Special Section

Transactions

Editor: Ernest Edmonds

In this issue we are pleased to present the first installment of the new *Leonardo* section ***Transactions***, edited by Ernest Edmonds of Creativity and Cognition Studios in Sydney, Australia.

Transactions, in the print and on-line versions of *Leonardo*, publishes short refereed papers and provides a fast track to publishing key new results, ideas and developments in practice. Many scientific communities offer publishing opportunities such as these, but until now they have not existed in our community. These vehicles are valuable to young researchers, in particular to Ph.D. students in the later part of their studies. Practicing artists are encouraged to report on new work and new concepts through Transactions.

Papers are solicited matching the stated aims and scope of *Leonardo*, but restricted to two pages of published material. A fast refereeing process is employed in which the result is restricted to "accept" or "reject."

The announcement of results or developments in a Transactions paper will not exclude that work from subsequent publication in a full *Leonardo* paper; however, any such submission will be considered by *Leonardo* in the normal way, as a new paper.

Papers should be submitted electronically in final camera-ready form at <www.leonardo-transactions.com>, where formatting instructions and a template may be found.

Associated with Transactions is a soon-to-be-launched open electronic database of new work, ***Research Announcements***. This will be a moderated web site that makes submitted Transactions papers available, with the author's agreement, from the date of receipt by the editor. Other announcements of research results and new practice may also be included.

Transactions will from time to time make calls for papers in specific areas. These announcements will not be exclusive; quality submissions on other topics will always be welcome.

The first Call for Papers is for contributions that address one of the following two areas: (1) The impact of the interactive arts on audience experience; (2) New art practice that also advances science or technology.

Special thanks to our Transactions reviewers: Paul Brown, Computer Arts Society; Dave Burraston, Creativity and Cognition Studios; Linda Candy, University of Technology, Sydney; Sean Cubitt, University of Melbourne; Ross Gibson, University of Technology, Sydney; Sue Gollifer, University of Brighton; Janis Jeffries, Goldsmiths College, University of London; Mary Lou Maher, National Science Foundation, USA; Lev Manovich, University of California, San Diego; Eduardo Miranda, University of Plymouth; Bonnie Mitchell, Bowling Green State University; Kumiyo Nakakoji, University of Tokyo; Frieder Nake, University of Bremen; Jack Ox, University of New Mexico; Doug Riecken, IBM; Cynthia Beth Rubin, Rhode Island School of Design; Stephen Scrivener, Chelsea College of Art and Design; Jeffrey Shaw, University of New South Wales; Mike Stubbs, FACT Liverpool.

Interactive Experience in Public Context: *Tango Tangle*

Zafer Bilda, Australasian CRC for Interaction Design, Creativity and Cognition Studios, UTS, PO Box 123 Broadway, 2007 NSW, Australia E-mail: zafer@it.uts.edu.edu.

In this paper I describe a pilot field study which involved evaluation of audience experience of an interactive artwork situated in a large open public space. This pilot is part of a larger project where the aim is to install a series of interactive works in Federation Square, Melbourne, Australia over a one year period. A key element of the project is to evaluate audience engagement with the works. Level of engagement with an interactive artwork depends on various factors such as aesthetic satisfaction, and how the audience constructs meaning, pleasure and enjoyment. Evaluating such experiences remains an open research problem.

The first work in Federation Square, *Tango Tangle* (Fig. 1), was made by the artist Ernest Edmonds and installed for a single session, providing an opportunity for a pilot audience experience study and feasibility test prior to detailed planning for the next stages of the project. It is anticipated that later installations will include multiple distributed screens, using urban screens in Australian and overseas cities.

Tango Tangle is concerned with color and sound, in time and through interaction with its environment. The work takes account of the sounds around it, sometimes directly, sometimes indirectly. It explores ambient influences on its own and on people's behavior. The screen shows various numbers of colored stripes and both the width of the stripes and the color set used change in response to sounds (Fig. 2). The work was driven from a microphone placed in the square and passers-by will be invited to talk or sing to the screen by one of the evaluators. If they agreed, they were video taped and briefly interviewed afterwards.

Method

Field observation involves watching people in the environment in which they would normally experience a product/system/artwork. In this approach the investigator directly observes and video records the interactions of the users/audiences rather than relying on participants' reports. The real context in which the artwork is experienced can give a greater degree of ecological validity and understanding of situated experience than investigations in the somewhat sterile environment of the laboratory. For the same concerns my research group has emphasized the concept of "Living Laboratory" [1-3].

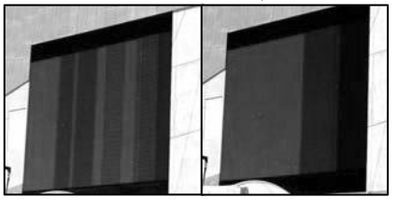
Tango Tangle was installed on a Mini Mac connected to and displayed on the big screen in Federation Square, Melbourne. The colors and the width of the bands change with different volume, pitch and rhythm of the sounds. The input device was a wireless microphone which was mobile and carried in the hands of people in the Square.

Two evaluators were located in a central spot in Federation Square, in front of the screen to ask people passing by to participate in a research study and try out what was going on on the big screen. They were not told that this was an interactive media, or an artwork. Participation was voluntary, and evaluators noted down people's responses and their reasons for not participating.

Participants willing to participate were given the wireless microphone to hold on to and were prompted to speak or sing to the microphone while they look at the screen. They were allowed to freely use the microphone. When a participant asked a question the evaluators answered their question. Some of the questions were "What is this for?" "What should I do?" "Is there a reaction to my voice?" In cases where participants were willing to explore more ways of interacting with the screen, they were encouraged to change the tone and volume of their voice. A participant's engagement with the work finished when s/he mentioned s/he had had enough.

I asked each participant whether s/he would be willing to be briefly interviewed. I designed this interview as a semi-structured one, to cover a central set of issues identified through consulting the artist. I explained to each participant that the video/audio recordings will be used for research purposes, then I took them to another spot set up for video recording. In cases where a participant did not want to be seen on camera, I recorded audio-only interviews.

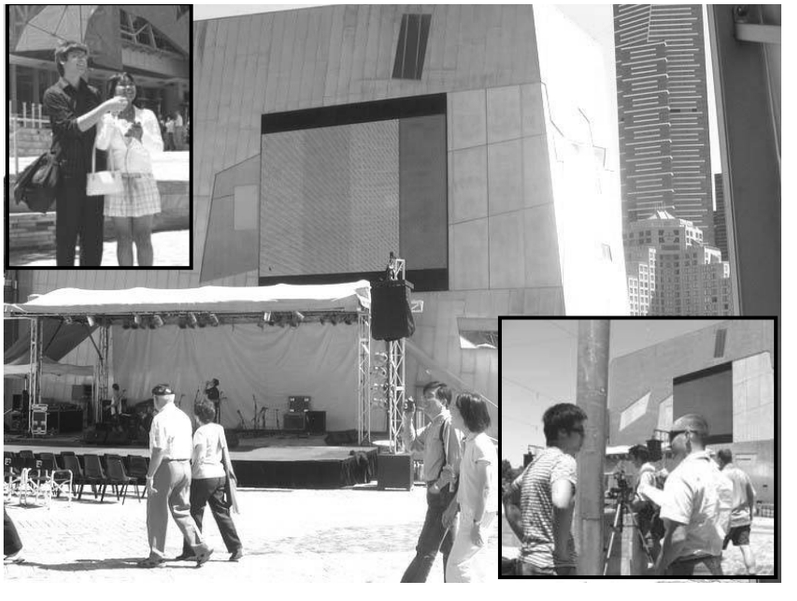
Fig. 2. Ernest Edmonds, *Tango Tangle,* changing colors on screen. (© Ernest Edmonds. Photo © Zafer Bilda.)



