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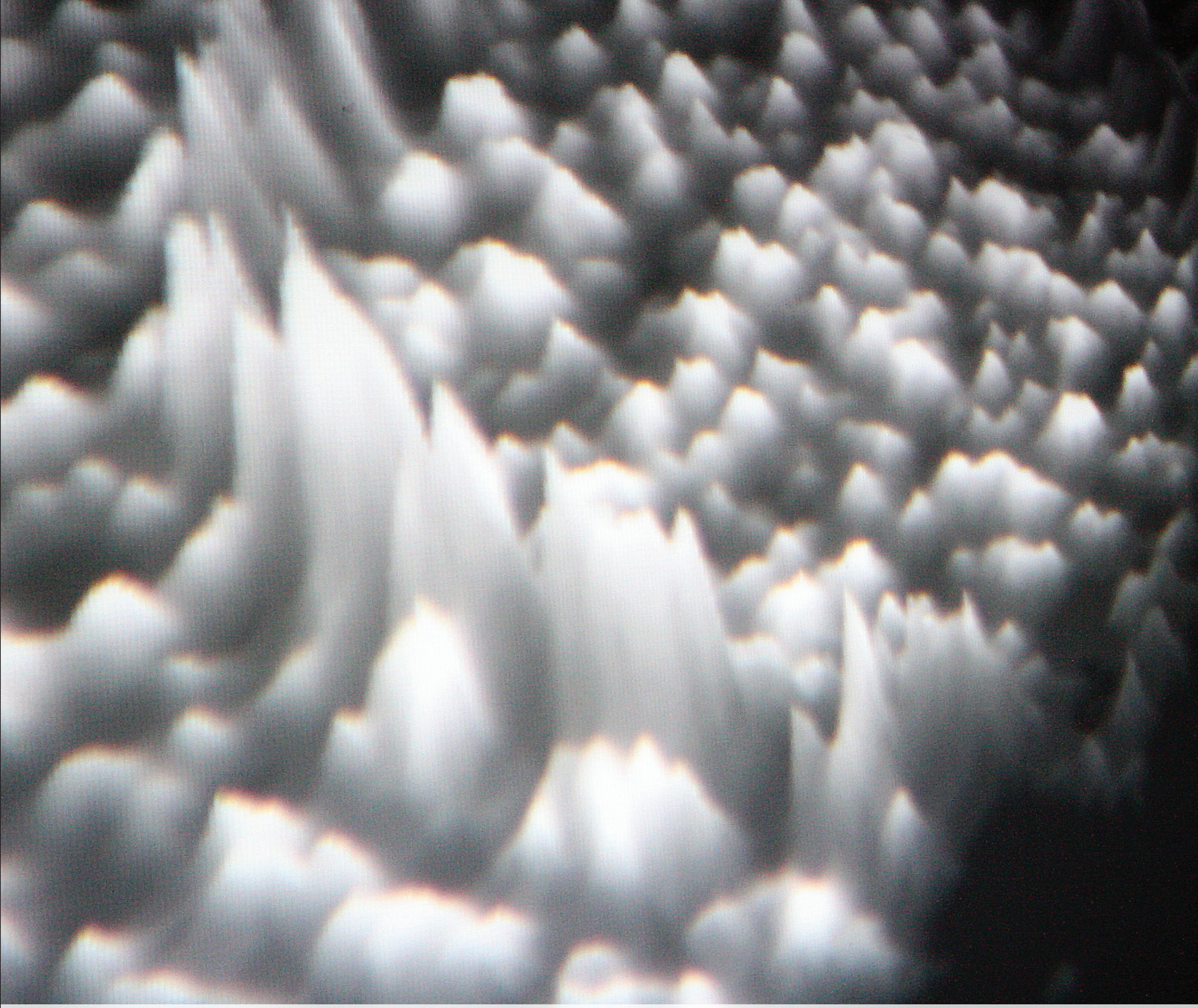

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Acknowledgements
Duke University

ACM
2 Penn Plaza, Suite 701
New York, New York 10121-0701 USA
800.342.6626 (US/Canada)
+1.212.626.0500
Fax: +1.212.944.1318
www.acm.org

Leonardo

www.leonardo.info

Main Editorial Office
Leonardo
211 Sutter Street, Suite 501
San Francisco, California 94108
USA
Fax: 415.391.2385
isast@leonardo.info
www.leonardo.info

Collaborating Society
Association Leonardo
8 rue Émile Dunois
92100 Boulogne Billancourt, France
Fax: 33.1.46.04.43.28
www.olats.org

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LEONARDO

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VOLUME 46 | NUMBER 4 | 2013

LEONARDO SPECIAL ISSUE: SIGGRAPH 2013 Art Papers and XYZN: ScaleArt Gallery

ART PAPERS

XYZN: SCALE

Front Cover
Digiti Sonus. © 2012 Yoon Chung Han, Byeong-jun Han.

Back Cover
Hybrid Basketry: Interweaving Digital Practice within Contemporary Craft. © 2013 Amit Zoran.

Guest Editorial

Tad Hirsch

It is with great pride that we present this special issue featuring selections from the 40th International Conference and Exhibition on Computer Graphics and Interactive Techniques (SIGGRAPH 2013). This issue is the result of an ongoing collaboration between Leonardo/ISAST and ACM SIGGRAPH to showcase the community of artists, designers, and scholars working with computer graphics and interactive technologies.

This issue presents selections from the 2013 SIGGRAPH Art Gallery, whose jury was chaired this year by Victoria Szabo. In her introduction, Szabo discusses the Gallery and this year's theme, "XYZN: Scale." We also recognize 2013 SIGGRAPH Lifetime Achievement Award in Digital Art recipient Manfred Mohr for his pioneering efforts in algorithmic art.

Finally, we are pleased to present the 2013 SIGGRAPH Art Papers selections. The Art Papers track was established in 2009 as a venue for serious scholarship on digital and interactive arts, with a strong emphasis on artistic practice. Art Papers explore the changing roles of artists and the methods of art-making in our increasingly networked and computationally mediated world. They are intended to inform artistic disciplines, set standards, and stimulate future trends.

Art Papers may take various forms, but they typically fall into one or more of the following categories:

1. Project Description: A description of creative work, with particular emphasis on its significance and historical and/or theoretical context.

2. Theory/Criticism: An exposition of a significant issue for contemporary interactive art and design practice.

3. Methods: A description of a novel technique for creative practice.

4. History: A discussion of significant but little-known or under-theorized antecedents to contemporary practice. In celebration of the SIGGRAPH conference's 40th anniversary, a special emphasis was placed this year on submissions about the early history of electronic and interactive art.

Art Papers are subject to a rigorous selection process. Each submission is evaluated by members of the Art Papers Advisory Board, the Art Papers Committee, and external reviewers, all of whom are recognized experts in their field. Each paper receives a minimum of four detailed reviews. The committee then meets to deliberate the final outcome of each paper at the Art Papers Jury Meeting. If there is not a clear consensus among the original reviewers, additional reviews are solicited. This year, the jury accepted seven papers from a pool of 49 submitted manuscripts (14% acceptance rate).

I would like to extend my sincere thanks to the Art Papers Committee, the Art Papers Advisory Board, SIGGRAPH contractors, and our colleagues at *Leonardo* for their hard work and dedication. And, of course, I offer my deepest gratitude to the reviewers (nearly 60 of them!) and the authors, without whom the fifth edition of Art Papers would not have been possible.

Tad Hirsch
UNIVERSITY OF WASHINGTON

ACM SIGGRAPH Distinguished Artist Award for Lifetime Achievement in Digital Art

Manfred Mohr

Manfred Mohr. Photograph courtesy of Estarose Wolfson.

The 2013 ACM SIGGRAPH Lifetime Achievement in Digital Art Award is awarded to Manfred Mohr for his pioneering achievements in creating art through algorithmic geometry. Beginning his creative career in the late 1950s as a jazz musician and painter, he focused on gestural abstraction. In 1962, he began exclusive use of black and white as means of visual and aesthetic expression. After he discovered Max Bense's information aesthetics in the early 1960s, his artistic thinking was radically changed. Within a few years, his art transformed from abstract expressionism to computer-generated algorithmic geometry. Encouraged by the computer-music composer Pierre Barbaud, Mohr programmed his first computer drawings in 1969. The combination of mathematics and music gives his work a core essence of rhythm and repetition.

In 1972, Mohr began producing sequential drawings and started working on the fixed structure of a cube. He renewed his work on the 4D hypercube in 1987, using four-dimensional rotation as a generator of signs. Since 1995, he has been a member of The Algorists, founded by Jean-Pierre Hébert and Roman Verostko. In 1998, after creating in black and white for more than three decades, Mohr began to use color to show the complexity of the work through differentiation. Four years later, he designed and built small PCs to run his "space.color" program, and in 2004 he wrote the program "subsets." The resulting images are visualized on LCD flat panels in a slow, non-repetitive motion. He then developed the program "klangfarben," which encompasses a body of paintings and animations based on the 11-dimensional hypercube, using its diagonal paths as compositional building blocks. The program runs on a PC, and the resulting images and animations are visualized in real time on two square LCD flat panels. His latest software, "Artificiata II," creates digital paintings and animations that are based on the 11- to 13-dimensional hypercube and uses diagonal paths as graphic elements. The animation algorithm contains random variations of speed and suites of stills that add a musical rhythm to this work. Mohr's creative exploration of visual complexity continues to the present day.

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Among his accomplishments are the Golden Nica from Ars Electronica, Linz, 1990; Artist Fellowship, New York Foundation of the Arts, 1997; and the [ddaa] d.velop Digital Art Award, Berlin, 2006. The ARC, Musée d'Art Moderne de la Ville de Paris, hosted his first one-man show of computer-generated images in 1971. Other venues for his solo shows include the Digital Art Museum, Museum for Concrete Art, and the Kunsthalle Bremen. The ZKM | Media Museum in Karlsruhe, Germany, is hosting a retrospective of his work—The Algorithm of Manfred Mohr, 1963—from 8 June to 1 September 2013, and he is a Featured Artist at Art Basel 2013.

Mohr has been represented in many group shows and museums, including the SIGGRAPH Pioneering Artists; Museum of Modern Art, New York; Centre Pompidou, Paris; ZKM (Center for Art and Media), Karlsruhe, Germany; Museo Nacional Centro de Arte Reina Sofía, Madrid; Museum of Contemporary Art, Los Angeles; National Museum of Modern Art, Tokyo; Museum of Modern Art, San Francisco; New York Digital Salon; MoMA PS1, New York; and the Leo Castelli Gallery, New York. His work is included in the collections of the Centre Pompidou; Joseph Albers Museum, Bottrop, Germany; Victoria and Albert Museum, London; Kunstmuseum Stuttgart, Stuttgart; Stedelijk Museum, Amsterdam; Kunsthalle Bremen, Bremen, Germany; Daimler Contemporary, Berlin; and the Musée d'Art Contemporain, Montréal.

ACM SIGGRAPH is honored to recognize Manfred Mohr, one of the pioneers of digital art. His exploration of n-dimensional hypercubes is a wonderful example for future artists using algorithmic techniques. His dedication to his craft, unique form of visual expression, and evolution as an artist from abstract expressionism to digital art all speak to his creative ingenuity.

Marcus Bastos

Marcus Bastos is an artist, curator and researcher focusing on the convergence of audiovisual, design, and new media. He received a PhD in communication and semiotics at the Pontifícia Universidade Católica de São Paulo, where he has been teaching and researching since 2003. He is author of the e-book *Recycling Culture* (NOEMA Gallery, 2007) and co-editor of the e-book *Appopriations of the (Un)common: Public and Private Space in Times of Mobility* (Sergio Motta Institute, 2009). He edited, with Lucas Bambozzi and Rodrigo Minelli, the book *Mediation, Technology, Public Space – A Critical Panorama of Art in Mobile Media* (Conrad, 2010). He was curator of Noise on Video (Itaú Cultural Institute, 2005) and of the exhibition Cellular Geographies (Fundación Telefónica, 2010). He has been the curator of VIVO Arte.Mov – International Festival of Art in Mobile Media since 2007.

Joanna Berzowska

Joanna Berzowska is Associate Professor and Chair of the Design and Computation Arts Department at Concordia University, as well as the founder and research director of XS Labs, a design research studio with a focus on innovation in the fields of electronic textiles and reactive garments. A core component of her research involves the development of enabling methods, materials, and technologies — in the form of soft electronic circuits and composite fibers — as well as the exploration of the expressive potential of soft reactive structures. She is the Head of Electronic Textiles at OMsignal, a Montreal startup developing a line of bio-sensing clothes together with a wellness application. Her art and design work has been shown in the Cooper-Hewitt Design Museum in NYC, the V&A in London, the Millenium Museum in Beijing, various SIGGRAPH Art Galleries, ISEA, the Art Directors Club in NYC, the Australian Museum in Sydney, NTT ICC in Tokyo, and Ars Electronica Center in Linz among others.

Marc Böhlen

Artist-engineer Marc Böhlen, aka RealTechSupport (Switzerland and USA), offers the kind of support technology really needs. He designs and builds information-processing systems that critically reflect on information as a cultural value through speculative robotic interventions. His projects query the relationship between people and automation systems in fundamental ways, with a focus on public computational media: the making of information for shared concerns in the public realm. He is on the faculty of the Department of Media Study at the University at Buffalo, New York.

Jonah Brucker-Cohen

Jonah Brucker-Cohen is an award-winning researcher, artist, and writer. He holds a Ph.D. in Electronic and Electrical Engineering from Trinity College Dublin. His work and thesis are titled “Deconstructing Networks” with projects that critically challenge and subvert accepted perceptions of network interaction and experience. His work has been exhibited at venues such as San Francisco Museum of Modern Art, MOMA, ICA London, Whitney Museum of American Art (Artport), Palais du Tokyo, Tate Modern, Ars Electronica, and more. His writing has appeared in publications such as *WIRED*, *Make*, *Gizmodo*, *Neural* and more. His Scrapyard Challenge workshops have been held in over 14 countries on five continents since 2003.

Teri Rueb

Teri Rueb is professor in the Department of Media Study at the University at Buffalo (SUNY) where she is founder and director of the Open Air Institute. Her work has been funded with major commissions from the Banff Centre for the Arts, Edith Russ Site for Media Art, Santa Fe Art Institute, La Panacée Centre Pour L'Art et Culture Contemporaine, Turbulence.org, the Arnold Arboretum, and the Boston Institute of Contemporary Art / Vita Brevis. She has exhibited her work worldwide at conferences and festivals including SIGGRAPH, Ars Electronica, ISEA, and Transmediale. She received a Prix Ars Electronica Award of Distinction in 2008 and has been nominated for the CalArts Alpert Award, Rockefeller Fellowships and the Boston ICA Foster Prize. She holds a doctorate from Harvard University, where she is currently Artist Resident at the MetaLab. Rueb lectures internationally and has been published by presses including MIT Press, University of Minnesota Press, and Routledge.

Brooke Singer

Brooke Singer is associate professor of new media at Purchase College, State University of New York, and co-founder of the art, technology, and activist group Preemptive Media. She engages technoscience as an artist, educator, nonspecialist, and collaborator. Her work lives “on” and “off” line in the form of web sites, workshops, photographs, maps, installations, and performances that frequently involve public participation in pursuit of social change. She has exhibited at MoMA PS1, the Warhol Museum of Art, the Banff Centre, the Neuberger Museum of Art, Diverseworks, Exit Art, FILE Electronic Festival, the Sonar Music and Multimedia Festival, and the Whitney Artport, among others. Recent awards and commissions include a Madrid Council's Department of the Arts commission, Turbulence.org commission, New York State Council on the Arts Individual Artist award, a Headlands Center for Arts residency, and a fellowship at Eyebeam Art + Technology.

Orkan Telhan

Orkan Telhan is interdisciplinary artist, designer, and researcher whose investigations focus on the design of interrogative objects, interfaces, and media, engaging with critical issues in social, cultural, and environmental responsibility. He is assistant professor of fine arts at the University of Pennsylvania School of Design. He was part of the Mobile Experience Lab at the MIT Design Laboratory and the Sociable Media Group at the MIT Media Laboratory. He studied media arts at the University at Buffalo and theories of media and representation, visual studies, and graphic design at Bilkent University, Ankara. He is working toward his PhD in design and computation at MIT's School of Architecture and Planning. His individual and collaborative work has been exhibited at a number of venues, including the Istanbul Design Biennial, Ars Electronica, ISEA, LABoral, Archilab, Architectural Association, Architectural League/ NYC, and the MIT Museum.

Anya Belkina
Anya Belkina studied at the Moscow Art College In Memory of 1905, the Rhode Island School of Design (BFA 1996) and the University of California, San Diego (MFA 2000). Prior to 2007, she was assistant professor in the Practice of Art at Duke University. She is currently assistant professor of new media at Emerson College in Boston. Her paintings are held in private and corporate collections throughout the United States. Her work in the area of new media has been presented nationally and abroad at conventional exhibition venues as well as in large-scale site-specific installations, video projections, broadcast media, and cover art for literary journals. Her animated shorts have screened at numerous national and international venues, including the annual SIGGRAPH conference, ANIMATOR, RIIFF, the Light Factory Museum, and the Museum of Fine Arts, Boston.

Sue Gollifer
Sue Gollifer is an artist, an academic, and a researcher at the University of Brighton, and an early pioneer of new media art. Her work is in both national and international public and private collections. She is the director of the ISEA International Headquarters and is on a number of national and international committees, including the Computer Arts Society, the Digital Art Museum, the ACM SIGRAPH Digital Arts Community, Lighthouse, and Phoenix Brighton. She has been a curator of a number of international digital art exhibitions, including ArCade, the UK Open International Biennale Exhibition of Digital Fine Art Prints 1995–2007, the SIGGRAPH 2004 Art Gallery: Synaesthesia, and currently the Intuition and Ingenuity art exhibition to celebrate the Alan Turing Centenary. In 2006, she was awarded an International Digital Media Arts Award for her exceptional services to the international new media community.

Mona Kasra
Mona Kasra is a new media artist, educator, and PhD candidate at the University of Texas at Dallas with a focus in arts and technology. Her research is centered around the reliability, impact, and power of the digital image in the networked era. She is especially interested in how digital images coupled with social-media technologies reconstruct the extent of public awareness and action against unjust sociopolitical affairs around the world. She holds a BA in graphic design and an MFA in video and digital art. Her work has appeared in numerous exhibitions in both gallery and online settings, and she has programmed and juried for several art exhibitions and film festivals. She was chair of the SIGGRAPH 2011 Art Gallery (Vancouver).

Timothy J. Senior
Timothy J. Senior is an external lecturer at the School of Humanities and Social Sciences at Jacobs University, where he is also a visiting junior fellow at the Centre for Visual Communication and Expertise (VisComX). He completed his DPhil in neuroscience at the University of Oxford in 2008, following which he held a visiting artist residency at Duke University and, more recently, a fellowship at the Hanse Institute for Advanced Study in Delmenhorst, Germany. In addition to his undergraduate teaching, which spans a wide range of interdisciplinary perspectives related to the brain sciences, he is conducting research in the cross-fertilization of ideas between contemporary artistic and scientific practices.

Basak Senova
Basak Senova is a curator and designer. She studied literature and graphic design (MFA in graphic design and PhD in art, design, and architecture at Bilkent University) and attended the 7th Curatorial Training Programme of Stichting De Appel, Amsterdam. She has been writing on art, technology, and media, developing projects, and curating exhibitions since 1995. She is editorial correspondent for Ibraaz, the founding member of NOMAD, and organizer of ctrl_alt_del and Upgrade! Istanbul. She curated the Pavilion of Turkey at the 53rd Venice Biennale (2009) and lectured as assistant professor at the Faculty of Communication, Kadir Has University, Istanbul (2006–2010). Her recent works include *Soft Borders* (São Paulo, 2010), *UNCOVERED* (Cyprus, 2010–2012), *The Move* [Adel Abidin. Rosa Barba. Runa Islam] (Istanbul, 2012), and *Translation* (Cabaret Voltaire, Zürich, 2013). Currently, she co-curates the 2nd Biennial of Contemporary Art D-0 ARK Underground (Konjic, 2013), and Symphony (Adel Abidin, Dubai, 2013). She was recently appointed chair of the SIGGRAPH 2014 Art Gallery.

XYZN: Scale

Introduction

Victoria Szabo

To see a World in a Grain of Sand
And a Heaven in a Wild Flower,
Hold Infinity in the palm of your hand
And Eternity in an hour.
—William Blake, *Auguries of Innocence*, 1803

This year's Art Gallery is organized around the theme XYZN: Scale. The exhibition draws attention to a key critical affordance of computer-based authorship: the ability to iteratively scale our digital representations at will: in-out-up-down, back and forth, plus and minus. These core functions enable us to change size and location over time, and at different degrees of resolution.

The SIGGRAPH 2013 Art Gallery explores how artists take advantage of these capabilities in the construction of and/or the aesthetic effects created by their work. We sought projects that engage the artful transformation of these scaling techniques to explore an idea, tell a story, or create an experience in a novel and engaging way. Some of the projects featured this year, such as *Four Mountains* explore an idea at different orders of magnitude, complexity, and depth, producing aesthetically interesting objects along the way. *Visualizing Federal Spending*, for example, takes a 3D graphical approach to this notion, while *Water Columns* offers a physical object that expresses ambient information through a sculptural form. Other works, such as *Traces: Plankton on the Move* and *Digiti Sonus,* compare and contrast the inner resonances of seemingly disparate microcosmic and macrocosmic systems. Still others transpose sensory experiences across different affective domains, as in *Cloud Pink,* or in *Rhumb Lines*, with its eternally present waterscape. Some projects are the work of individual contributors, like the masterful *Drawing Machine*, while others, such as *Shared Skies,* are larger-scale collaborations. *This Exquisite Forest* combines constraint and openness to create an animated film. Still others, such as *Spatial Hyperlink* and *Swarm Vision*, rely on participation by gallery visitors and the conference itself to create meaning, relying on digital communication technologies to collapse space and time in order to create novel experiences.

Taken together, we feel the XYZN: Scale gallery helps realize Blake- s expansive poetic idea for the 21st century, and for a diverse set of artists, dreamers, scientists, and visionaries.

Victoria Szabo
DUKE UNIVERSITY

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Hybrid Basketry: Interweaving Digital Practice within Contemporary Craft

Amit Zoran
MIT Media Lab
75 Amherst, E14-548
Cambridge, MA 2142
USA
amitz@mit.edu

Amit Zoran

ABSTRACT

Contemporary 3D printing and traditional craft rarely meet in the same creation. They tend to live in different worlds. In this paper, the author argues for merging these two distinct traditions. To that end, he developed hybrid basketry, a medium where 3D-printed structures are shaped to allow the growth and development of hand-woven patterns. While the 3D-printed plastic elements contribute the aesthetics of the digital curvatures and manifolds, the hand-woven reed, jute, and canvas fibers infuse the baskets with a unique organic appeal. The author discusses his motivation, describes the making process, and presents four hybrid baskets, integrating a deeper discussion on the place of craft and tradition within our contemporary approach to design and fabrication.

Introduction

Design language is constantly changing. Digital fabrication is on the rise, and parametric tools are transforming the design landscape. Three-dimensional printing is the hot topic of the day, enabling digital practitioners to rapidly implement their ideas [1]. The intrinsic nature of this programmable mode of creation has a major impact on the physical value of the produced artifact. In particular, digitally designed artifacts are intrinsically reproducible: one can always make another identical copy of a 3D-printed object. This style of production stands in stark contrast to traditional craft, where artifacts are individually produced, and repetition of the exact same design is almost impossible.

While craft and art are dynamic practices that respond to new technology trends, 3D printing is still a sterile domain, limited to digital media. In my work, I seek a dialog between digital practice and traditional craft, merging qualities to create a hybrid territory. I demonstrate that tradition can be merged into a hybrid, contemporary "making" practice that respects its double origins. While computational digital design enables an exploration of forms and structures free from traditional fabrication limitations, craft contributes an intimate engagement between the maker, the material, and the product.

In an early project, I merged digital fabrication with ceramic craft in a process that requires an actual restoration of traditional handcrafted objects [2]. I used innovative 3D fabrication techniques to articulate the absent form of the broken originals, thus creating something new while also commemorating what was lost. For example, by holding shards of pottery together with a 3D-printed lattice that follows its naturally implied form, a new object is created from pieces of a shattered one. In this way, technology is used not simply in the service of the revolutionary possibilities of digital production, but also in the service of other one-of-a-kind artifacts.

In the projects presented in this paper, 3D-printed structures are designed to accept the development of hand-woven fiber, intertwining the two different practices into a single artifact. In contrast to a fully digitized design process, hybrid basketry is a search for agreement and

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collaboration between practices. A unity among subjective investment, the use of organic materials, and uniqueness of the final artifact is sought. Here, I explore a synergy between digital practice and craft, based on equality rather than breakage and trauma as in my early work. Following this motivation, I present four hybrid basket projects that span a creative space of parametric design as well as manual artistry. But before delving into the artifacts, I will start by providing some context on the art of basketry.

Context: Basket Makers and Cultural Expression

> Looking at my work, people have to see many different pieces. Often my work is from dreaming—when I sleep, I dream the patterns and then I draw them, they become clear to me in time and then I put colors together. Each one, for me, is special. None are the same.
>
> -Thitaku Kushonya, workshop brochure

Thitaku Kushonya is a traditional basket maker from Maun, Botswana (Figure 1). Learning basketry from her mom, who used to make functional containers for domestic use, Kushonya gave it a modern interpretation by adopting a Western view on originality, uniqueness, and the individual. She doesn't want her work to be used, but rather to be presented and treated as artwork. Each of her coiled palm-fiber works has a different graphical pattern. Basket-making time can vary from a week or two up to several months, depending on the complexity of the work. Designs and patterns are not arbitrary; they are influenced by traditional Kavango style and dreams. Thitak emphasizes the uniqueness of the work and the originality of the graphic. She has her personal intention and technique, so she is the only person producing her baskets.

Figure 1. Thitaku Kushonya (right) in her basketry shop in Maun, Botswana. Photo © 2013 Amit Zoran.

I first met Kushonya in July 2011 while collecting materials on traditional African craft. I was mostly influenced by the level of engagement Thitaku, similar to other local makers, has with her practice—an intimacy that stood in stark contrast to the digital realm of my work. Collecting palm leaves in the Kavango delta, preparing the fibers and their pigments, designing and making the baskets: each of the making stages has potential for creative experimentation. For example, in addition to the variety of patterns and forms, Thitaku investigates alternative materials, such as fibers made from a green nylon bag mixed with palm fibers, and demonstrates the flexibility of a tradition that is often considered highly conservative.

Thitaku Kushonya is more than just a gifted maker. She is also the voice of the Botswana basketry tradition, traveling abroad, promoting the traditional craft, visiting local villages to collect baskets and train makers as producers of collected artwork rather than functional objects. Working with over 450 traditional weavers, Thitaku's organization, Botswana Quality Baskets, empowers makers to use their craft to become self-sufficient, assisting the producers with quality training, design, marketing, and logistics. In an age where mass-produced plastic and nylon containers are cheaper and more accessible, basket makers are looking for identity. Contemporary basketry in Africa, like other traditional crafts around the world, is losing its place as a practical tradition. While knowledge is still preserved by older generations, the search for modern identity is moving forward.

At the heart of basketry lies the practice of intertwining different material elements to reinforce an artificial structure. Unlike woodworking, blacksmithing, and pottery, basketry is not tied to a specific raw material or tool. Basketry practice grows from the inside out—like trees growing over time—in an organic and emergent process. This is the art of pattern repetition and structural growth, as discussed by Tim Ingold in his essay "On Weaving a Basket" [3]. But similar to cloth making, most baskets are based on organic materials, which makes it difficult to study their origins [4]. Recently, archeologists have demonstrated the possibility of an early use of bamboo basketry in Southeast Asia, even with the absence of stone tools [5], by reconstructing early craft conditions of a pre-agricultural period. Based on evidence from bird weavings, it is safe to assume that basketry is one of the oldest practices of humanity.

Ancient as it may be, basketry is a flexible craft that was independently developed by many cultures. It appears in a huge variety of forms, designs, and sizes. Raw material varies from bamboo and cane [6] to pine and leaves [7], and today even metal and plastic wires. Many basket traditions borrow elements from other crafts, such as wooden handles and legs. These qualities of basketry (adaptability, changeability, and usage of a variety of technologies and raw materials) make it a perfect domain for experimentation. Many contemporary makers have visualized this quality, and beautiful examples are illustrated by Billie Ruth Sudduth's *Baskets: A Book for Makers and Collectors* [8].

Exploration

As an accommodating, forgiving craft, basketry invites collaboration with digital practices. Technically, the construction of one-dimensional elements that use woven (or other) patterns, and the discrete nature of the basket's graphics, are relatively easy to model. Indeed, over the last few years several projects have articulated the use of computational technology to explore digital weaving. An example is the work of Rizal Muslimin [9], who demonstrates how computational design of woven structures can be implemented in architecture. While algorithms for digital weaving have been explored in an early work by Matilda McQuaid [10], Zubin Khabazi enabled designers to study and implement computational weaving using Grasshopper, a parametric plug-in to Rhino3D [11]. He divided a 3D surface into a woven pattern of warps (the longitudinal thread), and wefts (the transverse thread) creating networks of woven curvatures. This last work served as a starting point for my investigation.

Basket I

Due to its woven structure, I call this first work a basket, but it may resonate more with the traditional shape of a vase. Modifying Khabazi's weaving algorithm, this artifact demonstrates digital possibilities that cannot be implemented in traditional practice (Figure 2). Using an Objet Connex 3D printer, which allows a linear combination of two different printed materials, a smooth surface was deformed to a woven pattern by several linear steps (from the bottom up). *Basket I* demonstrates surface deforming, starting with a smooth texture and a single white color and developing to a woven pattern with black warps (Objet's flexible material) and white wefts (Objet's rigid material). In the bottom of the basket, I manually wove natural reed into the pre-designed 3D-printed wefts, to achieve a simple demonstration of hybrid structure.

Basket I demonstrates the potential in revising 3D printing and digital design to achieve traditional craft aesthetics, such as the woven pattern. Starting by designing a sleeve with freehand deformation of a cylindrical surface, I then decomposed the surface to warps and wefts. Based on Khabazi's work, my modification of his algorithm enabled a non-uniform woven development, allowing control of the relative distance of the warps from the base surface. This virtually designed structure was then printed in one piece, before weaving the wet, flexible reed inside it.

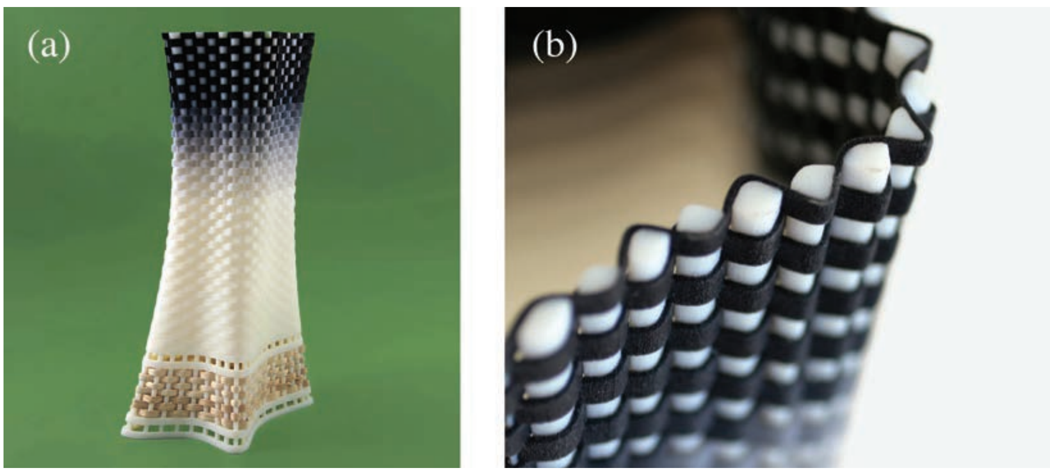

Figure 2. ***Basket I*, made by an Objet Connex 3D printer-and reed. © 2013 Amit Zoran.**

Basket II

Basket I is an aesthetic illustration of the potential of parametric design and multi-material 3D printers. However, the manual part of that work is limited and doesn't show a balanced exchange between the practices. As a digital practitioner, it was my first attempt to design for manual weaving. While *Basket II* still mainly relies on digital process, it presents a higher degree of investment and skill development for the maker (Figure 3).

In *Basket II*, I used a new implementation to join reed and 3D-printed structures, rather than the weaving technique. I used a structure of layers, where 3D-printed miniature arms (Nylon 12 material printed by a selective laser-sintering process) are the bases of the basket, and two separate horizontal and vertical reed layers cover it from the outside. Due to its size (60cm long), this basket when printed was divided into four separate parts that were glued together manually. Several virtual renders were made beforehand, to test dyes and different reed arrangements, prior to manually completing the design and gluing the reeds to the structure.

