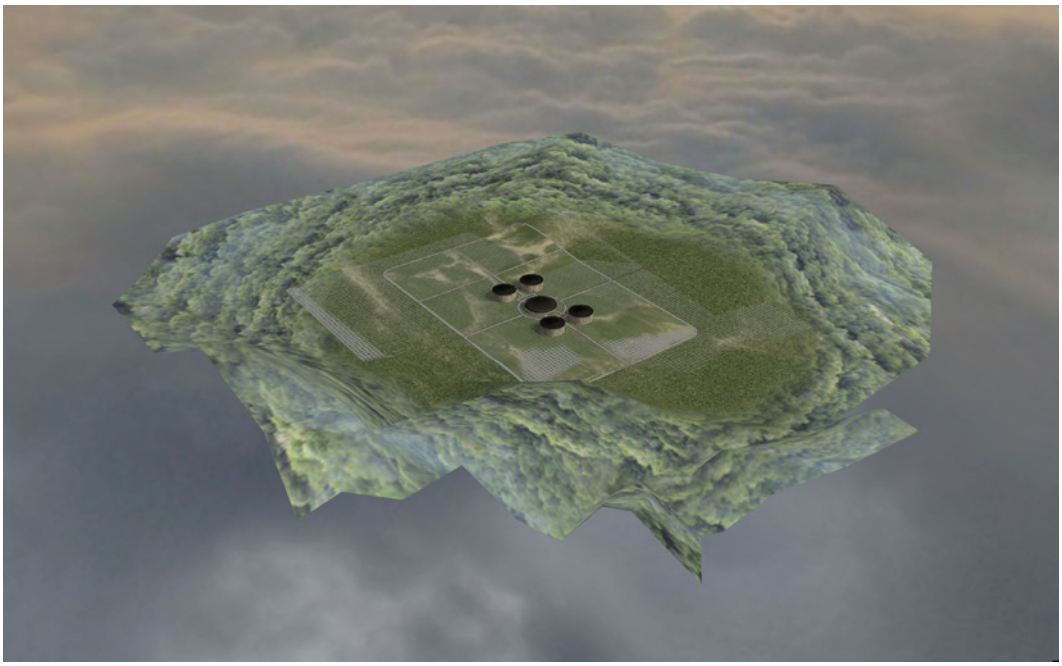
That Which Contains Emptiness is a series of multimedia works by Rodolfo Peraza exploring the interiors of abandoned historical spaces designed for social engineering and control. From this series, *JailHead.com* (2009/2017) is an ongoing web-based project that recreates in virtual reality the Cuban Presidio Modelo, an abandoned prison built after Bentham's Panopticon penitentiary model. The jail is located on the former Isla los Pinos—an island southwest of Cuba, now named Isla de la Juventud—and was considered a definitive example of efficient prisoner control. It became emblematic for housing historical figures both pre- and post-Cuban Revolution, including Fidel and Raúl Castro.

By virtually mirroring this existing architecture, *JailHead.com* explores internet surveillance as a regular praxis exercised by internet service providers (ISPs), governments, and corporations in our daily use of the internet. Wearing an Oculus Rift device, players are able to "walk through" the cells of the prison in an immersive experience. Conceived as a multiplayer video game, it can be played via a game server over the internet with other players around the world. Users' IP addresses become their "inmate" numbers, and they are able to interact with other inmates who are online at the same time.



JailHead.com, screenshot.
(© Rodolfo Peraza)

Rodolfo Peraza graduated from the Academy of Fine Arts in Camagüey, Cuba (1999) and earned an MFA in sculpture from ISA, the University of the Arts in Havana, Cuba (2005). He is the founder of Fanguito Estudio, an independent artist-run space in Havana dedicated to new media art. Since 2007 he has been developing software for video games and interactive works and showing internationally in places such as LOOP Barcelona, Perez Art Museum Miami, Mocca Museum in Toronto, the XXXI Biennial of Pontevedra in Galicia, and the XII Havana Biennial. Peraza's work is represented in collections such as the Jumex collection in Mexico City and AGO Museum in Toronto. Questions of isolation, loneliness, and identity are constant in Peraza's work, while his concerns go beyond the confines of geography through technology. Using the internet, social media, and animation, his body of work explores the moral, spiritual, and social modes of conduct governing society. He is particularly interested in big data analysis and digital culture and how these overlap with the visual arts.