Results

Out of 43 people invited to participate, 20 accepted to participate. From the remaining 23 people, 13 stated they were busy or in a hurry, 6 stated no reason, three of them did not want to be involved once they were asked to speak to the microphone, one stated she was too old for it.

Fig. 1. Ernest Edmonds, *Tango Tangle,* computer-controlled public installation with microphones and LED display, display screen 25 x 25 meters, 2006. (© Ernest Edmonds. Photo © Zafer Bilda.) (a) A couple interacting with the artwork. (b) Interviewing a participant.



Out of 20 participants (8 female, 8 male, 2 couples) who all spoke to the microphone, one female participant preferred to sing a little song. Four participants were in the 40+ age group, one participant was in 0-20 age group, the remaining 15 participants were in the 20-40 group. Average duration of participants' engagement was 59 seconds, with a standard deviation of 40 seconds.

Out of the 20 participants engaging with the work, I gathered interview data for 15 of them. How participants responded to the interview questions are summarized below:

1. Can you please describe what happened when you started speaking/ singing to the microphone?

All interviewed participants stated they noticed the change of colors and the width of the color bands on the screen as they spoke to the microphone.

2. What changes did you notice on the screen?

All participants referred to the interaction between sound/voice and changes on the screen.

3. What did it make you think of?

Tango Tangle made the participants think of sound waves, sunshine and the horizon, happiness, liveliness, a festive and party feel, some rhythm and music and discotheque. One of the participants thought of her similar past artwork experience in London, one participant wondered whether his emotions while he spoke were mapped with the colors, and another one stated he became self conscious and thought he was being monitored. Four of the interviewed participants stated that nothing or not much came to their mind about the experience.

4. What did you think it was about?

When the participants were asked what the whole experience was about, 9 of the 15 participants stated that it was related to interactive media. Three participants referred to their previous experiences with other similar interactive works. One participant thought it was a commercial and that the words would come up as she kept on looking at the screen. Two participants thought it was a highly self-conscious experience. Two participants thought it was a test of how colors map to emotions and how people react to colors, one participant thought that it was a trial of a new technology; another participant thought it was an ambient display.

5. Can you imagine this installation being in other contexts? What would the contexts be?

The responses were quite similar among participants: that it could be in an open space public context as they see currently, e.g. in shopping malls, sporting events, rock concerts, nightclubs, restaurants or dancing halls where high level of sound or music were involved. Three participants stated that they would have engaged more comfortably if it was in a museum/art gallery context, and that they would prefer an enclosed space with a feeling of an individual experience rather than an open and social one.

6. How do you think this experience can be improved?

Seven out of 15 interviewees stated they needed more guidance in terms of cues and prompts as to how they may interact with the work differently. These participants also mentioned that they felt shy or intimidated when they were asked to speak/sing to the microphone or try out different voices. Two participants stated that the experience would be improved in an immersive/enclosed space, where there would be no interruptions from outside. Four participants thought that the image was too simple and more variety on the screen would make the experience better. One participant suggested that this should be a night time experience rather than a daytime experience, because of its ambient and colored nature.

Serendipity

In the afternoon data collection session, musicians started to do sound checks on the stage below the big screen, getting ready for the jazz concert which was going to take place that night. The sound coming from the instruments was amplified in the square and was affecting the screen directly and immediately. Four participants who experienced the work in the afternoon were less in control of the changes on the screen because of the high volume of the music played on the stage. During the interviews, these participants related their experience more to music and suggested that ambient sound or music in the background would improve people's experience of the work. This suggests that individual interactive experience may be enhanced by social or other types of interactions as far as the input from other resources are recognized and interpreted by the individual. *Tango Tangle* reacted in an interesting way when the pianist of the jazz band was playing the piano for a sound check at the time of our testing. We took the wireless microphone next to the piano and video recorded the changes on the screen with respect to the rhythm and pitch of the piece she was playing. The rhythm of the changes on the screen was synchronized with the music and the color changes from one palette to the other were more immediately recognizable. Later on the pianist was interested to see how she could creatively have engaged with the work if she had the chance to see the screen while she was improvising.

Conclusion

In this paper I have presented an evaluation approach and issues that needed consideration for understanding interactive experiences in a public context situated in an external urban venue. *Tango Tangle* by Ernest Edmonds, as installed for a single session in Federation Square, was a pilot study for a series of interactive works installed on a public screen.

The audience in the public setting largely recognized the interactivity of the media immediately, engaged very briefly with the work and were highly self conscious about their behavior and voice during their engagement. The movement and colors apparent in relation to both ambient and direct sound created visual links for the audience to both environmental and urban iconography, indicating an immersion of the two in relation to this emerging digital artwork.

As the artwork and display were computer, screen and sound based, the technological capabilities of the venue directly affected the way the evaluators collected data and how they attracted the participants of the study. This research methodology, as well as the data collected, will inform future planning for later stages of the project.

References and Notes

1. Brigid Costello et al. "Understanding the Experience of Interactive Art: Iamascope in Beta_Space," in Y. Pisan, ed., *Interactive Entertainment*. (Sydney, Australia: Creativity & Cognition Studios Press, 2005).

2. Ernest Edmonds et al. "On Creative Engagement," *Visual Communication* **5**, No. 3 (2006) pp. 307-322.

3. Lizzie Muller and Ernest Edmonds. "Living Laboratories: Making and Curating Interactive Art," in *SIGGRAPH 2006 Electronic Art and Animation Catalog* (New York: ACM Press, 2006).

Special thanks to Ernest Edmonds for providing the artwork and discussing evaluation issues with me, and to Deborah Turnbull for her help in collecting data. A shorter version of this paper is published by ACM digital library, as part of the Creativity and Cognition conference 2007 demo session. This research/work was partly conducted within the Australasian CRC for Interaction Design, which is established and supported under the Australian Government's Cooperative Research Centres Programme.

CONSTRAINTS AND CREATIVITY IN THE DIGITAL ARTS

Linda Candy, Creativity & Cognition Studios, Faculty of Information Technology, University of Technology, Sydney NSW 2007 Australia E-mail: <linda@lindacandy.com>.

In art, truth and reality begin when one no longer understands what one is doing or what one knows, and when there remains an energy that is all the stronger for being constrained, controlled and compressed. —Henri Matisse

Constraints in creativity are both limiting and liberating. They are used to impose boundaries upon the creative space we occupy and at the same time enable us to grapple with inherent tensions between different demands, which may lead to a new idea, direction or artifact. When we choose particular forms, materials and tools for our creative work, we are also choosing the kinds of constraints that will shape our process and its outcomes.