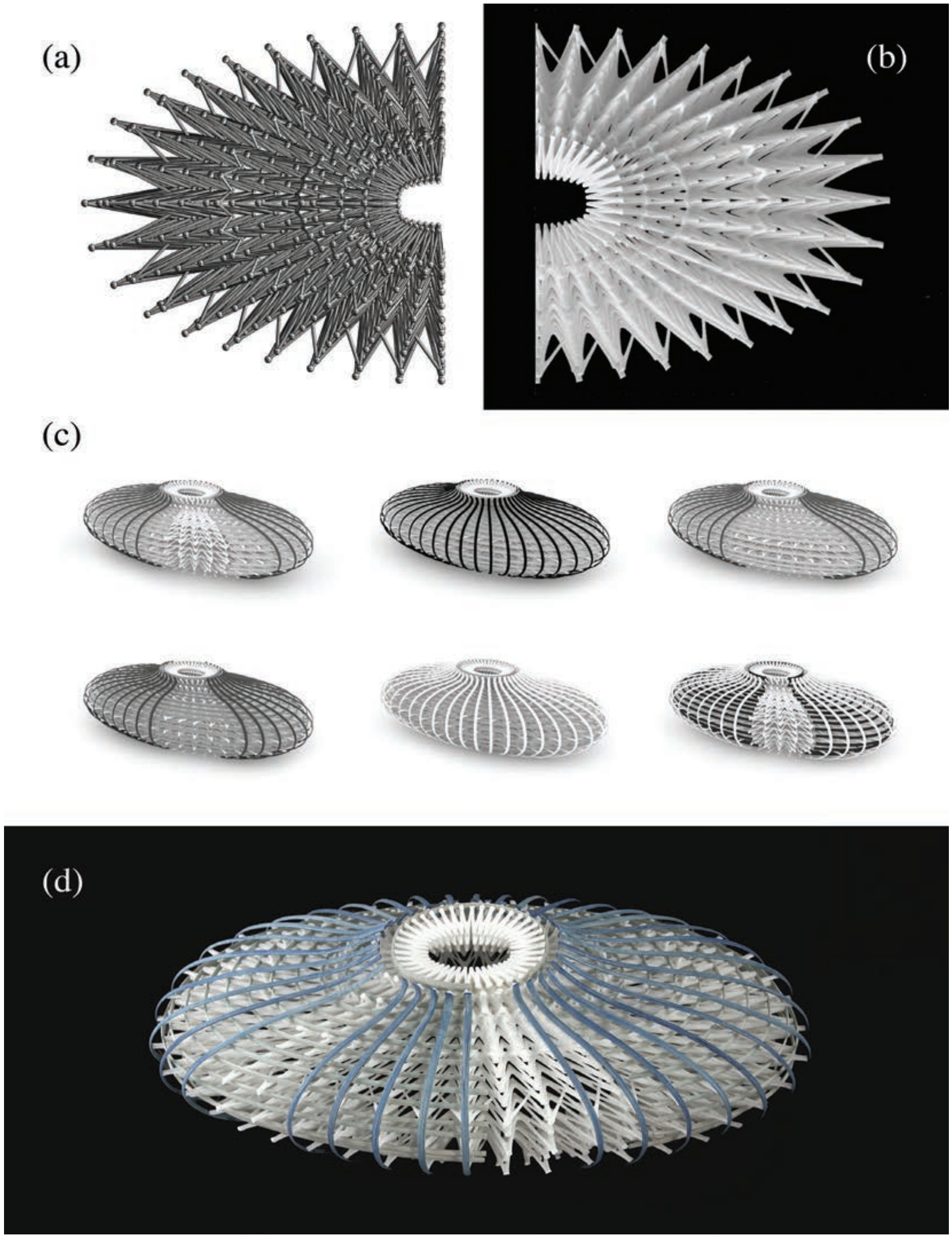

Figure 3. The making process of *Basket II*. (a) CAD design of the 3D-printed arms structure. (b) The 3D-printed Nylon 12 structure. (c) Six renderings of reed colors and arrangements. (d) The final basket (3D-printed nylon, reed, pigments, and glue). © 2013 Amit Zoran.

Basket III

Basket III demonstrates a weaving technique, wherein in a 3D-printed lattice guides the woven reed in pre-defined paths (Figure 4). Similar to the previous work, dyed reed was manually woven into the brittle 3D-printed nylon object, reinforcing it to a solid artifact. The design of the basket is based on 2D weaving guides (Figure 5) that were rotated to achieve a closed oval shape. The printed nylon acts as the basket's wefts, while the reeds are the warps.

This basket owes its shape to the marriage between the two materials. The 3D-printed structure alone doesn't resemble the final form, and the two elements are essential in order to achieve physical stability. In many aspects, the result was a surprise, since the final hybrid shape was not simulated during the design, and the aesthetic qualities of the basket first appeared while manually weaving the reed (which took approximately six hours). For me, this work was the first real "workmanship of risk" within the hybrid basketry project—a quality so essential to real craft [12], where the shape of the crafted object is never predetermined.

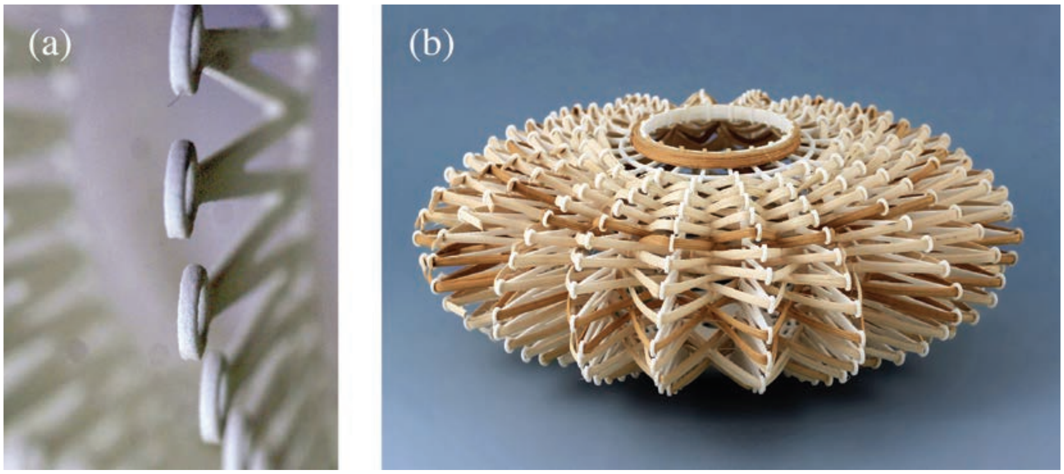

Figure 4. *Basket III*. (a) 3D-printed nylon structure, and (b) the complete basket with the dyed reed. © 2013 Amit Zoran.

Basket IV

The last project is, in a sense, the most accurate manifestation of my intention within hybrid basketry (Figure 6). Here, unlike the previous projects, the manual investment was greater than the digital one, as it took me almost a week of work (2-3 hours a day) to complete the weaving of canvas and jute ropes inside the 3D-printed construction. While the overall shape of the basket depends on the computational process (and may be difficult to achieve within traditional practice), the woven pattern was only partially pre-defined in the computer, and a lot of freedom was available for the weaving stage itself.

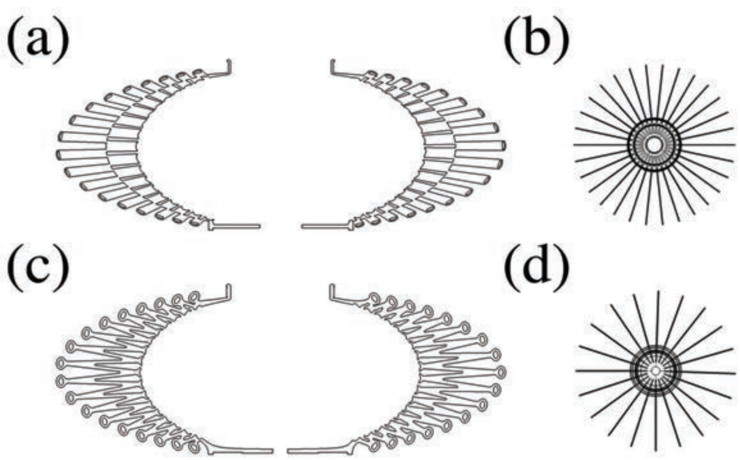

Figure 5. The design process of *Basket III*. (a) An early 2D support structure, and (b) its rotation plane. (c-d) The final basket's 2D support structure with its rotation plane. © 2013 Amit Zoran.

The 3D-printed sleeve was designed in a process similar to *Basket I*: starting with a sleeve and using freehand deformation of a surface, I sliced the surface to horizontal bands and used these slices to make deformed cylinders (Figure 7). This cylindrical weft structure constrains the weaving's vertical pattern. In addition, the horizontal density of the weaving process, the weaving pattern itself (such as how many wefts should be included in one loop), and the type of rope and its color (canvas or jute) allow for a vast design exploration during the making process. The result is a unique artifact, with a singular surface pattern. The 3D-printed structure offers

Figure 6. *Basket IV*: Nylon 12, jute and canvas ropes, pigments, and a rosewood plate. © 2013 Amit Zoran.

digital freedom, but it requires the woven rope for reinforcement and stability.

Summary

In this paper, I explore what have conventionally been treated as two divergent realms: emerging digital technologies and timeless hand-hewn craft. This work allowed me as a digital practitioner to be engaged in the making process and invest many hours practicing my new unique basketry skills. It is, in a sense, a physical manifestation of an intensifying desire to develop a new way of thinking about these polarities: the machine, as generator of control and innovation, and human manual skill, as preserver of artistic production and culture. This is an investigation of our digital culture and our potential to reclaim a lost material identity in the cyberspace of design and fabrication. Here, two distinguished practices, hand-woven organic fiber patterns and computationally driven 3D-printed structures, are assembled to become a hybrid material territory. My hope is to substantiate a this new hybrid territory for investigation and discovery, in which the value of artifacts produced by both machine and man can infuse our excitement about technological progress with a need to remember the very soil from which it came.

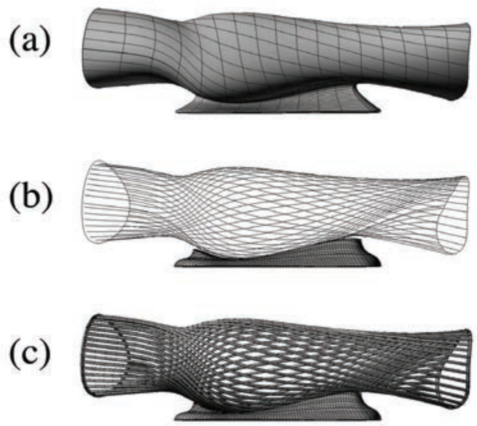

Figure 7. Three design stages of *Basket IV*: (a) lofting and twisting a sleeve surface to create the overall shape, (b) slicing the sleeve to horizontal stretches, and (c) creating a solid structure that can be 3D printed. © 2013 Amit Zoran.

While the motivation of this work was to encourage dialog between material practices, this essay demonstrates a work by one individual. While mastering the digital-design arena, I took only a few steps toward the craft of weaving. As such, the scope is limited to my subjective interpretation and perspective, and thus more work is needed, with more participation by creative makers to claim a cultural practice. Hopefully this project will inspire other makers to preserve and integrate, while still innovating and progressing.

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Work described in this paper will also be presented in this year's Art Gallery, XYZN: Scale.

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KIMA — A Holographic Telepresence Environment Based on Cymatic Principles

Oliver Gingrich, Alain Renaud, Eugenia Emets

Oliver Gingrich
EngD Candidate
Bournemouth University
126 Fernhead Road
London W9 3EN
United Kingdom
oliver@musion.co.uk

Alain Renaud
Bournemouth University
126 Fernhead Road
London W9 3EN
United Kingdom
arenaud@bournemouth.ac.uk

Eugenia Emets
Artist
emetsjane@gmail.com

ABSTRACT

***KIMA* is a holographic surround-sound installation that visualizes telepresence as both a phonetic and a synaesthetic phenomenon. The performance piece is based on the physical conditions of cymatics—the study of physically visible sound wave patterns. Two environments, a quad surround and a holographic interface, build the framework of a telematic experience that illustrates communication as wave forms while focusing on the relationship between sound and matter.**

Project Description

KIMA is an interactive art installation with multiple objectives: On the one hand, *KIMA* is designed to be a live performance that challenges conceptions of on-stage telepresence. On the other hand, *KIMA* is an interactive installation that can be explored by individuals. *KIMA* focuses on the intrinsic relationship between matter and sound, of the audio/visual. *KIMA* offers the chance to visually and phonetically experience how sound and image mutually influence each other, generate each other, and ultimately condition each other (Figure 1).

KIMA is designed to be a user-independent installation. When not performed by live artists (a performer and a vocalist), it can be experienced by audiences as an explorative installation in which two users interact remotely—creating a phonetic field alongside a holographic visualization of this soundscape. A user in space A creates sound through voice and movement to be transmitted and visualized in space B. The user in space B modifies not only the sound environment, but equally the cymatic patterns it generates. Sound is experienced as the essence of communication. On a perceptive level, *KIMA* presents the user with a new form of telepresent experience: Rather than focusing on photorealism in representation, *KIMA* looks at sound and matter as the bricks and mortar of communication.

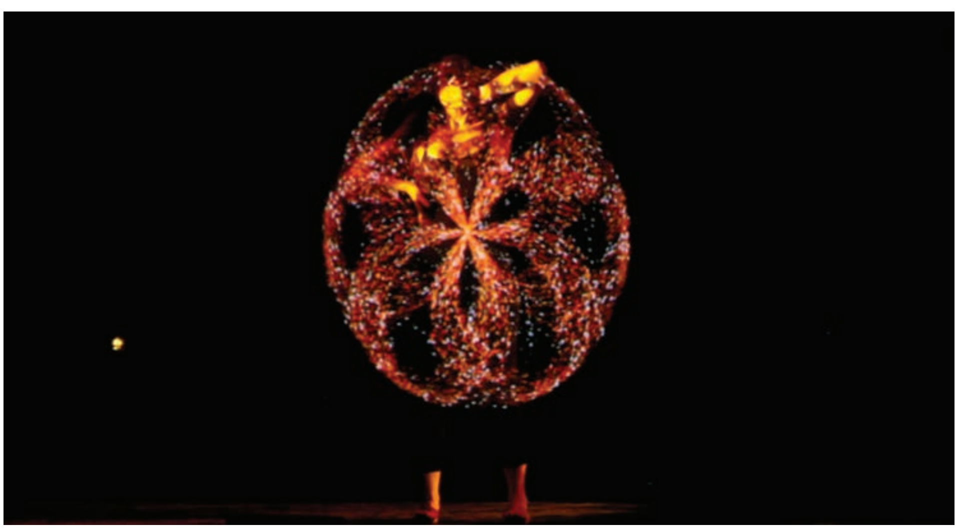

Figure 1. *KIMA* performed at Kinetica London. © 2013 Eugenia Emets.

 | Leonardo, Vol. 46, No. 4, pp. 332–343, 2013

KIMA is last but not least a research project, designed to investigate the relationship between sound and visuals on a very basic physical level. Cymatics is known as the area of research on the effects of vibrations, and in particular sound frequencies, on matter. Cymatics as a science can be traced to Ernst Chladni's 18th-century experiments. With a team of sound designers, a physicist, artists, and programmers, *KIMA* builds on these explorations as a scientific framework for sound-matter interrelations.

Technical Setup

On a technical level, *KIMA* combines an unconventional screen interface—a holographic screen with real-time motion capture input, mathematic sound visualization, and quad surround sound. Abstracting holographic telepresence as a visualization interface, sound becomes the primary layer of presence. In two remote setups—one audio/visual, the other purely phonetic—users experience actions and interactions as a sense of one another's presence. The soundscape of the first space is transmitted as holographic imagery into the second space, where it allows for real-time modulation of both vision and sound. Through methods of reflection and refraction, holographic screens allow for projection into space as opposed to onto a surface. Users can then interact with imagery generated in real time—in this case, affecting both shape and sound.

This shared soundscape is visually represented as a cymatic pattern on the holographic screen. Actions and movements in this space modify visuals and the soundscape in what becomes a perpetual feedback loop of communication. Technically, *KIMA* distinguishes itself from other telepresence art installations in concentrating solely on the relationship of sound and matter through motion tracking on a holographic screen interface.

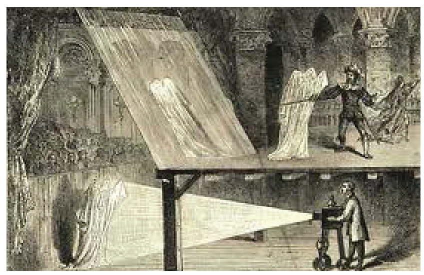

Figure 2. Edouard M. Charton, Classic Pepper's Ghost Display using glass, 1869.

Pepper's Ghost-based telepresence interfaces allow for life-sized, spatial representations of human interaction. Through the principles of reflection and refraction, images are projected into the physical space as opposed to onto a surface—allowing for onstage interaction with the visual form. This "holographic" representation (the perceived "hologram") appears as a life-sized image on stage to audience members in the auditorium. Overhead displays reference feedback streams for the presenter and the audience. As a spatial display technique, Pepper's Ghost projection serves as a platform for real-time communication (Figure 2).

In *KIMA*, this telepresence solution is adapted to display the mathematical interpretations of a sound stream rather than a life-sized person. The stream is then modified through motion capture (Microsoft Kinect) in real time for a two-way telepresence interaction. Real-time-generated imagery is literally superimposed onto the performer and user. Real-time interaction between two spaces affects the shape of the structure, its spatial position, and the sound pattern it represents. This results in a perpetual interplay of communication.

In its first rendition, *KIMA* was presented at Kinetica Art Fair London 2013, one of the UK's biggest forums for digital art—staged as a performance between a vocalist and a dancer. The presence of the vocalist is almost tangible. The result of the dancer's actions is relayed as interference pattern back to the vocalist. Whereas the sound from space A creates visuals in space B, these visuals can be modified, translated, and redefined through the dancer's movements—converging in an ever-changing joint telematic performance. Higher frequencies create different cymatic patterns, and the dynamic changes continuously through interaction.

Conceptual Setup

As a telepresence performance, *KIMA* explores new strategies in offering both a performance and an interactive user installation to audiences. In the tradition of telepresence art (Roy Ascott, Eduardo Kac, et al.), the act of remote communication is the core subject matter of *KIMA*, yet its focus is firmly on the intrinsic relationship between audio and visual. How does sound generate matter, what happens when sound modifies matter (for example, when we as humans act as instruments and create music with our movement and presence across spaces)? These questions are investigated both on an academic and artistic level.

A number of artists have played with sound waves as either visible or invisible structures of communication. In 1970, Bernhard Leitner's *Sound Cube* used surround sound to immerse users in the experience of "geometric" sound, a walk-through audio architecture. David Bowen's tele-present water made use of water currents to deform a geometric structure at a remote location. Telepresence sound has been generated by Pauline Oliveros in her Deep Listening Institute since the 1990s. Other than previous telepresence pieces, sound isn't the sole focus of attention, but more of a modus operandi for the larger theme of remote communication. Sound is understood as one of many strategies of remote communication between two spaces.

KIMA maps sound geometrically across two spaces, allowing the users to reference one another, to act as instruments within a composition they only partially influence. Performers or users thus form part of an ever-changing sound field that stands in the tradition of sound installation art (Wolf Vostell, Bill Fontana, et al.). *KIMA* "understands" sound patterns as part of a constantly changing force field that surrounds us, that we form part of—the essence of communication. *KIMA* extrapolates this invisible environment by visualizing communication as real-time interactive interference patterns based on mathematical principles.

In ancient Greek, "kima" means "wave." In this telepresence environment, users experience the wave form in its sonic and physical forms as a traveling, continuously adapting stimulus—as an interface of interactions. In contemporary art production, cymatics—as visualization of phonetic waves—have been the inspiration of artists around the globe. Telepresence art's long tradition dates back to 1983, when Roy Ascott staged *La Plissure du Texte*, and was further pioneered in the early 1990s (Paul Sermon [1], Tina Keane [2], Sommerer and Mignonneau [3] et al.). Recently, Paul Prudence—*BioAcousticPhenomena* (2010)—created visual references of cellular phenomena based on cymatic principles. *20Hz* by Ruth Jarman and Joe Gerhardt [4] is a sculpture generated by sound based on a geo-magnetic storm in the earth's atmosphere.

KIMA was conceived as a telepresence depicting cymatic patterns on a holographic interface. This visible structure of wave patterns is a continuum of user/performer interactions via body and voice in space. The work is a comment on the phenomenon of presence itself, at sound as an interference pattern, an orchestration of communication rather than mere representation of sound.

However, there is only limited available research on the intrinsic relationship between sound and visual telepresence. Academic research studies remain vague and inconclusive. With *KIMA* we attempt to fill this gap by providing a framework for future analysis of this specific aspect of telepresence. The work is distinguished from other telepresence installations in its specific focus on the intrinsic sound-matter relationship.

Experiential Setup

In *KIMA*, there are two types of communicative clues: On the one hand, users communicate with the space around them. They enter an invisible construct confined by the physical borders of the space—every movement induces a change in this sonic environment of echoes, frequencies, and geometrical attributes. Whereas one space allows for phonetic references only, the second space depicts a cymatic representation of these sound patterns, abstracting the presence of the other as interference patterns of communication.

The space itself and its exploration are central: Both performers are immersed in two distinctively prepared spaces, equipped with invisible sensors that enable navigation. A quad surround sound system provides feedback, and a holographic projection technology creates a volumetric sensation of light. Holographic screen displays use a transparent screen and methods of light reflection and refraction, thus allowing for the sensation of 3D without the need for 3D glasses. Employing visual cues and references that help to conjure the illusion of spatial depth perception, holographic screens map virtual information onto the real space—creating a plane of onstage interactivity between virtual images and live performers in a controlled-light environment. A dark environment along with a controlled-lighting solution plays a key role in this optical illusion.

By its very nature, a dark space engenders an immersive environment. How do we experience ourselves in such an environment once we sense another presence? On an experiential level, the dichotomy between you and me ceases to exist and gives way to an endless echo reverberating in both locations. In *KIMA*, information on the other presence is provided only through code—coded representation of sound or sound patterns transcoded into feedback loops. It is through this deformation of communication, through a veil of self and other, that we experience information on spatiality. *KIMA* looks at invisible presence on two levels: quad surround sound feedback loops and a visual representation of these sound patterns on the holographic screen. On this holographic screen, *KIMA* plays with notions of visibility and invisibility. Cymatic patterns only become visible when sound is emitted, i.e. when communication takes place.

"Invisibility" has been explored in contemporary art production and display. The Hayward Gallery's Invisible: Art about the Unseen, 1957–2012 was entirely dedicated to that theme. Jeppe Hein's *Invisible Labyrinth* (Centre Pompidou, 2005) explored architectonic presence through movement and sound relays [5]. In *KIMA*, the users remain almost invisible, as sound waves act as a medium of telepresence.

Whereas one space allows for sound as the sole reference to the other's presence, the other space displays a visual structure—a cymatic sound sculpture as representation of sound. Here, sound serves more as a prompter for cymatic effects—an interface for further interaction. This representation of sound as particle waveforms in a holographic environment is based on the voice of the other in the second space. Exploring both spaces, users can physically experience the difference between sonic and visual presence.

Holographic screen interfaces (here, a Musion Eyeliner screen) allow for spatial perception of visual information and for live onstage interaction with these visuals (in *KIMA*, via Microsoft Kinect). The Kinect camera traces z-depth information along with information on position, which serves as feedback to both Processing and Max/MSP scripts. Based on the principle of Pepper's Ghost, this creates an interface that can be experienced spatially. Any movement in this space creates further feedback both to the visual form on the display and the phonetic environment in both spaces. This cymatic telepresence setup can be performed (by professional performers) or simply explored. Both phenomena—cymatics and telepresence—have a long tradition in the visual arts, and both concepts have changed and evolved dramatically over time.

The second communicative layer is the phonetic interaction with the other. Within the dark space, we almost expect to feel the other, yet we can only hear him or her exploring another space—wherever that might be. Location references of the other are generated through sound panning and mapping to the user's own environment. Location cues are augmented through echoes, reverberation, and frequency changes, and the fact that all we hear, feel, or see are interference patterns of sound—coincidences of communication.

Following Paul Wazclawick's studies in communication [6], not to communicate is virtually impossible. In *KIMA*, users are constantly exposed to a stream of information generated by their environments and users that explore them. Immersed in the *KIMA* setup, users transcend the boundaries of the physical space to communicate with similar spaces through different patterns of communication. *KIMA* explores a new route in telepresence art by creating an interface for a new form of presence that concentrates entirely on sound and matter as the nucleus of communication.

Processing code, whether displayed as cymatic pattern or purely audible, is based on the physical principles of cymatics—wave patterns that result from sonic frequency changes. Mathematically correct formulas build the framework for visual references that emerge in real time as representations of the invisible. *KIMA* as synaesthetic experience remains within the conceptual framework of telepresence art, while focusing on the sound-matter relationship through cymatics.

Conceptual Issues: Cymatics and Telepresence

KIMA has three main conceptual frameworks: telepresence as a concept and art form, cymatics as a research subject and art practice alike, and, in a wider context, synaesthetic art.

Telepresence

As a concept, telepresence dates back to the 1980s when the term was coined by Marvin Minsky in his seminal article "On Telepresence." Later conceptions focused on a mechanical telematics angle, aspects of virtual reality, and only in recent years on day-to-day communication. Minsky's techno-centric definition of the term gave way to proponents of a senso-motoric approach such as Thomas Sheridan's and ultimately focused on remote user experiences, such as the perceptual definition championed by the ISPR. The concept of telepresence relies heavily on the concept of remote presence—a user-centric idea of perceived non-mediation.

In art practice, pioneering experiments such as Paul Sermon's *Think about the people now*, which won the Golden Nica in 1991, were echoed by installations by Tina Keane, Julian Freud, and others through the 1990s and 2000s. Telepresence art has evolved dramatically from its early incarnation (*La Plissure du Texte*) through installations such as Ken Goldberg's *Telegarden* in the mid-1990s and Eduardo Kac's *Ornitorrinco on the Moon* in 1993.

The more the internet started to dominate everyday life, the more telepresence art became popular. Raphael Lozano Hemmer's telepresence installation for Ars Electronica, *Displaced Emperors* (1997), shifted the focus from people to architectural telepresence environments. Sommerer and Mignonneau's *The Interactive Plant Growing* (1993) had a botanical, organic context.

Over the last two decades, telepresence has found new channels in performance art, theater, and sculpture. In performance art, groups like Ghislaine Boddington's Body>Data>Space have experimented with new forms of telematic communication. In theater, the English National Theatre recently found a new outlet in telepresence performances by projecting plays live into cinemas across the UK. Telepresence sculptures represent a diverse spectrum, ranging from architectural art to classic sculptural forms. The architecture collective Assocreation connected two remote locations through a shared pneumatic floor interface with *Bump* in 2010 [7]. Michael Takeo Magruder's *Data Flower* (2010) [8] presents a holographic sculpture as telepresence art—the visual form of an ever-changing flower based on a perpetual live internet stream of news feeds.

Figure 3. *KIMA* research performed at Kinetica London. © 2013 Eugenia Emets.

KIMA is a telepresence environment, a performative space, a sound installation, and a holographic sculpture—a communication interface that allows users and performers to experience the spatial qualities of the physical space as a communicative infrastructure. *KIMA*'s approach is new in that it shifts the focus from telepresence as remote representation to telepresence as audio/visual communication (Figure 3, 4).

Cymatics

The collective behind *KIMA* intends to use cymatic wave patterns in sound and image as a mediator for remote interactions. Cymatics, a terminology that derives from the Greek word κῦμα (wave), is known as the science of visible sound waves—the modal lines of particles or liquids within rigid environments as the result of sonic vibration. Ernst Chladni (1756–1827), the founder of acoustics, is known as the first to research vibrations and their effects on sand on rigid surfaces. Chladni demonstrated his famed laboratory setup at the French court and catalogued his studies to a certain degree.

In the 1960s, these experiments were further developed and academically contextualized by the Swiss scientist Hans Jenny, who looked at regularities in visual patterns and established a formula linking frequencies to visual patterns directly. His research and publications form a catalogue or atlas of wave patterns that now presents the backbone for future research for academics, musicians, and artists.

György Kepes, founder of the Center for Advanced Visual Studies at the Massachusetts Institute of Technology; Derek Kverno and Jim Nolen at Davidson College; and Thomas Cooper at Temple University all published diverse research papers on the subject. Recently Lewis Sykes from the Manchester Institute for Research in Art and Design investigated the subject in artistic and theoretic practice [9].

On a mathematical level, cymatic patterns have been discussed by Stewart and Colwell (1939) [10], by Elmore and Head (1985) [11] and maybe most importantly by Paul Bourke, research associate professor at the University of Western Australia [12].

In layman's terms, Chladni's patterns look at the movement of sound over rigid surfaces, at the acceleration of sine waves in a constrained environment such as a rectangular or round plate. Vibration patterns depend largely on the frequency itself as well as the rigidity of the surface and its confining boundaries. Modal residues settle where the speed of these frequencies equals zero. These points of zero acceleration are generally ordered symmetric "lines" arranged toward the center. Researchers have applied this model to three-dimensional space.

Cymatics have influenced artists and researchers alike. Looking at cymatic patterns on a plate or in a volumetric form means to look at the intrinsic relationship between sound and sight. A Chladni plate ultimately acts as a medium for two dimensions to interact, as a mirror of their relationship. For *KIMA*, this contextual framework has been informative on mathematical, phonetic, artistic, and academic levels.

Figure 4. ***KIMA*** **research performed at Kinetica London. © 2013 Eugenia Emets.**

Synaesthetic Art

Audio/visual art has a long-standing tradition in cymatics: On a phonetic and symphonic level, R. Pellegrino's studies on "The Electronic Arts of Sound and Light" (1983) [13] and Alvin Lucier's composition "Queen of the South" stand out as artistic interpretations of the subject. Lewis Skyes' "Augmented Tonoscope" is a synaesthetic art project that concentrates on analog sound-matter visualizations [14]. In the arts, Carsten Nicolai's Milch (2000) and Graham Wakefield's Chladni 2D and 3D Max/Msp patches have touched on the field of cymatics.

Experiments in synaesthesia, the relationship between sight and sound, go far beyond the arts and have been conducted in physics by Newton and in music by composers such as Louis Bertrand Castell over the centuries. In video and installation art, there is a long-standing tradition of experiments in synaesthesia spear-headed by Oskar Fischinger, Norman McLaren, John Whitney Sr. and Jr., and Mary Hallock-Greenwalt, whose color organs "Sarabet" and "Nourathar" were able to create sound while displaying correlating images at the same time.

As part of this long tradition of audio/visual art, *KIMA* is an attempt to be more than an audio/visual instrument for the body. It is an instrument for two, a perpetual composition of synaesthesia, in which users become composers and choreographers and their interactions become visual symphonies.

On an academic level, *KIMA* looks at how sound enhances telepresence experiences for individual users. Research on surround sound in telepresence setups to date is still relatively inconsistent (compare: Lombard & Ditton, 1997) [14, 15]. Studies diverge on the question of whether immersive sound enhances telepresence effectively and, if so, how much. *KIMA* investigates this intrinsic relationship. To this end, the physical setup will build the basis for future research, to be followed up by an academic evaluation based on interviews and questionnaires. *KIMA* is conceptualized as an investigation in audio/visual interrelations, an investigation of the role of sound in telepresence and the relationship between the visual and the phonetic.

KIMA **Technical Setup**

KIMA has three main dimensions:

A. Interactive immersive sound installation

B. A motion control interface

C. A visual interface

We will discuss the installation in all three aspects:

A. *KIMA* as an immersive sound environment.

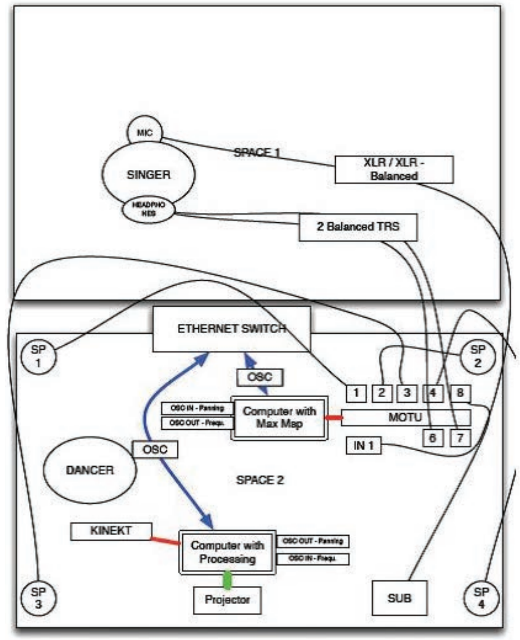

Figure 5. *KIMA* Technical Setup. © 2013 Alain Renaud.