JailHead.com, screenshot.
(© Rodolfo Peraza)

drumCircle[]

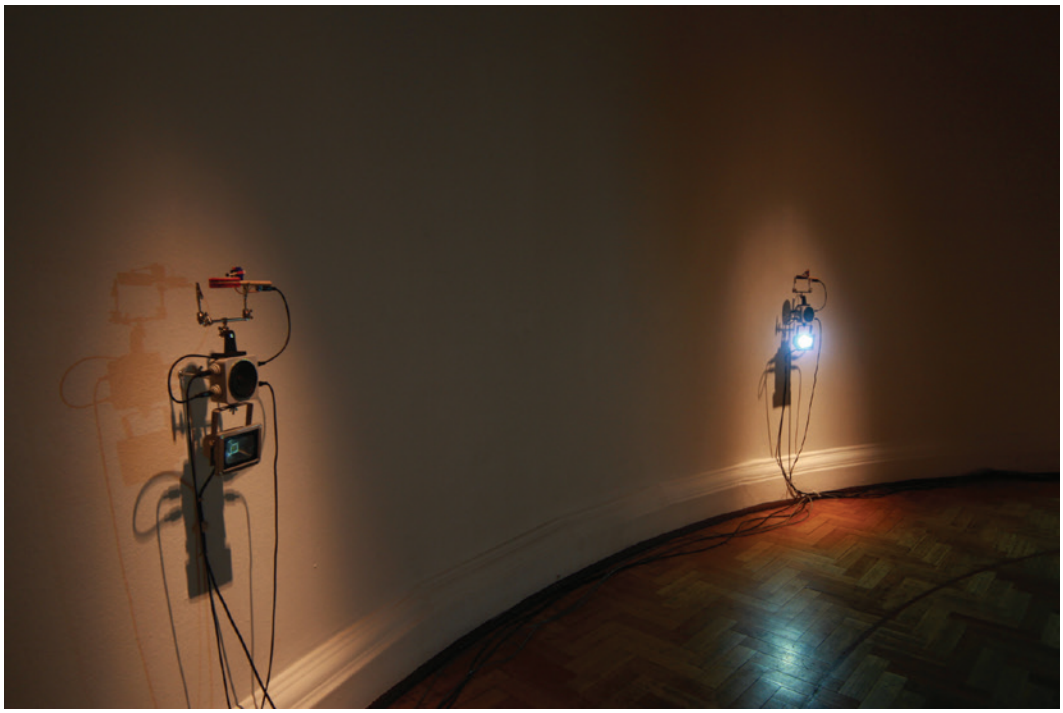
Christian Oyarzún
Chile
http://www.error404.cl/