Creativity may be seen as a process of exercising free choice in the context of a range of existing constraints. Constraints may be both negative and positive influences on the creative activity or task: the negative may be externally imposed or the result of unexpected phenomena, and the positive may be considered beneficial because they have either been self-imposed or have arisen from the intrinsic characteristics of the work itself. Constraints are restrictions that limit what the individual wishes to do, but such restrictions may also be seen as having a more positive and indeed, necessary function by providing the creative person with a more manageable creative space. A totally free or unoccupied space in which to begin a creative work is both unimaginable and probably undesirable. Constraints impose fundamental limits on our ability to think, perceive and create: for example, mental blocks are less amenable to change or control by the individual concerned than those that are self-imposed [1].

Boden characterizes constraints as a means of mapping "a territory of structural possibilities which can be explored and perhaps transformed to give another one" [2]. The way constraints within a particular genre are changed over time until an entirely new genre emerges is exemplified by the case of tonal music. Tonal music was developed over centuries by an exploration of the harmonic steps by which a melody could progress from one movement, phrase, chord or note to the next. There existed a structured space of chord successions by which to modulate from one key to another, and one would normally pass through successive neighboring keys. By the end of the 19th century, composers had gradually abandoned tonal constraints: pathways between modulations had become progressively shorter and the notion of an approved chord succession was increasingly problematic. Finally, Schoenberg took the step of dropping the final consonance indicating the end of a musical journey, and in doing so create a new field governed by different rules in which conventions of modulation and consonance could not be expressed. He saw that the tonal conventions were not arbitrary but were intelligible, mutually coherent constraints - in effect, a 'coherent generative system' to use Boden's terminology. The development of a conceptual space such as tonal music is a rich and complex enterprise that took many centuries to map to the point where composers set it aside in favor of a new atonal space.

In the digital arts, the creative process is fundamentally the same as in any other field of creative work. Some constraints are there because the artist chooses them; in others they are inherent to the context, the genre and the medium. The chosen genre is the basic creative conceptual space in which rules and conventions impose a set of boundary constraints within which the artist works. It is the choices made within this constrained space that create a distinctive individual style, which, if successful, is instantly recognizable as belonging to a particular person. In selecting a particular medium, the artist chooses a set of constraints that are inherent to it.

Digital technology brings with it special kinds of constraints that are both inherent to the nature of computers and also facets of a medium that is less than one hundred years old. The relative immaturity of the medium and its multi-faceted character are factors that have given rise to very different approaches to its use in the digital arts, from those who would "digitalise" existing forms to those who would change the very forms they work with. The constraints inherent in digital media are being handled in very different ways that have implications for the future of digital art process and the technology support it demands. The distinction between the digital medium and the digital tool for some artists does not exist, so fundamental is the nature of digital technology to their work. Manfred Mohr writes of the relationship between the algorithms he writes and the images that become exhibited artworks:

"My algorithms have developed over the years and have always drawn on my aesthetic decisions and knowledge as an artist. My programs are continually updated through an interactive procedure between my abstract ideas and the creation of my algorithms. When I declare a program to be finished, all results of the program are accepted as equal aesthetic possibilities. The results are shown in a variety of ways but they are never altered and/or chosen for aesthetic reasons. Since there are infinite numbers of possibilities, I have to choose some of them to show as 'still images.' All instances however, are chosen with the intent of showing the greatest possible variety and are in most cases chosen randomly by the program itself" [3].

An important characteristic of digital technology is that to use it to its full, you have to be prepared to make explicit the implicit assumptions that are in your mind as you develop the work. It is the very need for explicitness that makes it both challenging and rewarding to many artists. In order to work digitally, the constraints have to be specified in such a way as to make the computer generate an outcome that is satisfying to the artist. But, more importantly, the process of specifying the constraints in digital form can be best understood as an integral part of the creative process. The choice of whether to program or to use a software application can be critical to how much the artist has control over the character of the constraints to be specified.

For artists working in the constructive, concrete and systems art traditions, in particular, the attraction to the digital is directly related to the computer's capacity to represent and 'execute' the underlying structure of the works.

"The notion of *structure* implies something *recoverable*, in the sense that it is possible to look at an end result and determine the structures that generated it. It has a clear structure, and being clearly predictable, its structure is highly constrained" [4, p. 71].

If constraints (on elements of the work) such as colour, relationships between objects in the scene, sequences (in time-based work) and movement and location (in interactive work) are specified in a computer program, this can be used to understand their implications through to the visual appearance and, in total, the true nature of the underlying structure. This necessitates an explicit definition of what those constraints are.

These might be thought of as personal 'rules' that capture the significant elements that the artist chooses to focus upon. As Birgitte Weimer says [5]:

"I want to find not strict rules but to have my own rules in my work, and to find basic structures in things that I experience and what I see…I think that it is an inner necessity to find rules."

In Edmonds' case, he describes the expression of constraints in this way:

"Always, in the end, the selection of the colors and their juxtaposition is a matter of judgment that deeply affects the character, meaning or impact of the work. However, making those choices is often, even normally, made possible by the use of systems that limit the infinite possibilities and enable order to enter the creative process. When working on a piece, in whatever medium, my practice has been to select a line in a color space and divide it up in perceptually equal intervals, the color at each boundary point being included in the pallet for the work. Of course, the line can be very short, giving a set of very close colors, or long, including quite different hues, for example. It can also be curved or move only through levels of brightness. These methods lead up to and frame the final moment of selection. The choice is a matter of judgment that can only be made, in the end, by looking. This approach gives all the freedom I need" [6].

By focusing on underlying structure, the need to define constraints explicitly is at the heart of the creative process. The process of making explicit the constraints that together make up the underlying structure of a work or series of works, is, in effect, a kind of boundary definition of a personal creative space: it is the capacity to make the space highly personalized that attracts many artists to the problem of writing computer programs.

In June and July of 2002, a group of artists came together under the auspices of the COSTART research project to take part in an artist-in-residency program [7]. Some artists were concerned with developing real-time interactive works and audience participation whilst examined the correspondences between sound and image, whilst others concentrated on the interaction possibilities of sensor systems. Each project provided different challenges for both the technical requirements and the artistic intentions. In order to advance their work using digital technology, the artists had to define tight descriptions of the work they wished to realize in order to be able to develop a representation or mapping that could be made into digital form. These were artists who were already working digitally for the most part but, given access to new forms and tools as well as expertise, were able to bring some of their dreams nearer to reality. An example project was that of Gina Czarnecki, an artist who is deeply engaged in exploring real-time audience interaction in a process modelled on biological evolution. The outcome is work that challenges the audience to cooperate in selecting for breeding whilst embracing the question of willingness to participate in the possibilities highlighted. The preparation involved many hours of discussion between the artist and her collaborator, Mark Fell (Fig. 1).

Fig. 1. Screen Silvers Alter in development (© Gina Czarnecki. © Photo L.Candy.)

Prior to the residency the artist had developed a scheme for a video installation whereby people were able to select and evolve a virtual population. The artist and technologist together developed a specification that described what it did, and how the participant would engage with it. During this process, technical, creative and ideological issues were dealt with in parallel and required a trade-off between what the technical systems could handle in real time and the ideal image quality. The dialogue between the artist and technologist resulted in a more precise definition that could be mapped to a technical representation in digital form. This process gave rise to a better understanding of the constraints which the artist was working with, not only for the technologist's purpose, but for the artist herself, whose grasp of their implications for the digital constraints developed in parallel with the artistic elements.