In *KIMA*, sound acts as the main communication interface between two spaces. On a technical level, the sound engine written in Max/MSP [16] and controlled via the Open Sound Control (OSC) protocol is the mediating application of the system. The sound engine also processes audio information and sends it via OSC [17] to control the visuals. This process creates feedback loops for both environments. The audio signals are routed as raw audio data via Jacktrip and the Jackaudio Server (Cáceres et al., 2009) [18] over the network. Interpretation of this audio stream in Processing [19] is based on mathematical formulae of cymatics and sine wave functions of cymatics:

u(x,y,t) = A * sin(Kx*x) * sin(Ky *y) * cos(w*t)

In environment A, the audio is transmitted through contact microphones, capturing the low rumbling vibrations of the users in their space. A second condenser microphone communicates the conversations and noises emitted purposefully by the users. This sound signal is processed in real time over the network through Max/MSP and OSC into environment B.

All sound sources of environments A and B are automatically mixed and streamed through an array of four speakers plus a subwoofer in environment A. At the same time, a flattened version in a two-channel mix is sent to environment B. In environment B, one contact microphone and one condenser microphone are installed to record ambience as well as user audio input for real-time transmission. Two individual streams are sent to a Max/MSP patch for the mixdown in the application. Users hear interference patterns in the two spaces, to which they are, of course, invited to respond in real time.

Whereas environment A is set up as an immersive sound environment, environment B is equipped with a holographic projection system (Musion Eyeliner technology) to display cymatic wave patterns created in Processing along with stereo mixdown. Interference patterns are displayed both phonetically and visually as a materialization of communication. Sonic interactions create a sense of presence and dislocation, which results in an entirely new perception of environment, other, and self.

The overall sound environment represents an extension of naturally occurring, ambient sound signals produced by the users, thereby reinforcing the feeling of immersion and the level of engagements for the users (Figure 5).

B. *KIMA* as a motion capture interface:

Motion information is used in environment B to record and capture the position of the user and map it to the panning of the sound environment. The user in environment A is therefore able to hear the sound in quad. Spatial information is transmitted in real time for the user in space A to interact with. Visuals in space B integrate motion information in the display script. Ergo space B acts as a visual playground, whereas space A consists of an immersive phonetic sculpture.

C. *KIMA* as a visual interface:

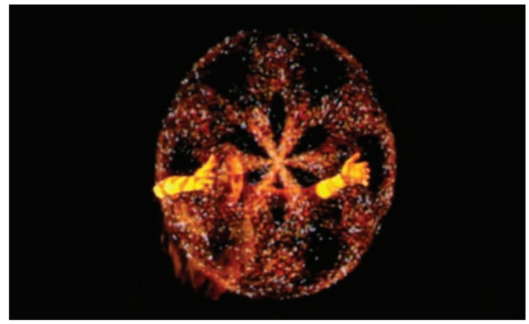

Figure 6. Real-time particles generated in Processing. © 2013 Eugenia Emets.

KIMA's visual display is programmed on the physical principles of cymatics: wave patterns created by different frequencies on rigid surfaces or inside a specified volume. The visual representation of interference patterns is based on mathematical formulae derived directly from the studies of wave patterns in contained spaces such as the Chladni plate. In line with existing studies on generative art, *KIMA*'s visual interface follows a set of rules to make the visual representation easier to read and more intuitive to interact with. *KIMA* is based on mathematical formulae that derive directly from Hans Jenny's cymatics.

Various studies in both generative art and complexity theory state that highly ordered systems reduce visual entropy [20]. *KIMA*'s telepresence experience is based on a highly ordered system to reduce entropy. The following rules have been laid out by the *KIMA* collective:

1. *KIMA* is autonomous: The aim is to create a completely self-generative, autonomous, and self-relying structure (Figure 6).

2. *KIMA* is cymatic: Both interfaces are based on principles of cymatics (sound creates and alters visual form).

3. *KIMA* is communicative: Interference patterns of communication are its visual and phonetic representation.

4. *KIMA* is more than the sum of its parts: It consists of wave forms and particles that form together in entropy (Figure 7).

5. *KIMA* is audio/visual: The color spectrum is related to frequencies; sound panning represents locations.

Figure 7. Before and After: Cymatic experiments using ferrofluids and the frequency range 432khz. © 2013 Oliver Gingrich.

6. *KIMA* is immersive: Physical space is mapped to a phonetic space, and different effects are attributed to it.

7. *KIMA* is user-focused: Visually and phonetically, centers are mapped to XYZ-coordinates of users.

8. *KIMA* is generative: Audio loops entail repetition of the form.

9. *KIMA* is interactive: Once you stop interacting, the structure disappears.

10. *KIMA* is communicative: The louder the signal, the more visible the structure becomes.

11. *KIMA* is responsive: The faster the user's movement, the faster the visual structure moves.

12. *KIMA* is iconographic: Structure is created around the center.

13. *KIMA* is predictable: Amplitude of sound waves controls particle emission.

These guidelines illustrate the conceptual underpinnings of the *KIMA* code. *KIMA* is at once self-reliant and autonomous. Like any other generative art installation, it is based on physical principles and is rule-based. Interference patterns, the single economic denominator of user communication, are displayed as a visual representation. Users are turned into theremins—musical instruments of a composition they can only influence but never solemnly direct. In this sense, *KIMA* is organised under Paul Watzlawick's premise of the impossibility of non-communication [21]. *KIMA* makes use of a holographic interface (the Musion screen), which in itself is based on Pepper's Ghost projection methods.

KIMA - Conclusions

KIMA has a dual agenda, being at once academic research and an art installation, as well as being a phonetic immersive environment and a visual sculpture. *KIMA* is a telepresence experiment that plays with new technology: a holographic display technique based on the principle of Pepper's Ghost and a coded, programmed sound environment.

On an academic level, *KIMA* is at the basis of a research evaluation of the impact of immersive sound on telepresence. On an artistic level, it creates a performative space for the public to engage in. The research collective understands telepresence not as a communication technology (such as Skype or similar), but as a concept of presence in a remote location. *KIMA* is conceptualized as an immersive perceptive experience of communication. Stripped of a visual representation of the other, we experience communication as something that is surrounding our senses, omnipresent like the wave forms that cymatics generate.

As a non-verbal, non-facial communication process across distance, *KIMA* invites the public to act as artist and create a phonetic environment that solemnly consists of communication.

KIMA also questions the conceptual context it operates in. Generative art is understood as art that consists of an autonomous system based on rules that form intelligent design. In the case of *KIMA*, a plurality of rules forms the structure of communication. On a visual level, these rules are based on cymatic patterns. On a phonetic level, the rules are interference patterns. This system is autonomous, yet dependent on user interference, on human interactions. Generative art aims for an autopoietic system that—once created—acts independently of human interference. *KIMA* is a generative art project, yet it requires human interactions—interference patterns of communication—to come to life. In this sense, *KIMA* is both interactive art and a generative art project facilitated through telepresence. Generative art and interactive art are neighborly disciplines, yet clearly defined and demarcated across academic literature. *KIMA* tries to break with the conventions of this artificial dichotomy of terminologies in constituting a piece that can be attributed to both worlds (Figure 8).

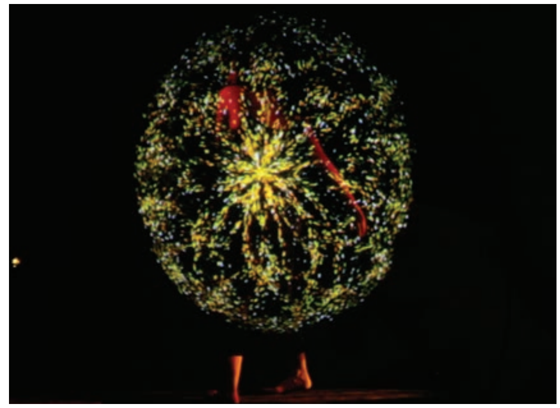

Figure 8. ***KIMA*** **research, performed at Kinetica London. © 2013 Eugenia Emets.**

First and foremost, *KIMA* is a piece on communication and the impossibility of non-communication. It understands spaces as representative immersive environments, as visual and phonetic echoes generated and created through communication. It is also an exploration of telepresence, of the essence of sound in establishing a sense of presence, a sense of other. This mediation process is the subject matter of the installation. Standing in a long tradition of pioneers (Roy Ascott, Paul Sermon) of telepresence art, we look at spatial environments as being filled with waveforms of communication. *KIMA* extrapolates these waves both on a visual and phonetic level, and reduces communication to an act of engagement.

In the next stages of project development, the research collective will focus on deeper exploration of cymatic aspects through research and realization of 3D variations of cymatic phenomena. Using the current model as a starting point, the aim is to create a more intuitive, flexible, and in a way more complex visual language for sound visualization, which would allow an even more immersive and fluid interaction experience. This development will proceed alongside experimentation both in the performance and installation setting with public participation. The collective plans to work with both voice and other instruments as sonic input for two-way communication. This will allow the project potentially to be used in the context of multi-instrument music performance in interaction with one or several dancers.

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Null By Morse: Historical Optical Communication to Smartphones

Tom Schofield
Culture Lab
Newcastle University
King's Walk
Newcastle upon Tyne NE1 7RU
United Kingdom
tomschofieldart@gmail.com

Tom Schofield

ABSTRACT

***Null By Morse* is an installation artwork that incorporates a military signaling lamp and smartphones. A series of Morse messages is transmitted automatically by the signal lamp. The messages are drawn from the history of Morse and telegraphy. A custom app for iPhone and Android uses the phone's camera to identify the changing light levels of the lamp and the associated timings. The app then decodes the Morse and displays the message on the screen on top of the camera image. This paper discusses the artwork in relation to the following theoretical aspects: It contextualizes the position of smartphones in the history of optical communication. It proposes an approach to smartphones in media art that moves away from futurist perspectives whose fundamental approach is to seek to creatively exploit the latest features. Lastly, it discusses the interaction with the phone in the exhibition context in terms of slow technology.**

Introduction

Null By Morse (NBM) is an installation artwork that explores optical communication on smartphones with a media archaeological approach. Media archaeology is a loose term employed to cover recent scholarship that seeks to re-examine the material history of technology to better, or at least differently, inform our evaluations of the present.

> Alternate histories of suppressed, neglected, and forgotten media that do not point teleologically to the present media-cultural condition as their "perfection." Dead ends, losers, and inventions that never made it into a material product have important stories to tell [1].

Recent work in this field has examined Japanese gramophone toys [2], shadow plays and Phantasmagoria [3], or whole histories of forgotten artefacts [4] to provoke new perspectives on Japanese family life in the interwar period, screen technologies, and a wide range of modern media, respectively.

Approaches from slow technology [5] have also pointed to our quickly disinterested attitude to many day-to-day technologies and the consequences for both user experience and the environment. *NBM* re-codes modern technology to enact and perform historical media and combines this with a slow-paced interaction. The effect is calibrated to result in a slow and contemplative experience. This experience is built on and through the material presence of historical and contemporary artefacts.

With *NBM*, I employ juxtaposition of two anachronistic pieces of technology (a vintage lamp and a high-tech smartphone and their associated modes of communication) to evoke a rich and fascinating series of historical events. By literally spelling out this history in its own visual language—the dots and dashes of flashing lights—*NBM* aims to underscore the influence of technological media on the way that humans are able to imagine new forms of communication.

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This short paper represents three main contributions: (i) to re-evaluate smartphones as part of the same "discourse network" [13] as early forms of optical communication, such as the Chappe Telegraph; (ii) to propose an alternative artistic approach to phone-based art that accepts failure as a part of innovation rather than focusing simply on ever-expanding technological affordances; and (iii) lastly, to consider the interaction with the installation phone in terms of theories of slow technology.

Figure 1. ***CPH Signals*****, installation view. © 2012 M. Schmeiduch, A. C. Marques, K. Frantzis.**

Related Work

The following three examples demonstrate the effectiveness of Morse code in both evoking histories of communication and provoking interactions within the public realm. *NBM* exploits these facets to draw attention to the rich material history of optical communication and the debt that contemporary technologies owe to early pioneers.

Morse code has been employed in a number of art projects over the last 10 years. Klara Hobza's *Morse Code Communication* [6] began with 12 light bulbs, which she manually switched on and off in Morse code. Over a three-year period, she increased the number of bulbs and their visibility until, with 1,200 bulbs and a prominent position over the city, she began to receive messages back from residents.

In 2004, Germaine Koh's *Relay* [7] caused room lights in Newcastle upon Tyne's Baltic art gallery to flash in Morse. The gallery's position next to a river with a rich industrial history supported Koh's statement that:

> the beacon merges early technologies for communication and navigation with some of the more contemporary methods by which information and desire flow [8].

Koh's work also caused local residents to believe that someone was trapped inside the building, and they called the police [9].

More recently, *#CPHsignals* [10] used a twitter-controlled signal lamp to communicate across

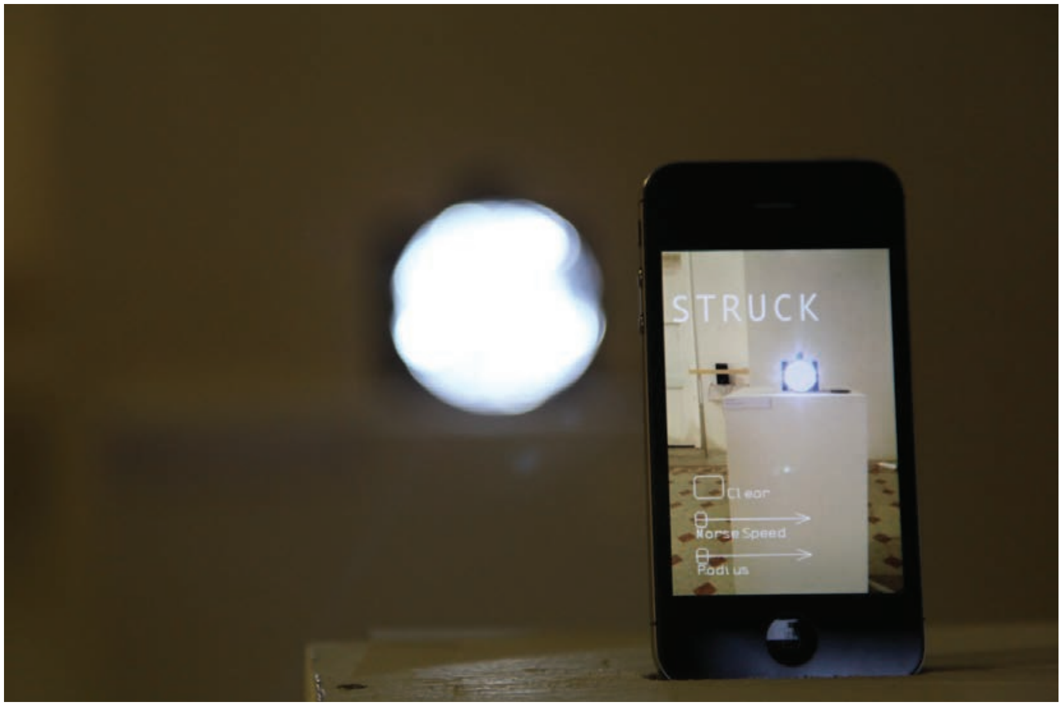

Figure 2. ***Null By Morse*****, installation view. © 2012 Tom Schofield.**

Copenhagen's harbor in Morse (Figure 1). The project aimed to:

> connect the two sides of the harbour, that are geographically close but still feel disconnected. Furthermore, it [showcased] how communication between remote locations was achieved in the past, in the context of Copenhagen's maritime culture [11].

NBM diverges from the above works by explicitly drawing upon the language of telecommunication's history and juxtaposing it with a contemporary and high-tech medium.

Technical and Installation Description

NBM consists of two main parts: (i) an automatically controlled military signaling lamp, and (ii) a smartphone installed on a plinth (Figure 2). The phone's camera points toward the lamp. A QR code printed on the plinth provides a link for Android phone users to download a version of the app that is running on the installation phone. The lamp has been retrofitted; its original incandescent bulb has been replaced by an LED bulb designed for car sidelights, which was chosen to allow for faster transmission. The bulb's flashing is controlled with an arduino microcontroller [12]. A simple circuit uses a transistor to switch current on and off to the bulb.

On the installation phone, an app that I developed uses the phone's camera to take measurements of pixel brightness. The area in which the brightness level is taken is defined by the user, who taps on the camera image over the lamp. The software uses the differing brightness levels to infer whether the lamp is on or off. The timing interval defines a dot, dash, inter-character or inter-word space. The app displays the messages it has received on the screen. Users can also download the app and use it in the gallery space on their own Android phones.

Communication in Military History: Technologies of Optical Telegraphs and Telegraphy

The use of signaling lamps marks only one installment in the varied material history of optical communication. Starting with signal fires and beacons, through the optical telegraph, including the Chappe model and maritime telegraphy, the history is tightly bound with the development of strategic military coordination. The Chappe telegraph used a series of wooden arm positions to relay encoded letters to the next telegraph, within sight of the first. The development of this optical telegraph eventually allowed Napoleon's army to manage logistical resources across the expanding French military conquests [13].

Fast forward 40 years or so, and the patchwork genesis of Morse code became imbricated with both art history and American civil conflict. Samuel Morse's failed ambitions as a salon painter diverted his career into that of an inventor at a time when the rumblings of war—first between Mexico and the United States and subsequently between the North and South—proved to be a financial stimulus for his new communication medium [14]. With *NBM*, I propose the smartphone as just one more development in this lineage. I further suggest that the very possibility of imagining smartphones, as well as many of the technical developments that make them possible, began in the early 19th century.

Given Samuel Morse's artistic ambitions, it is perhaps fitting that Morse code should acquire a second life in artworks as well as the military, maritime, and transport industries, all of which exploit its simple encoding system across different media. Kittler [15] maintained that epistemes (roughly defined as historically or culturally coherent areas of knowledge) are delineated technologically. By his thesis, we conceive of the continuity or congruence of objects, not simply because of the relationships between different discourses about them, but because they afford particular circumstances dependent on their materiality. Starting with the technological specificities of devices, such as the gramophone for instance, he discusses the effect on our capacity to hear and remember. In Kittler's epistemic terms, we belong to a "discourse network" made possible only because we can envision communication in ways that are indebted to pioneering early technologies. *NBM* reduces the smartphones' capacity to receive messages to the purely optical, to visually make the point that they exist in this continuity of such proto-technologies.

Trans-Media and Time

Perhaps the defining factor of Morse code and the reason for its continued presence in the imaginations of artists and the hearts of hobbyists is its capacity to be easily and sometimes manually expressed in a variety of media. It has been documented [16] how the transition of Morse from markings on tape (dots and dashes in the visual realm) to audio (dits and dahs) was a side effect of the noisy workings of mechanical relays, which caused operators to hear messages before they read them. As marks on tape, the transmissions were not necessarily dependent on time; they could be received and read later. As audio signals, the transmission necessitates a live conversation, which effectively ties the receiver to the spot. This static modality was formative in conceiving the core interaction of *NBM*.

As well as the difference between relying on time to differentiate one message symbol from the next compared to more complex single symbols sent one by one, there is a further technical possibility that was explored by early telegraph pioneers. The Cooke and Wheatstone telegraph [17] (Figure 3) made use of a parallel system of five wires which, in combination, caused a needle to point to the appropriate letter. These differing systems of communication strongly resemble current serial and parallel systems, and with similarly counter-intuitive efficiencies. Parallel systems that have the potential to transmit several (usually eight) signals at the same time often turn out to be less efficient than serial systems because the increased complexity causes unexpected effects (such as interference). Similarly, Morse's telegraph succeeded because its design, while inefficient, was simple and adaptable. Such similarities are more than simply metaphors. *NBM* refers to these histories to demonstrate that the unbounded era of communication that has occurred since the internet and subsequent ubiquitous mobile connectivity exists through many continuities. Not only the notion of telepresence itself, but also the material circumstances that make it possible—encoding, transmission, and network topology—exist on a historical continuum marked by similarity more than dissonance.

Apps and Futurism, Hubris and Failure

> if you succeed you will soon bask in glory [18]
>
> we have struck an iceberg, sinking

Alongside the anachronistic coupling of the iPhone and vintage lamp, *NBM* exploits another dissonance—that of hubris and failure. The messages relayed by the lamp are chosen as some of the most famous in the history of Morse and optical communication. The first of the above two quotes is drawn from an early experiment by the Chappe brothers. The second is from the distress call of the Titanic. Other messages in the installation include the famous "What hath God Wrought" from Samuel Morse's inauguration of the Washington to Baltimore telegraph line, and "Torture," a message blinked by Commander Jeremiah Denton, who was shot down and held captive by the North Vietnamese in 1966 [19].

What is striking to even a casual observer of this history is the polarized nature of the messages between the hubristic declamations of the inventor and the terse and defeated tone of those using the code to announce defeat or plead for help. This opposition between hubris and failure is echoed in the tension between the use of an iPhone as the installation phone for the project and the history of technological failure attending media art [20]. Apple, which has a "rarefied brand status in which it is now almost synonymous with American virtue" [21], is almost a metonym for futurism. The company's 2011 message, "It just works," repeatedly emphasized the infallibility and seamlessness of their technology [22]. As such, iPhones seem an incongruous medium for media art, whose own history has been described as that of a "panacea that failed" [23]. Technical and sometimes critical failure has been a persistent theme of computer- and electronic-based art at least since Burnham's 1970 exhibition Software at New York's Jewish Museum. Burnham himself suggests how the most successful examples of such art are those that "deal with the absurdity and fallibility of the machine" [24].

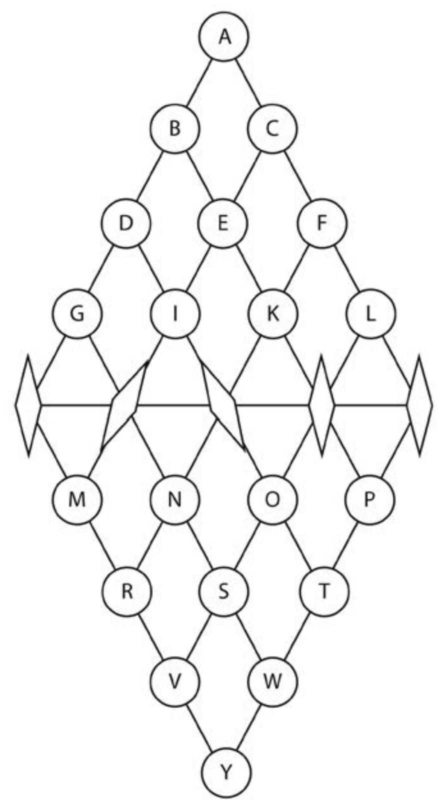

Figure 3. A Cook and Wheatstone telegraph. © 2012 Tom Schofield.

The experimental aspect of new-media art combined with the sometimes variable technical skills and training of its practitioners leads, regrettably, to artworks proving sometimes to be technically unreliable. This theme of failure finds celebration in the various glitch arts, such as Takeshi Murata's data moshing [25], which have become popular over the last five or 10 years.

Such practices are, of course, pre-figured by early pioneers such as Nam June Paik [26], whose experimental work with broadcast technologies explored their technical limits with occasionally expensive consequences.

Against a background of innovation and failure, *NBM* uses the iPhone as a rhetorical device to critique innovation for innovation's sake. The phone's reliability and associations with high tech are overturned as its technical complexity is reduced to a camera and a simple program. By recognizing failure and limitation as an integral part of innovation, we shift focus away from the notional and on to existing devices as we examine the technology we have for lessons to learn.

Figure 4. ***Null By Morse*****, audience view. © 2012 Tom Schofield.**

Static Interaction and Slow Technology

In the *NBM* installation, users approach the iPhone on the plinth. They pause and watch as the message is spelled out, letter by letter (Figures 4 and 5). This takes time and sometimes fails as other visitors pass between the phone and the lamp. If they choose to download the app and try it for themselves, they must hold the phone pointing at the light source and stay reasonably still. This interaction requires concentration, and the slow speed of transmission gives users considerable time for reflection. Hallnäs and Redström state that

> all design with deep roots in art is concerned with amplifying the presence of things to make them into something more than efficient tools for specific, well-defined tasks [27].

NBM is concerned with embodying evocative statements about media history, not with efficiently communicating information. Hallnäs and Redström further describe how slow technology

> is design concerned with how we relate to the expression of technology itself as we use it to do certain things [28].

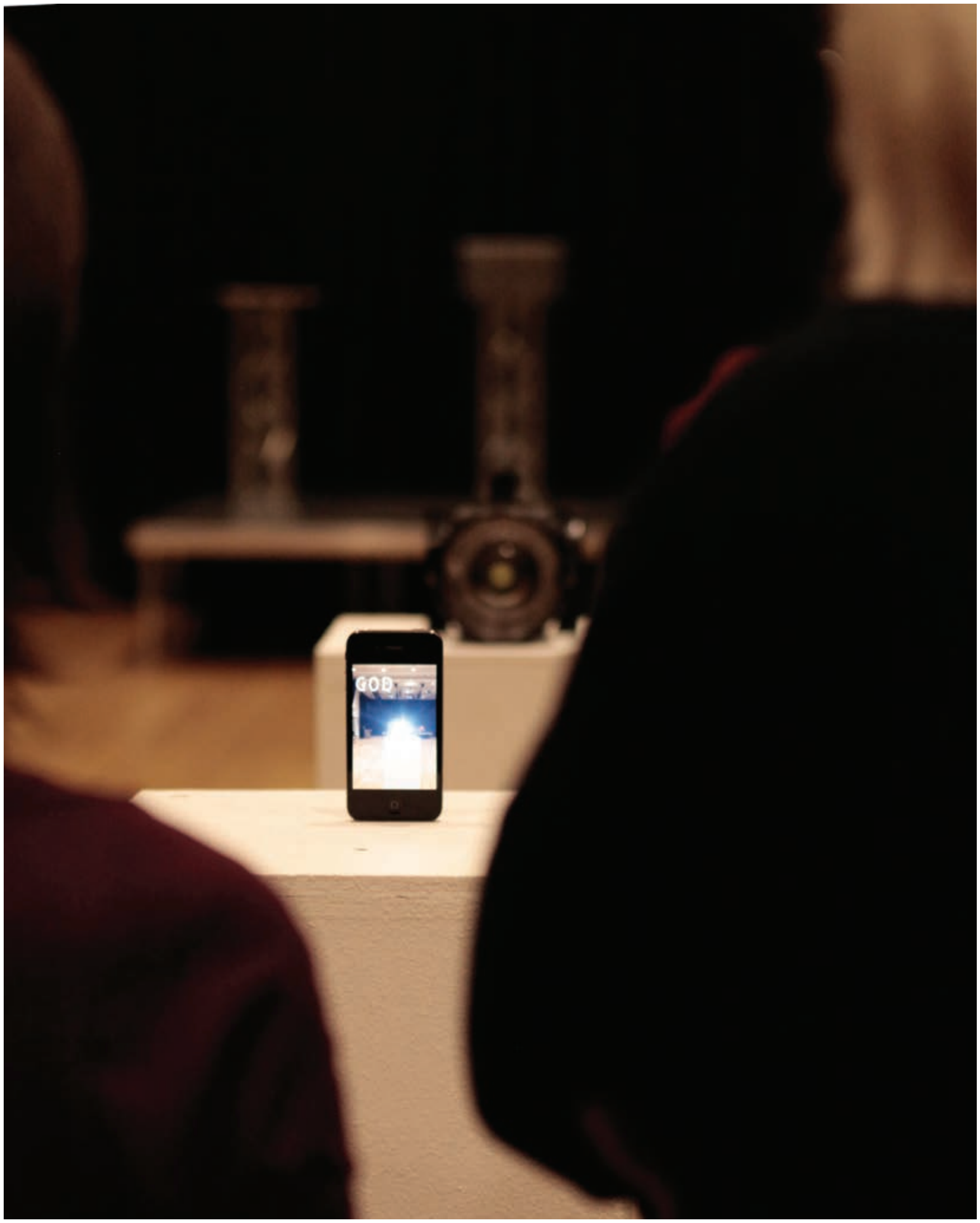

Figure 5. ***Null By Morse*****, audience view. © 2012 Tom Schofield.**

In *NBM*, what was previously seamlessly part of our environment is recoded to reveal the techno-historical conditions of the technology and its antecedents, as well as its implication in man-made disaster. Technology is "expressing itself" to reveal a sense of continuity in function and experience.

Commentators in HCI and design have pointed out the "Platonic" tendency of modern design to think of ideas separately from objects, "considering objects to be only derivative 'copies' of primordial ideas" [29]. *NBM* articulates a history that is based on the experiments of those who thought with their hands as well as their heads. The use of physical devices to demonstrate and enact this history recognizes the agency of those materials in a way that written discourse simply cannot.

Conclusions and Future Work

I have introduced *Null By Morse*, an artwork based on Morse signaling and smartphone technology, and described how smartphones fit into a continuum of networks that began with optical communication and continued through telegraphy into the 20th century. I have found similarities both in the systems of time-based serial or parallel communication and in the versatility of Morse as a protocol and smartphones as a medium. I have also discussed the creative and practical value in recognizing the tension between innovation and failure, suggesting this both as an avenue for artists to explore and as a realignment of our relationship to technology. Finally, I have described the capacity of slow technology to manifest these facets in experience. This last point I consider to be the metaphorical glue that holds the experience together for audiences in the exhibition space. The slow pace of *NBM* provides a degree of "breathing room" for audiences to reflect on both the evocative nature of the quotes being relayed and the communication process unfolding before them.

The history of Morse and telegraphy in general has proved a rich and productive one for artists and historians. In other work in progress, I am exploring other aspects of this history in ways that I hope will be productive in generating new experiences for audiences and suggestions for interaction design. One particular avenue I am keen to exploit is the physical relationship in which humans, such as telegraph operators, mediated between the domains of human and machine communication, position themselves as a type of secondary interface through which one accesses the connected world.

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Ut Pictura Poesis: Drawing into Space

David Griffin

David Griffin
Instructor
Ontario College of Art & Design University
23 Falcon Street
Toronto, ON m4s2p4
Canada
david@davidgriffinart.com

ABSTRACT

In 1735, Leonard Euler presented a solution to the practical problem of whether a route could be plotted to cross each of seven bridges in Königsberg once. His negative solution used the simplest of mark-making strategies to resolve a conceptual problem. Euler did not actually cross the town's bridges, but used them to resolve questions of connectivity, after which diagrammatic representations can be seen as the restructuring of logical problems to allow for inductive reasoning, for fruitful application beyond theory. But what if such a working graphic has as its target something that is simply incomprehensible? What are the upper limits of the denotational logic of such diagrams? This paper presents a drawing-research project that tests the cognitive advantages of technical graphics by directly engaging with things that cannot be made easier to understand through their use.

Introduction

In describing this portfolio of drawings, and grounding the questions raised by their implementations, I will start by citing the cognitive psychologist William Ittelson, who usefully characterized a mark made as an artefact of human intention as "decoupled" from its real-world source [1]. Ittelson crucially reminds us in the same paper that the "perception of markings is a pragmatic affair enmeshed in a complex of individual, social, and cultural processes, applied to the interpretation of forms that always underdetermine meanings" [2]. The drawing research project discussed here shows the scholar's decoupling to be deeply and perversely problematic when mark and surface are impossible to feel, so to speak, in the hand, and when the thing or relationship being delineated is out of this world. In this paper, I describe a portfolio of three drawings, inscribed onto the sort of troubling contexts where technical graphics are widely used to regulate the under-determination of our readings, to attenuate the oscillations, so to speak, of our lived experience.

I begin by simply describing the conditions of the making of these drawings, each of which adapts the conventions of some well-understood technical drawing system, to interrogate the capacities of these systems for representing ideas that are otherwise extremely difficult (never say impossible) to grasp, in the sense of our normal "2 metres/100 kilos" expectations. I then provide some context in which the reader can consider disciplinary uses of drawing as a practice of thinking, beginning from the abundance of the sketch, which straddles disciplines of art and design in particular, moving to Euler's parsimonious nodes and edges, to anthropological studies at opposite ends of our recorded history, where notations are used to get a working handle on murky or incomplete information. Finally, I address technical and epistemological problems posed by the drawings, all of which belie the smallness of the project's graphical beginnings (Figure 1): a set of humble thumbnails that set this author/artist on the course of a kind of time-space drawing practice with rhetorical dimensions. They are vitally invisible drawings, with referents that are likely impossible to fully recognize, in spite of their illumination by proposed networks of lines of light, inscribed on spaces we can know only in conjecture.

Drawing into space

The first of the three drawings is a topological diagram consisting of a one-second-long laser burst, aimed at the centre of our Milky Way Galaxy. This single line has approximately 300,000 kilometres of length, resulting from a series of questions related to orientation, distance, and other physical matters, in support of an event that will take one second to begin, and something on the order of 25,000 years to complete, assuming a definition for the word "complete" that allows room for the provisional.

