LEA

LEONARDO ELECTRONIC ALMANAC

VOL 19 NO 3 VOLUME EDITORS **LANFRANCO ACETI, STEVE GIBSON & STEFAN MÜLLER ARISONA** EDITOR **ÖZDEN ŞAHİN**

Live visuals have become a pervasive component of our contemporary lives; either as visible interfaces that re-connect citizens and buildings overlaying new contextual meaning or as invisible ubiquitous narratives that are discovered through interactive actions and mediating screens. The contemporary re-design of the environment we live in is in terms of visuals and visualizations, software interfaces and new modes of engagement and consumption. This LEA volume presents a series of seminal papers in the field, offering the reader a new perspective on the future role of Live Visuals.

LIVE VISUALS

Leonardo Electronic Almanac
Volume 19 Issue 3

When Moving Images Become Alive!

"Look! It's moving. It's alive. It's alive… It's alive, it's mov-
ing, it's alive, it's alive, it's alive, it's alive, IT'S ALIVE!"
Frankenstein (1931)

**Those who still see – and there are many in this
camp – visuals as simple 'decorations' are living in
a late 19th century understanding of media,** with
no realization that an immense cultural shift has hap-
pened in the late 20th century when big data, sensors,
algorithms and visuals merged in order to create 21st
century constantly mediated social-visual culture.

Although the visuals are not actually alive, one cannot
fail to grasp the fascination or evolution that visuals
and visual data have embarked upon. It is no longer
possible to see the relationship of the visual as lim-
ited to the space of the traditional screens in the film
theater or at home in the living room with the TV. The
mobility of contemporary visuals and contemporary
screens has pushed boundaries – so much so that
'embeddedness' of visuals onto and into things is a
daily practice. The viewers have acquired expecta-
tions that it is possible, or that it should be possible,
to recall the image of an object and to be able to have
that same object appear at home at will. The process
of downloading should not be limited to 'immaterial'
digital data, but should be transferred to 3D physical
objects. [1]

Images are projected onto buildings – not as the tra-
ditional trompe l'oeil placed to disguise and trick the
eye – but as an architectural element of the building
itself; so much so that there are arguments, including
mine, that we should substitute walls with projected
information data, which should also have and be
perceived as having material properties (see in this

volume "Architectural Projections" by Lukas Treyer,
Stefan Müller Arisona & Gerhard Schmitt).

Images appear over the architecture of the buildings
as another structural layer, one made of information
data that relays more to the viewer either directly or
through screens able to read augmented reality infor-
mation. But live visuals relay more than images, they
are also linked to sound and the analysis of this link-
age provides us with the opportunity "to think about
the different ways in which linkages between vision
and audition can be established, and how audio-visual
objects can be composed from the specific attributes
of auditory and visual perception" (see "Back to the
Cross-modal Object" by Atau Tanaka).

iPads and iPhones – followed by a generation of
smarter and smarter devices – have brought a radi-
cal change in the way reality is experienced, captured,
uploaded and shared. These processes allow reality
to be experienced with multiple added layers, allow-
ing viewers to re-capture, re-upload and re-share,
creating yet further layers over the previous layers
that were already placed upon the 'original.' This lay-
ering process, this thickening of meanings, adding of
interpretations, references and even errors, may be
considered as the physical process that leads to the
manifestation of the 'aura' as a metaphysical concept.
The materiality of the virtual, layered upon the 'real,'
becomes an indication of the compositing of the
aura, in Walter Benjamin's terms, as a metaphysical
experience of the object/image but nevertheless an

experience that digital and live visuals are rendering
increasingly visible.

"Everything I said on the subject [the nature of aura]
was directed polemically against the theosophists,
whose inexperience and ignorance I find highly
repugnant. . . . First, genuine aura appears in all things,
not just in certain kinds of things, as people imagine." [2]

The importance of digital media is undeniably evident.
Within this media context of multiple screens and sur-
faces the digitized image, in a culture profoundly visual,
has extended its dominion through 'disruptive forms'
of sharing and 'illegal' consumption. The reproducibili-
ty of the image (or the live visuals) – pushed to its very
limit – has an anarchistic and revolutionary element
when considered from the neocapitalistic perspective
imbued in corporative and hierarchical forms of the
construction of values. On the contrary, the reproduc-
ibility of the image when analyzed from a Marxist point
of view possesses a community and social component
for egalitarian participation within the richness of con-
temporary and historical cultural forms.

The digital live visuals – with their continuous potential
of integration within the blurring boundaries of public
and private environments – will continue to be the
conflicting territory of divergent interests and cultural
assumptions that will shape the future of societal en-
gagements. Reproducibility will increasingly become
the territory of control generating conflicts between
original and *copy*, and between the layering of *copy*
and *copies*, in the attempt to contain ideal participa-
tory models of democracy. The elitist interpretation of
the aura will continue to be juxtaposed with models of
Marxist participation and appropriation. [3]

Live visuals projected on public buildings and private
areas do not escape this conflict, but present interpre-
tations and forms of engagements that are reflections

of social ideals. The conflict is, therefore, not solely in
the elitist or participatory forms of consumption but
also in the ideologies that surround the cultural behav-
iors of visual consumption.

Object in themselves, not just buildings, can and may
soon carry live visuals. There is the expectation that
one no longer has to read a label – but the object can
and should project the label and its textured images
to the viewer. People increasingly expect the object
to engage with their needs by providing the necessary
information that would convince them to look into
it, play with it, engage with it, talk to it, like it and ulti-
mately buy it.

Ultimately there will be no need to engage in this
process but the environment will have objects that,
by reading previous experiences of likes and dislikes,
present a personalized visual texture of reality.

Live visuals will provide an environment within which
purchasing does not mean to solely acquire an object
but rather to 'buy' into an idea, a history, an ideology
or a socio-political lifestyle. It is a process of increased
visualization of large data (Big Data) that defines and
re-defines one's experience of the real based on previ-
ously expressed likes and dislikes.

In this context of multiple object and environmental
experiences it is also possible to forge multiple individ-
ualized experiences of the real; as much as there are
multiple personalized experiences of the internet and
social media through multiple avatar identities (see
"Avatar Actors" by Elif Ayter). The 'real' will become
a visual timeline of what the algorithm has decided
should be offered based on individualized settings of
likes and dislikes. This approach raises an infinite set
of possibilities but of problems as well.

The life of our representation and of our visuals is our 'real' life – disjointed and increasingly distant from what we continue to perceive as the 'real real,' delusively hanging on to outdated but comfortable modes of perception.

The cinematic visions of live visuals from the 19th century have become true and have re-designed society unexpectedly, altering dramatically the social structures and speeding up the pace of our physical existence that constantly tries to catch up and play up to the visual virtual realities that we spend time constructing.

If we still hold to this dualistic and dichotomist approach of real versus virtual (although the virtual has been real for some time and has become one of the multiple facets of the 'real' experience), then the real is increasingly slowing down while the virtual representation of visuals is accelerating the creation of a world of instantaneous connectivity, desires and aspirations. A visuality of hyper-mediated images that, as pollution, pervades and conditions our vision without giving the option of switching off increasingly 'alive' live visuals. [4]

The lack of 'real' in Jean Baudrillard's understanding is speeding up the disappearance of the 'real' self in favor of multiple personal existential narratives that are embedded in a series of multiple possible worlds. It is not just the map that is disappearing in the precession of simulacra – but the body as well – as the body is conceived in terms of visual representation: as a map. These multiple worlds of representations contribute to create reality as the 'fantasy' we really wish to experience, reshaping in turn the 'real' identity that continuously attempts to live up to its 'virtual and fantastic' expectations. Stephen Gibson presents the reader with a description of one of these worlds with live audio-visual simulations that create a synesthetic

experience (see "Simulating Synesthesia in Spatially-Based Real-time Audio-Visual Performance" by Stephen Gibson).

If this fantasy of the images of society is considered an illusion – or the reality of the simulacrum, which is a textual oxymoron at prima facie – it will be determined through the experience of the *live visuals becoming alive.*

Nevertheless, stating that people have illusory perceptions of themselves in relation to a 'real' self and to the 'real' perception of them that others have only reinforces the idea that Live Visuals will allow people to manifest their multiple perceptions, as simulated and/or real will no long matter. These multiple perceptions will create multiple ever-changing personae that will be further layered through the engagements with the multiple visual environments and the people/avatars that populate those environments, both real and virtual.

In the end, these fantasies of identities and of worlds, manifested through illusory identities and worlds within virtual contexts, are part of the reality with which people engage. Although fantastic and illusory, these worlds are a reflection of a partial reality of the identity of the creators and users. It is impossible for these worlds and identities to exist outside of the 'real.' This concept of real is made of negotiated and negotiable frameworks of engagement that are in a constant process of evolution and change.

The end of post-modernity and relativism may lead to the virtuality of truism: the representation of ourselves in as many multiple versions – already we have multiple and concurrent digital lives – within the world/s – ideological or corporate – that we will decide or be forced to 'buy into.'

It is this control of the environment around us and us within that environment that will increasingly define the role that live visuals will play in negotiating real and virtual experiences. The conflict will arise from the blurred lines of the definition of self and other; whether the 'other' will be another individual or a corporation.

The potential problems of this state of the live visuals within a real/virtual conflict will be discovered as time moves on. In the end this is a giant behavioral experiment, where media and their influences are not analyzed for their social impact *ex ante facto*; this is something that happens *ex post facto*.

Nevertheless, in this ex post facto society there are some scholars that try to understand and eviscerate the problems related to the process of visuals becoming alive. This issue collects the analyses of some of these scholars and embeds them in a larger societal debate, hinting at future developments and problems that society and images will have to face as the live visuals become more and more alive.