This paper has raised a number of issues about constraints in the creative process. It has suggested that bringing digital tools into the creative process leads to a more highly constrained creative space because of the inherent characteristics of the technology itself but that this can lead to new directions. In the digital arts, the computer's capacity to facilitate a more precise specification of the constraints which artists work with makes the technology an attractive medium to explore. For many, having the facility to specify their own artistic constraints implies using some form of programming techniques. Manfred Mohr's basic map is already geometric and therefore, on the face of it, more accessible to computational representation. Edmonds works with a very tight set of constraints and his interest in underlying structure over visual form can be satisfied because of the capability offered by computer programming. The new generation of digital artists has more opportunity to work digitally but that very 'freedom' can pose problems of what to select and how to exploit it fully. Specifying personal artistic constraints often requires the full power and flexibility of a programming language: to do that collaboration with technologists may be essential.

The use of digital technology in the arts is in its infancy relative to the other media familiar and available to artists today. If we are to fully understand both the degrees of freedom and types of constraint that apply as a result of using it in creative works, we need more experience, more practice and more research. To answer questions such as, What are the equivalents in digital technology of the overlapping conceptual spaces of 20th century music? there will need to be many more years of advances in the digital arts. The next step is to map the constraints of current digital technology that enhance and impede both the creative process and its outcomes as art forms for public exhibition.

References

1. S.M. Smith and D.R.Tindall "Memory blocks in word fragment completion caused by involuntary retrieval of orthographically similar primes". *Journal of Experimental Psychology: Learning*. Memory and Cognition **23**, 1997 pp 355-370.

2. M. A. Boden, *The Creative Mind; Myths and Mechanisms,* (Routledge: London 2nd Edition, 2004) p. 95.

3. M. Mohr, Personal Communication, (October 2002).

4. E.A. Edmonds, Art Practice Augmented by Digital Agents. *Digital Creativity*, **11**, 4 (2000) pp. 193-204.

5. E.A. Edmonds,"Structure in Art Practice: Technology as an Agent for Concept Development," *Leonardo* **35**, No. 1 (2002) pp. 65-71.

6. E.A. Edmonds, E.A. *On New Constructs in Art* (Sussex, UK: Artists Bookworks, 2005).

7. COSTART project accessed 1 March 2007 <http://research.it.uts.edu.au/creative/COSTART/>

INTERACTION AS A MEDIUM IN ARCHITECTURAL DESIGN

Joanne Jakovich and Kirsty Beilharz,
Key Centre of Design Computing and Cognition, University of Sydney,
NSW 2006 Australia.
E-mail: <joanne@jakovich.net>.

The recent integration of sensor-based interactive systems into buildings presents a significant aesthetic opportunity for architectural design. Beyond static, permanent structures, architecture can utilize sensor technologies to develop dynamic responses to human needs, expanding the creative palette of the architect to incorporate computer-mediated information exchange between inhabitants and the environment: *interaction*. This opportunity, however, remains largely unexplored since the conventions used to conceive, represent, and hence design architecture currently lack the capacity to incorporate the real-time and dynamic nature of interaction, precluding its use as a fundamental medium within which to design and build.

While the notion of "medium" is less familiar in architecture than in art, the specification of form and materials (e.g. steel, glass, lighting) implements creative expression in the mediums of space, light and time. These articulations influence human experience and behavior, implying that traditional architectural design anticipates, and arguably orchestrates, human interaction in and with the constructed space. Technological developments introduce a new dimension to this relationship; behavior within the space not only is an outcome of design but also is used to drive dynamic architectural elements in real-time: mechanical walls/doors/floors, operative surfaces, media projections, dynamic furniture, digital soundscapes, haptic climates, ambient info-displays, etc. Thus the behavior-response cycle informs and shapes design decisions and brings to light the necessity to reconceive static models of space.

Through our creative practice spanning interactive art and architecture, we are exploring the aesthetic potential of interaction, challenging and marrying concepts from interactive art and architecture to develop an understanding of interaction as a creative medium in which to design space. As a platform for further experimentation, we present a four-part framework to redefine the relationship between architecture and interaction in this new hybrid domain of spatial practice.

Merging Trajectories

As an intangible, temporal form of communication, interaction seems improbable as a medium for creative expression when compared to other visual or haptic media. The pioneering work by artist-programmer Myron Krueger in the early 1970s was first to establish its aesthetic potential. Krueger developed a series of "responsive environments" in which the audience could use full body gesture to interact with an array of spatially projected digital media. He discovered that the composition of the relationships between action and response drove the aesthetic experience, while the beauty of the visual and aural display was secondary. Notably, Krueger proposed "response" as a "new art medium based on real-time interaction between men and machines" [1]. More recently, interactive soundspace artist David Rokeby describes the "construction of experience" as the creative goal of the interactive artist and argues that the *content* of the artwork lies in the interactive experience itself [2].

In this way, the traditional dichotomy of audience and artwork dissolves. Cornock and Edmonds reframed the audience as "participant," proposing a systems-oriented framework for interactive art [3]. In this view, human participation drives generation of the artwork and is conceived as an integrated component of the art system. Building on this, Paine uses the analogy of *dialogue* to describe the reciprocality and context-dependency that characterizes interaction in the system [4]. By conceptualizing the art environment as a multi-part system varying over time, the artist is able to focus on the higher level structures that influence dynamic outcome rather than tangible elements such as form, color and so on.

Framework

The following presents a four-part framework for conceiving and implementing interaction as a medium in architecture. It is proposed as an analytical ground point to base practice, research and pedagogy occurring at the intersection of interactive art and architecture, and invites the reader to re-frame the ways in which we conceive and describe these.

I. Architecture

• *Architecture* is the theoretical and practical art of creating a plan of a complex object, or *system*, intended for human inhabitation or use.

• A *system* is a complex of interacting and interrelated components. A system has *structure* and, through interaction, behavior.

• *Structure* is the interrelationships within a system. It defines the behaviors between components and the behavior of the system overall. Structure may be fixed, responsive, adaptive, or autonomous.

• The *human component*, which is the human inhabitant or user, is an equal and integrated part of the system. For this reason, architecture is always concerned with human interaction with constructed systems.

• The *structure* consists of the subjective mapping from elements of the human experience to elements of other components of the system. This is the central creative concern of the architect.

• An architectural *plan* is primarily specified through structure. However, the medium in which this is implemented affects both the specification and the applied outcome.

• Once implemented, an architectural *artifact* is a system upon or within which human patterns of behavior adopt and adapt the relationships initially specified in the structure.

Fig. 1. *Sonic Tai Chi* (2005). (© Joanne Jakovich & Kirsty Beilharz) Interactive gesture-activated space. (Photo © Greg Turner)

II. Medium

• A *medium* is an intermediate *condition* between two states. In creative practice, this implies that a medium is the condition between states of intention and realization.

• A *condition* is itself a state—it is a state of transition, or transformation. A medium is a means for transferring or transforming information, e.g. an idea, into another form of that information, e.g. a creative representation.

• A medium is a *means for exchange*. It is the method for creative expression, but also for creative interpretation. In this

iterative way, it is a machine for continual creative exploration.

• A medium is a *method*, but it is not a material. A material is the specific substance or hardware chosen to implement the method, e.g. both a woodblock and an inkjet printer are materials used in the *medium* of print.

• The characteristics of a medium however, can be expressed according to the *shared affordances and constraints* of its materials. And in this way, a medium is both limited and enabled by the technologies available.