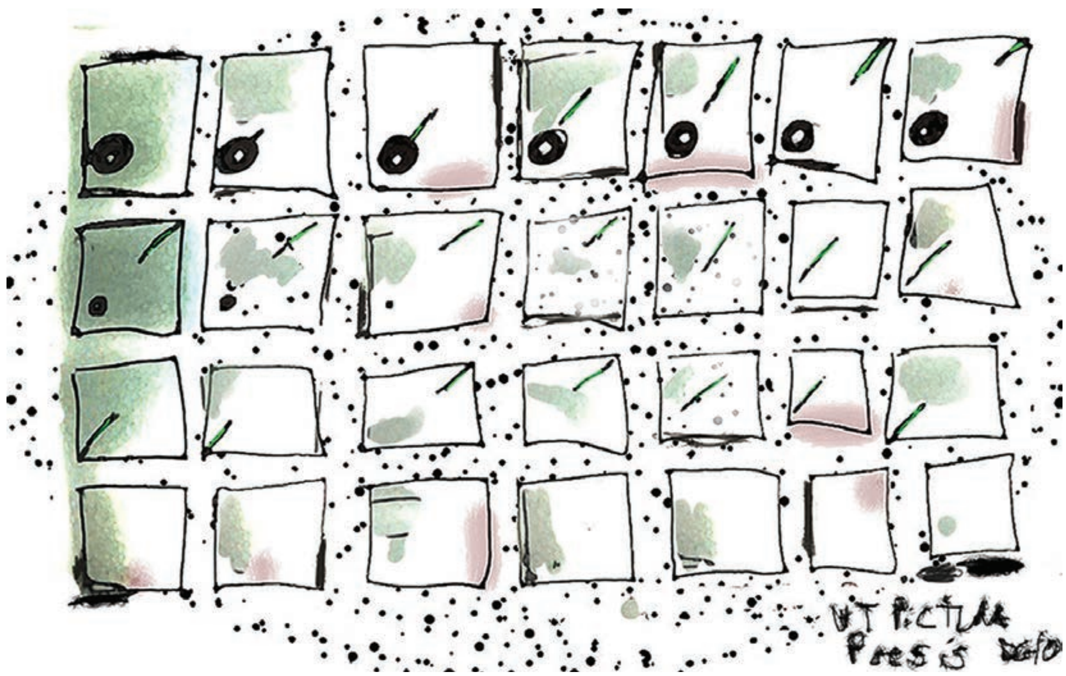

Figure 1. Preparatory sketches for Ut Pictura Poesis. In each of these tiny drawings, LASER is proposed as a kind of pure marking instrument, to draw on the surface of space itself as a support. These thumbnail sketches represent the germination of an idea for a series of drawings that, contrary to the expectations of graphic practices, are essentially invisible. They also epitomize, while obscuring, the capacity for diagrammatic drawing to help us express things that are quite inexpressible by mere thought. Ink on paper, approximately, 3x3 inches each; from the sketchbook of the artist. © 2012 D. Griffin.

The second and much smaller (briefer?) drawing inscribes a network between our small planet, our mote of dust, and the other planetary bodies in our local physical space—a metaphor, really, allowing us to extend our grasp to scales that are otherwise incomprehensible in the scales to which we are accustomed. This quasi-semantic diagram will actually connect us to those seven mythically charged bodies, for a period of time computed from the relative distances between us and them, beginning with the farthest and ending with the closest. This network will ultimately have the absurd property of around 10 billion linear kilometres of length, tied ineluctably to about four hours of active drawing.

The third drawing in the portfolio builds from the professional principles of multi-view orthographic projection, which is an analytical design-drawing method that constrains to sets of parallel views of a proposed object's sides. The multi-plane system, in its normal usage in industrial design, presents its users with a kind of totalized truncation: pictorial, in the sense of showing sets of true shapes and measured spatial relationships, but flattening and denuding them of visual detail, while mounting the inscription on an infinite parallel (indeed, impossible) orthogonal substructure. Reading from such a drawing, a fabricator can make the required object in accord with the compound needs of designer and client. As written, this rough description also identifies temporal and spatial dimensions, encoded through conventional adaptations: the drawings are spatialized images of distribution, in a time-factored multi-view format. In this final colossal drawing, three bisecting lines drawn through polar points on the planetary scale will form 12 wedges, flaring outward, amounting to another set of absurdities, delivered in the soft fiction of metaphor.

The proposed graphics will have an existence that is actually dubious, qua Drawing, at least from the point of view of consumers of art production. But they will not be any less marks on surfaces than the object of connoisseurship under glass, in a frame, in exhibition on the walls of an art gallery. Further defining our terms, the art theorist John Willats has described a pictorial representation as mapping spaces "out there" to the page, while a diagram maps logical relations [3], but these peculiar drawings—mapping space and time in conjunction—operate somewhere between these two classic categories. They will physically span the dimensions they map in diagrammatic form, at once tracing and creasing, oddly re-coupling Ittelson's mark and surface.

Drawing speculations

I am a visual artist, so the small sketches in Figure 1 provided a sufficiently potent creative spark for the general parameters of this work to emerge. But the history that allows an understanding of the theoretical implications of those little marks began in 1735, when the mathematician Leonard Euler presented a solution to the problem of whether a route could be plotted to cross each of the town of Königsberg's seven bridges only once. Reviewing the town plan in schematic terms, Euler's negative solution showed how the scope of a conceptual problem can be investigated using only points and lines, the simplest of mark-making strategies. The mathematician's method, which manages both largeness and smallness of scales, led to a metonymically driven insight: Euler did not actually cross the bridges, but used them as characters in a denotational scheme, to resolve questions of connectivity, after which diagrammatic representations can be taken as a re-structuring of logical problems to allow for inductive reasoning, for fruitful application beyond the merely theoretical.

This approach to graphical thinking has since become a critical tool in many fields, yielding methods for representing complex processes in the simplified, embodied-metaphorical terms of sequence and proximity. We now recognize that the structural simplicity of such diagrams exploits certain capabilities of the human visual system, displacing difficult logical, memory, and search requirements with a perceptually grounded context for making judgments [4], permitting views of relationships that are otherwise quite difficult to grasp, becoming therefore a kind of interface between intuition and interpretation; the diagram becomes both analysis and argument. More broadly, beyond the system and sequence analysis of nodes and edges, drawing has long been a core component practice for multiple disciplines, each of which benefits from the blended space of seeing, thinking, and making that happens on the page.

A brief review of the capacities of drawing as speculative thinking practice is in order, and the sketch will be our key example. Sketching is a robust research method in creative disciplines, where the user plays with the very tics, hesitations, and flourishes of the act of drawing itself, in a search for salience. The sketch provides a haptic search space useful for conjecture, for testing against experiential knowledge [5, 6], and for provisional re-construction of what researcher Nigel Cross has called design's "ill-defined" problems [7].

But evidence of the speculative spirit of the sketch lingers even in those drawing methods that seek to communicate more explicitly. Two examples of this articulate, speculative use of drawing intriguingly share a disciplinary motivation (that is, to understand incomplete human stories), even as they bridge extreme ends of our recorded history as a species. First, in the anthropological research of Alexander Marshack [8], the scholar applied the terms "time-factored" and "time-factoring" to describe paleolithic marked artefacts, specifically the figures the researcher traced on bits of bone and stone, seeking their significance as early examples of notation. Marshack's study suggests that the early scribe-scientists who made them were not idly notching or decorating the bone bits, but were in fact drawing temporal sequences, placing marks over time, and in time, and reading relationships within them. Marshack sought to demonstrate that these mark-makers were in fact tracking the moon across the sky [9], using a simple marking system of tilted lines and notches as a proxy for knowledge of a passing thing that could not otherwise be grasped by its witnesses. And at the other end of our recorded history, in the profoundly collaborative practice of stratigraphy [10], archaeologists draw through their dig sites in order to arrive at plausible narratives which could account for those sites, relative to the current state of knowledge, creating spatial/temporal cross-sections directed at the telling of some fragment of larger stories. Wickstead notes that while a collection of photographs might provide more comprehensive documentation, those at work in the field attest to the superiority of drawing for their purpose. Wickstead writes: "We draw contexts" [11], description and interpretation coming together in the laying on of hands, and pencils.

From a review of all of its instrumental uses, it becomes clear to those who study drawing that a primary motivation of the practice is measurement; this insight connects the haptic, emotionally loaded figure-drawing experience, with its loose gesturing between shoulder and paper, to more analytical systems such as projective orthography, or node-link diagrams, or the common music notation, with its oddly spatialized interval-scaling timeline and vertical pitch space. Across the range of my own mongrel artistic practices, I have identified this metric value in acts of representation of relationships between entities and forces, or a purely felt scaling of body to body. Of course, the measurement motivation has its most explicit application in geometrical drawing, suitably defined by the mathematician Felix Klein as working in "a space together with a set of transformations of that space" [12]. Geometric drawing is a visual-mathematical enquiry developed to take a measure of the field of sensible reality as a kind of wireframe accounting of dimension and incidence. The drawing itself enacts the principles it theorizes: "the acts of construction literally can be said to have taken place" [13]. Thus drawing allows inductive responses into the logic of a mathematical problem. Through work performed over external representations, then, our culture has moved from exploring natural principles in terms of location and change, as in Marshack's scribes, to the inscribed networks of computational visualizations, which allow sensate experience of a different kind of system, which is to say, information.

Impractical drawings

So if we take the generalized view of drawing as a vital (because simplest) cognitive assist, then what if a graphic, such as those that have been derived from Euler's ad hoc construction of nodes and edges, has as its target a thing that is simply incomprehensible in terms of the handfuls and footfalls to which we are naturally bound? What if we place node-link graphics in a space where their pragmatism is met by senselessness? The mark-making instrument used in these drawings will be the coherent light of LASER, here used for its linear values (that is, as lines of energy applied to the "geometry" of space itself as support, in a marking-up of unobtainable proportions). Such drawings must have multi-disciplinary entailments: in conversation with cosmological enquiries, they will become graphs writ large, equally measurable (from our earth-bound point of view) in temporal and spatial terms.

Marschack pithily reminds us that "the sky is a calendar" [14], graphically capturing how we have come to use its apparent features for a kind of temporal-spatial codex. Of course the sky is really only a calendar when its features are drawn together by the mind's eye and, moreover, when it is then shown to us by the workings of graphite on some surface. And when those remote features become marks on a surface, they then enter into the call and response of symbolic exchange. We read them as metaphor, recognized in inchoate projections, and they become characters in a scheme. Despite these proposed drawings' essential invisibility, through application onto the tangle of distortions and misunderstandings between what I know and what I do not, or cannot, know, witnesses to their making, in performance, will have an opportunity to examine intuition as a rational response to unreasonable quantities.

At the very least, this portfolio provides experimental frameworks for discourse, but how are we to judge their success or failure as drawings? What is the relationship between such a drawing and its putative object? Entering into more flows of metaphor, where are these drawings? Where exactly is "the centre" of a galactic mass, here and now, and so long from the moment of the line's inscription? How long must each line be in order to form a continuous connection between us and any of our neighbors (a question with at least two correct answers)? What is the significance of an external representation we cannot interact with, not because it is hidden away, but because it is beyond us? Among other things, the very idea of scale and scaling in this portfolio is muddied, possibly beyond measure, and yet we might still seek refuge in a cascade of diagrammatic, numerical, and literary views, at least to make them legible for a mixed audience of artists and scientists.

Finally, leaving aside any earth-bound obstructions (which are considerable, and which must be accounted for in their executions as drawings) we must answer questions about diffusion, or what might interfere with line formation and coherence in those spaces lying between the nodes of their enormous edges. Furthermore, what are the odds of such an occurrence? When and where is there a window of opportunity through which we might connect ourselves to all the planetary bodies on the same evening, for example, opening up the possibility of another conclusion devoutly to be wished: a multi-national, coordinated drawing activity?

Ultimately, this peculiar recoupling of mark and surface may not find resolutions to the problems of their implementation, because if we can know anything in this particular problem space, we know that our bodily measures actually prohibit direct mappings of our experience onto structures at either end of cosmic scales [15]. We are prisoners of this incomprehension, so it is problematic even to apply metaphorical terms to the situation. Yet we also know that drawing practices play key roles in formal systems for recording and understanding relationships, from particle interactions to planetary orbits, to the elbows and hips of the life-drawing studio. Well after Euler's elegance, quantum theories in the physical sciences have presented us with infamously strange questions to be addressed. Crossing bridges, as that mathematician did without doing, is the least of our difficulties in this problem space. Key drawing practices have developed in response to those questions. In the visual modeling of quantum-physical knowledge, for example, Niels Bohr's graphical models posited projective diagrams of atomic motion in an orbital mode [16], while Richard Feynman's diagrams [17], seeking to map probabilities to the page, have proven themselves useful beyond the work in which they had their flush of first successes.

The drawings in this portfolio interrogate the understood cognitive advantages of diagrams [18], inscribing what are surely the largest lines ever made in spaces about which we almost certainly know less than we think, asking after the upper limits of their denotational values. In drawing them, and seeing them drawn, we are forced to ask if connectivity is always a knowable state, even in the parsimony of diagrammatic reasoning. Seeking more questions, perhaps, than answers, this project offers collaborations between the abundance of artistic drawing and the deductive aims of the geometer. Finally, there is the sweet likelihood that, like the supernatural, otherworldly depictions of Renaissance painters, or even the indexical markings of modernist painting, our current state of knowledge is simply inadequate, which will reveal the project as a mere phantasm of a worldview.

As a fine artist's drawing-research project, reaching around the rhetoric of Euler's graphic insights or the pragmatic productions of design-drawing, seeking knowledge which may not be possible to know, the drawings are marks on surfaces which are equally temporal and spatial. There will need to be a range of consultations undertaken, and, moreover, there must be a pragmatic recognition of impossibility built into this work. This futility I think reflects some measure of the general condition of representation, at least from the perspective of the painter or the poet (I am unable to speak for the cosmologist). Certain of my colleagues have suggested that they are rhetorical drawings, in the bad sense (is there such a sense?). While possibly true, this characterization nevertheless represents vexing questions with intriguingly unstable answers—a condition to which any productive 21st-century art practice aspires. After all, they are not merely rhetorical. They will be drawn in fact, further confounding the meaning of that expression. As external representations with which we can only interact in the plan, they are free of aesthetics insofar as they cannot be directly apprehended, or at least not for long, and they are also free of use: they are not representative, cannot be exchanged, cannot exemplify or denote anything but some view of our own limitations. And, of course, they may be utterly wrong. The project will rely on technical and social interactions and communication, in support of gestures whose existence is equally a matter of time and space, and, moreover, of fantasy as a function.

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The Electric "Now Indigo Blue": Synthetic Color and Video Synthesis Circa 1969

Carolyn Kane
Assistant Professor
Department of Film and Media
Hunter College, CUNY
695 Park Avenue, Room 433 Hunter North
New York City, NY 10065
USA
carolyn.kane@hunter.cuny.edu

Carolyn Kane

ABSTRACT

Circa 1969, a few talented electrical engineers and pioneering video artists built video synthesizers capable of generating luminous and abstract psychedelic colors that many believed to be cosmic and revolutionary, and in many ways they were. Drawing on archival materials from Boston's WGBH archives and New York's Electronics Arts Intermix, this paper analyzes this early history in the work of electronics engineer Eric Siegel and Nam June Paik's and Shuya Abe's Paik/Abe Video Synthesizer, built at WGBH in 1969. The images produced from these devices were, as Siegel puts it, akin to a "psychic healing medium" used to create "mass cosmic consciousness, awakening higher levels of the mind, [and] bringing awareness of the soul." While such radical and cosmic unions have ultimately failed, these unique color technologies nonetheless laid the foundation for colorism in the history of electronic computer art.

> "[With] television … you're on the way to being a starchild … inner and outer space become one in unknown velocities of a cosmic zoom … the now indigo blue of life merges with the glowing beauty of man at his most human ..."
> -Ron Hays (1971) [1]

Introduction

In 1969, electronics engineer Eric Siegel asked: "After a trying day, why can't the viewer … sit down at his TV set and listen to music while watching the screen burst with beautiful colorful displays?" These "visual phantasies," he explained, "would relax you better than any tranquillizer and at the same time give your spirit a wonderful lift … working through your audio-visual senses into your mind and soul" [2]. Siegel was by no means alone. In 1970, Gene Youngblood wrote: "Television will help us become more human. It will lead us closer to ourselves" [3]. In their 1973 article, "A Color Video Collaborative Process," artists Dan Sandin, Jim Wiseman, and Philip Lee Morton wrote: "Central to our experience … is the use of high technology as an adjunct to personal and spiritual growth" [4]. Today these attitudes seem less optimistic than deluded, even a bit foolish. As contemporary television viewers—consumers rather—we know full well that the medium is commercially driven and seeped in fear-based content dealing in war, crime, scandal, horror, voyeurism, and atrocity occurring on global and local scales, 24 hours a day, seven days a week, punctuated only by brief commercials attempting to sell impossible fantasies. In the 21st century, television couldn't be further from the "soulful" embrace of the "glowing beauty of man at his most human." But given the not-so-distant past of these views, and their sheer abundance, one wonders how such mystical notions of television ever seemed logical, let alone normative? How did a group of technically minded artists, in collaboration with engineers, immerse themselves in sophisticated and challenging technological environments only to turn out a genre of work that conjured spiritualism and a mystical beyond? This article seeks to provide an answer through an aesthetic analysis of color in analog video synthesis circa 1969 in the work of Eric Siegel and Nam June Paik.

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Eric Siegel's Generative Color

Born in 1944, Eric Siegel attended high school in Brooklyn, and at age 13 he built his first TV set "from scratch." In 1960, he won second prize in a science fair for a "home-made closed circuit TV," a vacuum-tube device built from second-hand tubes and miscellaneous parts. The following year, he won yet another award: an honorable mention for his "Color through Black and White TV." While Siegel was dyslexic, when it came to electronics, Woody Vasulka notes, he was clearly a "whiz kid," and indeed, his contributions to the history of color in video synthesis are no less impressive.

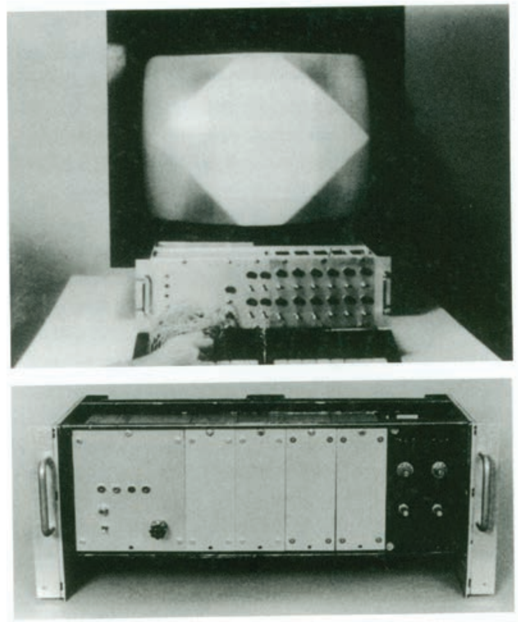

Figure 1. *Process Chrominance Synthesizer* (PCS) 1968, used in *Psychedelavision in Color*, first shown at Howard Wise's 1969 exhibition, TV as a Creative Medium. © 1969 Eric Siegel.

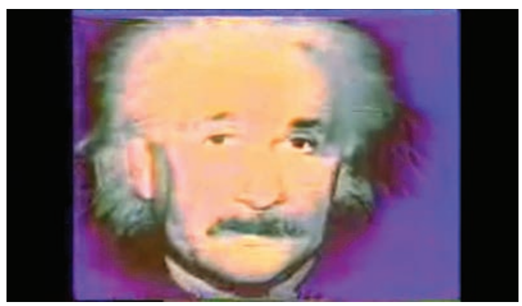

Figure 2. *Einstine* in *Psychedelavision* (1968). Psychedelic electronic colorism made with Siegel's Process Chrominance Synthesizer. © 1968 Eric Siegel.

From the late 1960s on, Siegel built innovative electronic systems, including color synthesizers, which he used to produce psychedelic video artworks [5]. His Process Chrominance Synthesizer (PCS, 1968) was the first device capable of taking a black-and-white video signal from half-inch tape or elsewhere, such as a portapak, and transforming it to color through the video-synthesis process (Figure 1) [6]. Siegel used the PCS to create *Psychedelavision in Color*, a single-channel program consisting of *Symphony of the Planets*, *Tomorrow Never Knows*, and *Einstine*, first shown at Howard Wise's infamous 1969 exhibition, TV as a Creative Medium. In the third piece, *Einstine*, the face of Albert Einstein is lit by rich oranges, purples, and magenta flames (Figure 2). For several minutes, the face shimmers and morphs into different hues, orchestrated to a Rimsky-Korsakov soundtrack. After viewing Siegel's *Einstine*, Woody Vasulka wrote: "I always wonder why it took Eric to introduce this new image so convincingly. Something extraordinary happened when we saw that flaming face of Einstine at the end of the corridor. For us, something ominous, for me, something finally free of film" [7]. Even while watching *Einstine* in 2012, something extraordinary still occurs: the colors, despite decades of degradation, are still rich and otherworldly, a testament to Siegel's truly unique color system. A closer look at the PCS helps explain how Siegel generated such awesome colors.

The PCS is a colorizer, meaning that it can add color to a monochrome signal. In the US patent application for the PCS, Siegel explains the device's unique ability to provide a means for "producing a color burst signal." A color burst signal is specific to analog video and television, a code used to monitor the synchronization of the color signal, or "chrominance subcarriers," at the beginning ("back porch") of each video signal [8]. In other words, Siegel introduced color information into a black-and-white signal by cleaning the incoming signal of any aberrations and then re-inserting a color-sync signal, adjusting its brightness, contrast (also known as "gain"), luminance component (lightness), hue (color, also known as "phase"), and saturation (also referred to as “amplitude”). The PCS could then generate chromatic signals for the new subcarrier because it had a new pseudocolor (pseudo implies “false” or machine-generated) component added to the input source [9]. The result was an entirely new electronic color palette, in wild and beautiful palettes beyond FCC and NTSC broadcast standards.

This beauty is again illustrated with Siegel’s Electronic Video Synthesizer (EVS, 1970). The EVS was the world’s first open-system analog electronic color synthesizer, “an instrument for the creation of color visual information,” Siegel explains, “with the possibilities of at least one thousand different pattern variations” [10]. The EVS could generate images independent of an input source (from film or other forms of optical media), though live camera input was possible. The abstract forms were produced using the system’s own self-generated colors and free-form patch matrix pulled from an IBM card sorter with connections formed by mini-banana plug cables of “adorable colors.” The first circuit board was built inside a color television set. The processing amplifier (“proc amp”) generated a raw signal and provided it with a black level, blanking signal, burst signal, and sync pulse. (In analog video, the vertical blanking signal refers to the rate at which each scan line is rendered on screen, usually in a black burst or black wave used to coordinate the broadcast signal with the reception signal, known as the “sync pulse.”) The EVS was built on BIC-VERO rack (a patch matrix board) with front knobs and switches that could be used to track changes on a monitor in real time. By manipulating the knobs, a “wide variety of patterns, colors, and motions could be created” [11].

These technical details, while likely obscure to contemporary readers, nonetheless illustrate the technical challenges circa 1969: what had to be mastered in order to get any color, let alone colors of an “almost unbelievable intensity and richness.” Siegel’s colors, as noted, continue to appear magical, even on degraded videotapes seen 40 years later. He developed a color system that could, unlike others at the time, activate the phosphors on the TV tube directly, without the intervention of a video camera. That is, they utilized the full potential of the CRT tube which the camera did not do because most analog video signals were at the time AC-coupled, meaning both AC and DC circuits were connected (the latter blocked by the former) to produce signals that were “highly inaccurate and resulted in an incorrect brightness level on the TV screen” [12].

Both synthesizers (the PCS and the EVS) point to the advent of the historical distinction between images produced by optical and indexical media like film or photography, versus those produced post-optically, through synthetic and informatic means, such as computer-generated imagery. The former bears a causal link between event and image artifact: a photograph is a literal sample of light from a particular historical moment. With electronic visual media, this link is broken. To put it differently, any image that appeared from the EVS or PCS did so only through the synthetic generative processes, ex nihilo, and thus they were not only “free of film” as Vasulka puts it, but also, of optical media, and therefore “natural” vision altogether. Herein lies one rationale to understand how electronic color in video synthesis became magical and otherworldly: it literally was.

WGBH & the New Television Workshop

Since 1951, WGBH has been a non-profit, education-based, public radio station based in Boston. In 1955 they incorporated the public television channel two to become the first non-profit television station in New England and a pioneer in public television. In the early years, the studio was full of “Harvard guys who produced boring, black and white television.” But this all changed in 1958 when visionary producer and director Fred Barzyk arrived and “began experimenting, pushing the studio’s envelope” [13].

In 1967, WGBH transitioned to color, and new video switches arrived at the studio. The switches were capable of basic chromakey (the process of removing a color from an image so that another image element may replace it) and titling effects. Artists interested in the new but still expensive media were drawn to WGBH's artist-in-residence program, the New Television Workshop (1972–1992). The workshop was supported by grants from the National Endowment for the Humanities, the Ford Foundation, and the Rockefeller Foundation, and from it emerged many pieces central to the history of video art. Early artists in residence included Nam June Paik, Stan VanDerBeek, Max Almy, Douglas Davis, Peter Campus, Trisha Brown, Ed Emshwiller, and William Wegman. Fred Barzyk oversaw the New Television Workshop for 10 years, during which time he watched, invited, and experimented with "hundreds of artists" who flowed in and out of the studio, all enthusiastic and eager to pioneer a new genre of electronic art (Figure 3).

Figure 3. Left to right: Fred Barzyk, Shuya Abe, and Nam June Paik with the Video Synthesizer at WGBH-TV, Boston, circa 1969. Image courtesy of Paik Studios/Nam June Paik Estate. Photograph © 1969 Conrad White.

But even before artists arrived at the New Television Workshop, Barzyk and his WGBH colleague, director David Atwood, were broadcasting experimental programs. In the mid 1960s, Atwood recalls, "we started … doing these light shows where we just did whatever came into our head. We mixed black-and-white cameras with telecameras, light show images, and then feedback … [we] broke all the rules" [14]. At the time, Barzyk and Atwood saw themselves as directors "fooling around with TV: in hopes of making a change and bringing out the 60s feel to some of our shows on public television" [15]. After realizing the vast possibilities for video in this relatively open-minded setting, they got a grant, and the doors opened. Most doors opened.

Those behind the doors to management and on the executive level viewed the incoming artists as a disaster waiting to happen, and after Paik's early residences at WGBH it is hard to argue with them. At the same time, the wild and unruly experiments that Paik conducted at WGBH (noted below) are today heralded as cornerstones in the history of video and electronic art, which add esteem to the WGBH name.

WGBH's national broadcast of *The Medium is the Medium* in March of 1969 featured the work of six artists: Allan Kaprow, Nam June Paik, Otto Piene, James Seawright, Thomas Tadlock, and Aldo Tambellini, each of whom made a short video using WGBH equipment. By far the most "controversial" contribution came from Paik with his *Electronic Opera #1* (Figure 4). For the segment, he brought a dozen "prepared televisions" into the studio, used three color cameras to mix the images with a nude dancer, tape delays, and positive-negative image reversals. Paik's *Opera*, as Youngblood puts it, consisted of "dazzling silver sparks against emerald gaseous clouds; rainbow-hued Lissajous figures [which] revolved placidly over a close-up of two lovers kissing in negative colors; images of Richard Nixon and other personalities in warped perspectives [which] alternated with equally warped hippies." The piece was set to the soundtrack of the *Moonlight Sonata*, interrupted periodically by Paik, who looked at viewers, yawned, and announced, "Life is boring." He instructed them to "close one eye" or "close one eye halfway" and finally, "turn off your television set" [16].

Figure 4. Nam June Paik, *Electronic Opera #1* (1968). Nixon's swirling head was broadcast in *The Medium is the Medium*. Image courtesy of Paik Studios/Nam June Paik Estate. © 1969 Nam June Paik.

The *Opera* was controversial for its strange technical setup and unorthodox use of Nixon's head twisting through synthetic video effects, but above all, because it featured a topless dancer. The dancer was supplied by a "WGBH type," Atwood explains, who had "connections everywhere in Boston. We never knew from where she came and never asked. She showed up, took off all but panties, stood on a pedestal, was directed by Paik, was recorded, and left … [It] was a minor scandal at the time." A topless dancer was definitely not what the station expected or hoped to see from a show on "the arts." But at this point the show was already receiving national recognition and strong support from the Ford Foundation, so the studio (reluctantly) honored such requests [17]. After *The Medium is the Medium*, the Rockefeller program was created, and Paik returned to Boston as a full-time artist in residence.

After the studio made the transition to color in 1967, a new financial arrangement mandated everyone to pay for studio time. This became expensive, because with color, the set-up time multiplied exponentially, and it would take "all day to get it right," whereas with black and white, they would "be ready to go in minutes" [18]. Frustrated with this, in 1970 Nam June Paik set out to create a low-cost alternative, a color manipulation system that resulted in the Paik-Abe Video Synthesizer (PAVS).

The Paik-Abe Video Synthesizer

Initially dubbed "The Wobbulator," the PAVS was a homegrown project engineered by Paik and his childhood friend and engineer Shuya Abe (Figure 5). They built the PAVS from the ground up with limited financial resources. The budget from WGBH was $10,000, which included airfare to and from Japan. In the haphazard and scavenger style that came to define him, Paik built the system using second-hand wires, television sets, and hardware parts (a method that stands in stark contrast with Siegel's systematic control and organization of every color and function). Barzyk recalls finding Paik setting up in the studio one day wearing tall rubber boots. Upon inquiry, Paik explained: "If I don't wear them, I get electrocuted" [19].

For special effects, Paik sought low-cost, highly creative alternatives. He "bought all manner of crap," Atwood says, "plastic dishes, cheap busts of famous composers, and anything plastic that cost nothing and would distort light." He even used a record turntable to construct and spin objects at either 33 rpm or 78 rpm. Barzyk once found "a mound of shaving cream … whirling around on top." A roommate of Paik's recalls he even made his own bed out of old console TVs with a mattress placed on top. He ate off disposable paper plates and used plastic utensils, which he cited as the "greatest American invention." Paik's style was fast, cheap, and messy, but effective: under the studio lighting, the rotating shaving cream "transformed into a mélange of color and images" [20].

On August 1, 1970, the PAVS embarked on its maiden voyage on channel 44 in a four-hour debut called *Video Commune: The Beatles From Beginning to End*, a broadcast of "far out imagery never before seen by the world." *The Commune* featured a variety of images, such as Japanese television commercials remixed through the synthesizer and set to the Beatles soundtrack, providing at least one element of continuity in an otherwise unstructured visual spectacle. While *Video Commune* marked a "milestone" in the transformation of broadcast television, using the PAVS, let alone controlling it, was another issue altogether. Even Paik admits the PAVS was a technical nightmare. It's a "sloppy machine" Paik said, "like me," and Atwood concurs: it was "a miracle that it even made an image." The WGBH engineers, who sat at the mixers and switchboards in the control room, loathed the PAVS even more, just as they abhorred the ways in which the artists "incorrectly" used the expensive studio equipment ("holding down three and four buttons at once," a [Cagean] method that had the engineers "in agony") [21]. There was also a time when, during the PAVS's debut on channel 44, it burned up the studio's very expensive chromo filter transmitter. Paik had simply ignored FCC color limits, which is also to say he neglected to run his colors through the vector scope and compress them. Eventually, Paik saw value in the vector scope and, after he left WGBH in the early 1970s, artist Ron Hays arrived and developed a systematic method for controlling color and image synthesis patterns with the PAVS.

Figure 5. The Paik-Abe Video Synthesizer (PAVS), 1969 / 92. 183 x 56 x 66 cm. 12 monitors, two video disc players. Image courtesy of Paik Studios/Nam June Paik Estate. © 1992 Nam June Paik and Shuya Abe.

The End of the Liquid Rainbow

By the late 1970s, these wild and psychedelic color experiments had been harnessed for stable commercial applications. Nonetheless, the colorful world of video synthesis circa 1969, illustrated above in the work of Paik and Siegel, was one of transcendental immersions and cosmic union between humans and machines, and this world, it must not be forgotten, created the groundwork for a future of vibrant electronic art.

In sum, while the mystical video synthesis produced in the late 1960s and the early 1970s may have seemed misguided, given the radically new and unstandardized technology, the utterly alien color palettes these pioneers generated, the relatively free and unfettered experimental approach to the work, and progressive cultural contexts that bolstered them, these mystical and utopic visions should now seem grounded by material fact. The "now-indigo blue" of video synthesis symbolized an "equipment-free aspect of reality" that Walter Benjamin once identified as the "blue flower" in the land of technology [22], a revolutionary hue that could only appear, circa 1969, if televised.

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The Emergence and Growth of Evolutionary Art – 1980–1993

Nicholas Lambert, William Latham, Frederic Fol Leymarie

Nicholas Lambert
Department of History of Art,
Film and Visual Media
Birkbeck College
University of London
United Kingdom
n.lambert@bbk.ac.uk

William Latham
Goldsmiths College
University of London
United Kingdom
w.latham@gold.ac.uk

Frederic Fol Leymarie
Goldsmiths College
University Of London
United Kingdom
f.leymarie@gold.ac.uk

ABSTRACT

One of the most interesting—if frustrating—aspects of charting the history of computer art is trying to understand the intersections of specific technologies and artistic experimentation. It is rarely as clear-cut as a simple linear influence of one to the other, partly because artists are able to envision all kinds of possibilities that technology might enable them to realize in some kind of form, but as they do so, the technology is itself shaped, especially in terms of how it is perceived by others. Do artists find a way to give technologies an aesthetic outlet, or do some technologies possess—or facilitate—a characteristic aesthetic that finds its expression through specific artists? Certainly, in the history of computer art it would seem that particular aesthetics, technologies, and artists are closely intertwined in certain periods. This intertwining of art, technology, and ideas stolen from the natural world has never been so arguably merged as the period in the history of computer art from 1980 to 1993. We take as the defining start of this period the initial work of Mandelbrot on fractals that became known as the Mandelbrot set and led to his famous illustrated art-science book *The Fractal Geometry of Nature*. In 1993, this first highly creative period in evolutionary computer art came to an end with major publications by pioneers Karl Sims, Stephen Todd, and William Latham.