The contemporary concerns and practices of live visuals are crystallized in this volume, providing an insight into current developments and practices in the field of live visuals.

This issue features a new logo on its cover, that of New York University, Steinhardt School of Culture, Education, and Human Development.

My thanks to Prof. Robert Rowe, Professor of Music and Music Education; Associate Dean of Research and Doctoral Studies at NYU, for his work in establishing this collaboration with LEA.

My gratitude to Steve Gibson and Stefan Müller Arisona, without them this volume would not have been

possible. I also have to thank the authors for their patience in complying with the guidelines and editorial demands that made this issue one that I am particularly proud of, both for its visuals and for its content.

My special thanks go to Deniz Cem Önduygu who has shown commitment to the LEA project beyond what could be expected.

Özden Şahin has, as always, continued to provide valuable editorial support to ensure that LEA could achieve another landmark.

Lanfranco Aceti
Editor in Chief, Leonardo Electronic Almanac
Director, Kasa Gallery

1. 3D printing the new phenomenon will soon collide with a new extreme perception of consumer culture where the object seen can be bought and automatically printed at home or in the office. Matt Ratto and Robert Ree, "Materializing Information: 3D Printing and Social Change," *First Monday* 17, no. 7 (July 2, 2012), http://firstmonday.org/ojs/index.php/fm/article/view/3968/3273 (accessed October 20, 2013).
2. Walter Benjamin, "Protocols of Drug Experiments," in On Hashish, ed. Howard Eiland (Cambridge, MA: Harvard University Press, 2006), 58.
3. " The point here is not to issue a verdict in the debate between Adorno and Benjamin, but rather to understand the debate between them as representing two sides of an ongoing dialectical contradiction." Ryan Moore, "Digital Reproducibility and the Culture Industry: Popular Music and the Adorno-Benjamin Debate," Fast Capitalism 9, no. 1 (2012), http://www.uta.edu/huma/agger/fastcapitalism/9_1/moore9_1.html (accessed October 30, 2013).
4. Paul Virilio, *Open Sky*, trans. Julie Rose (London: Verso, 1997), 97.

IMPROVISING SYNESTHESIA

Comprovisation of Generative Graphics and Music

by

Joshua B. Mailman

Department of Music
University of California, Santa Barbara
jmailman-at-alumni.uchicago.edu

INTRODUCTION

Recent artistic practices and technologies are re-shaping the definitions and categories of musical and visual artistic creativity. New categories arise, such as *comprovisation*. In my own creative practice, I pursue new connections between embodiment, spontaneity, and technology. Recent technologies provide opportunities to combine hierarchical process aspects of composition with the embodied spontaneity that characterizes improvisation.

For me this has led to the development of the *Fluxations* and *FluxNoisations* interactive systems, each of which enables the performer to spontaneously create – through a fully embodied *immersive* process – audio-visual trajectories that are *expressive*. [1] Such trajectories are intended to have aesthetic value emanating from prior aesthetic experience of musical and visual art works. In this case the development of such systems has arisen through careful and systematic analysis of prior works, analysis that is computational but inspired by phenomenology of listening. For instance, new ways of systematically analyzing the flux of texture in music have inspired generative technologies: new ways to synthesize texture as controlled through

ABSTRACT

Through recent artistic practices and technology of interactive systems for music, composition and improvisation have more and more blended and interconnected with each other – a sui generis *situation now called* comprovisation. *The concept of comprovisation applies equally well to the spontaneous generation and manipulation of computer graphics, especially as such graphics are systematically coordinated audio-visually, while being subject to spontaneous manipulation by a performer.*

This is explained in terms of the Fluxations *and* FluxNoisations *Human Body Interfaces, interactive dance systems that generate music and graphics spontaneously in response to hand and body movement. They enable spontaneous expressive shaping of coherent complexity and variety. Thus a multi-layered multimodal experience arises. The aesthetic experience of this multimedia spectacle relates to experiences of various prior music and visual art of the 19th, 20th, and 21st centuries, as well as to hypothetical physical realities. Thus a kind of cybernetic phenomenology of art is pursued and enacted through an embodied cybersynthesis of art with simulated alternate reality. Call it a pragmatic speculative realism, an adventurous* technoetic *'what if.' As compared to more traditional forms of improvisation, the opportunities for risk-taking and aesthetic exploration rise to a new level of uncertainty, as the reactions of the improviser simultaneously draw from and target both visual and aural modalities, such that the intentions toward each fuse together.*

bodily dance movement. The analytical and creative processes constitute a cybernetic *techné*, which similarly fuels the computer graphics that are generated spontaneously through these systems.

CORPOREAL BEYOND CATEGORIES

Consider how the distinction between music composition and improvisation is blurred by the artistic practices and technology of interactive systems. In music this

phenomenon has been discussed since the 1980s (by Joel Chadabe, [2] David Rokeby, [3] and George Lewis [4]). Recently the term *comprovisation* has been coined to denote this *sui generis* situation, as discussed by Richard Dudas, [5] Sandeep Bhagwati, [6] and myself. [7] [8] [9] The concept of comprovisation applies equally well to the spontaneous generation and manipulation of computer graphics, especially as such graphics are systematically coordinated across audio-visual domains while being subject to spontaneous manipulation by a performer. This paper explains comprovisation (especially
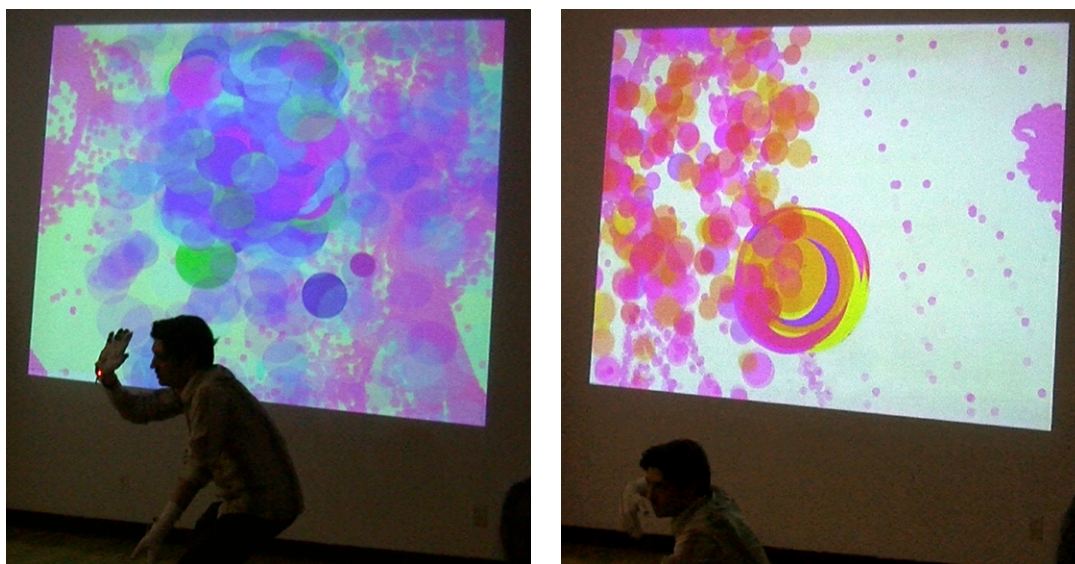
Figure 1. Stills from *Montreal Comprovisations* No.1 and 2, Joshua B. Mailman, 2012. Filmed on June 15, 2012, at Skin—Surface—Circuit: Embodying the Improvisatory, ICASP-McGill Center for the Critical Study of Improvisation Interdisciplinary Conference, in Montreal. The first photo shows a blue-oriented bubble explosion in progress; the second shows one red-oriented bubble explosion in progress in the upper left and another just begun toward the center of the screen. Photos by Stephanie Khoury. View at http://vimeo.com/fluxations/mc1. © Stephanie Khoury, 2012. Used with permission.

Figure 2. Stills from *"Firefly Fury" (Marathon Demonstration)*, Joshua B. Mailman, 2012. Filmed on June 18, 2012, at the Columbia Computer Music Center, Columbia University, New York. The picture on the right shows a higher density of foreground ellipse because the right wrist is flexed outward, as compared to the picture on the left, where it is flexed inward. Photos by Danielle Y. Robinson. View at http://vimeo.com/fluxations/ff. © Danielle Y. Robinson, 2012. Used with permission.

as it relates to my own artistic and technological practices) and details how comprovisation is manifested through the live computer graphics component of the *Fluxations* and *FluxNoisations* Human Body Interfaces (interactive dance-music-graphics systems) developed by myself and Sofia Paraskeva. [10] [11] [12] [13] [14] Figures 1 and 2 show photos from *Fluxations* performances in Montreal and New York. [15] Montreal Comprovisation No.1 is shown at http://vimeo.com/fluxations/mc1.