Christian Oyarzún

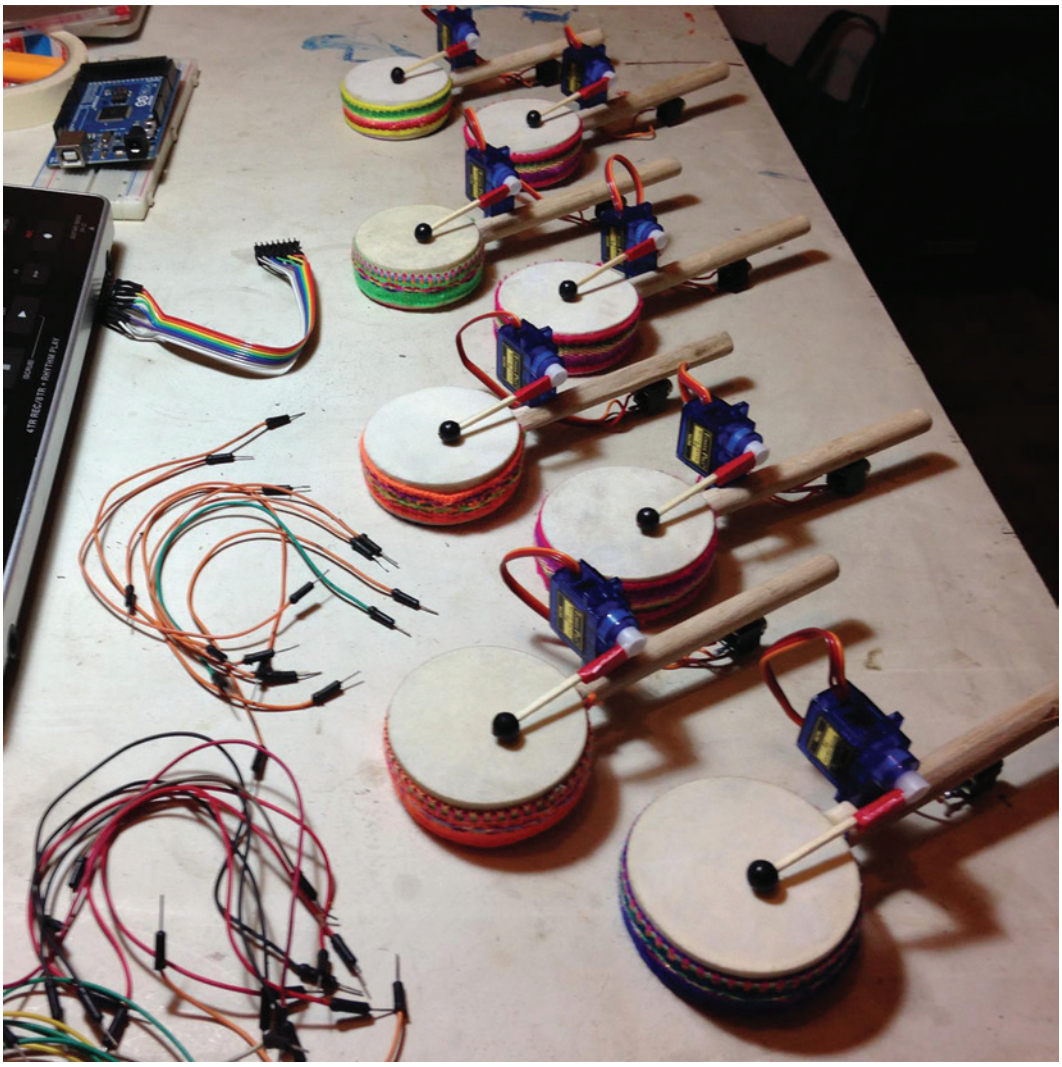
drumCircle[] (2015) is an autonomous percussion and light instrument composed of an ensemble of eight connected den-den drums mounted to LED spotlights that create a temporal and spatial network of interactions between these machines and the viewer. Arranged in a circle pointing inward toward the center of the installation, these modules project light and sound patterns bidirectionally, creating an immersive and ritualistic technological experience that brings to light connections between technology, corporeality, and time.

Technically, *drumCircle[]* is an eight-step light and drum sequencer machine that "transduces" mechanical and electrical energy into shadows, lights, and sounds. Informed by the ideas of philosopher Gilbert Simondon, *drumCircle[]* understands transduction as not only the transformation and translation of one kind of signal into another, but also as a process that extends to our daily relationships with technological tools as techno-political schemes that give rise to our experience of life.

drumCircle[] seeks to make explicit how our notions of space and time are shaped by technology, creating relationships of dominance and meaning between subjects and objects, modifying our cognitive processes and the symbolic relationships we create with our environment.



drumCircle[]. (© Christian Oyarzún)



drumCircle[]. (© Christian Oyarzún)

Christian Oyarzún is an artist, musician, and programmer. He is Assistant Professor of design and media arts at the Universidad de Chile and is an active member of the Hackeria collective. Since 2005 Oyarzún has performed live music and visuals under the name of voodoochild. Working in installations, net.art, algorithmic drawings, real-time sound-reactive graphics, figurative videogames, and abstract visual machines, Oyarzún creates objects and experiences with code, reflecting on our everyday interactions with technology and their techno-political consequences. He is currently developing projects related to dystopian narratives and speculative design. His work from 1999 to the present can be found at his web archive: <www.error404.cl>.