Artist-Researchers and New Graphics Technologies in the 1980s

Although the emergence of personal computers by 1980 enabled a new generation of artists to start experimenting with digital images, especially due to the Apple Mac, Commodore Amiga, and Atari ST, in 1984–85, as advanced graphics and sound capabilities became available, there were those who continued to be closely associated with academic and corporate research centres. The Xerox PARC model was undoubtedly influential in providing a template for research collaborations, and IBM in particular supported some interesting developments. In such environments, artists could leverage the power of multiple networked computers, use software that was still under development, and utilize video displays and printers that were far more advanced than those available elsewhere.

The emergence of computer graphics as a major aspect of commercial TV and film production, in addition to its use for scientific visualizations and military simulators, drove the development of new graphics technologies. One key area was the simulation of natural landforms, vegetation, seascapes, and other environmental features. Hitherto, the public perception of computer graphics (as represented in films such as "Tron" and "War Games") had been of vector 3D shapes and textured solid models. However, during the 1980s, a new and increasingly ubiquitous image appeared: the "fractal," a word coined by Benoit Mandelbrot and visualized as the Mandelbrot set [1, 2]. This radically changed the idea that computer graphics had to look artificial; along with other techniques, it raised the possibility of simulating the natural world. Mandelbrot himself referred to the collision of abstraction and naturalism that occurred when fractals were first used by Richard Voss and others to generate landscapes:

> What a profound irony that this new geometry, which everyone seems spontaneously to describe as "baroque" and "organic", should owe its birth to an unexpected but profound new match between those two symbols of the inhuman, the dry, and the technical: namely, between mathematics and the computer [3].

Such a possibility had actually been raised back in the early 1950s by Alan Turing himself [4]. Fascinated as he was by the symmetries and structures produced by organisms, he realized he could investigate the area of morphogenesis using the new Ferranti computer. Unfortunately, his death occurred in the middle of this ground-breaking work, and his thoughts on evolutionary systems cannot be deduced from his surviving notes. Yet he pre-empted a whole area of biological and genetic research in the 1980s that was also preceded by John Conway's Game of Life [5].

It was *The Blind Watchmaker* by biologist Richard Dawkins that inspired the first true flourishing of artificial life (A-Life) in the computational medium, and crucially gave rise to a number of aesthetic innovations [6]. Dawkins named the new emergent forms after the surrealist paintings made by Desmond Morris that contained "vaguely animal-like shapes," which Morris described as "biomorphs" [7]. Dawkins created genetic rules for each tree that enabled them to mutate as different lineages were bred together. He made the tree-like forms symmetrical about their vertical axis for reasons of parsimony and aesthetics, as well as "because [he] was hoping to evolve animal-like shapes, and most animal bodies are pretty symmetrical" [8].

Dawkins noted that despite experimenting with other growth patterns, the symmetrical plan generated the most interesting, and indeed "lifelike," results. This was a lucky outcome, but later Dawkins deliberately added genes to control the segmentation of the forms, mirroring the importance of segmented bodies in the animal kingdom [9]. With segmentation and symmetry combined, the resulting forms had the greatest diversity and therefore "fitness." Yet the original decision was fortuitous, and the outcomes truly emergent.

It would seem that both Dawkins and Mandelbrot, though scientists by training and vocation, were well aware of the aesthetic potentials of their discoveries. In Mandelbrot's case, the similarities with natural forms were striking and obvious, especially after they were applied to textures and landscapes in 3D programs by Alan Norton and others [10]. However, Dawkins' evolutionary forms would encounter the work of an artist already immersed in the concepts of mutation and generation.

The Early Computer Artworks of William Latham

William Latham started working with computers in 1985 after completing his MA degree in fine art at The Royal College of Art in London. At an early stage in his career, he took the concept of evolving forms and freely developed it into a distinctive artistic style, which incorporates natural and artificial elements. Latham is also interesting for having gradually moved away from art in 1993 and into computer games, which incorporate ideas and code taken from his earlier art work.

Latham was interested in the evolution of form even before he discovered computing. "During the period 1983 to 1985, using a set of rules, he designed and termed "FormSynth," for the transformation of shapes, he set out to sketch huge drawings of multiplying, changing forms (Figure 1).

The logic and consistency of Latham's possible worlds arises from his concept of an evolutionary approach to the making of sculpture. The complexity and vitality of the forms he devised is

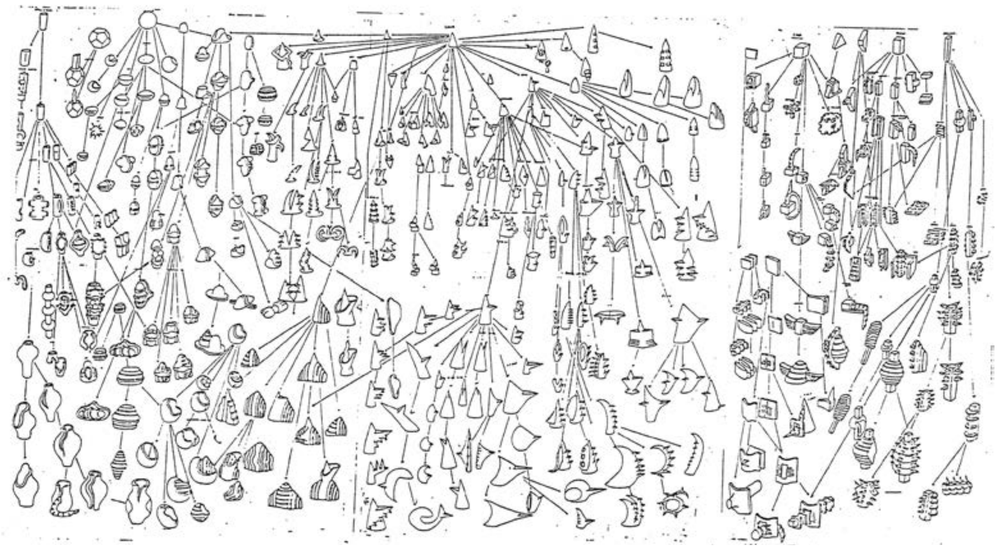

Figure 1. FormSynth evolutionary drawing, William Latham. 1983-85. Details of a two-meter, hand-drawn FormSynth tree. © 1983-85 William Latham.

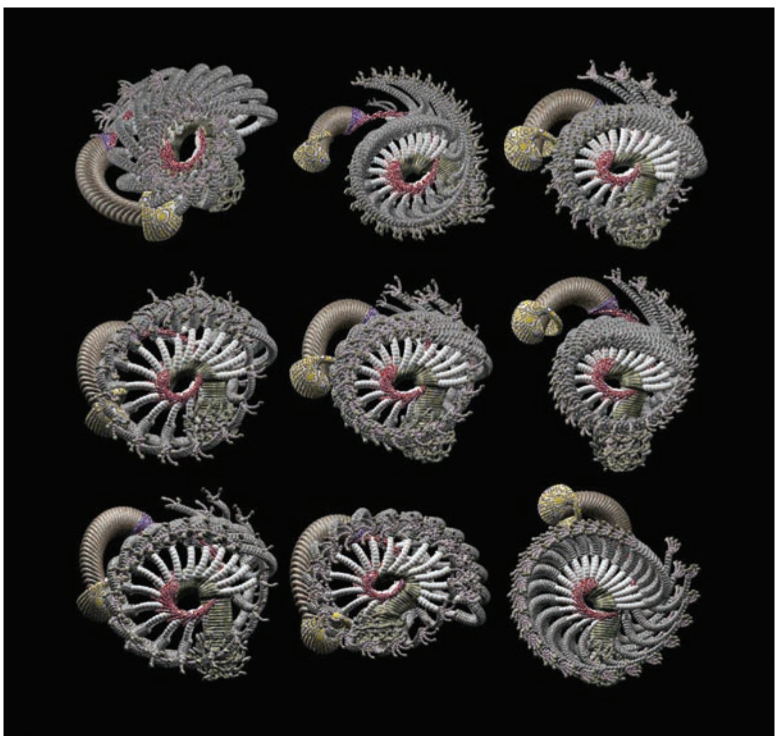

Figure 2. FormGrow/Mutator Generated Art, 1989. Nine mutations (ribbed branched structures), evolved forms resulting from the use of a Mutator session within FormGrow. © 1989 William Latham.

derived from the step-by-step accretion of "operations" on simple initial forms such as cones, spheres, or tori [11].

John Lansdown, in his introduction to "The Conquest of Form", Latham's 1989 exhibition at the Arnolfini in Bristol, UK, considered that Latham and others working with him (in particular Stephen Todd and Mike King) were exponents of "another form of sculpture" [12]. This is derived from the illusory yet real appearance of these works: their seeming materiality is defeated by the obvious departures from our physical reality (Figure 2). Even this system could produce unexpected results [13].

In 1987, Latham was appointed artist and research Fellow at IBM's UK Research Labs in Winchester, where he began working with mathematician and programmer Stephen Todd on a system called FormGrow. This built on FormSynth and allowed simple construction rules such as bulging and hollowing objects. As he worked with this system, building up a new library of rules, Latham realized that some of his long repeated sequences of FormSynth operations could be condensed into new rules, such as those for growing tendrils and horns.

Later on, by the end of 1988, Latham and Todd started using an "add on" new system they developed, called Mutator, that managed the data from FormGrow and began to cross-breed forms together, by identifying their basic components as "genes" and allowing these to be recombined and modified to produce large evolutionary trees of computer-generated imaginative 3D forms (Figure 2). As Latham says: "Mutator derives its methods from processes of nature, and was partly inspired by a simulation of natural selection" [14]. Importantly, the Mutator system enabled the artist to pick, breed, and marry natural-looking forms at will based on their aesthetic quality, which gave the artist a highly intuitive and minimal interface.

This system has an overall appearance that could be called "organic" and seemingly aims toward natural yet fantastical forms. Latham's stylistic decision on which operations to use was made at the level of the core design of the program itself, ensuring that all images bear his imprint, to a degree. The aesthetic of these images, while inspired by nature and science-fiction, remains very much their own. These are forms that would have been inconceivable without the computer to perform all the millions of possible changes, transformations and developments that Latham foresaw (Figure 3).

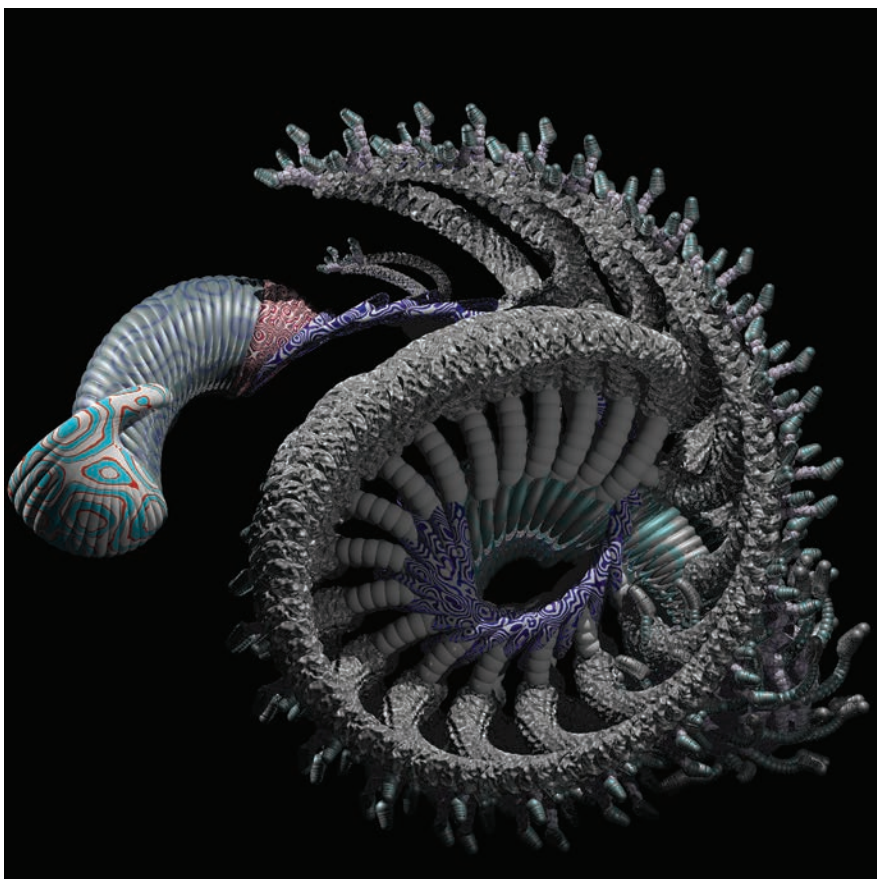

Figure 3. Mutation X. Raytraced. 1989. Final evolved form resulting from a Mutator session. © 1989 William Latham.

One might justifiably question the artist's role in images that are not merely assembled by the computer in its capacity as a tool, but generated directly by it. Where is the human input? Latham counters that his input is at the level of the software itself, which imparts not only the formal construction of the objects but also more intangible aspects of their style as well. Latham's major influences are science-fiction imagery—one is reminded especially of H.R. Giger's designs for the "Alien" films [15] and the seminal book *On Growth and Form* by biologist D'Arcy Thompson, which revealed the mathematical structure underpinning the shapes of life forms [16]. By shaping the code that in turn creates the images, Latham's involvement is at the conceptual rather than practically artistic level, though he also exercises further artistic judgment in choosing certain paths for his images to grow and develop, and their final visual quality in terms of color and texture.

Karl Sims and Artificial Life

Although Richard Dawkins had given impetus to simulations of evolution, it was not until Dawkins himself introduced his "Biomorphs" that a number of major figures in this emerging area, including Karl Sims, began developing their own concepts [17].

From this, Sims developed a program that used the basic genetic concepts of selection, reproduction, and sexual combination to evolve an artificial genotype, and in so doing represent the Darwinian idea of "fitness" in action (Figure 4).

Figure 4. Extinct Image, Karl Sims, 1990. From "Artificial Evolution for Computer Graphics," ACM SIGGRAPH '91 Conference Proceedings, Las Vegas, Nevada, July 1991 (c) Karl Sims.

"A-Life, then, is fundamentally concerned with understanding and formalizing the underlying dynamic structures of living things" [18]. A-Life art, defined in the simple sense outlined above, engages with the same ideas: it is a form of art practice that begins to take on, in various ways, the abstract dynamics of nature.

In terms of the creative process, both Sims and Latham primarily use the human as a cost function in a Monte Carlo-type simulation to explore a multi-dimensional parameter space in which the unevenness of parameter space is covered. Interestingly, during this period, the use of constraints played a small role, apart from individual mutate-able parameters with maximum and minimum values and the implicit constraints of Sims' Lisp Code and Latham's FormGrow logic. In addition, the automatic culling of generated forms (based on mathematical criteria) to reduce the size of the search space was limited. Replacing the artist (as a fitness function selector) was also very limited.

In his 2001 essay that considers the origins of A-Life and art, Mitchell Whitelaw points to a 1987 seminar by Christopher Langton in Los Angeles as the starting point for this area. Looking for precedents in art for the concept of artificial biology, he points to Goethe's analogies between living creatures and works of art, and Klee's understanding of his "picture plane as a kind of contained, artificial world" [19].

Whitelaw also points to Kasimir Malevich's Suprematism, which, although it renounced realistic and imitative painting, viewed the pictorial image as an object in its own right: "a work of pure, living art," as Malevich put it. Malevich also considered a machine to be a "technical organism" and used similar biological metaphors for technology [20].

An Evolutionary Aesthetic?

Do new aesthetic forms in digital art depend on an understanding of the software and programming? Latham, of course, worked extensively with programmers, but he arrived at the computer with a strong sense of process in art. His evolutionary sketches show a means of deploying form in an evolutionary methodology. Because he had been interested in evolving forms even before he used computers, he was able to apply the most distinctive computer quality of all: the modelling of dynamic processes.

These artistic systems are not wholly deterministic, running an image through pre-set parameters until it reaches perfection. Indeed, Latham realized early on that the most interesting outcomes of his program were quite unforeseen by him: his evolutionary program could arrive at unexpected conclusions. Even if an artist programs the computer from the start, there will always be an important element of mystery in the working of the software.

Such quirks render the computer less mechanistic (and predictable) and more "artistic," because the outcome of certain operations cannot always be foreseen. This unpredictability can be harnessed in the same way as the chemical reactions of pigments, or the densities of stone. In other words, an artist develops a feel for its working and gradually incorporates its idiosyncrasies into their work, which itself changes subtly or overtly to accommodate these properties.

This is evident in FormSynth and Mutator, where Latham's choice of operations performed on the initial shapes guided their eventual appearance. Latham's stylistic involvement was, in a sense, pre-visual; it affected the starting point and development of all images generated through the program rather than just a single artwork. Although he modified of the program's underlying code, there were visual consequences because in this way Latham determined the visual environment in which his shapes could develop. Latham compared the artist to a gardener who guides the growth of a plant but is not the source of its life. This is itself a new development for art [21].

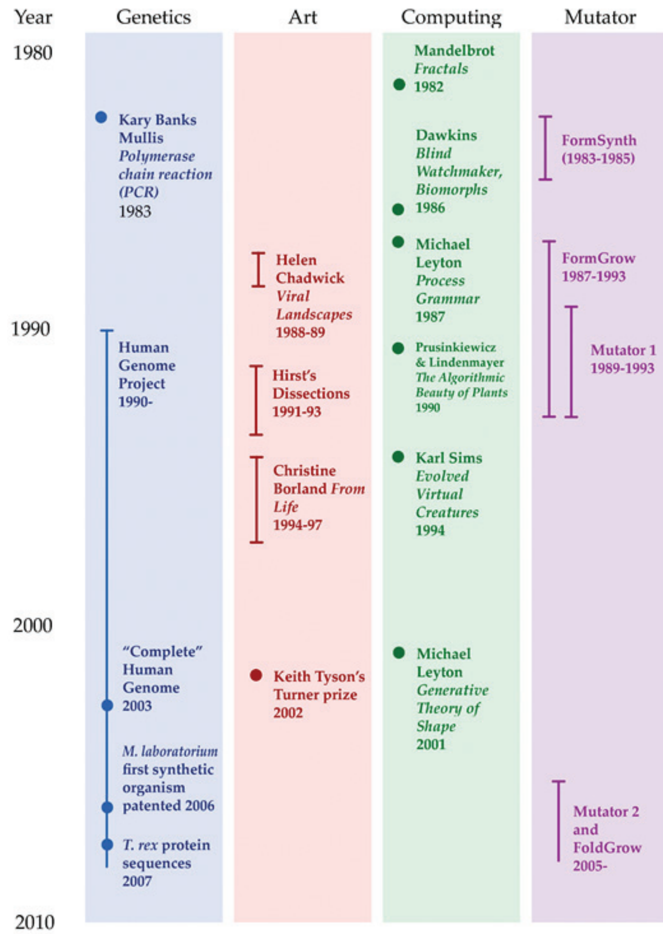

Figure 5. Timeline 1980 – 2010. © 2012 William Latham and Frederic Fol Leymarie.

Mitchell Whitelaw sees in this a factor that is identified in a more general sense as the artist's "signature" or style, because the "formal vocabulary of elements and transformations" that takes place in Latham's work gives it a distinctive visual form. However from a purely exploratory, even scientific, perspective in terms of A-Life, it is also a limitation. The selection Latham exercises is primarily an aesthetic one that gives a "non-natural" aspect to the genetics of his work [22].

Latham's Organic Art images are the product of evolutionary processes and thus indirect products of his artistic vision. They are "indirect" in the sense that Latham developed the program to evolve shapes along particular visual lines, but its continued operation is not dependent on his intervention. Like Harold Cohen's AARON simulated painting program [23], the widely distributed Organic Art software could continue to create Lathamesque images long after his demise, with varying inputs and changes from computer users. The encoding of his evolutionary process in software allowed him to make it portable and then distribute it widely as digital code. Again, this widely distributed software may produce images not directly conceived by the artist, but the images will be inherent within the parameters of the software. Latham is responsible for assembling these elements according to his vision and requirements, but the final image is the result of the software's own working through these possibilities.

Unlike AARON, however, with its complex relation to Cohen's creative input, Latham's software has a straightforward input procedure and generates images from his initial input parameters. AARON is not so straightforwardly instructed; it seemingly derives its own decisions about what to draw from its understanding of art.

There are two different forces at work here. Firstly, there is the artist's control exercised by writing or mastering the appropriate software to create images. Secondly, there is the serendipitous aspect of accidental discovery inherent in an open-ended program where absolute control yields to experimentation and chance discoveries. In Latham's work, the evolutionary nature is the result of a programmer's control in setting up the initial conditions, then exercising further choice over the outcomes of these experiments. A fascination with growth and artificial, yet naturalistic, forms is essential to his art.

Conclusion

The period from 1980 to 1993 was initially dominated by fractal art led by Benoit Mandelbrot, followed by radical developments in evolutionary art as the impact of mutation systems such as Dawkins' Biomorphs gained momentum with a number of key evolutionary art figures such as Karl Sims and the Latham-Todd tandem, whose work was shown extensively at SIGGRAPH during the period from the late 1980s to the early 1990s. These evolutionary artists were able to define core rules for growth of computer graphic forms and then use a mutation system that enabled them to pick and breed purely based on aesthetics to rapidly explore vast areas of multidimensional parameter space, not knowing what they would discover. Importantly this work enabled highly intuitive and artist-friendly interfaces to be developed with the addition of cross-breeding to zoom in on pleasing emerging outcomes.

In parallel to this emergence of evolutionary art using computers, related work was being done through the 1980s in other scientific and technological areas. In the area of perception and computer vision, Michael Leyton was, for example, exploring the representation of shapes as processes that transform them, generating a plausible causal explanation for their "history" [24], a concept very much akin to Latham's own thinking in his development of the FormSynth system. In the area of the computer simulation of plant development, the use of procedural graphics combined with rule-based L-systems was becoming mature, building from the early works of biologist Aristid Lindenmayer [25]. Also in parallel, rapid developments were occurring in evolutionary biology and genetics, in particular from 1990 with the launch of the Human Genome Project, while in more traditional visual art, strong influences of biology were also noticeable, for example in the works of Chadwick's viral landscapes, Hirst's animal dissections, and Borland's preoccupation with anatomy (Figure 5).

Though by the mid-1990s Sims and Latham had become involved in new commercially focussed projects outside computer art, the core themes and ideas were taken up by new groups of artists including Jon McCormack and Steven Rooke, and then extended further with the full emergence of the artificial life research field and associated conferences [26].

Becoming interested again in research, Latham moved back into academia in 2005 and became professor of computer art at Goldsmiths, University of London in 2007, where he collaborated with professor Frederic Fol Leymarie and worked again with Stephen Todd after a gap of 12 years. His recent work has included re-applying the old FormGrow and Mutator systems rewritten in Java and OpenGL to the world of genomics and scientific visualization in collaboration with the structural bioinformatics team at Imperial College London [27, 28].

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Early History of French CG

Cécile Welker
Université Sorbonne Nouvelle Paris 3 and École nationale supérieure des Arts Décoratifs de Paris
France
cecile.welker@univ-paris3.fr

Cécile Welker

ABSTRACT

This paper provides an historical summary of the emergence of computer graphics research and creation in France between 1970 and 1990, a period of innovation that transformed artistic practice and French visual media. The paper shows the role of these developments in the history of art, the evolution of digital technology, and the expansion of animation and visual effects in the film industry.

Early History of French Computer Graphics

The first books devoted to the discipline of computer science were published in the late 1970s, in Britain and the United States [1]. In France, the first symposium on this topic took place in 1988 [2], and Pierre Eric Mounier Kuhn in particular has been a leading voice for the discipline since the 1990s. At the same time, the subdiscipline of computer graphics (CG) has had very little presence in this history of computers and computer science, although some initiatives exist, since CG affects the history of technology, the history of images, and the history of special effects [3]. If the state of the industry is sometimes studied in the United States, this is not the case in France, where researchers and authors have so far only focused on the history of major groups [4] and networks [5].

This paper presents a history of computer graphics in France, as a heritage that is worth keeping alive, since France was very active in CG in the early 1980s. Based on the dynamics of French creativity, the government's plan, known as "Recherche-image" [6], has promoted many initiatives. Post-production companies, research laboratories, and training programs were created and geared towards specialized CG [7]. SIGGRAPH Computer Animation Festival selections are evidence of this. Since 1987, 6–13 percent of selected films were French [8], but still we know little of this history. If some landmark events in the history of computer graphics occurred in France [9], no books, no theses relate a French history of CG. When we look at the reference books [10], only a few lines are devoted to French practitioners and outputs.

For this reason, a research program devoted to the history of CG in France is now gaining popularity [11]. Our research constitutes a historical archive from the perspective of preservation. Indeed, if this topic deserves to be discussed, and should eventually lead to a comparative study between France and other countries, such as the United States or Japan, an overview of French CG history needs to be written first.

By relying on historical documents and testimonies of computer graphics pioneers, this paper presents a historical overview as well as descriptions of some significant initiatives that took place in France between 1970 and 1990. It aims to highlight why and how this environment of computer graphics was constituted and to summarize its origins.

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Scientific Research

Even before the creation of genuine academic research teams, isolated individuals conducted critical work in the field of computer graphics. In the early 1960s, Pierre Bézier [12], at Renault, invented the curves that bear his name and are still used in the objects that surround us, in the texts we read, for instance. At the same time, Gilbert Comparetti [13] presented the basics of what animation software should be, developed the idea into a tool, and tracked its development of computer-animated productions [14]. Since he is considered "the father of the French computer-animated cartoon" [15], in 1965, a research team was formed in Grenoble that gave rise to the first thesis in the field of computer graphics [16]. In 1971, Henri Gouraud, after graduating from the École Centrale and Sup Aero (in Paris), obtained a PhD from the University of Utah. He collaborated with all the men who were to develop computer graphics in the 1970s, such as John Warnock, Ivan Sutherland, Tom Stockham and Dave Evans. The result of his research—the Gouraud shading—is still programmed in the heart of today's graphics cards (Figure 1). In 1972, Ed Catmull, future cofounder of Pixar, and Fred Parke created the first 3D film [17] using Gouraud rendering, whose results were published in the United States [18]. In France in the early 1970s, a team was formed in INRIA [19] as well as a graphic working group within the AFCET [20]. They organized many meetings and workshops, including the Seillac seminar [21] in 1976, which brought together researchers from around the world in order to standardize graphics software. Research teams multiplied: École des Mines de Saint Étienne [22], ENST Paris [23], ACROE Grenoble [24], as well as other teams in Lille, Toulouse, and Nantes. In 1980, the Eurographics Association was created, while Institut national de l'audiovisuel [25] was established along with Arc Senans in 1981, a seminar on processing and image synthesis applied to audio/visual creation.

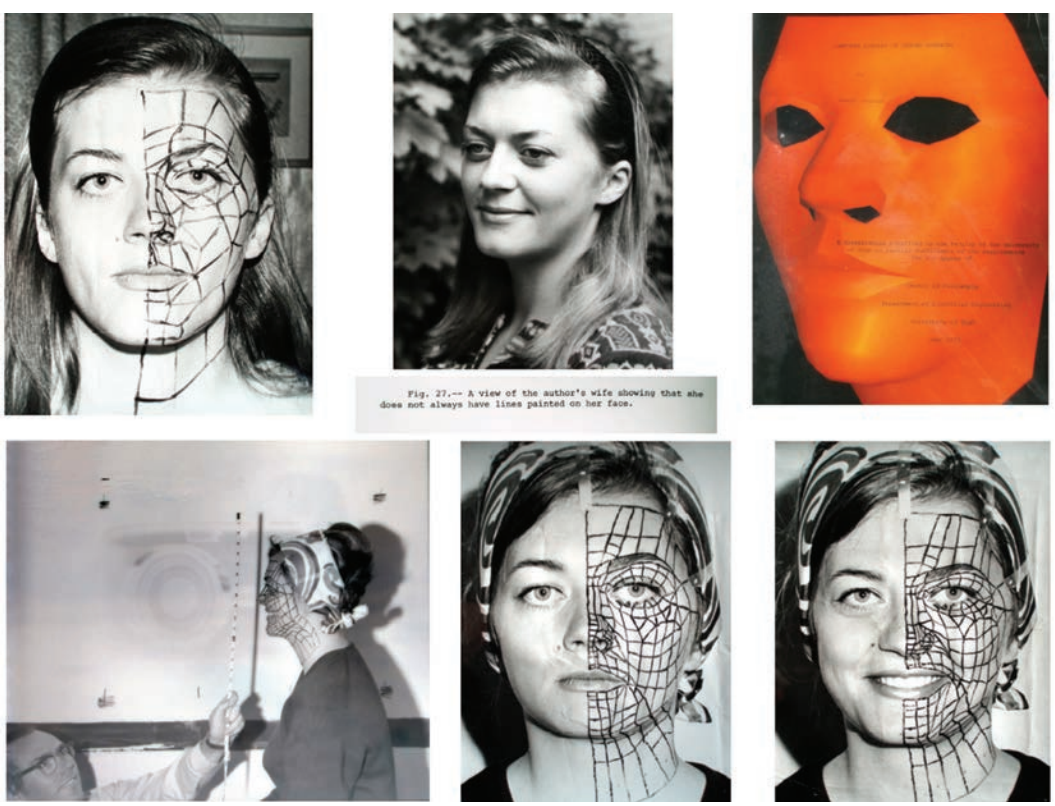

Figure 1. A view of the artist's wife showing that she does not always have lines painted on her face. © 1971 Henri Gouraud.

Many initiatives demonstrated the emergence of a circle of researchers working on developing computer graphics in France. This is confirmed by the report Michel Lucas produced in 1995, which describes "the evolution of research on computer graphics from 1965 to 1995" [26]. In parallel, artists showed an increasing interest in computers, ranging from computer-assisted painting to the use of computers as medium.

Figure 2. "Hunger," Peter Foldès. © 1973 National Film Board of Canada.

Artistic Experimentation

The first generation of computerized still images was created by Frieder Nake, Georg Nees, and Michael Noll, who worked on "the principle of chance" theorized by Abraham Moles in 1971 [27]. Manfred Mohr, for his part, systematized the idea of series, and presented the very first museum exhibition [28] in France of works calculated using a computer. The journal *Computer and Automation* had already organized a contest of drawings by computer in 1963. This episode was decisive, for the selection criteria were not merely mathematical or technical, but also artistic. The exhibition Cybernetic Serendipity in London in 1968 would be one of the first consequences of this change in status. It is therefore often cited as a precursor to what is now called digital art [29].

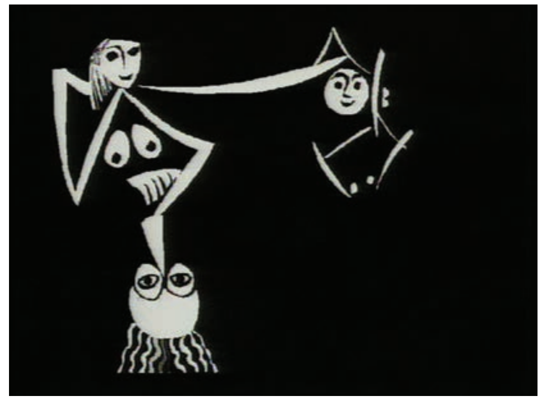

Figure 3. "Femme spectacle." © 1987 Michaël Gaumnitz.

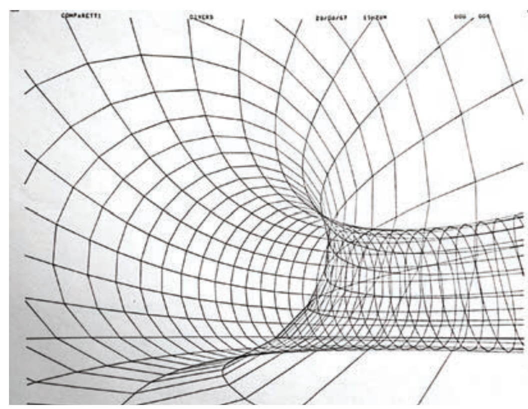

Figure 4. "Jeu avec la caméra et sa focale." © 1967 Gilbert Comparetti.