Figure 3 shows the hardware-software setup employed in *Fluxations*. [16] [17] Several aspects of this setup were developed and employed by Paraskeva prior to the collaboration, in her multimedia installation *Rainbow Resonance*. [18]

SPONTANEOUS VISUAL ART PERFORMANCE? ADDRESSING THE CHALLENGES

As Hazel Smith and Roger T. Dean argue, many kinds of graphic art are improvisatory in their creative process, which is not necessarily and not even usually observed by the art viewer. [19] Unlike the case with music, there has not really been a tradition of live-performed improvised graphic art, mostly because of the nature of the medium, which is in many ways inherently different from music. Both music and graphic art can be experienced sequentially in a narrative way on the one hand; and can both be experienced paratactically in a synoptic way on the other. [20] Nevertheless each has its own preferred default mode from which one gains the other kind of experience. [21] The default mode of music experience tends to be sequential whereas the default mode of visual art experience tends to be synoptic. Though much is gained by striving against the grain, music by default is more sequential and visual art more synoptic in the way they are most immediately experienced. The prospect of live-computer graphics potentially disrupts this

Figure 3. The hardware-software setup for *Fluxations* and *FluxNoisations*. Typically the computations are distributed between two or more computers. OSC messaging is used to transfer the data between them. © Joshua B. Mailman. Used with permission.
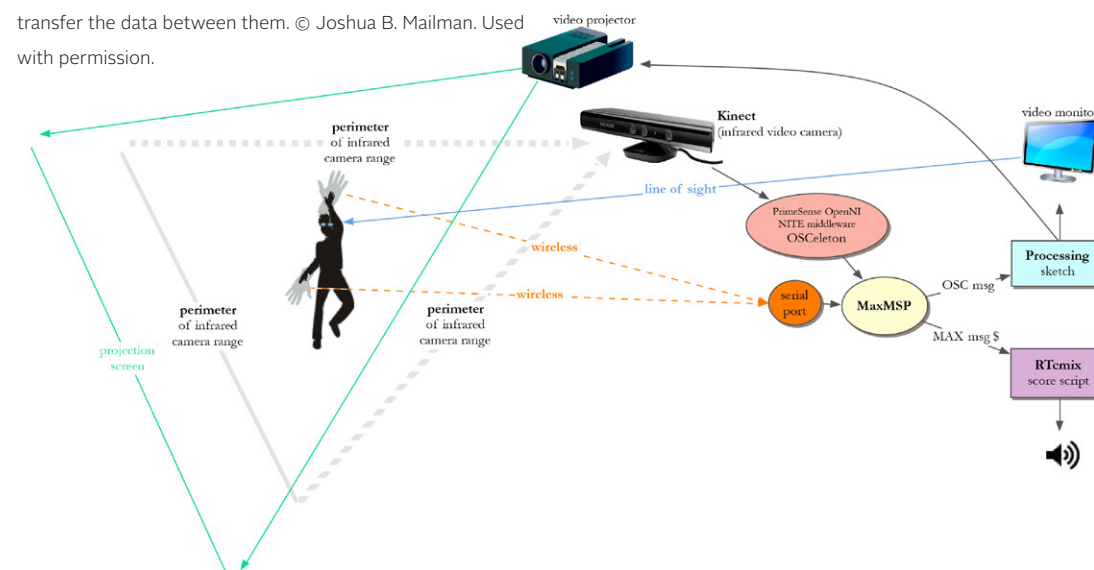
default, addressing a challenge that is insuperable with non-technological means.

The synoptic immediacy of visual art demands that sufficient content be presented to the viewer at any moment in time; this sets up a huge obstacle thwarting the live-improvisation of visual art. How can sufficient visual complexity be generated spontaneously? How can it be improvised?

This depends partly on how improvisation is defined. Though improvisation can be defined simply as "the simultaneous conception and performance of a work," its relevance can also "extend beyond the *performing* arts, in which the whole work unfolds in the presence of an audience," as remarked by Dean and Smith. [22] [23] [24] Visual art has mostly been *non*-performing art; yet even in this realm we can see how widespread and diverse is the inclination to improvise visual art or conceptualize visual art as improvisatory. Kandinsky's paintings called *Improvisations* are obvious examples, though perhaps Andy Goldsworthy's environmental art works are more apropos in this case, as they exploit and steer the complexity found in nature, and also respond to the "state of changes" in natural environments. [25] Michael Snow's chemical-heat improvisations on film stock are another example. Such examples of the improvisatory inclination in non-performing visual arts (painting, sculpture, and film), considered together with the well-known fascination with improvised live music performance, suggests that the fusion of these is even more tantalizing, if only it were possible to achieve sufficiently complex results in such a fusion. In this way Kandinsky's, Goldworthy's, and Snow's non-performing visual art improvisations underscore the urgency of this essay's topic, which is the spontaneous creation or completion of visual art in the presence of spectators: improvisation of visual art as an observed performance. How is sufficient visual complexity to be generated in this case? How can

a visual improviser break through the barrier to sufficient visual complexity?

There are certainly various kinds of visual performance art, though they are not necessarily always improvised, and usually more performative in emphasis than they are visual. That is, the interest lies in attending to the performance itself as much as to the visual art created in or through that performance. We attend more to the performing than to the performed. In the case of 'performance drawing,' complexity arises somewhat predictably from the gradual accumulation of visual imagery.

Visual improvisation is still nowhere near as prevalent or established as musical improvisation is; nevertheless the relatively recently surging art of computer graphics animation has started to break down the complexity barrier, making it easier to generate sufficient visual complexity spontaneously in the moment of performance. Thus visual art improvisation is more viable, promising, and compelling, than it was in the past.

For example an exception that has been breaking down the complexity barrier is the practice of VJ-ing, the quasi-improvised computer graphics made with video crossfading mixing software as visual accompaniment to live computer dance music in clubs, enabled by such software as Ableton Live and Grand VJ. [26] Usually such practices employ canned images and patterns that are combined, recombined, and filtered on the fly – this is more akin to the way a DJ mixes and filters audio clips than to the way a musician improvises. It is macro-improvising with pre-made materials.

One approach is to spontaneously manipulate complexity already in the environment for instance through live filtering, scrubbing, and processing of recorded audio or video. If done with pre-synthesized

or pre-recorded sounds, this usually produces a degree of chaos that thwarts expressivity in the moment of performance. [27] The performer can compensate for this limitation by physically making and recording in real-time the sounds to manipulate, a kind of live-musique concrète, as Michel Waisvisz famously achieved with his *hands* interactive system. The use of Jitter to process pre-recorded video or a live video feed is analogous to such practices. Thus such digital manipulative practices are an obvious analogical link between improvised (spontaneously created and performed) technological sonic and visual art. (Arvid Tomayko-Peters and Steve Schwartz's *Oleophobic* (2010) is a recent example that employs pre-collected physical materials (colored oil and water and audio samples) to improvise a colorful audio-visual spectacle with complexity in both the audio and visual domains, though these complexities only weakly correlate with each other across the audio and visual modalities. [28] On a more ongoing basis, in the 2000s, the audio-visual interactive performance trio Cécile Babiole, Laurent Dailleau, and Atau Tanaka (called *Sensors_Sonics_Sights*) stands as one of the highpoints of the genre). [29]

The conceptual influence of visual art on musicians and sonic artists is well recognized. [30] [31] Yet even tighter links are possible, through the coordination of pre-composed generative algorithms whose control input is manipulated improvisationally. [32] In this case computer graphic art can take a lesson from music, applying this to specifically visual phenomena that are much less immediate in the sonic realm: geometry, texture, and color. Quantitative music comprovisational processes can be applied directly to these aspects of visual perception in order to manipulate complexity in live performance. Specifically, since the 1980s, but even more so recently, some technologically inclined musicians have been developing ways to "improvise" complexity, by exploiting stochastic compositional

methods pioneered originally by Iannis Xenakis [33] in the 1950s, but now expanded and implemented with live interactive generative hardware-software technology. This has been called *interactive composing* or, since 2010, *comprovisation*, which is the use of technology to generate complexity that is spontaneously controllable. [34] [35] [36] This is to use controlled chance procedures, stochastic methods, to produce complexity that is sufficiently and appropriately regular. Such regulated complexity cancels out, and thereby neutralizes, the features that are *not* being manipulated expressively in the moment of performance. This practice has interesting side effects that relate back to improvisation in a different way, as discussed in a later section of this essay.

COMPROVISATION

The philosopher Bruce Benson describes improvisation as activity between composition and performance. [37] Though performative in its way, comprovisation – as the word suggests – straddles whatever divide persists between composition and improvisation, and does this through the use of interactive technology. Consider *Comprovisation*. [38] [39] [40] [41] [42] [43] [44] It is a kind of musical creativity that relates composition and improvisation in an unprecedented fashion, one which was impossible to achieve with older technologies. *Comprovisation* is compositional in two respects: (1) it involves composing music-generating algorithms as guided by aesthetic concerns, and (2) it may involve the planned choreography of physical movements. *Comprovisation* is improvisational in three ways: (1) it may involve spontaneously decided physical movements; (2) planned (choreographed) movements may be spontaneously ornamented with expressive nuanced deviations; (3) the quasi- stochastic algorithm may be regarded as 'improvising' since its determining of certain details cannot be predicted

Stochastic Interactive Looping (SIL)

Music (audio)

Graphics (visual)

Figure 4. (a) The basic scheme of algorithm-input interactivity for the music generation of Fluxations; (b) The basic scheme of algorithm-input interactivity for the graphics generation of Fluxations. © Joshua B. Mailman. Used with permission.

in advance (this component could be programmed to function according to knowledge-based improvisational rules rather than stochastically).

As Chadabe explains it *interactive composing* "redefines composing and performing." [45] He outlines a practice in which the composer creates a particular compositional process or interface and algorithmic technology with which a performer interacts to make music in a semi-spontaneous way. For example "the computer's function in [Chadabe's] *Solo* is to compose automatically the notes of a melody, its accompaniment chords, and other aspects of the music, and to interpret the positions of a performer's hands in relation to two proximity-sensitive antennas [sensors]."[46] The player triggers changes through his movement, but cannot foresee exactly what chord will be played next. He moves in response to what he hears. The music making algorithm "responds to a performer in a complex, not entirely predictable way, adding information to what a performer specifies and providing cues to the performer for further actions."