III. Interaction

• *Interaction* is the combined *reciprocal action* between two or more *agents* that have an effect on each other.

• *Agents* are (some of) the *components*, or elements of components, in a system.

• An *agent* may be any human, computer, building or software system, for example, that has the capacity for producing a non-predetermined response or an action—that is, a response that is based on the specific information and context acquired from the current interaction.

• Agents possess a means for receiving *information* from others, and for expressing (displaying) information in return.

• Interaction produces *feedback*. Feedback is the direct and implicit information about how actions are interpreted by the opponent agent(s).

• *Feedback* occurs directly through reciprocated action, or indirectly through the overall effect of system actions. Feedback motivates and informs further actions.

• Through reciprocal action, a *dialogue* develops which is specific to the present interaction. The dialogue is not repetitive, but grows based on information exchange over time.

• The *dialogue* is a unique temporal account of the interaction. Cross-referencing of these accounts produces generalized rules about the cause and effects of actions.

IV. Interaction as a Medium in Architecture

• *Interaction* is the real-time condition between two or more agents that acts as a mechanism for exchange. That is, interaction drives exchange because feedback informs action.

• As a mechanism of exchange, interaction has the potential to *communicate creative ideas*. Ideas are expressed inherently in the structure of the system that enables interaction.

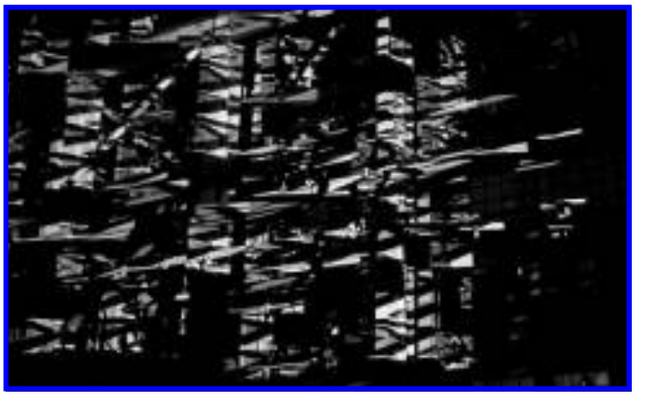


Fig. 2. Joanne Jakovich, Jin Hidaka & Satoru Yamashiro, *Soft Inversions* (2006). Large-scale installation using projections on the structural members of an abandoned turbine hall. (© Joanne Jakovich, Jin Hidaka & Satoru Yamashiro. Photo © Kota Arai.)

• The design of the *system structure* aims to achieve functional and aesthetic spatial goals through the medium of interaction. This is the main creative focus of the *architect*.

• As a medium in architecture, with its own inherent *affordances* and *constraints*, interaction can be used to bring certain qualities to a built environment, just as do light, texture, form and so on.

• The *aesthetics* of a space are hence conceived according to how one interacts both directly and indirectly with the environment, through exploratory gesture and/or interaction in addition to passive perception of conventional spatial media.

Implications for Implementation

Our creative explorations of this framework have unearthed a rich discussion on the role of technology in interaction. While we have experimented with the use of generative cellular automata systems in gesture-activated soundspaces (Fig.1) [5] we have also explored the extent to which simple interaction is augmented by the overlaying of the digital display with physical host space itself (Fig. 2) [6]. We discovered that implementing interaction as a medium does not require expensive or complex hardware and software systems, but rather requires a great deal of experimentation in the developmental phase to ascertain the particular aesthetic qualities of the mode of interaction in use. Indeed, the capacity to design and construct simultaneously, and to iteratively re-design/reconstruct based on user testing, is an exciting feature of this medium. Unlike previous modes of design which involved envisioning a future built space using sketches and models, this process enables a live mode of observation and modification that occurs in parallel to full-scale construction.

The Future

It is interesting that some of the key exponents of interactive art are architects and that the work of eclectic groups like Archilab [7] embodies this very synergy of fantastical, dynamic structures that favor artistic outcomes more than serving architectural functions. This same adventurousness pushes boundaries of imagination, unfettered by constraints of domain specific techniques. Thus the framework presented formalizes the relationships between conventionally, perhaps artificially, distinct disciplines of architecture and interactive art and elicits ways in which one can inform the other. We envision that through the medium of interaction, new creative expression and understanding of space can augment the richness and inherent dynamism of the architectural and urban systems we inhabit.

References

1. Myron Krueger, "Responsive Environments," in Randal Packer and Ken Jordan, eds., *Multimedia: From Wagner to Virtual Reality* (New York, U.S.: Norton & Company Ltd., 2001).

2. David Rokeby, "The Construction of Experience," in Clark Dodsworth, ed., *Digital Illusion: Entertaining the Future with High Technology* (New York, U.S.: ACM Press, 1998).

3. Stroud Cornock and Ernest Edmonds, "The Creative Process where the Artist Is Amplified or Superseded by the Computer," *Leonardo* **6**, No. 1 (Winter 1973) pp. 11-16.

4. Garth Paine, "Interactivity: Where to from Here?," *Organised Sound* **7**, No. 3 (2002) pp. 222-224.

5. Joanne Jakovich and Kirsty Beilharz, "'Sonic Tai Chi': Auditory Gestures in Reactive Soundspaces," in *The Second Australasian Conference on Interactive Entertainment* (Sydney, Aus.: Creativity & Cognition Studios Press, 2005) p. 243.

6. Soft Inversions (2006), <http://www.jakovich.net/19.php>, accessed 3 March 2007.

7. Marie-Ange Brayer, Frederic Migayrou and Fumio Nanjo, *Archilab's Urban Experiments: Radical Architecture, Art and the City* (London, U.K.: Thames & Hudson, 2005).

A Pleasure Framework

Brigid Costello, School of English, Media and Performing Arts, University of New South Wales, Australia. E-mail: <bm.costello@unsw.edu.au>.

As an interactive artist I dread the type of audience participant who spends very little time with my work and who then says, "that they 'got it' but that it didn't 'do much' " [1]. My work focuses on producing an experience together with audience participants, and "getting it," in the sense of understanding a message, is not really the point. I want my participants to engage with and explore my artworks, because if they don't, they won't help produce the experiences that I have tried to create opportunities for.

One strategy that I have been working with lately is to focus on the stimulation of play as a method of achieving engagement and exploration. Not only are players very engaged when at play, they also shift between the states of play and exploration. In Lieberman's description of play, exploration is seen as a precursor to playful behavior. Through exploration the unfamiliar becomes familiar and only then does play occur [2]. Other studies of playful behavior report an oscillation between the states of exploration and play, with the player switching back and forth between the explorative goal "what can this object do" and the playful goal "what can I do with this object" [3]. Player boredom is the common trigger for the switch back to exploration, with the player then seeking new features or possibilities to play with.

The interplay between these two goals of play and exploration has also been seen to occur when an audience participant encounters an interactive artwork [4]. While an interactive art experience will usually involve a certain amount of explorative unfamiliarity, it may not necessarily lead to playful familiarity, and indeed in some cases this may be quite undesirable. If it does, however, the oscillation between play and exploration may drive audiences to experience deep levels of engagement with the work. With a hope of tapping into this deep engagement I, therefore, decided to focus my interactive art practice on the stimulation of playful behavior.