Although art production in these years was mostly inspired by geometric abstraction, the artist Charles Csuri and the engineer James Shaffer won the Computer and Automation contest in 1967 for their work *Sine Curve Man*. This was a move toward figurative representation, as they created computer programs that were more flexible and produced portraits using deformation. Computer memory and printouts were limited, so these preliminary works were expressed in black and white. Some products, however, are recognizable by their colors. Hervé Huitric and Monique Nahas developed an interest in color and its algorithmization, making silkscreen frames printed from a computer [30]. Pierre-Louis Neumann attempted to reproduce his own conceptual approach through programming so as to find the most accurate composition, which he then realized in painting. Peter Foldes [31] came up with the idea of animating these two-dimensional drawings by computer. His first tests, carried out with the support of the National Film Board of Canada and entitled "Metadata" and "Hunger" [32] (Figure 2), depicted an animation interpolation process using digital technology that creates "a flat perspective effect through chained metamorphoses" [33].

Graphics tablets appeared in the early 1980s and allowed experimentation by designers as well as artists in 2D-animated productions. In 1985, Michaël Gaumnitz began to work on Graph 8, a paint system made by a French company, X-Com, with which he has directed several short films for television, "Femmes" and "Le courier des téléspectateurs" series [34], in particular (Figure 3). These videos captured the moving image, "the image being drawn" [35].

Many French researchers had already experimented with 3D-animated images in the 1970s. Gilbert Comparetti [36] (Figure 4) and Manfred Mohr [37] provided outstanding examples of 3D animation work using Wireframe.

After the military, medical imaging, and industrial applications, another area began to incorporate the interest of CG imagery, the audio/visual. A market for computer graphics appeared in France in the 1980s, with the initiative of the company Sogitec in particular, which declaimed "the hopes for a new world created by the computer" [38].

From Flight Simulators to the Audio/Visual Industry

In 1981, in response to a commission from the aircraft manufacturer Dassault, Sogitec established a computer graphics department, under the direction of Claude Mechoulam, in order to develop a flight simulator system and real-time image generation [39]. Like the U.S. company Evans & Sutherland, Sogitec was a striking example of the impact of the military in the history of computer graphics. Very quickly, the company turned to new productions, when Xavier Nicolas, head of broadcasting, utilized the potential of these systems to model and animate images for TV and film [40]. The first applications included rendering and skinning in television commercials, thereby supporting the development and learning of the relevant techniques. Advertisers such as Canon [41], GDF [42], and BNP [43] promoted their brands by launching themselves into modernity. Sharp communicated "a journey to perfection" in 1983 [44], incorporating new images [45] in an ad for copying machines and calculators (Figure 5). The same year, André Martin and Philippe Quéau presented "Maison vole" [46], the French-scripted short film, whose images and sounds are totally synthetic (Figure 6), co-produced by Sogitec and the research and development department of the Institut national de l'audiovisuel.

Figure 5. "Sharp." © Sogitec.

Figure 6. "Maison vole." © 1983 André Martin, Philippe Quéau, Ina-Sogitec.

The cinema started using digital effects later. In 1986, Christian Guillon directed the special effects in CG of the first French full-length animated feature [47], "L'unique" [48] (Figure 7). Then everything accelerated when the main creators of actual 3D opened their own studios. In 1985, the architect Pierre Buffin, with Henri Seydoux, created BSCA, which later became Buf compagnie [49].

Figure 7. "L'Unique." © 1986 Jérôme Diamant-Berger.

Simultaneously, five students were meeting over weekends and realized "La vie des bêtes" [50] (Figure 8), which resulted in the creation of the studio Mac Guff Ligne [51]. After a few achievements in the Ina and Sogitec, Georges Lacroix, Renato and Jean-Yves Grall created Fantôme [52], known for the series "Fables géométriques" [53] (Figure 9).

The possibilities offered by the virtual camera and synthetic objects suddenly freed writers and directors from physical restraints due to gravity, reminding us that these early images were created by adapting the techniques of flight simulators. They would make excessive use of this new freedom, especially as textures and animations were still very poor. Early computer graphics illustrate both modernity, often using a universe of science fiction, and the technical constraints of the time [54].

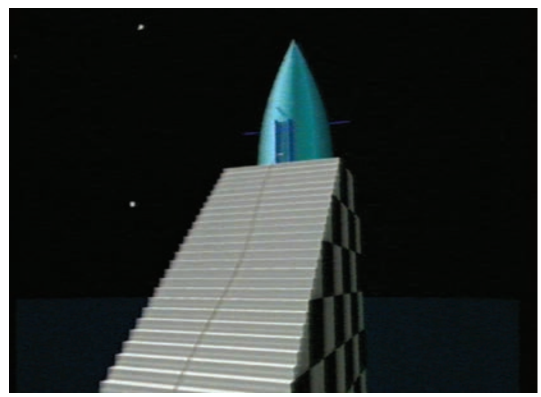

Figure 8. "La vie des bêtes." © 1987 MacGuff.

Digital techniques contributed to the invention of new visual and fictional worlds. The French pioneers also experimented with purely artistic perspectives.

Towards Digital Art and Virtual Reality

In 1975, IBM France dedicated an issue of its magazine to art and computers [55]. Alongside international works, there were many French achievements, such as research and artistic work by Pierre-Louis Dahan and Phac Le Tuan [56], the Groupe de Belfort, and CAD with images by Jean-Marc Brun and Michel Théron [57]. In 1976, Vera and François Molnar created one of the first programs for image generation, Molnart. Hervé Huitric

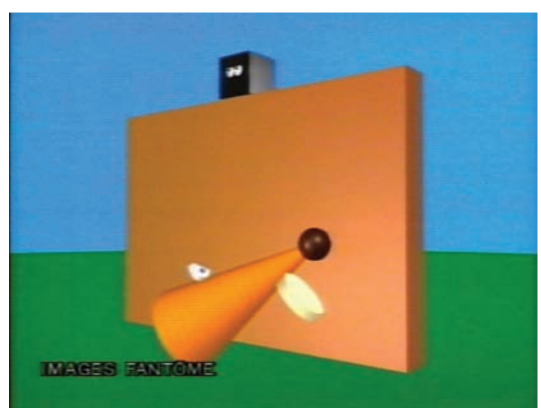

Figure 9. "Les fables géométriques." © 1988 Renato, Georges Lacroix, Jean-Yves Grall, Fantôme.

and Monique Nahas made their first movie on a computer in 1979 [58] as part of the activity of the computer group of Vincennes, which was created a few years earlier. The Art and Technology of Image Department (ATI) of Université Paris 8 was created in 1982, and the department AII, Workshop Image and Computing, was also created at the École Nationale Supérieure des Arts Décoratifs de Paris in the same year [59]. The ATI team, consisting of Hervé Huitric, from fine arts; Monique Nahas, professor of theoretical physics; Michel Bret, painter and professor of mathematics; and Edmond Couchot, designer of interactive installations, "set up a hybrid research program and teaching syllabus, at the crossroads between art and programming"[60].

Figure 10. "La petit danseuse." © 1985 Michel Bret.

Figure 11. "La plume." © 1988 Michel Bret, Edmond Couchot, Marie-Hélène Tramus.

The notion of interactivity with the viewer was not born with the computer: *Op'art* is just one example among many [61]. In this line, the apparatuses built by Edmond Couchot, Yaacov Agam, and Myron Krueger in the 70s [62] react to the viewer's movements by shifts in light and sound to incorporate notions of temporality. Piotr Kowalski allowed the viewer to act remotely on a synthetic image [63], or to intervene in real time on the video [64], and in 1982, Tom DeWitt developed an interactive screen [65, 66]. The first trials of computer graphics at ATI plunged the spectator deeper into interactive installations and virtual universes, implementing the principles of virtual reality, gradually distinguishing different degrees of interactivity. "La petite danseuse" [67], a model synthesis, began to execute typically digital movements (Figure 10). "La plume" [68] was the beginning of what would later become "Je sème à tout vent" [69], where viewers blowing on feathers or synthetic flowers on the screen realize that they have an impact on their movement (Figure 11).

These works laid out the principles of virtual reality, as defined by Fuchs in 1996 [70]. The various features of what is called virtual reality—changing time and place through interactions—and the purpose of this reality are implemented in order to "enable one or more people to experience some sensory-motor and cognitive activities in an artificial, digitally created world which may be imaginary, symbolic, or may simulate some aspects of the real world" [71].

Works like "The legible city" [72] and "Pissenlit" [73] are historical examples of this virtual reality. In the first example, viewers are involved without substitution in the action, sitting on a bike that allows them to feel closer to the reality of this virtual city, even though it is made up of words. In the second case, viewers' breath symbolizes the wind that puts the flower in motion on the screen. Since these pioneering works, several interfaces have associated immersion (sensing) and interaction (acting upon). They gave rise to varying degrees of motor skills, while interactive possibilities for telecommunications, then rapidly expanding, brought the notion of "dispositif" to the forefront.

Broad public acceptance of the computer as medium was nurtured by the dominance of computer graphics in film and television production, and the technology's role in creating digital art.

Towards Expansion

Nowadays, the greatest part of "the turnover of a number of French companies is obtained abroad, while many computer animators choose to work abroad" [74]. Where do these talents and skills derive from? The "French touch" has been exported since the 1990s, first as expertise in software [75]. Indeed, many ingenious pioneers strove to develop their own tools. In 1985, Pascal Terracol and Olivier Emery produced one of the first commercially available 3D animation software packages for the PC, Imagix-3D [76]. When it was lent to MacGuff, this software helped to initiate the company's activities [77]. The most striking example is the software Explore. In 1986, Jean-Charles Hourcade, along with Daniel Borestein and Alain Nicolas, merged the 3D studio Ina and Thomson CSF into the new company TDI [78], thereby laying the foundations of Explore, which became "the best-selling 3D software in 1991" [79]. It was sold in 1993 to Wavefront, and its bases can still be found today in Maya.

Then, creativity took over. Sogitec produced 80 commercials for the English market from 1984 onwards. When the company merged with TDI to become ExMachina, "it soon appear[ed] that the film market [was] not sufficient for the development of the company" [80]. It therefore branched out to produce films for theme parks and special events, especially in the US and Asia. ExMachina opened an office in Tokyo as early as 1992, partly in order to commercialize rides [81]. "Sub Oceanic shuttle" [82] was the first CG product of Iwerks Entertainment and was followed by many others. After the success of "La cité des enfants perdus" [83], the special effects supervisor of "Batman and Robin" used Buf compagnie "to work on 56 shots of the film" [84]. Buf later developed the visual effects in film after film in the U.S. [85].

Although directors have testified that exchanges between the French and Americans existed at the time—as the festival Imagina in Monte-Carlo, which encouraged the use of graphics work in Europe, illustrates—productions during these years were very different. "Maison vole" [86] was produced in late 1982, the very year "Tron" [87] was released. Three years later, Pixar produced "Luxo Jr." [88]. Was it simply that means and techniques were quite different? Or is it that these "nouvelles images" were regarded differently in the two countries? There were many French productions in those pioneering days, and today French expertise is still recognized. Should we go so far as to suggest that there is such a thing as a French school of computer graphics? Or did 3D productions develop uniformly on all continents? This research now deserves to be taken further: a thorough analysis of the productions, as well as a comparative historical approach of the three countries that evince outstanding creativity and imagination—the United States, Canada, and Japan—should be the next steps.

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Cloud Pink

Yunsil Heo
Hyunwoo Bang
Seoul National University
yunsil@yunsil.com

Cloud Pink, © 2012 everyware.

Yunsil Heo, Hyunwoo Bang

Cloud Pink is an immersive media installation with a giant stretchable fabric that covers the entire gallery ceiling. Viewers can poke this sky with their fingers, stirring the simulated pink cloud that floats on it.

Lying down on a hill, with your eyes filled with the endless blue sky, your perspective is suddenly distorted, and clouds drift at the tip of your nose. You stretch your arms up to the sky to touch the clouds but you can't reach them. It's another world just above your head: clouds. Touch the pink clouds drifting on a giant fabric screen and remember your childhood clouds of dreams. I spent countless sleepless nights just to realize my unproductive and romantic cloud of words. But isn't it beautiful to feel the clouds at your fingertips?

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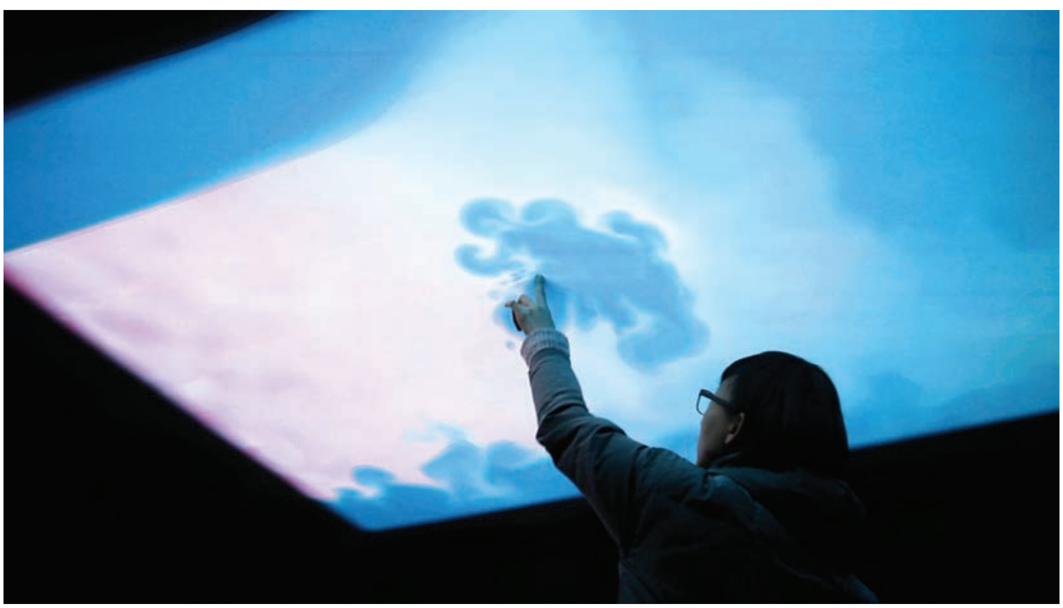
Cloud Pink, © 2012 everyware.



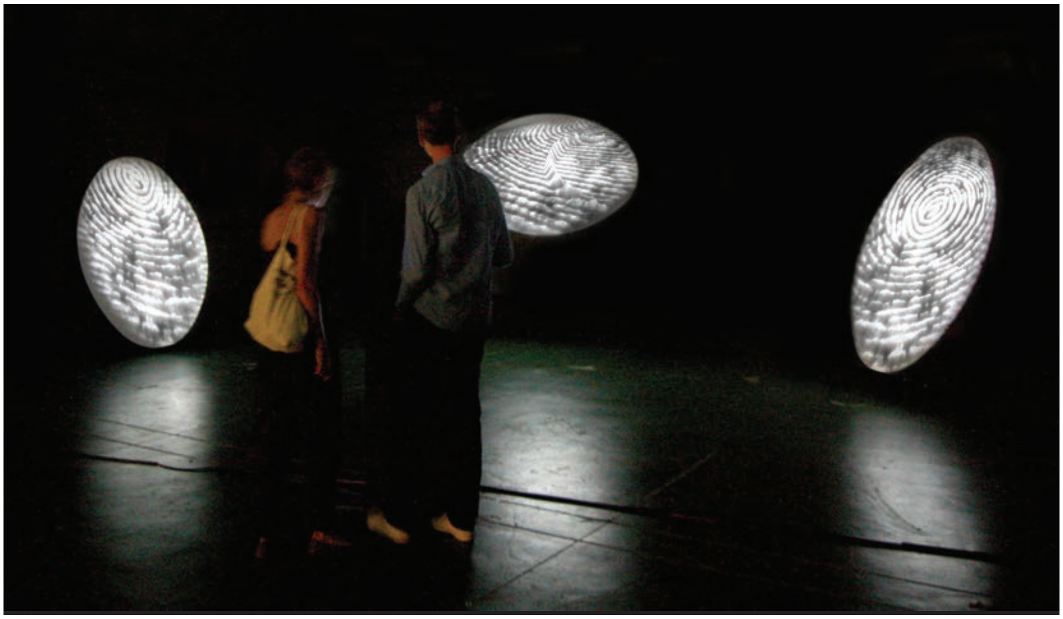
Cloud Pink, © 2012 everyware.

Digiti Sonus

Yoon Chung Han
University of California, Santa Barbara
yoon@mat.ucsb.edu

Byeong-jun Han
Korea University
hbj1147@korea.ac.kr

Yoon Chung Han, Byeong-jun Han



Digiti Sonus, © 2012 Yoon Chung Han, Byeong-jun Han.

Fingerprints are unique biometric patterns on human and primate bodies. They are clearly recognizable patterns that can be manipulated and saved into large databases. Due to their distinct and unique visual patterns, they have been useful for personal identification and security. In this digital era, many computing machines and digital interfaces use fingerprints as secure keys to identify and access personal information.

We believe fingerprints are the most intuitive and powerful source of data that represent an individual's pure voice and identity. There is no trick or filter on the fingerprint patterns. Only the simple, spiral pattern displays the truth of human birth, genes, and growth. Thus, fingerprints are a powerful resource not only for revealing societal identities, but also for exploring our bodies' inner, unconscious, and pure voices.

Digiti Sonus is an interactive audio/visual art installation based on fingerprint sonification. Transforming fingerprints' unique patterns into sonic results allows the audience to experience the discovery of sensory identities. The sonification of data produces a real-time music composition as a representation of integrated human identities. The distinct visual features of fingerprints as an open musical score are executed in diverse ways and converted into three-dimensional animated images. By varying the starting point of animated visuals, the musical notes are reorganized in different orders and duration, and they resonate in listeners' bodies and minds.

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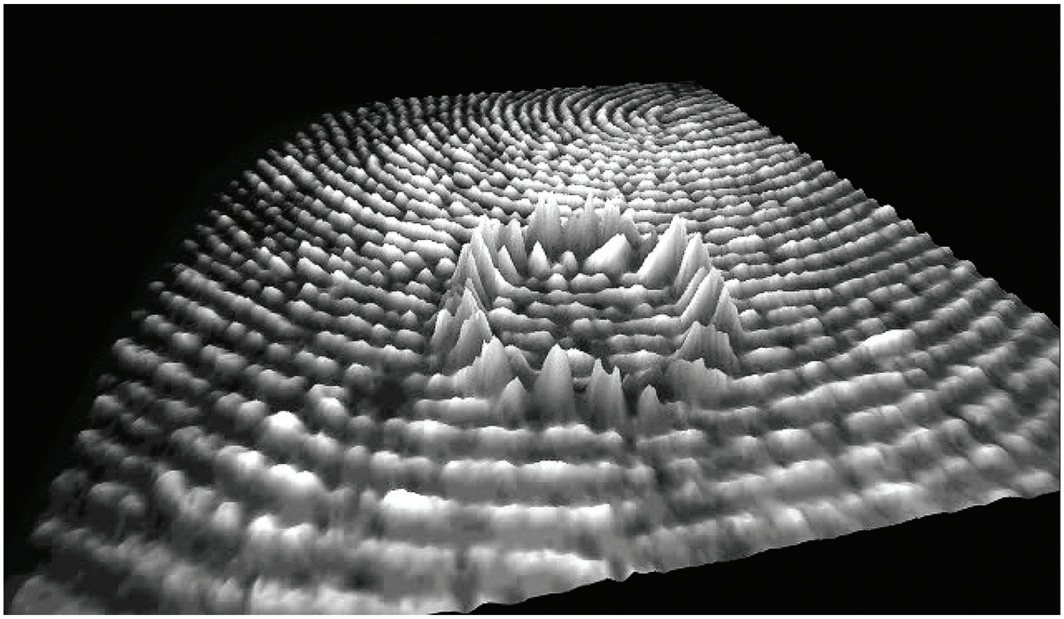


Digiti Sonus, © 2012 Yoon Chung Han, Byeong-jun Han.

Digiti Sonus, © 2012 Yoon Chung Han, Byeong-jun Han.

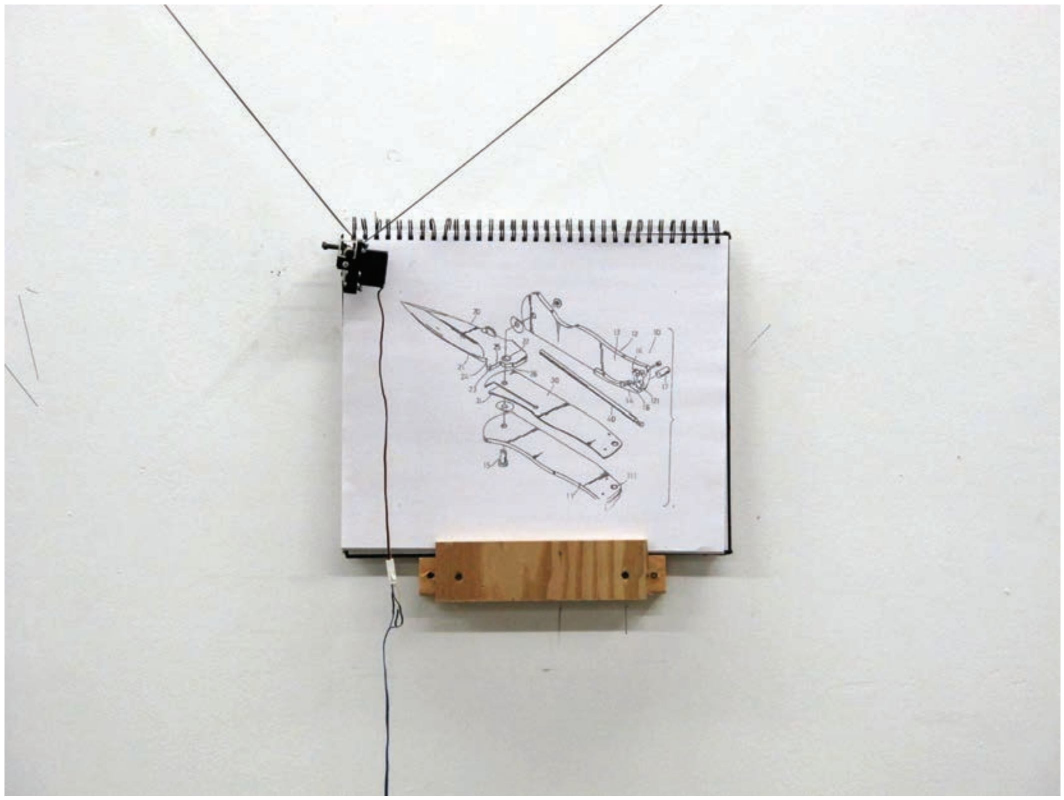
In this artwork, sonification can serve as an effective technique for representing complex information like human body patterns, due to the auditory system's ability to perceive a broad range of stimuli. Transforming fingerprints' unique patterns into sonic results allows listeners to discover sensory identities. The data is transformed into different XYZN scales and magnified into an immersive audio/ visual representation. Listeners can "perform" musical sounds, providing input that results in dynamic audio/visual output.

This work is the result of DaVinci Media art project 2012, which is supported by Seoul Art Space and Geumcheon art space.

Drawing Machine

Robert Twomey
University of Washington
rtwomey@u.washington.edu

Robert Twomey



Drawing Machine, © 2013 Robert Twomey.

Drawing Machine is the latest in a series of conceptual subtractions from the parameters of drawing as an art act. A precision-controlled CNC device labors in place of the artist, working with unfaltering patience and inhuman precision to fill a sketchbook with images over the course of the exhibition.

This project marries my technical interests in motor control, image vectorization, and machinic spectacle with my history as a painter. Drawing has been my most heartfelt and originally self-defining activity as an artist, but I find it difficult to place the value of drawing in the context of other readily available image-reproduction technologies. A doppelgänger or substitute, this project reintroduces drawing as the output of a laboring machine, raising questions of absence and presence, expression, and the value of the handmade.

The uneasy combination of technical fascination and artistic desire is a recurrent theme throughout my work. In other projects I have reflected on computer vision, natural language processing, and speech recognition, colliding these techniques with personal content to illuminate essential questions of identity, embodiment, and cognition in our time.

Drawing Machine, © 2013 Robert Twomey.

Drawing Machine examines multiple notions of scale. As a mechatronic system, the twin-pulley hanging plotter system is designed to be inherently scalable. The drive belt and modular pulley system can expand the working space of the machine from 14 inches x 17 inches (the size of the sketchbook) to a 12 foot x 20 foot wall, and it can operate with the same sub-millimeter precision across those scales. Beyond these physical qualities, *Drawing Machine* examines the dynamics of plasticity and material resistance in digital fabrication processes: how the relative ease of transformations in software manifests as time-to-manufacture, duration, and cost when realized in the material world.

In the larger context of my art practice, I wish to achieve some reconciliation of my ambition to vanguard technical explorations with the tradition and history of a studio-based practice. This piece is one incremental excursion in that larger project.

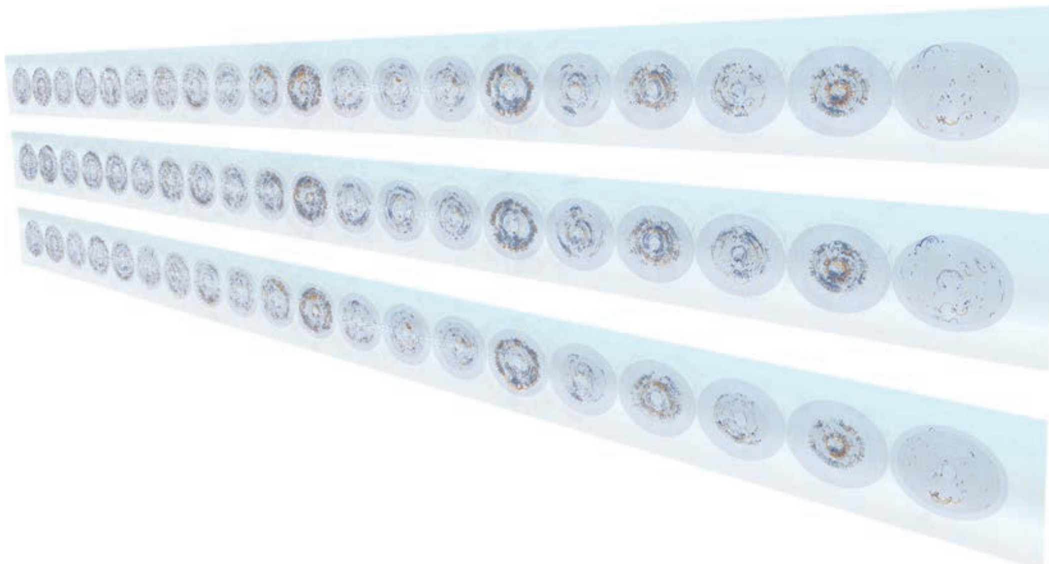
Expressive Maps

Santiago V. Lombeyda
California Institute of Technology
slombey@caltech.edu

Data courtesy of:
Barbara Wold Lab
California Institute of Technology

Original tools developed in collaboration with:
Katherine Fisher-Aylor
Wold Lab
California Institute of Technology

Santiago V. Lombeyda



Set of three gene expression maps, wall-mounted, © 2013 Santiago Lombeyda.

Expressive Maps is an artistic visualization of a complete mouse DNA sequence, taken from embryonic mouse muscle tissue, stretched out in a line. Each individual spiral represents a single chromosome (mice have 20, versus 23 in humans), and active sections perform calls across the corresponding chromosome addresses. It displays three stages of development: before specialization, 60 hours after specialization, and 60 hours post-specialization with an inhibitor present. Each stage has been printed on vellum, so one "map" can be placed on top of another to reveal differences.

The pioneering science of genetics and molecular biology works on trying to understand amazingly complex systems that regulate life—systems encapsulated at a microscopic scale. Despite their size, these systems carry all the information necessary to describe, architect, regulate, and enable our existence.

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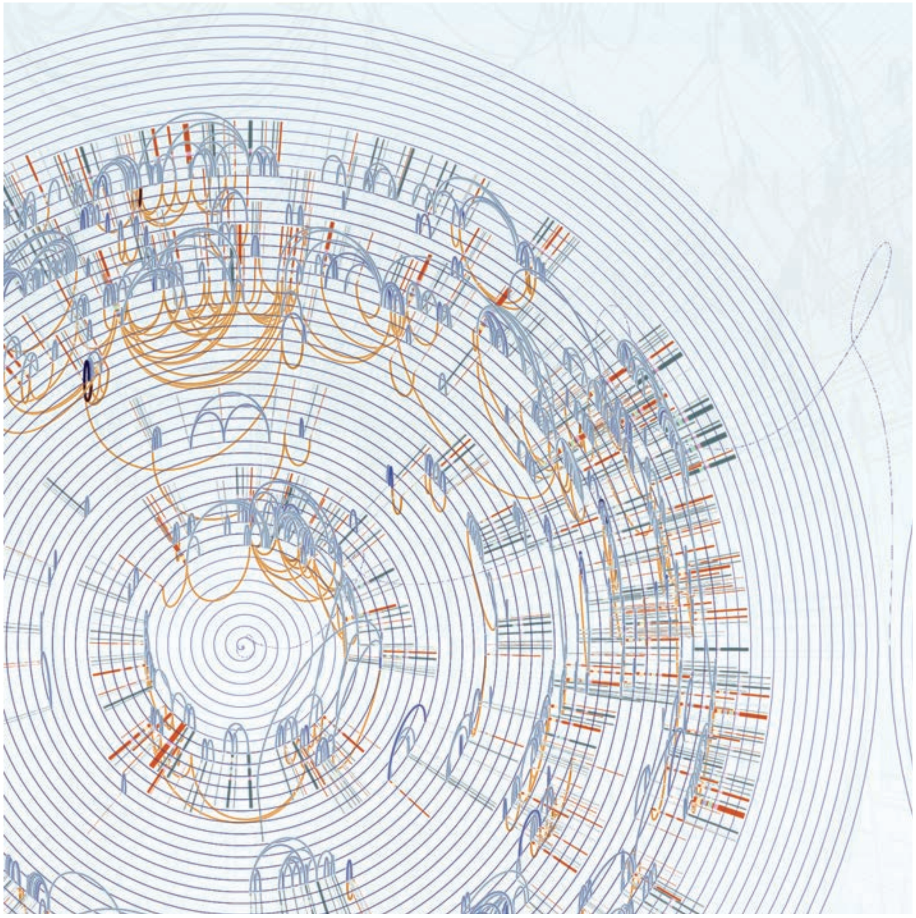


5in x 5in Zoomed-in detail of one chromosome, © 2013 Santiago Lombeyda.

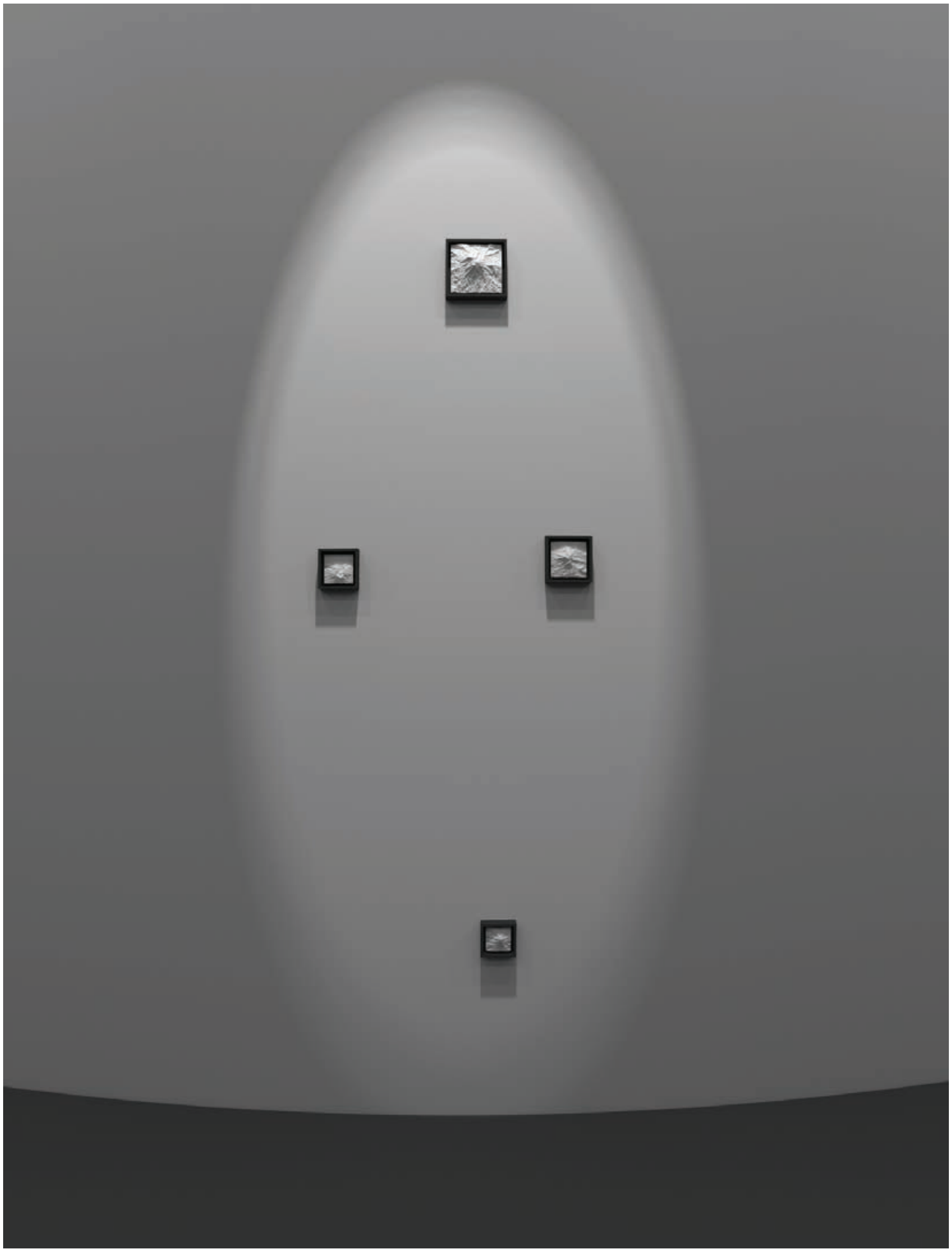
At the core are macromolecules (DNA) too small to observe "in action." And yet if we were to stretch it out, one single DNA chain would measure between three and nine feet in length. Using experiments, we can measure the rate of "calls" across the DNA, triggering or inhibiting specific segments or genes. Studying these interactions before and after specialization (the process of self-determining the type of specific muscle cell it will become) provides a key to understanding cell dynamics. Graphics visualization tools are valuable tools in this challenging area of active research.