Dispersiones

Leo Nuñez
Argentina
http://www.leonunez.com.ar/

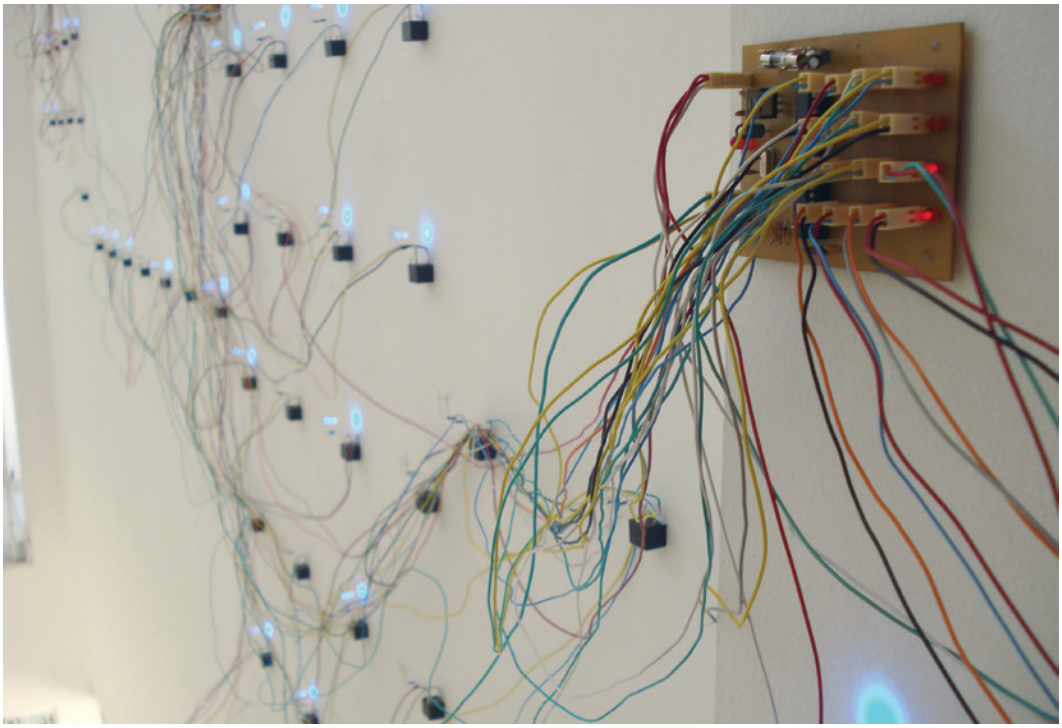
Leo Nuñez

Dispersiones. (© Leo Nuñez)

Dispersiones (Dispersions) (2012/2017) is a site-specific physical network comprised of a series of interconnected relays that produce an artificial and interactive soundscape. The work appears to be a messy web of hundreds of tangled wires through which sounds travel, following an algorithm of artificial life. Using only the metallic clicking sound of the relays, the network behaves as a complex system of electromagnetic actuators that interact with the viewer.

Organized in a rhizomatic matrix of lines resembling a convoluted urban city, each individual relay acts as a "living" agent that activates the space and the architecture. Once a viewer's movement is detected, the system unleashes an infinite flow of sound and light.

Dispersiones fits into Leo Nuñez's body of work that uses discarded technological waste along with industrial and raw materials to create laboriously hand-crafted electromechanical interactive installations that speak to the appropriation and adaptation of new technologies within the context of Latin American culture.



Dispersiones. (© Leo Nuñez)

Leo Nuñez is a professor at the National University of Tres de Febrero in the MFA and BFA programs in Electronic Art, and cofounder and director of Espacio Nixso, an educational and collaborative workspace in Buenos Aires for the promotion of technological knowledge to artists, art schools, and children. Nuñez has received numerous awards and honors for his work, such as the MAMBA/Fundación Telefónica award, the Argentinian National Salon award in new technology, and the VIDA 10.0 and VIDA 12.0 from Telefónica in Spain. He has been a scholar at the Centro Cultural de España en Buenos Aires and at the Center for Digital Arts and Experimental Media at the University of Washington. His work has been exhibited in group and solo shows in Madrid, St. Petersburg, Washington D.C., São Paulo, Rosario, Los Angeles, Seattle, Buenos Aires, Lima, Bogotá, and other cities.