To develop practical strategies for stimulating play I decided to examine in detail the experiential qualities of play. One of the features that all play has in common is that it is pleasurable or "a source of joy and amusement" [5]. I chose to focus on pleasure as an experiential goal, and this led me to develop a framework of thirteen categories of pleasure that could be experienced during a playful experience. My aim was to develop a tool that could be used to aid my design of such experiences; a tool that could be used for conceptual development, for reflective practice and for participant evaluations.

This framework of the thirteen pleasure categories of play was developed as a synthesis of the ideas of six theorists, all of whom approach play and pleasure from different perspectives. Firstly, the framework was inspired by the theories of philosophers Karl Groos and Roger Caillois whose ideas arose out of their desire to accurately define a play experience [6, 7]. In contrast, psychologist Mihaly Csikszentmihalyi was more concerned with play as a type of pleasurable experience, while psychologist Michael Apter focused on the stimulation of play [8, 9]. Lastly, the framework drew on the ideas of game designers Pierre Garneau and Marc LeBlanc, who were interested in delineating the types of fun in games [10, 11].

The synthesis of these different ideas was influenced by my focus on interactive art experience, and some aspects of these theorist's ideas were not included in the framework because I felt they did not suit this art context. The names of each category were also carefully chosen to suit both this context and with an eye to being easily understood within participant evaluations. Although exploration, as we have seen above, is sometimes characterized as a separate process to play, it was included in the framework because of the entwined nature of play and exploration and the importance of exploration within an interactive art context.

Once developed, the effectiveness of the framework was tested, firstly by using it to analyze the descriptions of thirty existing interactive artworks. These were all well-known artworks that I judged to be playful in some way. Many of them were also works regarded as very effective pieces of interactive art. Secondly the framework was applied to the actual experience of three pieces of existing interactive art within an exhibition context. These tests resulted in some refinements being made to the framework, particularly to the names used to describe each category.

An outline and brief description of each of the thirteen categories of pleasure contained in my final framework appears below:

Creation is the pleasure participants get from having the power to create something while interacting with a work. It is also the pleasure participants get from being able to express themselves creatively.

Exploration is the pleasure participants get from exploring a situation. Exploration is often linked with the next pleasure, discovery, but not always. Sometimes it is fun just to explore.

Discovery is the pleasure participants get from making a discovery or working something out.

Difficulty is the pleasure participants get from having to develop a skill or to exercise skill in order to do something. Difficulty might also occur at an intellectual level in works that require a certain amount of skill to understand them or an aspect of their content.

Competition is the pleasure participants get from trying to achieve a defined goal. This could be a goal that is defined by them or it might be one that is defined by the work. Completing the goal could involve working with or against another human participant, a perceived entity within the work, or the system of the work itself.

Danger is the pleasure of participants feeling scared, in danger, or as if they are taking a risk. This feeling might be as mild as a sense of unease or might involve a strong feeling of fear.

Captivation is the pleasure of participants feeling mesmerized or spellbound by something or of feeling like another entity has control over them.

Sensation is the pleasure participants get from the feeling of any physical action the work evokes, e.g. touch, body movements, hearing, vocalizing, etc.

Sympathy is the pleasure of sharing emotional or physical feelings with something.

Simulation is the pleasure of perceiving a copy or representation of something from real life.

Fantasy is the pleasure of perceiving a fantastical creation of the imagination.

Camaraderie is the pleasure of developing a sense of friendship, fellowship or intimacy with someone.

Subversion is the pleasure of breaking rules or of seeing others break them. It is also the pleasure of subverting or twisting the meaning of something or of seeing someone else do so.

I did not include the categories developed by behavioral psychologist Berlyne in the overall framework, but I consider these to act as modifying variables for each of the pleasures. Berlyne, like Ap-

ter, focused on the arousal of play. He describes his categories as discrepancies, which as the name suggests arouse by piquing interest. These four categories are novelty or change, surprise content, complexity and, lastly, uncertainty or conflict [12]. These variables, I am suggesting, will have an effect on the strength of pleasure that can be evoked by each category in the framework. For example, a work may be trying to arouse pleasure in discovery, but this pleasure will not be felt very strongly if the things that the participant discovers are not perceived to be either novel, surprising, complex or unexpected.

These thirteen pleasures of play should be seen only as possible categories that a participant might feel pleasure in during a playful interactive art experience. They may not occur at all, and it is even possible that a certain category might cause displeasure rather than pleasure. It is also expected that the pleasures would very rarely all occur strongly within a single artwork experience. One trend revealed by the analysis of existing playful artworks was that these artworks elicited strong scores for just two or three of the pleasure categories, with each work involving a different combination. So it is certainly not being suggested that an artwork that stimulates pleasure in all of the categories will be effective, nor is it being suggested that the framework has any bearing whatsoever on whether something is "good" or "bad" art. What is being suggested is that the framework might be a useful design tool to enable artists and other designers to think in a more detailed and focused way about the type of playful experiences that they want their work to elicit.

I have applied this framework within my own practice both during the conceptual development of a work and during a formal participant evaluation. I have also used it as a tool to help me reflect on and evaluate the effectiveness of two of my existing interactive artworks.

The framework was used during conceptual development to create a picture of the type of pleasures that I wanted my new work to evoke. I also used it to make decisions about which pleasures would be key pleasures and which would be subordinate. I was then able to temper the development of my ideas based on these pleasures. When deciding whether to take one path or another I would find myself questioning which of these paths would act to elicit the kind of experiential pleasures that I was aiming for. I also found myself paying a lot more attention to the balance and strength of the work's pleasures, working to ensure that my proposed key pleasures were actually key.

This new work was later tested during a formal participant evaluation, with the evaluation explicitly asking participants to identify any of the thirteen pleasures that they had experienced. The participants' answers matched almost exactly the list of pleasures that I had been working with during my conceptual development. This result confirmed that the pleasure framework was for me a valuable practice method for the conceptual development of playful interactive art.

I was less successful at applying the framework to two of my existing artworks. I again used it to develop a picture of the key pleasures in these works but found in participant evaluations that some areas of my characterization were quite different from that revealed by participants. In reflecting on these results I decided that my characterizations had been adversely influenced by my artistic dissatisfaction with these two works. My characterizations were coming too much from a creator's perspective and not enough from a participant's perspective.

As a tool for participant evaluation, however, the pleasure framework was very effective at clarifying the experiential pleasures that were evoked by each of these works. The surprises in these results have also been very useful when considering which paths to take in future developments of the works. Some of the directions I was considering taking before the evaluations I now realize could act against some of the works' key pleasures. While I still may decide to make these changes, if I do so it will be with a clearer awareness of their effect upon the experience evoked by the work.

The framework was definitely effective as a participant evaluation method. The fifteen participants that were tested had no trouble understanding the thirteen categories. Interviews, conducted after they had identified their pleasures, were rich in experiential detail that was clearly prompted by the categories. The pleasure categories also seemed to give interviewer and participant a common language for discussing their experience of each work.

This framework of thirteen pleasures that might be evoked by a playful interactive art experience is not a formula for making interactive art but rather a practice method that encourages detailed contemplation of an artwork's experiential pleasures. In my practice, the framework was most effective when used right from the beginning of an artwork's conceptual development. It was also a very effective tool for participant evaluations of prototype works. While I cannot yet tell how successful the framework has been in terms of helping me decide on future developments of my works, it definitely has been a catalyst for fresh ideas and new directions.