These expressive maps are not only scientifically accurate and meaningful, but they are snapshots of a dynamic system, minute and yet quite "grandiose," and ultimately awe-inspiring.

Four Mountains

Mark J. Stock
mstock@umich.edu

Mark J. Stock



Rendering of work on display, © 2013 Mark J. Stock.

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Rendering of one of the Four Mountains *on display*, © 2013 Mark J. Stock.

Four Mountains consists of tiny, rapid-prototyped models of four tall stratovolcanoes in the US Pacific Northwest, each isolated, framed, and arranged on the gallery wall to scale, viewed from above, from the point of view of a god (or an astronaut). It draws attention to not only the mountains' detailed, crisp forms, but also to the empty spaces in between.

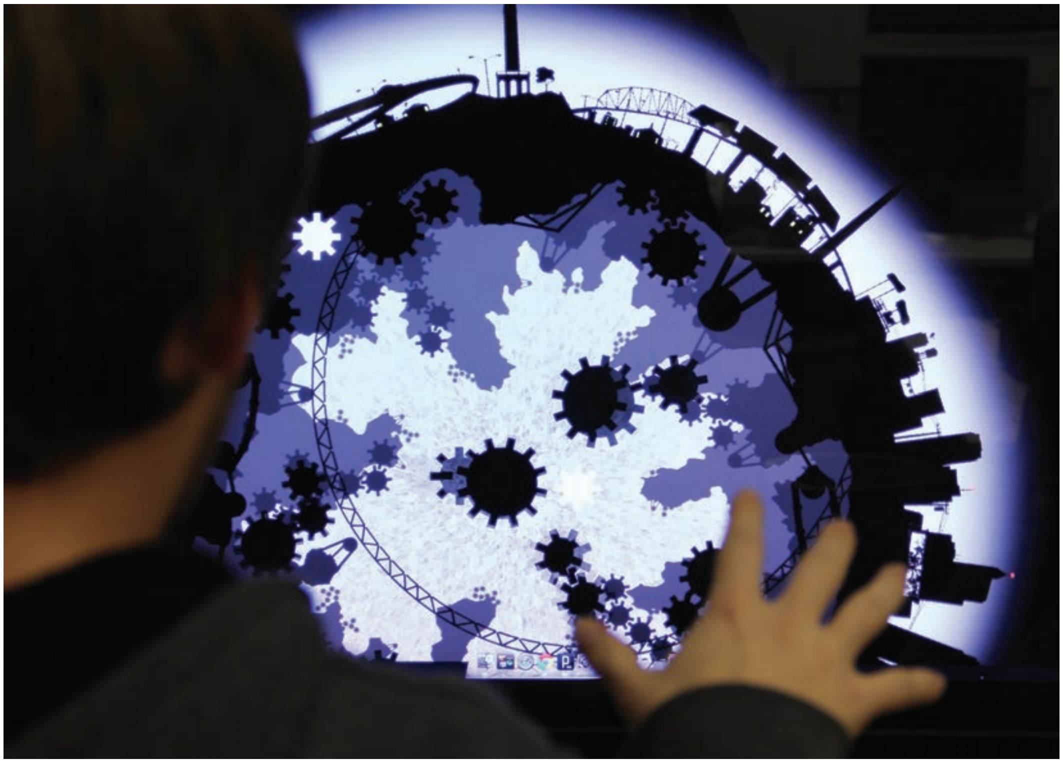
Contrast the attention given to the peaks with the empty spaces between them. The featureless gallery walls are a placeholder for ordinary landscape. This plane has no characteristic scale save that imposed by the mountains. The frames make a prison-like separation between the zones that reinforces their unequal standing. Sculpture is being reinvented by rapid-prototyping (3D printers) and alternative manufacturing techniques. The accurate mountain models in this work would not have been possible without several key pieces of computational geometry and image-processing technology, including LiDAR-acquired data from the US Geological Survey, 3D printing systems, and a number of pieces of custom and open-source software.

This project is a departure from my usual work, but does not stray far from my roots of using computational authorship to investigate natural phenomena from vantage points freed from the constraints of our beings. Much of my work leverages computational-physics software to generate alternate spatiotemporal realities, generally featuring fluid dynamics. But unlike physical fluid flows, the structure of which is normally observed indirectly, mountains are so massive and seemingly timeless that their visual forms are etched indelibly into our minds, and to see them any other way requires us to do something extraordinary. The act of miniaturization short-circuits this relationship. What was far away and dramatically steep is now just a corrugated sheet of laser-sintered nylon. What was once unattainable now fits in a pocket. By transforming the subject from its physical reality into the digital realm, we are able to manipulate it, free of the limitations of mass and energy, and thus break our traditional relationship with it.

Long View

Patrick Fitzgerald
Daniel Link
Lee Cherry
Jim Martin
Dwayne Martin
Deptartment of Art + Design
College of Design
North Carolina State University
pat_fitzgerald@ncsu.edu

Patrick Fitzgerald, Daniel Lunk, Lee Cherry, Jim Martin, Dwayne Martin



Long View. Gesture-interactive installation, © 2013 Patrick FitzGerald.

Long View is a gesture-based interactive installation that offers the viewer the ability to affect animated elements in a projected space in ways that the artists hope will increase awareness of our fragile and temporary relationship to our planet.

Our piece integrates open-source, physics-based gaming engines in Flash with our own gesture-based interactive system that uses the Microsoft Kinect as an input device. The installation allows and encourages viewers to interact with the projected elements by moving their hands and bodies in a natural way. The projected "planet" view exhibits visual and behavioral changes over time and "evolves" as human technology and industrialization advances. Viewers can play with these "ecosytems" to change them in various ways. The piece itself loops and metaphorically creates a conundrum about humanity's long-term relationship to the earth.

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Long View. Gesture-interactive installation, © 2013 Patrick FitzGerald.

It relates to the SIGGRAPH 2013 Art Gallery theme XYZN: Scale in that it covers vast epochs of time and creates different experiences depending on viewers' proximity to the projection. We are interested in creating interactive systems and experiences that are intuitive and require no learned grammar. We believe that in the future, gesture-based interactive spaces and experiences will become a common way for individuals and groups to interact with media, environments, and each other.

Rhumb Lines

Barbara Mary Keating
E CLIPS
pmnogue@eclips-training.com

Collaborators: James McAleer (Steadi-Red), Sam Keating

Barbara Mary Keating

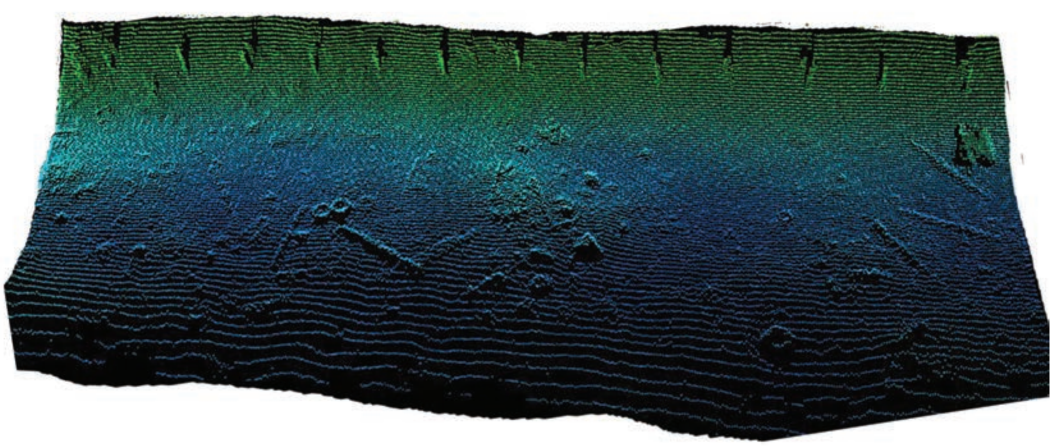
Still image from Red One footage, © 2011 Barbara Keating. Photo James McAleer.

Rhumb Lines is a playful, immersive, cinematic, interactive video installation that explores how we think we know where we are in time, space, and history. It invites viewers to navigate a mesmerizing series of interlinked videos using location data and scanning the horizon to seek out hidden co-ordinates and signs of the River Tyne's magnetic attraction for artists over the centuries, translated into beautiful Red One super-wide-screen images. Viewers scroll a map generated from sonar-scan data, with the GPS tracks overlaid to trigger corresponding videos. They scrub through the cinematic widescreen videos seeking journey intersections, and the frames of video are graded to look like archive paintings. Device control creates an apparent suspension of "real" time that could be staged on any waterway in the world with sonar-scan survey data.

I was brought up by the sea, and the UK is an island nation with a significant maritime history. The River Tyne was the first place to have a Life Brigade, and subsequently painted narratives of the sea turned from wreckage and war to the saving of lives. I began to imagine a point where all possible journeys in time and space intersect in the river's mouth. Using daymarks, lighthouses, and modern instruments, I set out to explore it. I'm fascinated by navigational history, theory, and technology ancient and modern, and the logical outcome of following a rhumb line. After taking an initial bearing, one proceeds along that bearing, without changing direction as measured relative to true north. An infinite spiral is traversed, because the earth is round.

Still image from Red One footage, © 2011 Barbara Keating. Photo James McAleer.

With the above in mind, I looked at local archive paintings of the river and began colour-grading video to resemble some of the paintings. I then experimented with reverse zoom, filming from vessels, panning and tilting to keep the piers at the river mouth in centre frame, but it is not possible to achieve this effect manually or in post-production. We adapted software to make GPS control the camera zoom, matching the speed of the vessel precisely using Red One digital technology. GPS tracks were recorded during filming, day and night.



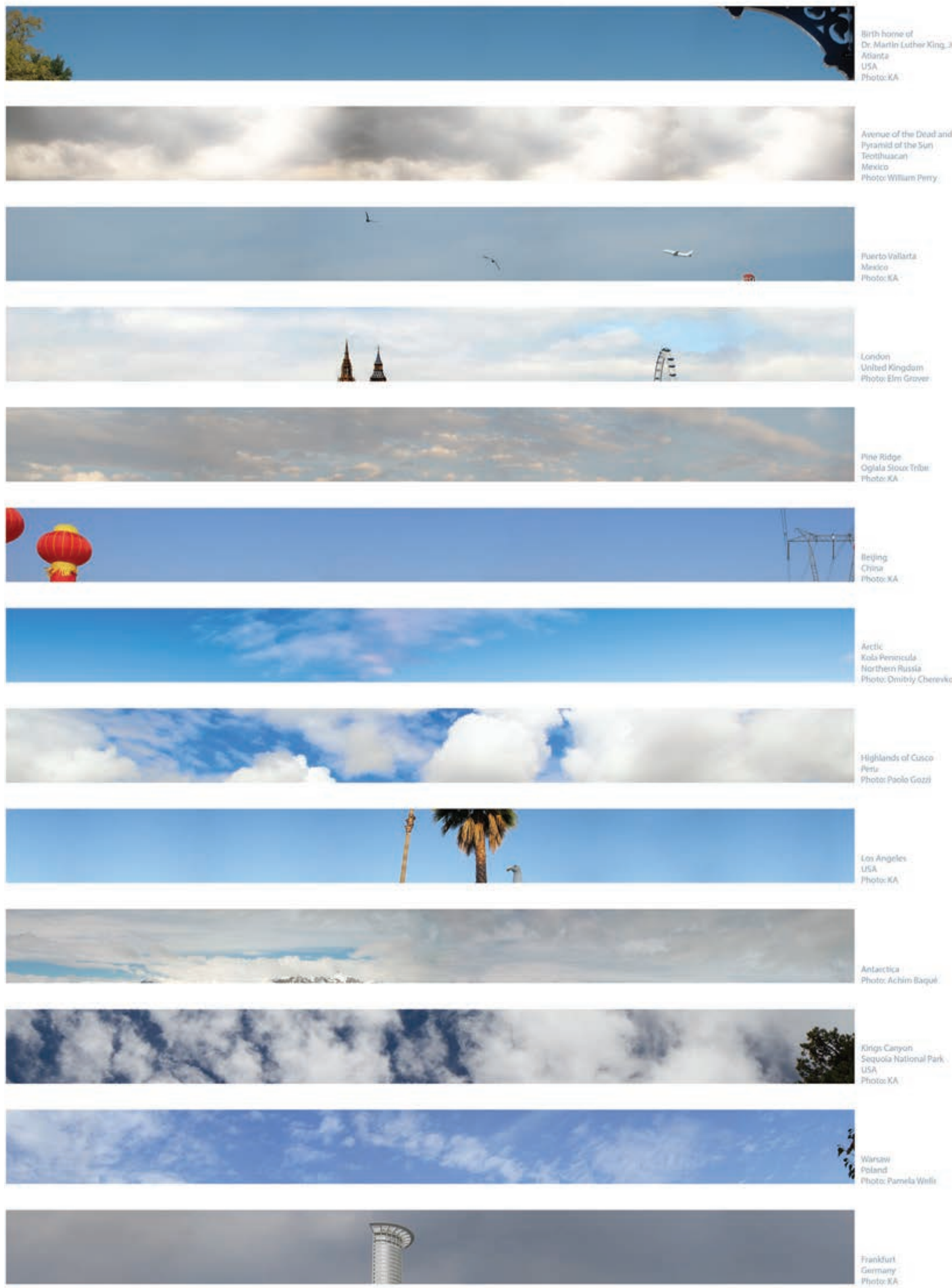
Sonar scan of riverbed, © 2011 Barbara Keating.

Shared Skies (13 global skies)

Kim Abeles
Abeles Studio
kimabeles@earthlink.net

shared-skies.org

Kim Abeles



Shared Skies, © 2012 Kim Abeles.

Shared Skies is a series of digital prints and sculpture using photographs of skies collected from four sources: my own journeys, artists who participate as they travel worldwide, international friends through social media, and some purchased from photographers through stock photo sites.

The work speaks to the connections among global, local, and personal. As people look toward the sky each morning, through the day and night, the sky speaks to their personal and local concerns. In a global sense, we observe the effects of our environmental decisions and find community through a seamless sky.

Shared Skies began as a permanent, large-scale artwork that I am creating for the new Anderson-Munger YMCA in Los Angeles. As part of the process to consider the implications of the idea, I started by making digital prints with groupings of 13 skies each. These are being produced by Sundog Multiples, a print atelier at the University of North Dakota. Each sky is identified with the location and the name of the photographer. For this ongoing series, there are currently hundreds of sky photographs from 38 countries and all the continents.

The project would not be possible without the networking that the internet provides. These skies can be requested and sent by anyone with a camera and access to a computer (public or private). The sky as a metaphor can be felt and understood by all.

Spatial Hyperlink

Wan-Ying Lai
Ming-Chang Wu
Shen-Guan Shih
National Taiwan University of Science and Technology
overture0927@gmail.com

Wan-Ying Lai, Ming-Chang Wu, Shen-Guan Shih

Spatial Hyperlink, © 2013 Wan-Ying Lai, Ming-Chang Wu, Shen-Guan Shih. Photo © 2013 Ming-Chang Wu.

Spatial Hyperlink, a telecommunications art installation, explores an ideal social interaction. The work encourages viewers' awareness of others' psychological states via speaking boxes through which images and sounds can be transmitted over unknown distances. Devices installed in different places become a giant communication network. Users are able to influence remote doors by opening their own. With each opening, the people and the scenes behind the doors become visible to people in other locations around the world.

Each door opening creates a unique experience, a personal assemblage made up of sounds and images created by interactions with the piece. In addition, the sounds of knocking and the user voices are anchored in space and attract passersby to come near and respond. Communications across remote distances are precipitated and accelerated when people happen upon the installation in action, creating a *Spatial Hyperlink*. The linking process itself consists not only of accumulating sounds and images, but also the users' exploratory behavior. Users can talk, smile, transmit a kiss, or just ignore the opportunity. In this way, a new kind of social interactive mode emerges the moment a knock on the door is answered.

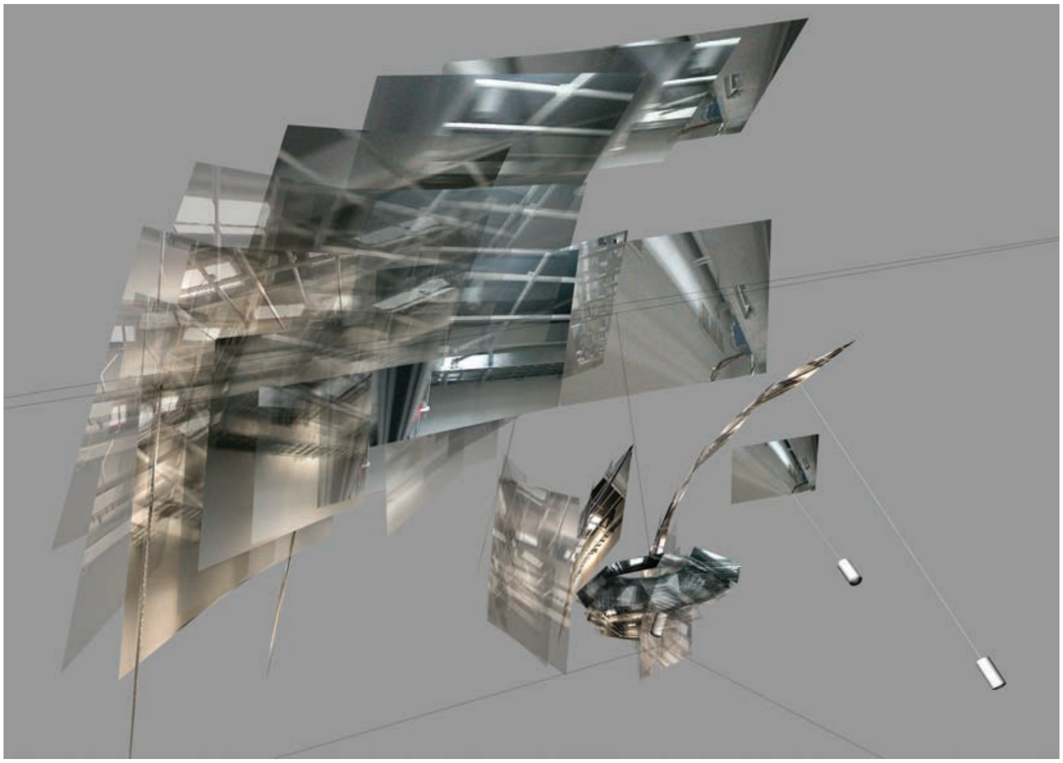
Spatial Hyperlink, © 2013 Wan-Ying Lai, Ming-Chang Wu, Shen-Guan Shih. Photo © 2013 Wan-Ying Lai.

Spatial Hyperlink, © 2013 Wan-Ying Lai, Ming-Chang Wu, Shen-Guan Shih. Photo © 2013 Ying-Torng Chen.

Swarm Vision

George Legrady
Marco Pinter
Danny Bazo
University Of California, Santa Barbara
legrady@mat.ucsb.edu

George Legrady, Marco Pinter, Danny Bazo



Swarm Vision, © 2013 George Legrady.

Swarm Vision is an installation consisting of multiple pan-tilt-zoom cameras on rails positioned above spectators in an exhibition space. Each camera behaves autonomously based on programmed rules of computer vision.

In the installation, four visualizations are featured on two screens or projections. The first screen features what each of the three cameras sees. The second screen shows a 3D reconstruction of the environment featuring a live video stream of the location of the cameras and the images they generate. Each camera continuously produces 10 still frames per second and fills the 3D space with up to 100 images per camera, their size and location determined by the focal plane and focus location. Early images fade away, creating a continuously changing sculptural structure.

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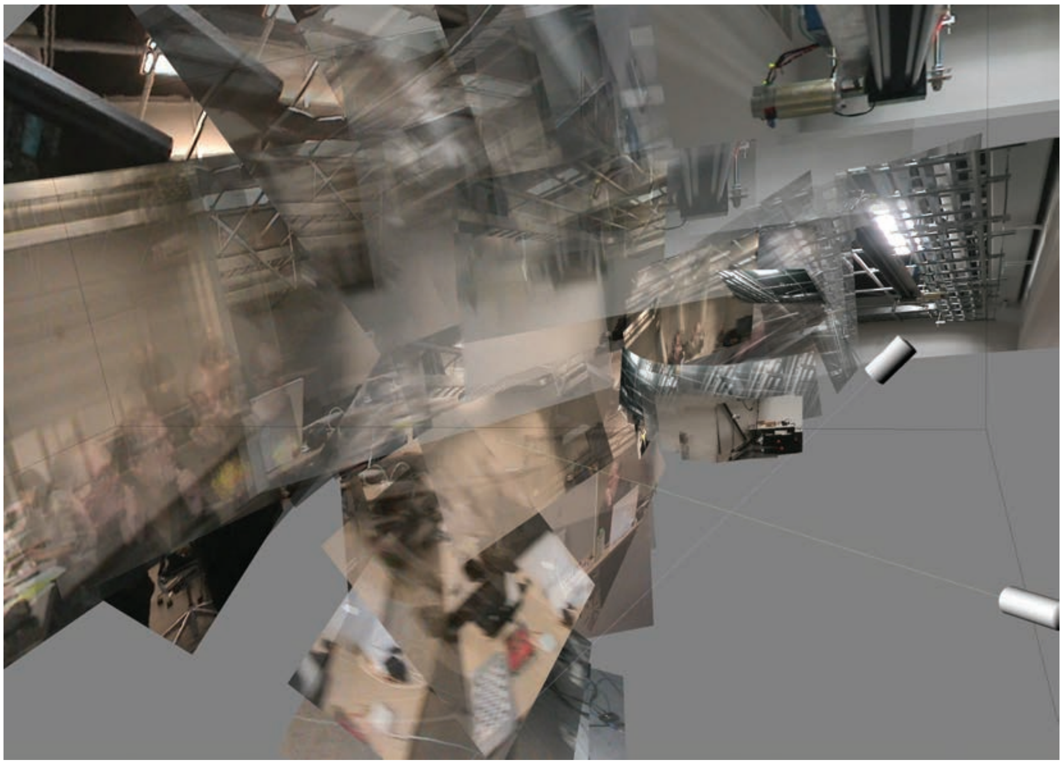


Swarm Vision, © 2013 George Legrady.

In the exhibition setting, visual segments of spectators who enter the viewing space populate the images, leaving an imprint of their presence that is later erased as the images sequentially fade away. With the two screens, viewers can perceive both individual cameras' behaviors (microcosmic) and their relationships to each other (macrocosmic). The project explores the transformative condition of the photographic process as it transitions from the still, transparent image to one that is reified within physical space.

The installation synthesizes knowledge and experience from the three collaborators to translate human perception and cultural usage of the photographic image to machine vision. Contributions from George Legrady address the function and our perception of photography. Danny Bazo's background in robotics, visual arts, and image processing helps realize many technical aspects of the project. Marco Pinter's extensive background in engineering, medical robotics, and research provides a logistic framework.

This Exquisite Forest

Aaron Koblin
Chris Milk
Google, Inc.
www.exquisiteforest.com

Aaron Koblin

This Exquisite Forest, ©2013 Google + Tate Modern.

Conceived by Chris Milk and Aaron Koblin and produced by Tate Modern and Google, *This Exquisite Forest* was inspired by the surrealist game "exquisite corpse" and its idea of collaborative creation. The project lets users create short animations that build off one another as they explore specific themes. The result is a collection of branching narratives resembling trees to which anyone may contribute. The project lives online and as a physical installation at the Tate Modern (through June 2013). At the museum, visitors can explore the project as a life-sized projection and contribute animations using high-end digital drawing tablets.

Our work is about exploring the line between a pre-determined experience and an open one. We're interested in thinking about how much freedom the viewer should have within the artwork. For example, in *This Exquisite Forest*, we give artists an open canvas to create any animation they like, but also the power to moderate and set rules for how that animation may evolve. Likewise, with *The Johnny Cash Project*, participants are given a single frame as a template, but then they are free to interpret that frame in any way they choose.

  | Leonardo, Vol. 46, No. 4, pp. 410–411, 2013

This Exquisite Forest, ©2013 Google + Tate Modern, Photo Tate Media.

We have tried a similar approach with interactive film. In *The Wilderness Downtown*, we let viewers change the experience by focusing it around their childhood homes using Google Maps and Street View. And with our fourth project, *Three Dreams of Black*, viewers can control the camera and create 3D sculptures that persist in the film for everyone to see.

New advances in web-browser technology have been at the core of each project. The web is intrinsically a great example of the SIGGRAPH 2013 Art Gallery theme. *This Exquisite Forest* is built around scale; it requires the participation of thousands of people to fulfill its goal of creating an evolving forest of animations.

Traces: Plankton on the Move

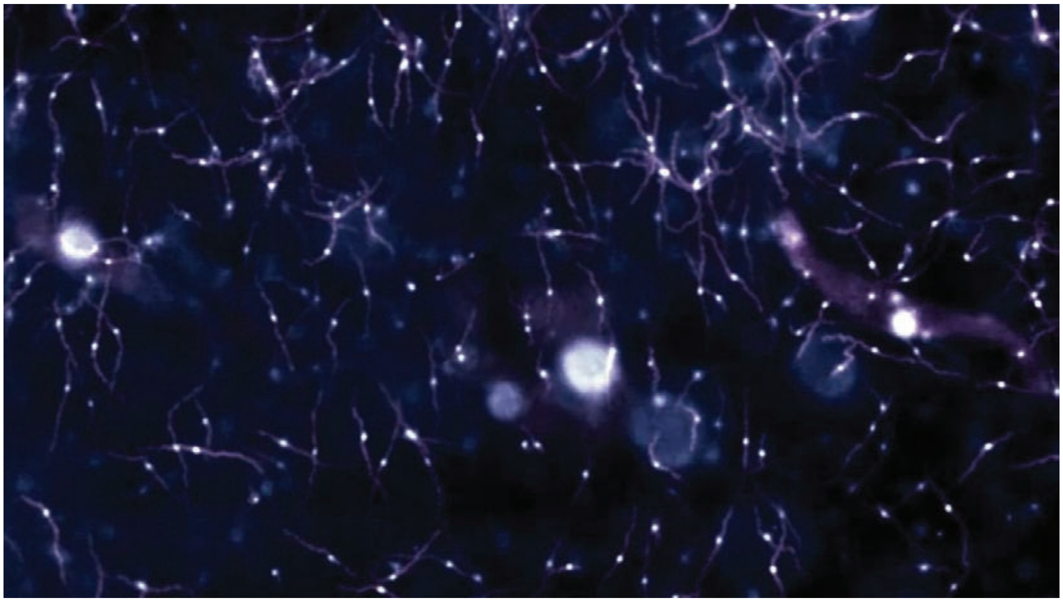
Cynthia Beth Rubin
C B Rubin Studio
rubin@siggraph.org
CBRubin.net

Susanne Menden-Deuer
University of Rhode Island
www.gso.uri.edu/smdlab

Elizabeth Harvey
University of Rhode Island
gso.uri.edu/elizabeth-harvey

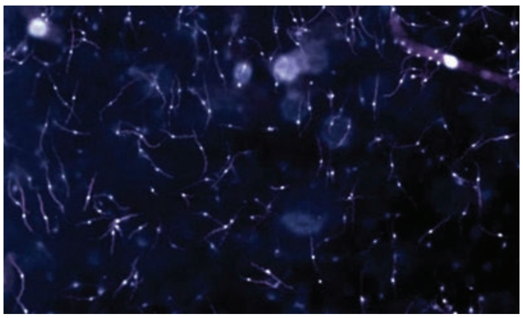
Jerry Fishenden
Independent Composer/Developer
fishenden.com

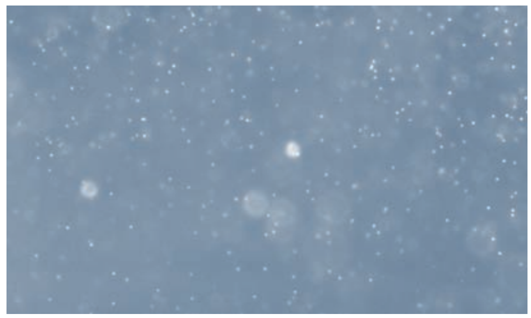
Cynthia Beth Rubin, Susanne Menden-Deuer, Elizabeth Harvey, Jerry Fishenden



Still from Traces: Plankton on the Move, © 2012 Cynthia Beth Rubin. Elizabeth Harvey, Susanne Menden-Deuer.

Traces is a collaboration between the artist Cynthia Beth Rubin and the Menden-Deuer Lab at the Graduate School of Oceanography, University of Rhode Island, which studies plankton, the microscopic marine creatures that comprise the most basic piece of our food chain. The original micro-captures are of specimens in small batches of water, devoid of any association with their native environment, and filmed in flat grays. In Rubin's transformation of the raw video, she imagines the plankton moving in water that is infinitely deep, making these mystical creatures leap beyond the confines of the microscopic world into an enticing world of color and movement that begs us to relate to them as part of nature. She does not just reveal the generally unseen life in our ocean waters; she makes it accessible.





Still from Traces: Plankton on the Move, © 2012 Cynthia Beth Rubin. Raw video by Elizabeth Harvey, Susanne Menden-Deuer

The scientific study of plankton motility was funded by the National Science Foundation (Biological-Oceanography Award 0826205 to S. Menden-Deuer).

The series grew from a practical concern. Researcher Elizabeth Harvey captured the image of a magical moment: an encounter between a predator, Favella, and its prey, Heterosigma akashiwo. The color balance of that image needed an artist's touch to come alive. From this scientifically accurate work, Rubin moved to bringing the same sense of imagination and wonder to the world of microscopic plankton that she has long explored in the world of imagined human memories. What does it take to make the depiction of a space feel real, inhabitable, and even familiar? How can we step out of our own world into the activity of the ocean?

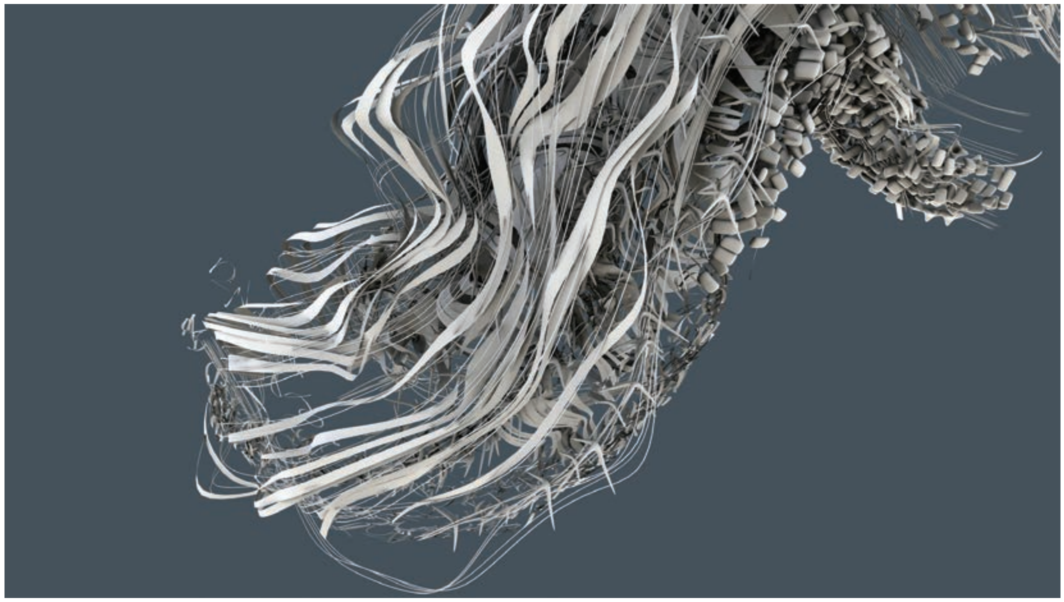
Technology makes this possible. From the digital capture of microscopic plankton to the ability to put these images into analytical and modifying video software, technology makes the intertwining of visual sources an avenue for exploration. At the outset, the artist spent weeks understanding the forms of the plankton, learning to relate to them, and generating variations of the video. The final colored version was selected in discussion with the scientists, balancing scientific and artistic focus. The sound score by Jerry Fishenden was composed specially to add classic drama to the video.