Comprovisation is similar except that it emphasizes expressivity apparent in the performance, though without sacrificing complexity. Therefore the important point about comprovisation is to generate complexity algorithmically in such a fashion that its qualities can be dynamically altered in a perceptible and conceptualizable way. A comprovisational interactive system is designed to separate the details generated by algorithms from the higher level features (macro features, emergent properties) manipulated by the performer. The performer therefore can spontaneously express herself with her movements, by knowing under all possible conditions exactly what kind of feature trajectories she can effect, and what the algorithms will do to supply the complex detail undergoing such trajectories.

The expressive trajectories themselves – in order to be expressive – must occur along conceptual dimensions the performer can comprehend and perceive, and which the audience might subconsciously sense or perhaps even consciously comprehend if properly instructed. Yet they need not correspond to natural sights and sounds that would be caused by the performer's actions in the actual physical world. Neither must they exclude all connection to the dynamics of the real physical world. There is room for both. The created audio-visual world can combine realistic physics with synthetic fantasy and remain expressive as long as the continuums of its dynamism are comprehendible.

In a flux of complexity, comprehension arises not from individualistic features but rather from intensities of emergent, holistic, macro-features, which are computed as statistical tendencies. By being conceptualized and quantified as intensities, these simultaneously can serve as vessels of expression – or "vectors of transmission" for feeling as Alfred North Whitehead says [47] [48] – and with sufficient care and technology can be mapped from physical motions of a dancer-performer. The number of such qualities is theoretically infinite – I have researched and written on many of these in regard to music and its expressive or narrative potential. [49] [50] [51] [52] As examples consider: an intensive continuum from steady smooth rhythm to syncopated irregular rhythm, an intensive continuum from thin transparencies of consonant harmony to muddier densities of dissonance, an intensive continuum from soft blended textures to highly differentiated staccato texture.

The situation for expressive generative graphics is analogous. Comprehension of trajectories within a flux of complexity arises not from individualistic features but rather from intensities of emergent, holistic, macro-features, which are computed as statistical
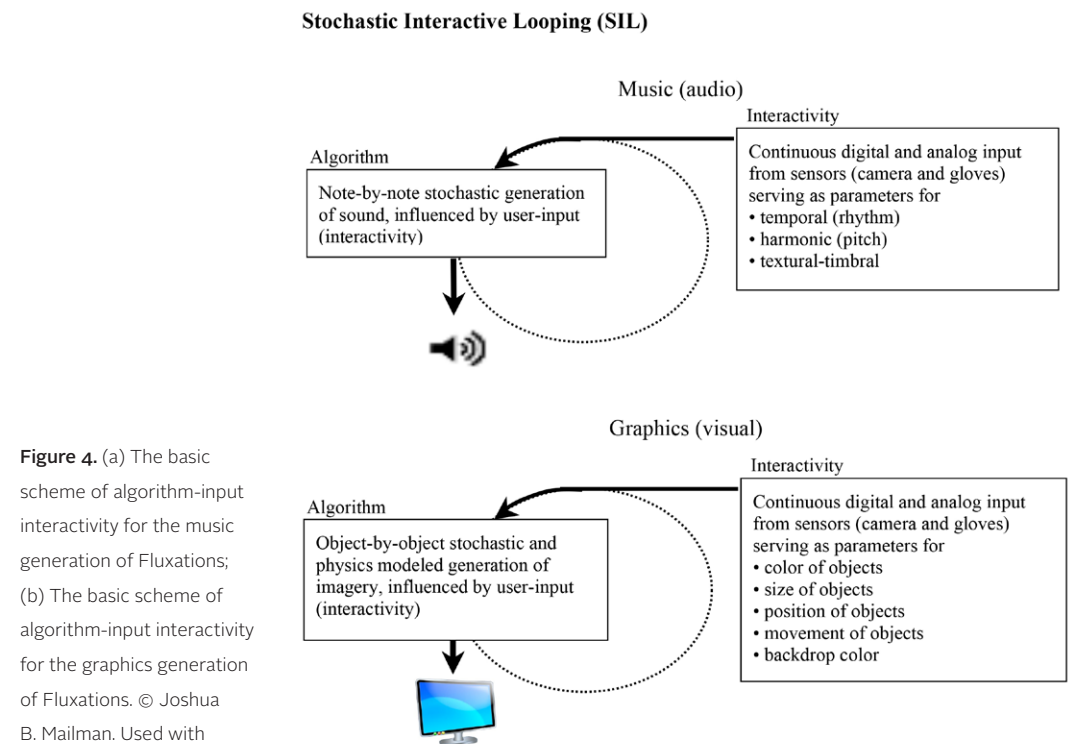
tendencies. The visual field is conceptualized in terms of orderings and continuums of macro-states or statistical tendencies along physical and psycho-physical continuums such as spatial location, speed of movement, and various dimensions of color space. Thus the flux of visual complexity can be expressively steered through physical movement of the body.

Though other generative strategies might be used to generate complexity, I prefer to use mostly stochastic methods (statistically controlled randomness) for real-time interaction because they are regulative, as explained above. They introduce no assumptions to further complicate the interactivity. [53] The performer can rely on the algorithms to *not* produce unintended patterning that would distract from the expressive trajectories she is trying to effect. [54]

Figure 4a diagrams the basic scheme of interactivity for the music generation: *stochastic interactive looping*. [55] Continuous digital and analog input from sensors (camera and gloves) steers various intensities of rhythmic quality, harmonic quality, and texture-timbral quality generated by the stochastic algorithm.

The most recent version of *Fluxations* has up to 15 parameters feeding into the music generating algorithm.

Figure 4b diagrams the interactivity for the graphics engine. Again, continuous digital and analog input from sensors (camera and gloves) steers various aspects of the generated visual imagery: color of objects, size of objects, position of objects, movement of objects, and the backdrop color. To maintain sufficient complexity, the steering is indirect. Like the music engine, the graphics engine employs stochastic methods (random number generators and Perlin noise). Additionally, however, it also employs real-world physical modeling (gravity and inertia). Together, these create complexity that can be maneuvered expressively and perceived as being coherent.

MULTIMODAL IMMERSION, EXPRESSION, COMPLEXITY, AND CONTINUITY

Fluxations and *FluxNoisations* are operated by a musician-dancer moving around a room in front of a *kinect* infrared camera while wearing wireless sensor gloves,

as shown above. This movement steers algorithmically generated music and graphics. As the musician-dancer moves, the audible and visible qualities of the music and graphics are linked systematically to the perform-er's motion, to enable expressivity.

Comprovisation technologies, such as these, are not just interactive but more specifically are expressive and often fluid as well: they enable a wide spectrum of smooth and abrupt changes which the performer can exert according to plan or impulse. This spectrum of kinds of changes (smooth vs. abrupt) occurs in co-ordination in the music and the graphics generated in *Fluxations*. Abrupt and smooth changes are enabled by linking intensities of macro-qualities directly to absolute and relative spatial location (position of the torso or angle of the wrist for instance). Since the physical space we move in is continuous, smooth qualitative change is effected by slow motion of the performer; abrupt qualitative change is effected by sudden motion. Since the qualities of both the music and graphics are sculpted in this way by the per-former's motion, a sudden qualitative change in the music is accompanied by a sudden qualitative change in the graphics, and vice versa; a smooth trajectory of qualitative change in the music is accompanied by a smooth trajectory of qualitative change in the visuals, and vice versa.

In this way, the graphics coordinate noticeably with the music, creating an immersive world, whose cor-related audio-visual trajectories are expressively steered and sculpted like fluid by the motions of the human body moving through continuous space. Aural and visual interconnect in *Fluxations*. Its prismatic particle systems and fluctuating continuities of color, texture, harmony are maneuvered by the planned or spontaneous actions of the performer. The genera-tive algorithms are designed to maximize both variety and coherence of the musical and visual experience,

including cross-modal relations between them and evolving emergent patterns of particles and bubbly explosions. For instance, *Montreal Comprovisation No.2* differs from *Montreal Comprovisation No.1* in that, in it, my improvising emphasizes a rhythmic pulse and various degrees of syncopation; the difference in style is not achieved through any change to the sys-tem but rather through spontaneous body and glove maneuvers. (Montreal Comprovisation No.2 appears at http://vimeo.com/fluxations/mc2.)