Acknowledgments

This research was conducted at the Creativity and Cognition Studios at the University of Technology, Sydney. It was supported by a grant from the Faculty of Arts and Social Sciences at the University of New South Wales.

References and Notes

1. L.C. Throop, "Field of Play: Sensual Interface," in *Designing Pleasurable Products and Interfaces* (Pittsburgh, USA: ACM, 2003) pp. 82-86, p.85.

2. J.N. Lieberman, *Playfulness: Its Relationship to Imagination and Creativity* (New York: Academic Press, 1977) p.110.

3. Corrine Hutt, "Exploration and Play in Children," in Brian Sutton Smith and R.E. Herron, eds., *Child's Play* (Florida: Robert E. Krieger Pub. Co., 1985), pp .231-250, p. 246.

4. B. Costello, L. Muller, S. Amitani, and E. Edmonds, "Understanding the Experience of Interactive Art: Iamascope in Beta_space," in *Inter-active Entertainment 2005* (Sydney, Australia: Creativity & Cognition Studios Press, 2005) pp. 49-56.

5. Roger Caillois, *Man, Play, and Games* (London: Thames and Hudson,1962) p. 6.

6. Callois [5].

7. Karl Groos, *The Play of Man* (London: William Heinemann, 1901).

8. M. Csikszentmihalyi, *Beyond Boredom and Anxiety: The Experience of Play in Work and Games* (San Francisco: Jossey-Bass Inc., 1975).

9. Michael J. Apter, "A Structural Phenomenology of Play," in J.H. Kerr and Michael J. Apter, eds., *Adult Play: A Reversal Theory Approach* (Amsterdam: Swets & Zeitlinger, 1991) pp. 13-42.

10. Pierre Garneau, "Fourteen Forms of Fun," *Gamasutra* (2001), <http://www.gamasutra.com/features/20011012/garneau_01.htm>, accessed 18 Jan 2006.

11. Robin Hunicke, Marc LeBlanc and Robert Zubek, "MDA: A Formal Approach to Game Design and Game Research" in *Challenges in Game Artificial Intelligence: Papers from the 2004 AAAI Workshop* (San Jose, California: The AAAI Press, 2004) pp. 1-5.

12. D.E. Berlyne, "Laughter, Humor, and Play," in G. Lindzey and E. Aronson, eds., *The Handbook of Social Psychology* (Reading, Mass.: Addison-Wesley, 1968) pp. 795-852.

Fundamental Insights on Complex Systems arising from Generative Arts Practice

D. Burraston, Creativity & Cognition Studios, Faculty of IT, University of Technology, Sydney, PO Box123, Broadway, NSW 2007, Australia.
E-mail: <dave@noyzelab.com>.

Algorithmic-based music underwent a paradigm shift over the last two decades of the 20th century with the advent of complex systems research. Complex systems such as cellular automata (CA) produce global behaviour from rule-based interactions of simple cells. CA have had a distinguished and esoteric history—in computer science since its foundation to their present-day influence in Artificial Life, as well as numerous other important disciplines. They are fascinating objects, producing more pattern than a single human is capable of observing within their own lifetime. The different classes of behaviour they produce, whether ordered, complex or chaotic, make them interesting to artists and scientists alike. This wide variety of behaviour represents an important generative tool for the artist. However, chaotic behaviour dominates rule space, which has serious implications for application and investigation. Obtaining a variety of *pattern for free* is thus a challenge to the artist and scientist alike.

CA are discrete dynamical systems in terms of space, time and values assigned to cells. The set of all possible global states of these cells is termed the *state space*. The set of all possible rules for any particular CA architecture is termed the *rule space*. A concise definition of CA is given by Andrew Wuensche and Mike Lesser [1]:

A cellular automaton (CA) is a discrete dynamical system which evolves by the iteration of a simple deterministic rule.

Wuensche has stated: "Traditional mathematical methods and analysis cannot in general provide a description of the long term behaviour of discrete dynamical networks except for the simplest special cases" [2].

Stephen Wolfram has proposed twenty key unsolved problems in the theory of CA [3]. The seventh problem asks: *How is different behaviour distributed in the space of cellular automaton rules?* The task of assigning behaviour to a rule is known to be undecidable [4], but a number of approximations have been attempted. An extensive amount of research by the CA scientific community has been conducted towards producing behaviour prediction parameters to discern the structure of rule space. Unfortunately, as the size of the CA rule space is increased the total number of rules becomes astronomical and the amount of chaotic behaviour increases dramatically.

The magnitude of the numbers of rules is extremely large, increasing in a dramatic manner even if only neighbourhood size or the number of possible cell states is increased. Tommaso Toffoli and Norman Margolus also discussed the problems of rule choice [5]. They point out that binary rules with just 9 neighbours, amounting to 2^{512} rules, is "the square of the estimated number of elementary particles in the universe!" Wentian Li has commented on the binary one-dimensional 5 neighbour rules: "Even if we can produce a spatial-temporal pattern from each rule in 1 second, it is going to take about 138 years to run through all the rules. Considering the redundancy due to equivalence between rules upon 0-to-1 transformations, which cut the time by half, it still requires a solid 69 years" [6] .

This problem continues to engage the scientific community and is the subject of much debate.

In confronting systems of such behavioural complexity for the purpose of art, the artist is placed in a possibility space of truly vast proportions. Given that the potential for random behaviour increases with rule space, choosing CA rules at random does not represent a successful artistic strategy, unless one is actively seeking randomness. This problem has great implications for the use of CA in both scientific and generative arts practice.

I approached the problem of rule space structure from an artist's perspective in the context of generative music practice. Hal Chamberlin noted that the production of algorithmic data for musical control "may be highly ordered, totally random, or somewhere in between" [7]. It follows then that all CA behaviours are "interesting"; the music practice problem is to find a mixture of behaviour from the overwhelming chaos. This is in contrast, but not in opposition to, the scientific approach of predicting behaviours in order to locate complexity within rule space.

The techniques are based on recent perspectives of CA theory called *global dynamics* [8] and music composition practice, to provide empirical evidence regarding rule space structure. A concrete and navigable graph structure for rule space can be created using CA state space graphs called attractor basins. My initial investigations were done manually, by printing out subtrees and examining the resultant rule groupings, as shown in Fig. 1. Much to my surprise, I discovered that CA dynamics are perfect for constructing structure within their own rule spaces. In-depth details and further empirical evidence for the applicability of creating structures in larger rule spaces is given in my thesis [9, 10].

Generative music experiments have the capability to both produce music and inspire further development of complex systems research. The discovery of a connection between state space and rule space from this research into generative music has implications for future work in both science and music. This will serve to encourage interdisciplinary collaboration between the arts and sciences in that task. Detailed analysis of the results is ongoing and may provide further new insights into the wilderness of rule space. The underlying notion of behaviour mixtures benefits from its own generality, and the method of creation is not dependent on any particular aspect of musical theory, e.g. scale, mode or chord. The artistic approach taken provides an interesting and alternative method of studying rule spaces of complex systems in general, independent of musical application.

References and Notes

1. A. Wuensche and M. Lesser, *The Global Dynamics of Cellular Automata: An Atlas of Basin of Attraction Fields of One-Dimensional Cellular Automata* (Addison-Wesley, 1992); available as PDF from <www.ddlab.com.>.