Visualizing Federal Spending

Rebecca Ruige Xu
Missouri State University
rebeccaxu@missouristate.edu

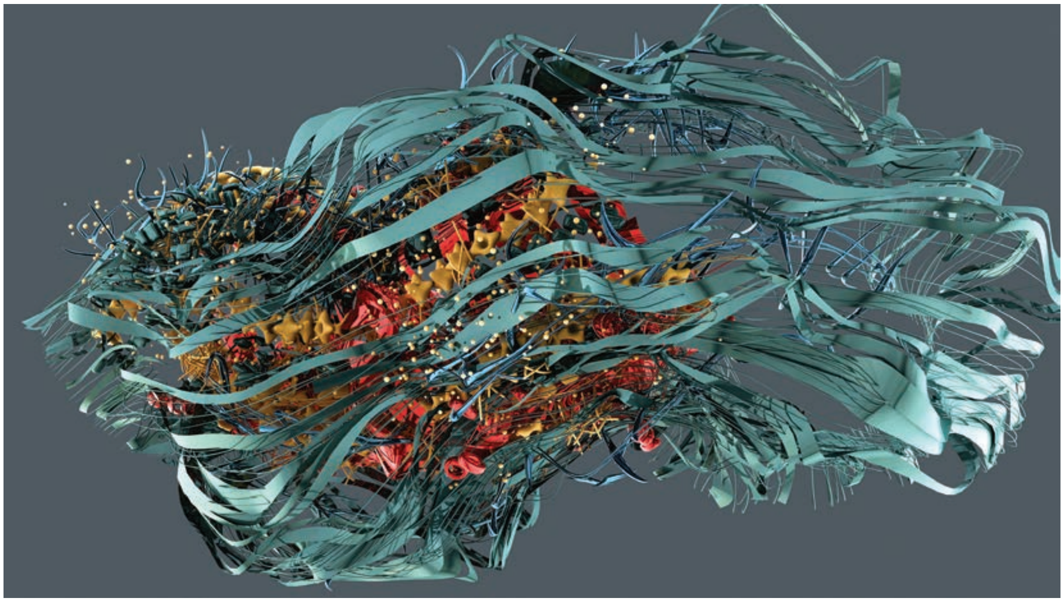
Sean Hongsheng Zhai
Red Dot Blue Square LLC

Rebecca Ruige Xu, Sean Hongsheng Zhai

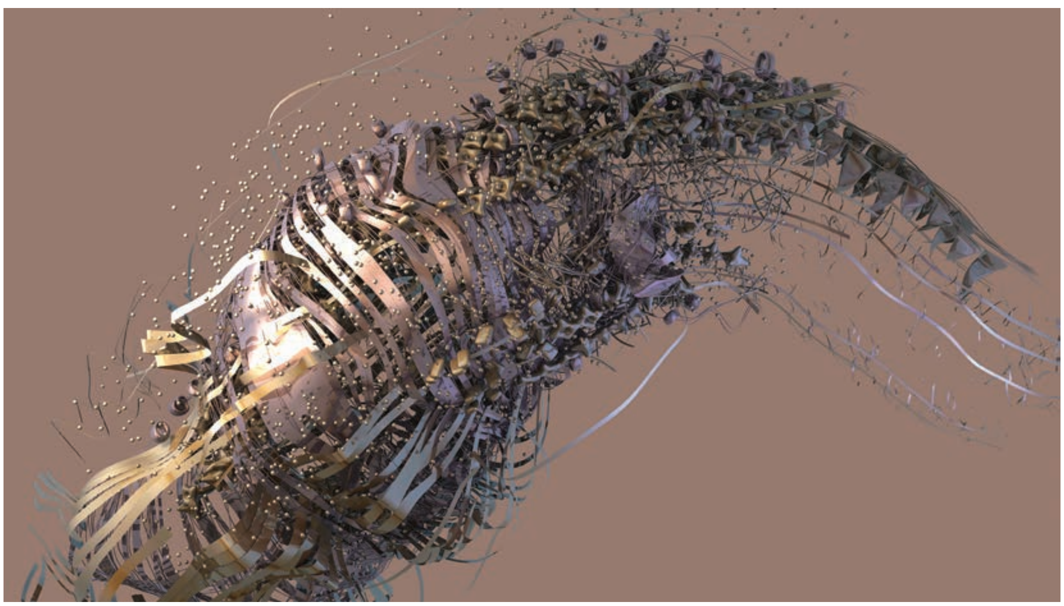


In this project we explore an aesthetics-oriented approach to visualizing federal spending in the United States as 3D compositions in a photorealistic style. Using procedural modeling with Python programming and Maya API, an organic flow of intermingled geometrical units is formed to represent the profile of federal spending for each state, loosely resembling the idea of money flow. The total amount of spending is scaled to a per capita basis to make different states comparable, while the overall surface area or volume occupied by each type of geometrical pattern represents its associated spending data.

With data provided by the Transactional Records Access Clearinghouse at Syracuse University, we analyzed federal spending by agencies and then mapped this data to distinguishable geometric patterns. Often, the shapes hint at what they represent: for example, leaf shapes for agriculture, spikes for military-related spending, cubes for housing, and torus (life buoys) for education. Unsurprisingly, top spending categories like social security and health and human services, seen as floating ribbon shapes, are dominant attributes for most states.



Visualizing Federal Spending, © 2012 Rebecca Ruige Xu, Sean Hongsheng Zhai.



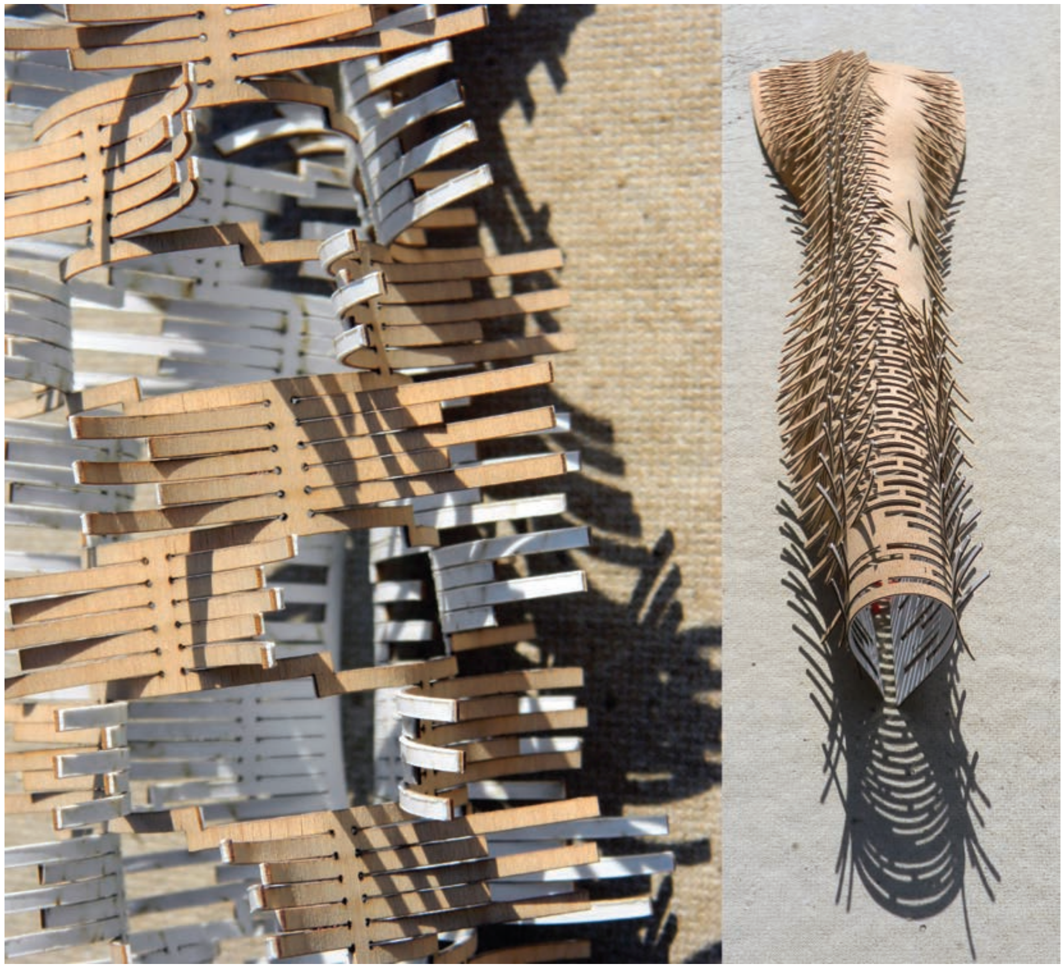
Visualizing Federal Spending, © 2012 Rebecca Ruige Xu, Sean Hongsheng Zhai.

To create an aesthetically sophisticated but not overwhelming presentation of the dataset, we further fine-tuned the per capita scales while maintaining the interrelation among different types of spending. Photorealistic rendering produces shadings with vivid nuances, endowing the geometries with a tangible quality and enhancing the sense of volume. The complicity of the output reflects the intricate nature of the subject and allows more exploratory freedom for viewers to observe and then make their own sense of the embedded information. We also hope this project will stimulate further research on the topic of federal spending.

Water Columns

Mark Weston
University of South Florida
mw@usf.edu

Mark Weston

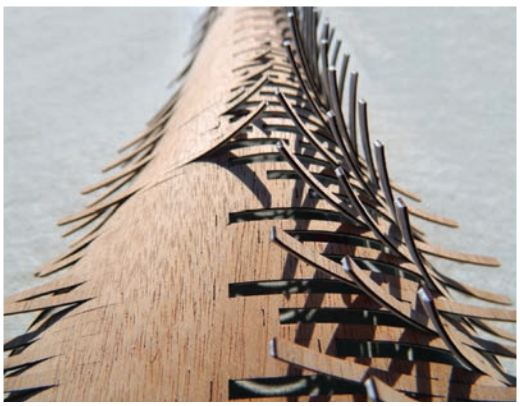


Water Columns, © 2012 Mark Weston.
Photo Dan Greenberg.

Water Columns consists of three extremely lightweight, passively actuated kinetic sculptures that take advantage of the relative tendency of wood to absorb moisture from the atmosphere to create passive engines for actuation of a long array of bi-laminate filaments. The sculptures change shape over the course of the day as relative humidity rises and falls with the ambient temperature.

  | Leonardo, Vol. 46, No. 4, pp. 416–417, 2013

This project iterates error. It is evident in natural systems that specific situations demand specific solutions. These solutions do not emerge in perfection, but instead derive from eons of accidents. Similarly, the iterative nature of digital design allows us to rapidly create and discard innumerable virtual notions in an almost time-lapse analog of biological evolution. We can instantly amass manifold errors, find the singular best mistake, and repeat it forever unto perfection. In the massive potential scale of these deliberate derailments hides an equally massive potential for making nonsense, and therein lies the knuckleball.



Water Columns, © 2012 Mark Weston. Photo Dan Greenberg.

Water Columns, © 2012 Mark Weston. Photo Dan Greenberg.

Perfecting the forced error with computers requires an art that can balance knowledge and technique against measured carelessness, with a willingness to repeatedly miss central goals until fresh opportunities re- form at the fringes. As the contemporary practice of architecture continually seeks such fresh economies in computer modeling and digital fabrication, it becomes possible to produce a modern architecture that leverages these techniques to reintroduce handmade material quality to the stark modernist conception of space-making. This new material saturation cannot, however, be allowed to stagnate into decadence; the ecological problems stemming from our messy habitation of earth force us to acknowledge that too much is at stake. This suggests, therefore, a process that foresees the creation of buildings that possess a saturated material character by virtue of the use of performative, intelligent materials that blur the boundary between beauty and pragmatism.

From these ideals emerges a multi-disciplinary practice, combining experimental materials, digital fabrication, and physical computing with traditional notions of making in order to generate interactive and complex physical environments. The goal of *Water Columns* is to re-situate architecture between art, construction, environment, and activism, where work is conceived in a constant, non-linear interplay between hand-making, computer modeling, computer simulation, and CNC tooling.

Leonardo Network News

The Newsletter of the International Society for the Arts, Sciences and Technology and of l'Observatoire Leonardo des Arts et Technosciences

To contact Leonardo: *<isast@leonardo.info>*

ON-LINE ACCESS TO JUST ACCEPTED ARTICLES

Leonardo Just Accepted is a new publication mechanism for rapid access to articles recently accepted for publication in Leonardo. Select articles accepted for publication will be posted unedited on the MIT Press web site as Leonardo Just Accepted approximately a year before appearance in the print journal. Articles recently posted as Leonardo Just Accepted include "The Logic of Color: Theory and Graphics in Christine Ladd-Franklin's Explanation of Color Vision," by Jeremy Kargon; "Ten Questions Concerning Generative Computer Art," by Jon McCormack, Oliver Bown, Alan Dorin, Jonathan McCabe, Gordon Monro, and Mitchell Whitelaw; and "Open Source Architecture: An Exploration of Source Code and Access in Architectural Design," by Theodora Vardouli and Leah Buechley. To access Leonardo Just Accepted articles, visit <www.mitpressjournals.org/toc/leon/0/ja>.

LEONARDO AFFILIATE MEMBER: THE INTERNATIONAL GRADUATE CENTRE FOR THE STUDY OF CULTURE AT JUSTUSLIEBIG-UNIVERSITÄT GIESSEN

Leonardo/ISAST welcomes the International Graduate Centre for the Study of Culture at JustusLiebig-Universität Giessen (JLU GCSC) to the Leonardo Affiliate Program. The Centre offers a doctoral program tailored to the needs of Ph.D. students, with an excellent research environment and the support that students need in order to excel in their academic as well as non-academic careers. The GCSC's academic framework reflects a pluralistic understanding of the study of culture. JLU aims to enhance dialogue among the disciplines, to foster self-reflexive, interdisciplinary and international approaches to the field and to promote these insights. See <www.leonardo.info/isast/affiliate-members.html> for further information.

NEW FROM THE LEONARDO BOOK SERIES

***Illusions in Motion*, by Erkki Huhtamo.** Beginning in the late 18th century, huge circular panoramas presented their audiences with resplendent representations that ranged from historic battles to exotic locations. Such panoramas were immersive but static. There were other panoramas that moved—hundreds, and probably thousands, of them. Their history has been largely forgotten. In *Illusions in Motion*, Erkki Huhtamo excavates the neglected early manifestation of media culture in the making. For more information see: <www.leonardo.info/isast/leobooks/huhtamo.html>.

***The Fourth Dimension and Non-Euclidean Geometry in Modern Art*, by Linda Dalrymple Henderson.** In this groundbreaking study, first published in 1983 and unavailable for over a decade, Linda Dalrymple Henderson demonstrates that two concepts of space beyond immediate perception—the curved spaces of non-Euclidean geometry and, most important, a higher, fourth dimension of space—were central to the development of modern art. See <www.leonardo.info/isast/leobooks/henderson.html>.

LABS REVIEW PANELISTS, 2013

Leonardo Abstracts Service (LABS) has named its review panelists for 2012–2013. The panelists are: Yiannis Colakides, co-director of NeMe (New Media), Limassol, Cyprus; David Familian, artistic director of the Beall Center for Art and Technology at University of California Irvine, Irvine, California; Tom Leeser, Program Director of the Art and Technology Program in the School of Art and the Director of the Center for Integrated Media at the California Institute of the Arts, Valencia, California; Andrea Polli, Associate Professor of Fine Art and Engineering at the University of New Mexico Albuquerque; Edward Shanken, researcher at the Amsterdam School for Cultural Analysis at the University of Amsterdam (UvA) and a member of the Media Art History faculty at Donau University in Krems, Austria; Charissa N. Terranova, Ph.D., Assistant Professor of Aesthetic Studies, School of Arts & Humanities, The University of Texas at Dallas; and Shawn Decker, Professor in the Art and Technology Department and the Sound Department at the School of the Art Institute of Chicago.

LABS, consisting of an English-language database, Spanish-language database and French-language database, is a comprehensive collection of Ph.D., Master's and MFA thesis abstracts on topics at the intersection of art, science and technology. Individuals receiving advanced degrees in the arts (visual, sound, performance, text), computer sciences, the sciences and/or technology that in some way investigate philosophical, historical or critical applications of science or technology to the arts are invited to submit abstracts of their theses for consideration.

The LABS project does not seek to duplicate existing thesis databases but rather to give visibility to interdisciplinary work that is often hard to retrieve from existing databases. Abstracts are reviewed for inclusion in the LABS databases twice a year (30 June and 31 December). The databases include only approved and filed thesis abstracts. Authors of the abstracts most highly ranked by the panel are invited to submit articles for publication in the *Leonardo* journal. See <http://leonardo.info/isast/LABS.html> for more information.

YONA FRIEDMAN'S IDEAS FOR SELF-RELIANCE POSTED ONLINE

A website about the life and work of architect and Leonardo Honorary Editor Yona Friedman (b. 1923) has been published on the Net. The website includes a biography, an extensive bibliography and over 1,000 images, organized by themes and projects, with brief introductions. Yona Friedman is internationally known for his work based on his controversial thinking and reasoning. In the last 10 years, his work has regained worldwide attention through numerous publications and exhibitions and has become an object of study in the arts, sciences and sociology. For more information: <www.yonafriedman.com/>.

Leonardo, The International Society for the Arts, Sciences and Technology

Leonardo/ISAST Headquarters
211 Sutter Street, Ste. 501
San Francisco, CA 94108, U.S.A.
Tel: 415-391-1110
Fax: 415-391-2385
E-mail: <isast@leonardo.info>
Web: <leonardo.info>

Leonardo Music Journal
E-mail: <lmj@leonardo.info>
Web: <leonardo.info/lmj>

Association Leonardo
8, rue Émile Dunois
92100 Boulogne Billancourt, France
E-mail: <info@olats.org>
Web: <www.olats.org>

Leonardo Book Series
211 Sutter Street, Ste. 501
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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.html>
E-mail: <isast@leonardo.info>

Affiliate memberships also available for non-profit organizations, educational institutions and corporations working at the intersection of art, science and technology.

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

Print 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 CD is published annually. *Editor-in-Chief:* Nicolas Collins.

World Wide Web
The Leonardo On-Line web site (www.leonardo.info) publishes organizational information, the Leonardo Electronic Directory and more. *Managing Editor:* Patricia Bentson.

Electronic Journal
Leonardo Electronic Almanac (leoalmanac.org) 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. *Co-Editor:* Ozden Sahin.

Leonardo Reviews
The Leonardo Reviews Project, through a panel of reviewers, publishes reviews of relevant books, journals, electronic publications and events. Reviews are published on the Web (leonardo.info/ldr.html), and selected reviews are published in *Leonardo Electronic Almanac* and in *Leonardo*. *Editor-in-Chief:* Michael Punt.

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

Labs Databases
Databases of master's and Ph.D. theses.
English LABS: <leonardolabs.pomona.edu>; *Coordinator:* Sheila Pinkel.
Spanish LABS: <www.uoc.edu/artnodes/leonardolabs>; *Coordinator:* Pau Alsina.
French LABS: <francolabs.univ-paris1.fr>; *Coordinator:* Annick Bureaud.

AWARDS

Frank J. Malina Leonardo Award for Lifetime Achievement recognizes eminent artists who through a lifetime of work have achieved a synthesis of contemporary art, science and technology. Winners include Gyorgy Kepes, Nicolas Schöffer, Max Bill, Takis and Abraham Palatnik.

Leonardo Award for Excellence recognizes excellence in articles published in Leonardo publications. Winners include Rudolf Arnheim, Otto Piene, Charles Ames, Frieda Stahl, Donna Cox, Janet Saad-Cook, George Gessert, Alvin Curran, Karen O'Rourke, Eduardo Kac, Hubert Duprat with Christian Besson, José Carlos Casado with Harkaitz Cano, Bill Seaman, Arthur Elsenaar with Remko Scha, and Steve Mann.

Leonardo New Horizons Award for Innovation is given to individuals or groups for innovation in new media. Winners include Critical Art Ensemble, Gregory Barsamian, Graham Harwood, Evelyn Edelson-Rosenberg, Jean-Marc Philippe, Jaroslav Belik, Peter Callas, Patrick Boyd, Christian Schiess, Kitsou Dubois, I Wayan Sadra, and Ewen Chardronnet.

Makepeace Tsao Leonardo Award recognizes organizations or groups that have increased public awareness of art forms involving science and technology, particularly through exhibitions. The first award was given to La Cité des Arts et Nouvelles Technologies de Montréal.

Leonardo Global Crossings Award recognizes excellent work by international artists, professionals and scholars in the globally emerging art-science-technology field. Winners include Abdel Ghany Kenawy and Amal Kenawy (Cairo, Egypt) (2005).

Leonardo-EMS (Electroacoustic Music Studies) Award for Excellence is awarded for the best contribution to the EMS symposium by a young researcher, as decided by a joint jury. Winners include criticalartware (Jon Cates, Ben Syverson and Jon Satrom) and Michael Bullock (2008).

Leonardo Art Science Student Contest Award is a juried award for student work selected from projects received through an open submission process. The first Leonardo Art Science Student Contest award (2008) was given to Hiroki Nishino, Michiko Tsuda, Jaewook Shin, Byeong Sam Jeon, Margarita Benitez and Markus Vogl.

The Leonardo Scholarship for Media Art Histories, a collaborative project between Leonardo/ISAST and the Department for Image Science (Danube University), awards a juried half-tuition scholarship for the Master of Arts (MA) course in MediaArtHistories at Danube University to a candidate who demonstrates the potential to contribute to the new field of Media Art Histories in this time of critical worldwide challenges. The first scholarship has been awarded to Fran Ilich Morales Muñoz (2010).

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 Multimedia
- ACM SIGGRAPH
- Ars Astronautica
- Artnodes (Spain)
- Association Leonardo (France)
- College Art Association (USA)
- Creativity and Cognition Studios, University of Technology Sydney (Australia)
- Donau University (Austria)
- Electronic Music Foundation (USA)
- Fondation Langlois Research Documentation Center (Canada)
- MIT Press (USA)
- Pomona College (USA)
- School of the Art Institute of Chicago (USA)
- The University of Plymouth (UK)
- Sabanci University (Turkey)

For more information, please visit <leonardo.info/collablist.html>.

LEONARDO PROJECT WORKING GROUPS

Leonardo hosts working groups on projects with a topical focus:

Cultural Roots of Globalization (FCM) Editorial Committee
Mark Beam, Annick Bureaud, Steve Dietz, Marina Grzinic, Roger Malina, Yukiko Shikata.

Leonardo Education and Art Forum (LEAF)
Adrienne Klein, *chair*; David Familian, *incoming chair*. See <www.leonardo.info/isast/LEAF.html> for more information.

Leonardo Space Arts Working Group
Annick Bureaud, Richard Clar, Roger Malina, Jean-Luc Soret, Arthur Woods.

Lovely Weather: On the Cultural Context of Climate Change Editorial Committee Ramon Guardans, Annick Bureaud, John Cunningham, Andrea Polli, Janine Randerson, Jacques Mandelbrojt, Drew Hemment.

Scientists' Working Group Tami Spector, *chair*; Piero Scaruffi, Roger Malina, Robert Root-Bernstein.

Artists and Scientists in Times of War Working Group
Michele Emmer, Sheila Pinkel, Ana Peraica, Randall Packer, Roger Malina.

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/isast/org-membership.html> for more information.

Affiliate Members Arizona State University Art Museum; Australian Network for Art and Technology; CalArts|California Institute of the Arts; De Montfort University, Institute for Creative Technologies; Danube University, Department of Image Science; Emily Carr University of Art & Design; Ontario College of Art & Design; Plymouth University; Pomona College; School of the Art Institute of Chicago, Master of Fine Arts in Sound; School of Visual Art MFA Computer Art Dept.; UCLA; Art|Sci Center; Universidad Autonoma de Occidente, Engineering Dept.; University of Calabria, Evolutionary Systems Group; University of Caldas, Arts & Humanities; University of San Francisco, College of Arts and Sciences; University of Technology, Sydney, Creativity & Cognition Studios; University of Texas at Dallas, Arts and Technology.

LEONARDO/ISAST BOARDS AND COMMITTEES

Classified Advertisements

GET THE WORD OUT

Announce a job opportunity, new project, publication or upcoming event to Leonardo's targeted community.

Option 1: classified ad in print journal
Present a short, text-only message to *Leonardo and Leonardo Music Journal* subscribers. *Leonardo* is published bi-monthly and *LMJ* is published annually.

Option 2: classified ad in email newsletter and on web
If you want to get the word out far and fast, you can present your message to the Leonardo community in the Leonardo Network Newsletter. Your ad will also be posted on the Leonardo On-Line website.

Option 3: display or full page ad in print journal
If your ad includes graphics, you can place a display ad or a full-page ad in *Leonardo or Leonardo Music Journal.*

For rates, schedule deadlines and payment options, visit: <leonardo.info/isast/placeads.html> or email the Leonardo Editorial Office: <ads@leonardo.info>.

Leonardo/ISAST members will receive a 20% discount!

SONYA RAPOPORT'S IMPOSSIBLE CONVERSATIONS?, FRESNO ART MUSEUM, 17 MAY–1 SEPT 2013.
ImPOSSIBLE CONVERSATIONS? is a new interactive project that invites viewers to participate in a simple matching experiment under controlled conditions. The results of this experiment will become part of the work exhibited at the museum. ImPOSSIBLE CONVERSATIONS? is structured on Alvin Roth and Lloyd Shapley's Marketing Design and Matching Theory, which won the 2012 Nobel Prize in Economics. This theory explores how people, institutions and companies select each other to create stable matches. The work takes the form of a series of collages: Each consists of a black-and-white photograph of a pattern and design painting that Rapoport created and exhibited in the late 1960s, combined with a contemporary newspaper advertisement and juxtaposed with a short text appropriated from the media. The project merges art with economic science, illustrating both centralized (controlled) and de-centralized (random) mechanisms for matching, while encouraging exhibition visitors to interact with her composite artworks. More information is at: <www.fresnoartmuseum.org>.

ERROR: GLITCH, NOISE, AND JAM IN NEW MEDIA CULTURES, edited by Mark Nunes, brings together established critics and emerging voices to offer a significant contribution to the field of new media studies, exploring the ways in which error can serve as a critical lens for understanding the principles of informatic control that govern our contemporary network society. By offering a timely and novel exploration into the ways in which error and noise "slip through" in systems dominated by principles of efficiency and control, this collection provides a unique take on the ways in which information theory and new media technologies inform cultural practice. For more information visit: <www.continuum books.com>.

REPRESENTATIONZ is a new blog covering how symbols, images and language affect our daily lives—from representation in art, science and culture to cryptic puzzles. The blog is run by Paul Fishwick and can be viewed on the web or via smartphone apps. Twitter and RSS feeds are available. See <www.representationz.com> for more details.

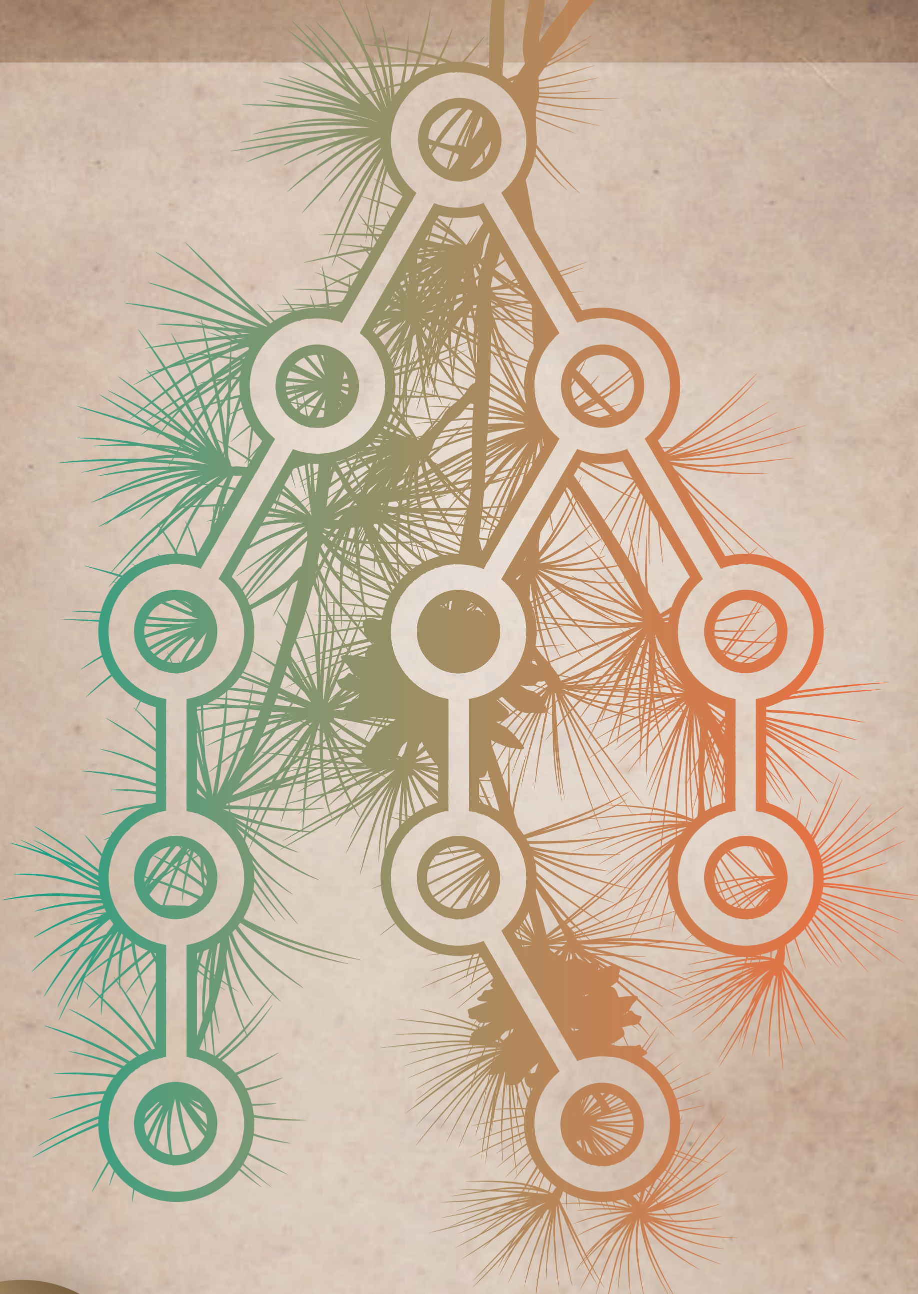
THE DIATROPE INSTITUTE has partnered with Amazon.com to create an online bookstore specializing in art, science and technology titles. Our stock includes both new and used items. We will also search for and special order hard-to-find books in the field. Please visit us at <www.diatropebooks.com>. For more information e-mail us at <info@diatropebooks.com>.

THE THURSDAY CLUB. An open forum discussion group for anyone interested in the theories and practices of cross-disciplinarity, interactivity, technologies and philosophies of the state-of-the-art in today's (and tomorrow's) cultural landscape(s). Originally set up in October 2005 by GDS, the Club has grown to include 300 members: artists, technologists, scientists—in fact, a growing diversity of people from different communities worldwide who are connected via a mailing list and online forum. Organized and supported by the Goldsmiths Digital Studios (GDS) and the Goldsmiths Graduate School, Goldsmiths, University of London, U.K. <www.thethursdayclub.net/>.

CHUA's CIRCUIT WEBSITE. The Evolutionary Systems Group (ESG) presents CHUA's CIRCUIT <http:// 160.97.10.253/chuaweb/>, collecting Chua's different Attractors, videos, music, sound and animations. The website shows new forms of digital art and has as starting point six papers with the title "The Gallery of Chua's Attractors," published in six consecutive issues, since January 2007, in the International Journal of Bifurcation and Chaos. The six papers, together with a CD-ROM containing music from Chaos, have become a book with the same title. An experimentation with high school students on chaos is the main focus of this site.

MASTER OF RESEARCH IN COMPUTER MUSIC. The computer is becoming increasingly ubiquitous in all aspects of music. The new MRes in Computer Music at the University of Plymouth (UK) provides an exciting opportunity to pursue a research project of your choice while enhancing your career with a post-graduate academic qualification. Projects range from the development of music technology to musical practice using computers. The training conveys skills necessary to progress to more advanced research towards a Ph.D. The course is delivered in the context of the Interdisciplinary Centre for Computer Music Research (ICCMR). For more information, please contact Eduardo Miranda <eduardo.miranda@plymouth. ac.uk>.

THE CONCEPTUAL INFORMATION ARTS (CIA) PROGRAM AT SAN FRANCISCO STATE UNIVERSITY'S ART DEPARTMENT stresses experimental art at the juncture of science, technology and culture, offering both BA and MFA degrees. Contact Paula Levine. Website: <userwww. sfsu.edu/~infoarts/>. Tel: (415) 338-2291.



Author/Artist Index