INTERACTIVE SYSTEM DESIGN FOR MULTI-LAYERED MULTIMODAL EXPERIENCE

To maximize the variety of expression, I took a multi-layered approached to both the music generation and the graphics generation. The music and graphics each have three layers: (1) background, (2) foreground, and (3) direct interaction. There are no additional layers, beyond these six; for instance there are no pre-com-posed layers; all layers are algorithmically generated and interactive. The background layers continue their activity always; their qualities (colors, shapes, locations, distributions, rhythms, harmonies) affected by the per-former's movement. The foreground layers activate to varying degrees in response to right-hand wrist flexing of the performer. Their qualities are also affected by the full body motion of the performer. The direct layer is the only one that allows the performer to initiate an event directly, by pressing a button on the left-hand glove, which triggers a percussive attack synchronized with a bubbly explosion of colors, whose qualities are systematically coordinated with the four other visual and audio layers. The wireless sensor gloves – which also affect several qualities of the other visual and audio layers – were designed, built, and programmed by my collaborator Sofia Paraskeva in consultation with me, expanding on an earlier version of her gloves which predated our collaboration. [56] Figure 5 shows
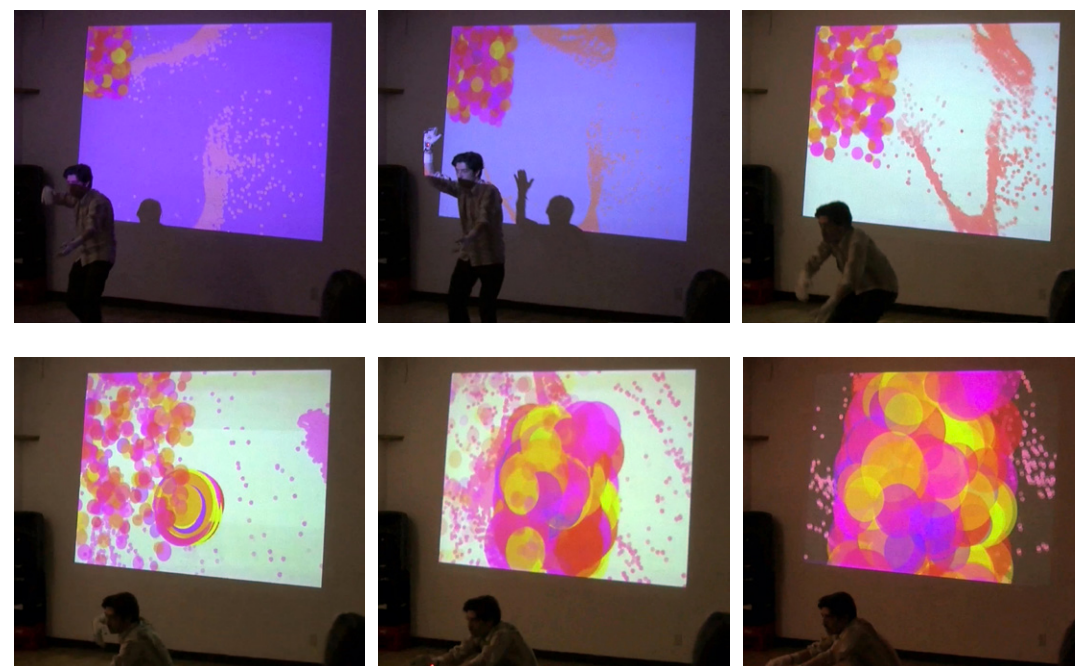
Figure 5. The progress of two successive direct layer explosions of bubbles, first from the upper left corner: stills from *Montreal Comprovisation No.1,* Joshua B. Mailman, 2012. Photos by Stephanie Khoury. View at http://vimeo.com/fluxations/mc1. © Stephanie Khoury, 2012. Used with permission.

the progress of two successive bubble explosions each directly initiated from the glove during *Montreal Comprovisation* No.1.

The three visual layers link to each other through their emphasis on *ellipses*. The size, shape, position, move-ment, and color of these ellipses vary in all three layers according to the position and movement of the per-former, but the way these vary in each layer is differ-ent. That is, the systematic dependency of ellipse size, shape, position, movement, and color is different in the background layer as compared to the foreground layer, and is different again in the direct layer.

Though not identical, neither are the layers indepen-dent of each other. Their activities mutually interact. For instance the music engine's pool of pitches sys-tematically expands, contracts, and shifts, according to the performer's position, but at all times this dynamic pool is shared by all three music layers. Thus the har-monic coherence of the entire complex surface of the music is orchestrated under all conditions of simplicity and complexity, of consonance and dissonance, as well as sudden vs. gradual change.

Though no one aspect binds them all together, the three visual layers also intersect in various ways. For instance the direct layer and the foreground layer share a pool of colors which shifts dynamically accord-ing to the position of the performer. The background layer itself consists of a solid backdrop and a particle system, the colors of each of which fluctuate differ-ently. Both, however, present activity whose vertical and horizontal position on the screen correlates to the vertical and horizontal position of the performer's left hand. (The left hand movement perturbs the minia-ture bubbles which comprise the background layer's particle system; the left hand movement also deter-mines the source location of the direct layer's bubble explosions.) The foreground layer determines position by a different strategy. It uses the Perlin noise function to determine the location of its objects. I used Perlin noise (smooth randomness) to determine the coordi-nates of the ellipses because I want the eye to follow each new ellipse when they occur in quick succession as happens at fast tempos. To be noticed, a newly appearing ellipse should appear nearby the previous one, which increases the likelihood it will catch the attention of the observer's darting eyes. The random but smooth nature of Perlin noise tends to ensure this
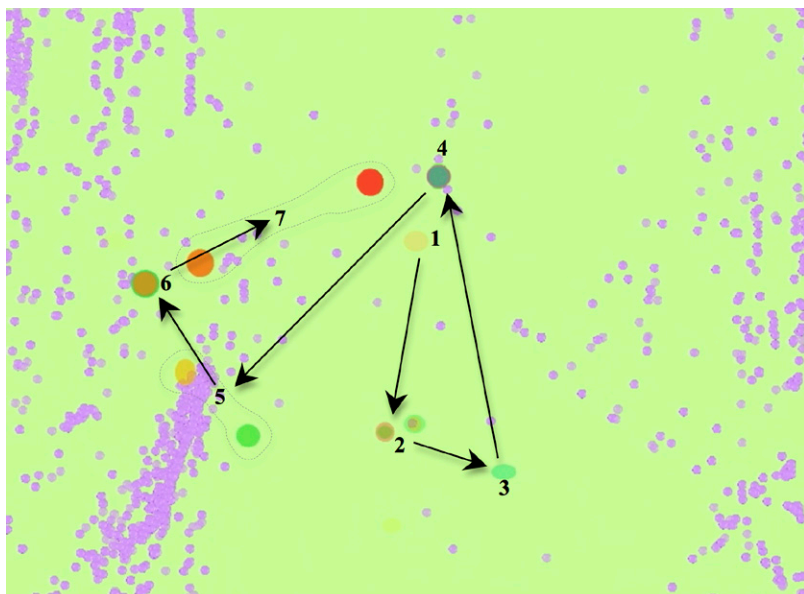
Figure 6. Dance of the ellipses (Perlin noise dance): The proximity and ordering in which foreground layer ellipses appear as their locations are determined by the smooth randomness of the Perlin noise function. Fast tempo excerpt from *Full Body Comprovisation No.1* at 4:22 (direct screen capture), Joshua B. Mailman, 2012. © Joshua B. Mailman, 2012. Used with permission.

while providing lively motion, so the ellipses seem to dance around the center of the screen, as shown in Figure 6.

The size of the foreground layer ellipses maps directly from the tempo (temporal density) of the music, which is controlled by flexing the left wrist and by tempo multiplier buttons on the left hand. Larger ellipses correlate to slower tempos, their size and rate of appearance are thus made inversely related. It adjusts to all the gradations in the aural and visual field of perception: from perceiving events individually, on the one hand, to perceiving an emergent texture of event multitudes, on the other.

The video *Full Body Comprovisation No.1* illustrates some of these interactions in three overlapping expressive trajectories. It shows increasing tempo with decreasing ellipse size, then increasing pitch variety with increasing color hue variety, then gradually closing the lowpass frequency filter (muffling the sound) with darkening the backdrop (gradually to black): three trajectories in succession created by flexing the left wrist, moving forward toward the camera, and then moving the hands closer together (shown in the video clip at http://vimeo.com/fluxations/vid3).

Of course the most obvious cross-modal link in *Fluxations* is rhythm. Both the visual and the aural streams share precisely the same foreground rhythm. This is

most obvious when the foreground rhythm is syncopated, an effect controlled by degree according to the bending of the left wrist. The videos *Firefly Fury* and *Full Body Comprovisation No.2* illustrate such flux of syncopation, along with other trajectories of flux. (This is shown in three clips: http://vimeo.com/fluxations/vid4, http://vimeo.com/fluxations/vid5, and http://vimeo.com/fluxations/vid6.)

Besides rhythm, *Fluxations* embeds numerous other subtle cross-modal links, which can serve as vessels of bodily expression. One example is that the hue of the solid backdrop in the background layer smoothly shifts according to the lateral movement of the performer; simultaneously the pitch pool of the music engine smoothly shifts (transposes) around the circle of 5ths according to that same movement. Proximity between the performer's hands smoothly affects the darkness vs. brightness of the backdrop as well as the closing and opening of a low-pass frequency filter (timbral darkness vs. brightness) in the music engine.

THE POETICS, TECHNÉ, TECHNOETICS, OF FLUXATIONS: PRAGRAMATIC SPECULATIVE REALISM

As in the everyday world we experience, countless nuances of movement produce some or other result

through elaborate semi-predicable systems of cause and effect in *Fluxations*. Yet its cause-and-effect dynamics are deliberately unconventional. In programming interaction responsive music- and graphics-generative software, one could demonstrate such cause-and-effect responsiveness in a conventional way by reproducing, amplifying, or emulating the sights and sounds actually physically produced directly by the user: the sound of a foot hitting the floor, the image of a body moving across the room.