2. A. Wuensche, *Attractor Basins of Discrete Networks*, D.Phil. thesis (Univ. of Sussex, 1997); available as PDF from <www.ddlab.com>.

3. S. Wolfram, "Twenty Problems in the Theory of Cellular Automata," *Physica Scripta*, **T9** (1985) pp. 170-183.

4. K. Culik, L. Hurd and S. Yu, "Computation Theoretic Aspects of Cellular Automata," *Physica D* **45** (1990) pp. 357-378.

5. T. Toffoli and N. Margolus, *Cellular Automata Machines: A New Environment for Modeling* (MIT Press, 1987).

6. W. Li, "Complex Patterns Generated by Next Nearest Neighbors Cellular Automata," *Comput. & Graphics* **13** No. 4 (1989) pp. 531-537.

7. H. Chamberlin, *Musical Applications of Microprocessors* (Hayden, 1980).

8. Wuensche and Lesser [1].

9. D. Burraston, *Generative Music and Cellular Automata,* Ph.D. Thesis (UTS, 2006).

10. The thesis, plus all electronic data and music included on the CDROM, are available from <www.noyzelab.com> for free download.

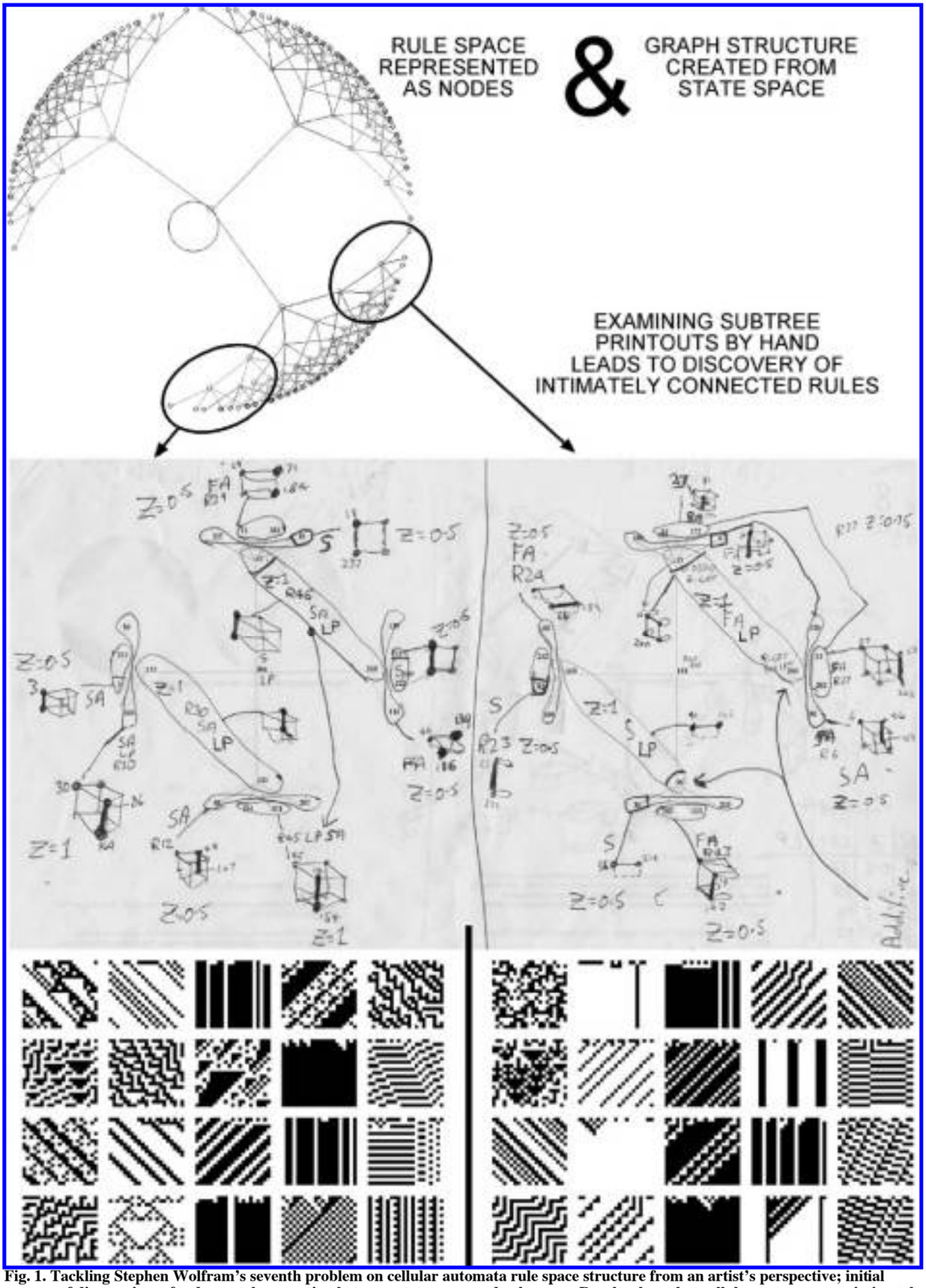


Fig. 1. Tackling Stephen Wolfram's seventh problem on cellular automata rule space structure from an artist's perspective; initial process of discovering a fundamental connection between state space and rule space. Results show that cellular automata can intimately structure their own astronomically sized rule spaces. (© D. M. Burraston)

CALL FOR PAPERS

Nanotechnology, Nanoscale Science and Art

Leonardo Special Section
Guest Editors: Tom Rockwell and Tami I. Spector

Over the last decade, "nano" has become *the* buzzword signifying everything from imagined atomic-scale robotic utopias to small electronics. For scientists the shift toward nano has also become ubiquitous; what used to be referred to as "molecular" has been reframed as "nano," 27 journals devoted to nanotech/nanoscience are now published, and the National Science Foundation and other granting agencies have devoted a significant amount of funding toward nanotech/nanoscience. Among engineers, scientists and science-studies scholars, discussions of the potential of nanotech/nanoscience abound, including conferences that debate the pros and cons of a nano-hegemony and attempt to debunk some of the hype. Artists, however, have only begun to explore this emergent scientific field, leaving it wide open for creative interpretation. With this special section of *Leonardo* we hope to ignite artists' interest in the exploration of nanotech/nanoscience and encourage scientists, scholars and educators to contemplate the implications of an art-nanotech/nanoscience connection.

Leonardo, in collaboration with the Exploratorium under the auspices of the Nanotech Informal Science Education Network, will publish a series of special sections periodically over the next 5 years exploring the intersections of nanotech/nanoscience and art. We are especially seeking submissions of artworks (visual, performance, sound, etc.) with artists' statements explaining the relationship of the work to nanotech/nanoscience; essays from scientists, engineers and scholars exploring the connection between nanotech/nanoscience and art; and essays and visuals aiming at nanotech/nanoscience education that uses the arts as a pedagogical tool.

Interested artists and authors are invited to send proposals, queries and/or manuscripts to the Leonardo editorial office: Leonardo, 211 Sutter St., Ste. 501, San Francisco, CA 94108, U.S.A. E-mail: <isast@leonardo.info>. Editorial Guidelines for Authors can be found at <www.leonardo.info>.

This project is supported by the National Science Foundation under Grant No. ESI-0532536.