Imaginario Inverso

Astrovandalistas
Mexico / Brazil
http://www.astrovandalistas.cc/

Astrovandalistas

Imaginario Inverso (*Reverse Imaginary*) (2015/2017) is part of Astrovandalistas's ongoing investigation into the industrialization of our social imaginary through the commercialization of scientific knowledge. Through a series of workshops, talks, and exhibitions using conceptual prototyping, futurecasting, reappropriations, and micronarratives, *Imaginario Inverso* proposes different frameworks for reflecting on the geopolitics of technology development and the reinterpretation of technologies for more personal uses.

In 2014 and 2015, Astrovandalistas worked in the El Paso–Juárez border region building alternative communication networks. The first prototype was a reinterpretation of NASA's laser communication technology (LLCD, LCRD, OPALS) that used a laser modem to open a high-powered long-distance channel across the sociopolitical distance marked by the border. While working on the laser modem, Astrovandalistas started to explore the possibility of using lasers to create other kinds of local networks and began to engrave rocks using a glyphic alphabet of their own design. During a series of public workshops, they invited people from El Paso and Ciudad Juárez to use their laser to carve their own future predictions for the region into rocks and later redistributed the engravings on both sides of the border.

During SIGGRAPH 2017, Astrovandalistas will open an office in the Art Gallery where they will engrave predictions about the future onto rock and city debris collected from the greater Los Angeles area. Part site-specific minimalist installation, part laboratory and workshop, the work is an open platform that invites direct participation and creates an opportunity for manifesting anxieties about the future.

Astrovandalistas is a translocal collective that focuses on the development of projects that combine research, artistic action, technology, and activism under the logics of urban hacking and open knowledge. Founded in Tijuana in 2010, Astrovandalistas operates as a laboratory of decentralized action in different locations in Latin America, the United States, and Europe. Their strategy is to generate technologies that can be easily replicated by people in different places. Their actions are guided by the use of public space for creating individual and/or collective experiences and the development of tools that enable new forms of human-to-human communication mediated entirely by open technologies.

Imaginario Inverso. (© Astrovandalistas)

Announcements from the Leonardo Community

Sign up to receive our biweekly e-newsletter for the latest in Leonardo/ISAST news, as well as announcements and opportunities of interest to the art/science community, at **<leonardo.info/sign-up>**.

To submit an opportunity or announcement, visit **<leonardo.info/opportunities>.**

Facebook.com/LeonardoISAST
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LEONARDO'S 50TH ANNIVERSARY GLOBAL EVENTS

Starting mid-2017, we invite you to participate in our 18-month-long celebration of *Leonardo*'s 50th anniversary. A half-century ago, kinetic artist and astronautical pioneer Frank Malina set out to meet the needs of artists and scientists working across disciplines by using the "new media" of the time, offset print publishing. *Leonardo* represented a unique vision that served as an international channel of communication among artists, with emphasis on the writings of artists using science and developing technologies in their work.

Today documenting and capturing the creative innovators and provocateurs of culture is not enough. If media is the messenger, then *Leonardo* must expand its scope to represent the unique works and challenges we face in the 21st century. As a network of networks, *Leonardo* is reimagining the next 50 years. We invite you to come along with us on this journey of rediscovery and reinvention and to join us at the following 50th anniversary events in 2017:

- **11–18 June 2017:** International Symposium on Electronic Art (ISEA), Manizales, Colombia. "Next Fifty," chaired by Felipe C. Londono, Symposium Director.
- **22 June 2017:** Laboratório de Arte Eletrônica at PUC-Rio, Rio de Janeiro, Brazil. Chaired by Rejane Spitz Laboratório/Núcleo de Arte Eletrônica; Departamento de Artes & Design | PUC-Rio sponsored by NVDIA.
- **3–6 July 2017:** art*science, Bologna, Italy. "The New and History," chaired by Pier Luigi Capucci in collaboration with La Comunicazione Diffusa Associazione Culturale.
- **21–23 August 2017:** Balance-Unbalance, Plymouth, United Kingdom. "Overview," convened by Mike Phillips and Ricardo dal Ferra, supported by the Eden project.
- **Fall 2017:** Milieux, Concordia University, Montréal, Quebec, Canada. Chaired by Bart Simon, Institute Director, and Harry Smoak.
- **Fall 2017:** Semaphore Research Cluster, University of Toronto, Toronto, Ontario, Canada. "First Fifty—Next Fifty," chaired by Matt Ratto, Director, Semaphore, and Adam Tindale, Associate Professor, OCAD.