Yet this seems hardly the point in the artistic realm, including comprovisation. To reproduce exactly and only the same cause-and-effect dynamics the everyday world has might be science, engineering, or entertainment, but not art, which is both less and more than reality. Indeed, Roy Ascott's concept of "*technoetics*" promotes the role of technologically mediated art practices for expanding consciousness and creating meaning, as opposed to profit-motivated use of technology. [57] [58] [59]

Whether subscribing specifically to Harold Bloom's "anxiety of influence" theory [60] or not, it is hardly controversial to acknowledge that artists learn from appreciative-critical reception, interpretation, and

analysis of previous art, even if technology is employed in their subsequent creative responses. [61] Every aspect of artistic craft – whether inherited, refined, or invented anew – is itself a kind of technology, falling under Aristotle's category *techné,* which was in 2011 the basis for an ISEA panel discussion, and now a forthcoming book exploring the thesis that "the creation of work is the creation of concepts, joining the efforts of theory and praxis in one process (*techné*), and that the results of our works are the expression of an ontological proposition (*worldmaking*)." [62]

Through an intricate *techné* of interactivity-to-algorithm parameter mapping, *Fluxations* provides its own musical and visual living environment; not one that mimics the everyday world exactly, but rather one that presents a flux of coherent complexity, and, in so doing, maximizes one's ability to explore and experience a coherent interweaving of sights and sounds I have found aesthetically appealing in works by great composers, painters, and visual artists. These include composers such as Wagner, Liszt, Schoenberg, Varese, Stravinsky, Crawford Seeger, Wolpe, Carter, Babbitt, Ligeti, Reich, Riley, and Partch, improvisers such as Charlie Parker, and visual artists such as Kandinsky, Moholy-Nagy, Clyffird Still, Jackson Pollock, Helen
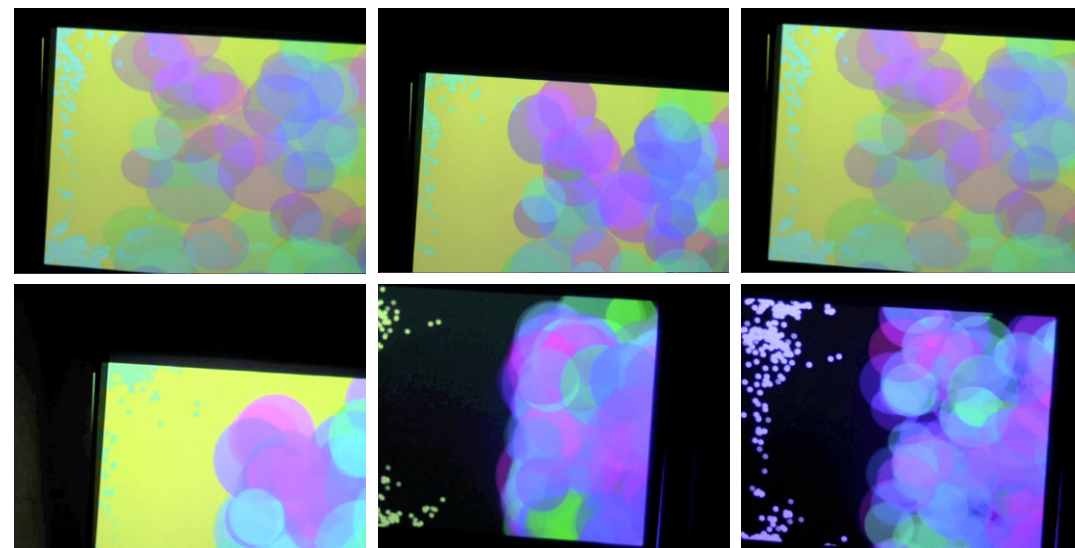
Figure 7. Stills from *"Firefly Fury" (Marathon Demonstration)*, Joshua B. Mailman, 2012. In a bubble explosion, the translucent colors of the large bubbles (oriented to a blue hue) interact as they overlap, reminiscent of the early 20th century artworks of Kandinsky and Moholy-Nagy. Because of motions of the hands and body, in the last two frames the background darkens and the small ellipses in the background particle system shift from green to lavender. Photos by Danielle Y. Robinson. View the video at http://vimeo.com/fluxations/ff. © Danielle Y. Robinson, 2012. Used with permission.
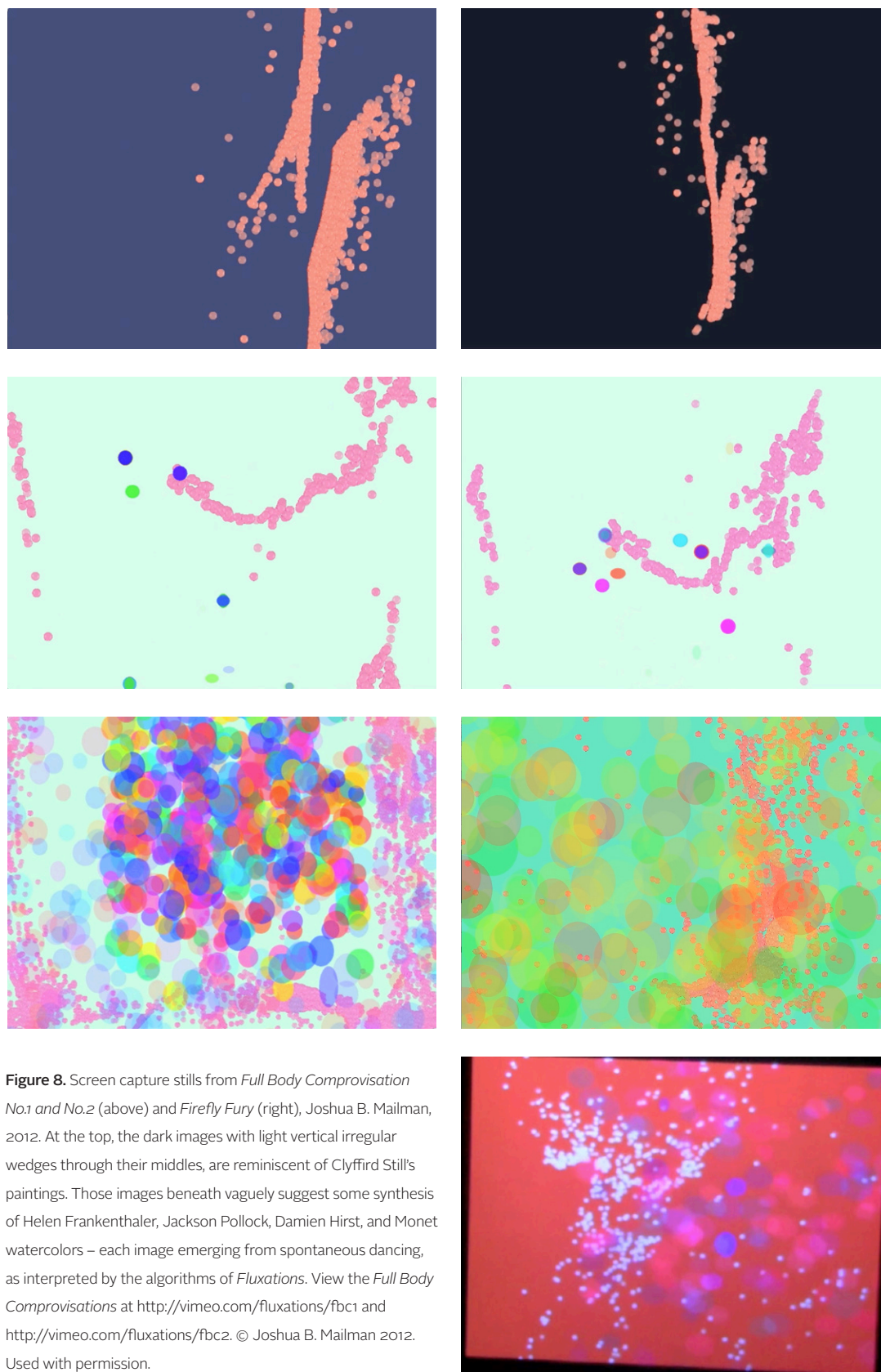
Figure 8. Screen capture stills from *Full Body Comprovisation No.1 and No.2* (above) and *Firefly Fury* (right), Joshua B. Mailman, 2012. At the top, the dark images with light vertical irregular wedges through their middles, are reminiscent of Clyffird Still's paintings. Those images beneath vaguely suggest some synthesis of Helen Frankenthaler, Jackson Pollock, Damien Hirst, and Monet watercolors – each image emerging from spontaneous dancing, as interpreted by the algorithms of *Fluxations*. View the *Full Body Comprovisations* at http://vimeo.com/fluxations/fbc1 and http://vimeo.com/fluxations/fbc2. © Joshua B. Mailman 2012. Used with permission.

Frankenthaler, Stan Brakhage, Harry Smith, John Whitney – even Damien Hirst. For instance, the still frames in Figure 7, captured from *"Firefly Fury,"* relate to the use of superimposed translucent circles in some art works of Kandinsky and Moholy-Nagy. At the top of Figure 8, the dark images with light vertical irregular wedges through their middles, at the moment they arose during the performance, reminded me of Clyffird Still's paintings. Those images beneath vaguely suggest some synthesis of Helen Frankenthaler, Jackson Pollock, Damien Hirst, and Monet watercolors – each image emerging from my spontaneous dancing, as interpreted by the algorithms of *Fluxations*. I was somewhat aware of the associations during the performance. I was also vaguely aware of their possibility when designing and adjusting the algorithms.

Some of the music analyses that inspired *Fluxations*, have themselves been computational, constituting a *cybernetic phenomenology* of music. [63] [64] [65] [66] [67] That is, some of what I learned from all sorts of theorizing, analysis, and casual observation I have programmed into the generating algorithms of *Fluxations* as well as *FluxNoisations*. The logistics of these systems are designed to maximize variety with respect to such diverse artistic styles, while also organizing such diversity into a dynamical coherence of cause-and-effect flux. This is interpretive analysis, systematic theorizing, and creative practice all in one process: *techné,* as a worldmaking endeavor.