For more information, visit <leonardo.info/50th-anniversary>.

SCIENTIFIC DELIRIUM MADNESS 2017

Scientific Delirium Madness is a collaborative initiative of Leonardo/ISAST and the Djerassi Resident Artists Program, which is an art/science residency that takes place over the course of four weeks. This year from 28 June–26 July, twelve participants will explore and expand what's possible when six scientists and six artists are connected. For more information, visit <leonardo.info/residencies>.

PARTNERS IN ART AND SCIENCE: BECOME AN AFFILIATE MEMBER!

The Leonardo Affiliate Member Program provides a collaborative environment where leaders from top-ranked universities and independent nonprofits in the cross-disciplinary field of art, science and technology can interface and share best practices, research and opportunities with their peers across institutional boundaries. Visit <leonardo.info/members> for more information.

LEONARDO ART SCIENCE EVENING RENDEZVOUS (LASER) TALKS

LASER is Leonardo/ISAST's international program of evening gatherings in over 20 cities around the world that bring artists and scientists together for informal presentations and conversations. Visit <leonardo.info/laser> for locations and dates.

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Benefits of Membership
Artists, scientists, engineers, researchers and others interested in the contemporary arts and sciences are invited to join Leonardo/ISAST. Benefits include reduced rates for Leonardo/ISAST publications, eligibility to participate in Leonardo working groups and special invitations to Leonardo-sponsored events.

For further details, visit <leonardo.info/members> or email <isast@leonardo.info>.

Affiliate memberships also available for nonprofit organizations, educational institutions and corporations working at the intersection of art, science and technology. Visit <leonardo.info/members> *for more information.*

MISSION STATEMENT
The critical challenges of the 21st century require mobilization and cross-fertilization among the domains of art, science and technology. Leonardo/ISAST fosters collaborative explorations both nationally and internationally by facilitating interdisciplinary projects and documenting and disseminating information about interdisciplinary practice.

PUBLICATIONS

Journals
The *Leonardo* journals are scholarly peer-reviewed journals of record. *Leonardo*, published bimonthly, is the official journal of Leonardo/ISAST. *Executive Editor:* Roger F. Malina. *Leonardo Music Journal* with audio companion is published annually. *Editor-in-Chief:* Nicolas Collins.

Leonardo Website
The Leonardo website (<leonardo.info>) publishes organizational information, the Leonardo Electronic Directory and more.

Electronic Journal
Leonardo Electronic Almanac (<leonardo.info/lea>) is an electronic journal dedicated to providing a forum for those who are interested in the realm where art, science and technology converge. *Editor-in-Chief:* Lanfranco Aceti.

Leonardo Reviews
Leonardo Reviews, through a panel of reviewers, publishes reviews of relevant books, journals, electronic publications and events. Reviews are published on the web (<leonardo.info/reviews>), and selected reviews are published in *Leonardo*. *Editor-in-Chief:* Michael Punt.

The Leonardo Book Series
The Leonardo Book Series (<leonardo.info/books>), published by the MIT Press, highlights topics related to art, science and developing technologies. *Editor-in-Chief:* Sean Cubitt.

LABS Databases of Master's and PhD Theses
English LABS: <collections.pomona.edu/labs>; *Editor-in-Chief:* Sheila Pinkel.
Spanish LABS: <uoc.edu/artnodes/leonardolabs>
French LABS: <francolabs.univ-paris1.fr>

ARTECA
ARTECA is a curated space for essential content linking the arts, sciences, and technologies created by The MIT Press in partnership with Leonardo/ISAST. It houses thousands of pages of book and journal content published by The MIT Press: nearly 200 books and 500 journal issues from 4,000 contributors with new and archival content added regularly. ARTECA was built for researchers, scholars, artists, educators, students, and practitioners in the arts, science, design, new media, and technology communities. It offers hybrid open access and subscription-based access to published materials as well as a growing collection of gray literature—research output created outside of traditional commercial or academic channels—which has become increasingly more important in scholarly communication. Visit <arteca.mit.edu> for more information, to subscribe, or to sign up for a free 60-day trial for institutions.

COLLABORATIONS WITH OTHER ORGANIZATIONS
Leonardo/ISAST frequently collaborates with other organizations on topics of current interest by collaborating on conferences or workshops and by publishing special sections in *Leonardo* or co-sponsoring events. Current collaborators include:

- ACM SIGGRAPH (U.S.A.)
- Artnodes (Spain)
- Association Leonardo (France)
- College Art Association (U.S.A.)
- DXLab (U.S.A.)
- Electronic Music Foundation (U.S.A.)
- Fondation Langlois Research Documentation Center (Canada)
- International Symposium on Electronic Art (ISEA) (U.K.)
- MIT Press (U.S.A.)
- Pomona College (U.S.A.)
- School of the Art Institute of Chicago (U.S.A.)
- University of Dallas at Texas, ArtSciLab (U.S.A.)
- University of Plymouth (U.K.)

LEONARDO PROJECT WORKING GROUPS
Leonardo hosts working groups on projects with a topical focus:

Leonardo Abstracts Service (LABS) Peer Reviewers
Alan Boldon; Yiannis Colakides; Angus Forbes; Copper Frances Giloth; Lawrence Harvey; Tom Leeser; Iannis Zannos; Ionat Zurr

Leonardo Education and Art Forum (LEAF)
Alan Boldon, *Chair*; Ruth West, *Chair-Elect*. See <leonardo.info/leaf> for more information.

Book Series Committee
Sean Cubitt, *Editor-in-Chief*; Annick Bureaud; Steve Dietz; Zhang Ga; Machiko Kusahara; Roger Malina; José-Carlos Mariategui; Laura U. Marks; Anna Munster; Monica Narula; Michael Punt; Sundar Sarukkai; Joel Slayton; Mitchell Whitelaw

Leonardo's 50th Anniversary Committee
Anniversary events and collaborations are made possible with in-kind support from the following: Nina Czegledy, *partnership liaison*; Brad Jerger, *designer*; Scott Trent, *Project Delphi curator*; Steve Musial, *web developer*; Sheila Pinkel; Marc Hebert. Danielle Siembieda, *Chair*. See <leonardo.info/50th-anniversary> for more information.

AFFILIATE MEMBERS
Leonardo/ISAST invites organizations and corporations working at the intersection of art, science and technology to join the Affiliate Membership Program. Visit <leonardo.info/members> for more information.

Current affiliate members include:

- Alliance for the Arts in Research Universities (a2ru)
- Art Center College of Design, Media Design Practices/Lab & Field
- California Institute of the Arts, Herb Alpert School of Music
- Cultural Programs of the National Academy of Sciences
- Cyland Media Lab
- Djerassi Resident Artists Program
- Minerva Foundation
- Ontario College of Art & Design University
- Polytechnic Museum, Moscow, Russia
- Pomona College
- School of the Art Institute of Chicago, Sound Department
- University of California, Davis, Art/Science Fusion Program
- University of California, Los Angeles, Art|Sci Center
- University of California, Santa Cruz, Institute of the Arts and Sciences
- University of San Francisco, College of Arts and Sciences
- University of Texas at Dallas, Arts and Technology
- University of the Arts London, Central Saint Martins
- York University

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THE JOURNAL OF MEDIA ARTS AND CULTURAL CRITICISM

Afterimage is a bimonthly journal of photography, independent film, video, new media, and artists' books, published by Visual Studies Workshop. Since its inception in 1972, *Afterimage* has addressed these media through thought-provoking criticism, seminal theoretical analysis, and timely news coverage. *Afterimage* provides a forum for a unified discussion of disciplines generally treated separately in other publications and locates common ground among media arts, while recognizing the characteristics unique to each.

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