CYBERNETIC PHENEMENOLOGY OF ART CYBERSYNTHESIZED WITH SIMULATED REALITY

The *techné* used to create *Fluxations* – its immersive world of fluid dynamism – derives partly from *cybernetic phenomenology* of art (music and visual art), but not exclusively. The *techné* for this interactive system fuses with the *techné* of simulating real-world physical systems, such as the velocity- and proximity-responsive motion of particles in fluid and the effects of inertia and gravity on elements emitted from an explosion. The affective results of artistic developments and real-world physics fuse together in the synthetically immersive environment of *Fluxations*. To do this, for instance, I programmed the elements emitted in the direct layer explosions to wobble like real bubbles moving through the air, even though real bubbles do not partake in explosions in the real world. Also I adapted Andrés Colubri's GPU particle system algorithm which is distributed as part of his GLGraphics library for Processing. [68] Simulating physical reality, the background layer particles move in proportion to the proximity of a disturbance and the speed of that disturbance. (As mentioned above, the disturbance in this case is the detected motion of the performer's left hand.) Yet, to this simulation of real-world physics, my adaptation contributes distinctively non-realistic (surrealistic?) behavior. I make the size and color of the particles vary according to the posture and position of the performer – a behavior that bears no obvious relation to ordinary physical reality.

Art – and specifically interactive technological art – is the opportunity for physically enacted adventures of thought. Separating out some aspects of reality and resynthesizing these with unreal behaviors creates a dynamic alternate reality to experience – a pragmatic *techné* fueled pursuit of *speculative realism*, [69] which Ian Bogost writes about as *alien phenomenology*, [70] which I write about in relation to music and media, [71] and which was hinted at by Roy Ascott who writes:

Art is a form of world building, of mind construction, of self-creation, whether through digital pro-gramming, genetic code, articulation of the body, imaging, simulation, of visual construction. Art is the search for new language, new metaphors, new ways of constructing reality, and for the means of redefining ourselves. It is language embodied in forms and behaviors, texts and structures. When it is embodied in moistmedia, it is language involving all the senses, going perhaps beyond the senses, calling both on our newly evolved cyberception and our rediscovered psi-perception. Moistme-dia are transformative media; moist systems are the agencies of change. The moist environment, located at the convergence of the digital, biological, and spiritual, is essentially a dynamic environment, involving artificial and human intelligence in non-linear processes or emergence, construction, and transformation. [72]

It is quite an adventure. Ascott is here inspired by the *visionary pragmatism* espoused by philosopher Rich-ard Rorty [73] who "eschews the sanctity of philosophy in favor of the artist's visionary impulse and search for metaphor that leads to the continual construction of reality and of the self, thereby denying the passive ac-ceptance of any canonical description [of reality]." [74]

Where's the pragmatism? It relates to what I said above about perceiving coherence in a flux of com-plexity. That is, with the live visuals of *Fluxations*, the pragmatic payoff comes from exploiting and repurpos-ing our usual ability to make sense of the dynamic en-vironment we live in. Specifically, the primary aspects of the real-world simulating particle systems enable the flux of complexity – sometimes a turbulent storm of colorful activity – to be perceived as somehow *coherent,* despite its departures from ordinary reality. Through so much experience, we are used to compre-hending the complex motions of liquid dynamics, to

such an extent that such comprehension is not foiled by systematic changes to the coloration and propor-tionality of the liquid components. The perception of alien but coherent complexity sails on the winds of familiar naturalistic physics.

The role of liquid dynamics and fluidity is not coinci-dental. It relates to Ascott's focus on "moist" to depict a "post-biological" juncture of humans and machines (the "wet" and "wired" merged). Liquid stands iconi-cally for the fascinating coherent complexity of life, of the dynamism of living organisms. I have previously discussed the narrative resonance of water sounds in electroacoustic music, and how this influences the conceptualization of musical form. [75] I have also previously addressed ways in which poetic allusions to naturalistic-meteorological metaphors of flow (riv-ers, winds, torrents) influence the interpretation of musical form. [76] A fluid conception of musical form, what has been called *dynamic form* [77] [78] [79] [80] [81] [82], has been the driving force behind the design of the musical and visual aspects of the *Fluxations'* interac-tive system. An example of such an influence is my own prior use of liquid metaphors to name emergent qualities of musical texture that I modeled *cybernetic phenomenologically.* [83] [84] [85] [86] [87] These same tex-tural emergent qualities ultimately inspired aspects of the music engine of *Fluxations*, and then its live visuals as well.
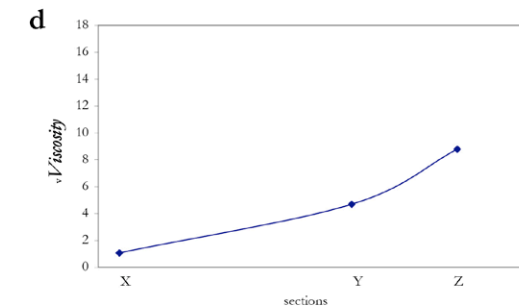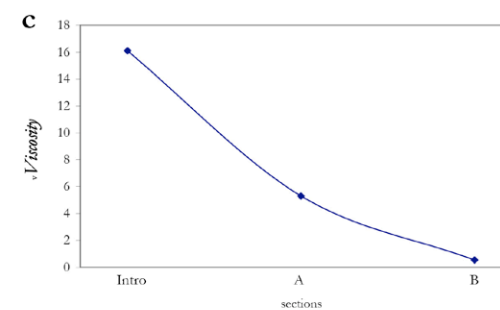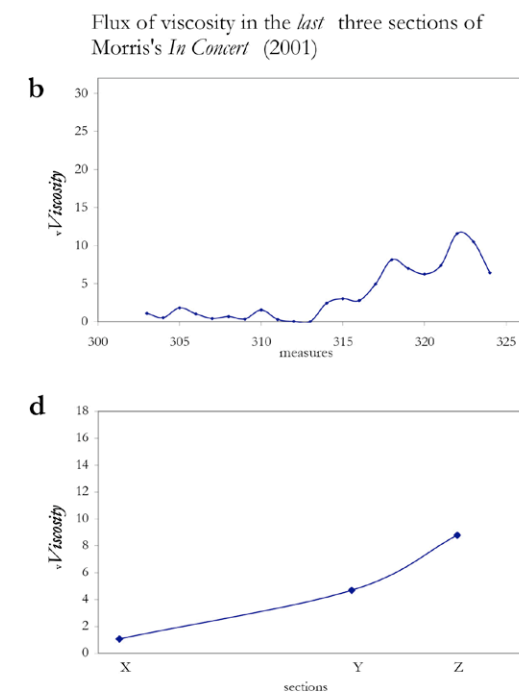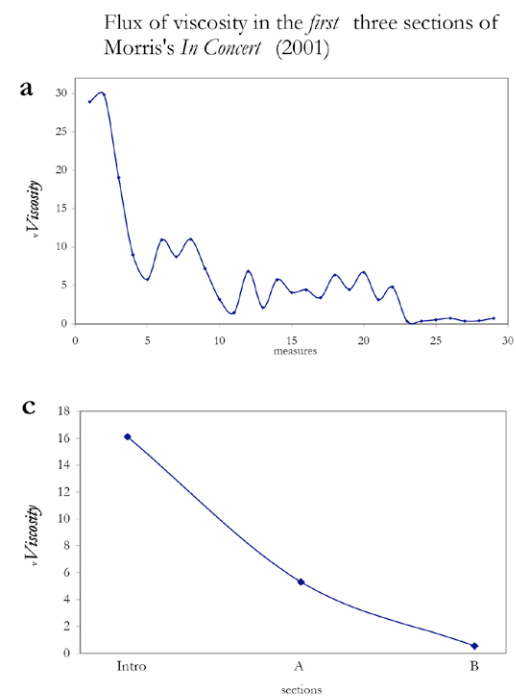
Figure 9. The fluid form of the beginning and ending of Morris's In Concert (2000), depicted in terms of the textural vessel: viscosity. This is shown computed measure-by-measure (top) and section-by-section (bottom). © Joshua B. Mailman, 2012. Used with permission.

FORGING FLUX OF AURAL AND VISUAL TEXTURE, AS INSPIRED FROM AESTHETIC EXPERIENCE

In modeling a fluid conception of musical form (*dy-namic form*) I am drawn to the flux of polyphonic texture in Renaissance (15th century) music of Dufay and Isaac as well as in modern (20th and 21st century) music of Ruth Crawford Seeger and Robert Morris. In terms of the notes in which their compositions are written down, the liquid emergent qualities of a polyphonic texture can be defined as intensities. For instance, the *viscosity* of a span *S* of music can be defined thus:

$$_V Viscosity(S) \ = \ \frac{\sum\limits_{e \in S}(u_e)^2}{\sum\limits_{e \in S}u_e}$$

where u_e denotes the duration of an event (the dura-tion for which a note is sustained), this is the sum of the squares of the durations divided by the sum of the durations, the reasoning for which I explain

elsewhere. [88] [89] (*Fluidity* is defined as the inverse of viscosity. [90] [91]) With such computational modeling, the fluid form of the beginning and ending of Morris's *In Concert* (2000) are depicted in Figure 9.

Such composed textural flux inspires the improvisato-ry control of textural flux enabled by the music engine of *Fluxations*, as shown in Figure 10. Here the dancer-performer is shown increasing viscosity (decreasing fluidity) of the generated music by lowering his body toward the floor.

The same action also increases the size of the bubble particles in the background layer of the live visuals, which is accomplished with the following line of Pro-cessing code: [92]

renderPartFilter.setParameterValue("brush_size", maxHeadHandsHeight);

The color hue of the background layer's bubble particles changes according to the direction the performer is facing, measured as the distance between left and right shoulders along the horizontal (x-axis) plane.

Colubri's GLgraphics particle system acts as a kind of dynamic stencil whereby what appears as a backdrop is actually a curtain with moving holes that represent the particles; their color is the background color that shows through. Therefore I create the shoulder driven control of bubble particle color in the background lay-

er with the following line of Processing code (which is in HSB): 93

background(scaleShoulderWidthTo255(abs(Lshoulderx – Rshoulderx)), 255, 255, 255);

The correlation between shoulder orientation and bubble particle color, and, as explained above, the correlation between vertical position of the body, the textural viscosity in the generated music, and the size of bubble particles in the background particle system are aspects of a dreamt-up system, behaviors of an invented world of coherent cause-and-effect, a physical-technologically enacted "what-if." Three video clips

Vertical position of the body: controlling music texture and particle system bubble size
Viscosity (vs. fluidity) of the music texture and the size of the particle system's bubbles are both controlled by crouching vs. standing upright

Figure 10. Vertical position of the body controlling music texture and particle system bubble size in *Fluxations*, Joshua B. Mailman, 2012. Viscosity (vs. fluidity) of the music texture and the size of the particle system's bubbles are both controlled by crouching vs. standing upright. Each varies on a continuum. Varying degrees of viscosity in the music texture (left column); vertical positions (center column); varying size of bubbles in the particle system (right column). Photos by Sofia Paraskeva. © Joshua B. Mailman and Sofia Paraskeva, 2012. Used with permission.
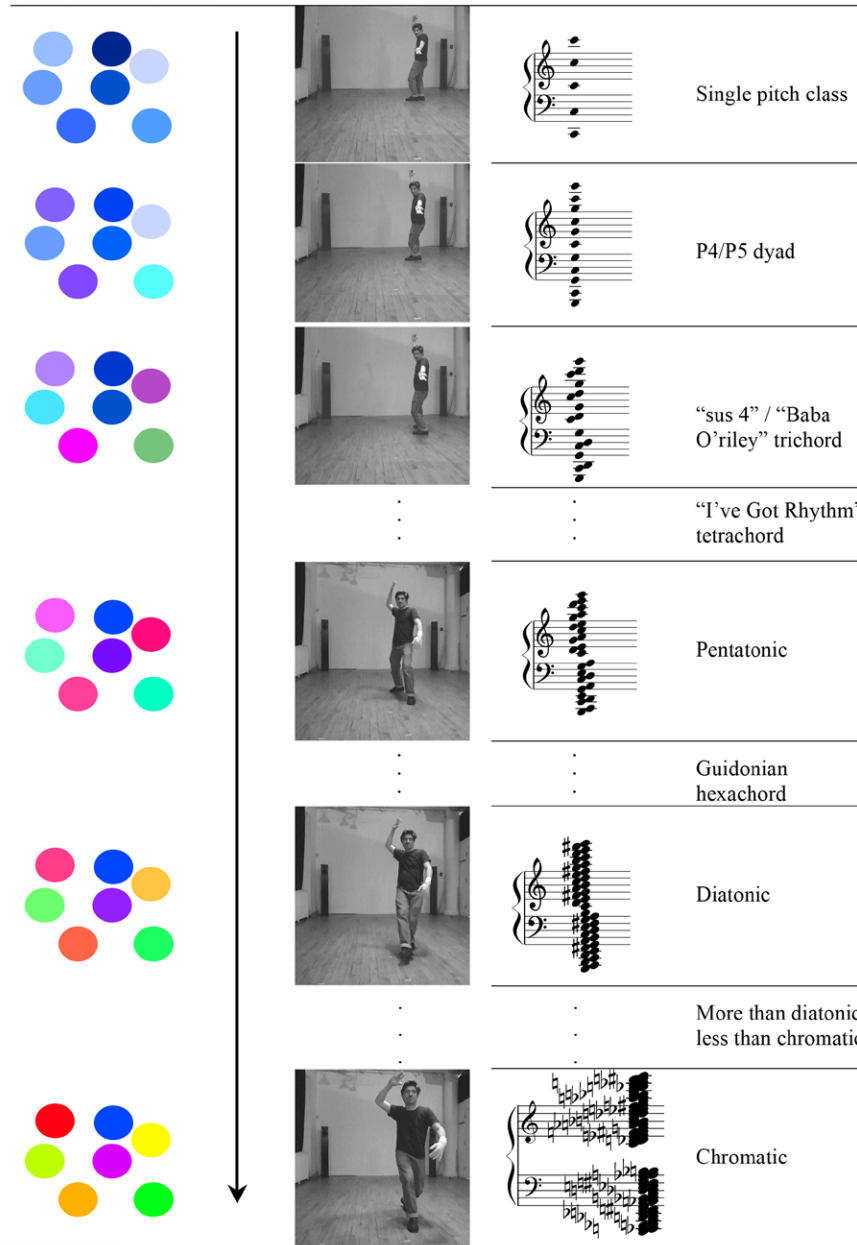
Figure 11. Filling in (populating) blue space and the circle 5th harmonic space by moving forward. From fewer hues and more shades to more hues and fewer shades (left column); from distant to close to the camera (middle column); and hollow to full harmonic space (right column). Photos by Sofia Paraskeva. © Joshua B. Mailman and Sofia Paraskeva, 2012. Used with permission.

Figure 12. Stills from *"Firefly Fury": Marathon Demonstration*, Joshua B. Mailman, 2012. Showing gradual increase of color hue variety in the foreground layer: it starts with just shades of blue (when in the farthest back position), then expands to include purple and green (as the dancer moves forward), and then expands further to include a yet broader range of hue: red, yellow, orange, the whole rainbow (as the dancer moves even closer toward the camera). Photos by Danielle Y. Robinson. View the video at http://vimeo.com/fluxations/ff. © Danielle Y. Robinson, 2012. Used with permission.

show background particle system bubbles smoothly shifting between pink, purple, blue, green, and red as the shoulder orientation of the performer shifts. The video clips are here: http://vimeo.com/fluxations/vid7, http://vimeo.com/fluxations/vid8, http://vimeo.com/fluxations/vid9.

DESIGNING AN IMMERSIVE INTERACTIVE ENVIRONMENT FOR COMPROVISATION OF COLOR AND SHAPE TRAJECTORIES

The live visuals of *Fluxations* are designed to optimally balance some potentially competing priorities: (1) Enable both smooth and abrupt change to musical and visual qualities through corresponding smooth vs. abrupt motions of the body, such that these changes

and their correspondences could be witnessed by an observer; (2) Enable maximum varieties of change: as many kinds of change as possible, having multiple aesthetic appeals, each accessible at the discretion of the performer; (3) Ensure internal coherence of the system's dynamism (avoid arbitrary unconnected transitions between states); (4) Systematically correlate visual flux with musical flux and vice versa (algorithmic synesthesia [94]); (5) Ensure that the generated music and visuals are, as often as possible, aesthetically appealing according to my own phenomenology of prior musical and visual art works, my knowledge of musical and visual art theories, and what is known about audio and visual perception and cognition; this last consideration includes the tendency towards sufficient complexity, so the observer-listener remains captivated.

CYBER-EMBODIMENT OF A MACRO INSTRUMENT

For reasons of space, I won't discuss every way the system addresses these priorities – it would require a lengthy technical document, which may be forthcoming. Some of them have already been addressed above (the size and location of ellipses in the foreground layer for instance). Figure 11, however, summarizes one instance of how I attempt to address all these priorities.

In the generated graphics, the range of color hue of the direct layer and foreground layer ellipses and the kind of pitch-class set (arpeggiated chords) chosen by the music algorithm are all controlled by the performer's forward vs. backward location. Backward position chooses narrower ranges of hue and smaller pitch-class sets (fewer distinct pitches). For instance, in one of the color modes, when the dancer-improviser is in the back position (away from the camera), the ellipses are blue; then moving slightly forward, the hue range expands to include purple and green, and then expands further (as in Figure 12) to include a broader range of hue: red, yellow, orange, indeed the whole rainbow.

Three excerpts from *Firefly Fury* illustrate such dynamism. The first one shows increasing hue (and pitch) variety in the foreground layer; the second excerpt projects a decreasing then increasing trajectory of hue (and pitch) variety, also in the foreground layer. The

third clip (which is from near the end of the 15-minute improvisation) shows increasing then decreasing hue (and pitch) variety, this time in the direct layer, that is, in the bubble explosions. The three excerpts are shown here: http://vimeo.com/fluxations/vid10, http://vimeo.com/fluxations/vid11, http://vimeo.com/fluxations/vid12.

At the same time, however, the color field theories of Johannes Itten and Joseph Albers [95][96] are implemented dynamically in the system, in this way, as Figure 13 depicts it: when increasing the range of hue by moving forward toward the camera, the range of shades (brightness levels) gradually *de*creases. So now compare depth positions in the performance space. At the back position, where a narrower range of hue is enacted (just blue), a wide range from dark to light shades occurs; moving forward toward the camera, the range of brightness gradually narrows, excluding darker shades more and more. (Refer to Figures 11 and 13.) This way, the performer triggers a variety of colors at every position, but the kind of variety (hue vs. shade) varies according to position, and thus the flux of kind of variety also acts as a vessel of expression for the improvising performer to sculpt trajectories of intensities over time (*temporal dynamic form*). As with the generated music, so also the algorithmic and interactive *technés* of the visual imagery are designed to coordinate continuous spatial logic with visual aesthetics inspired by abstract paintings, sculptures, and film.
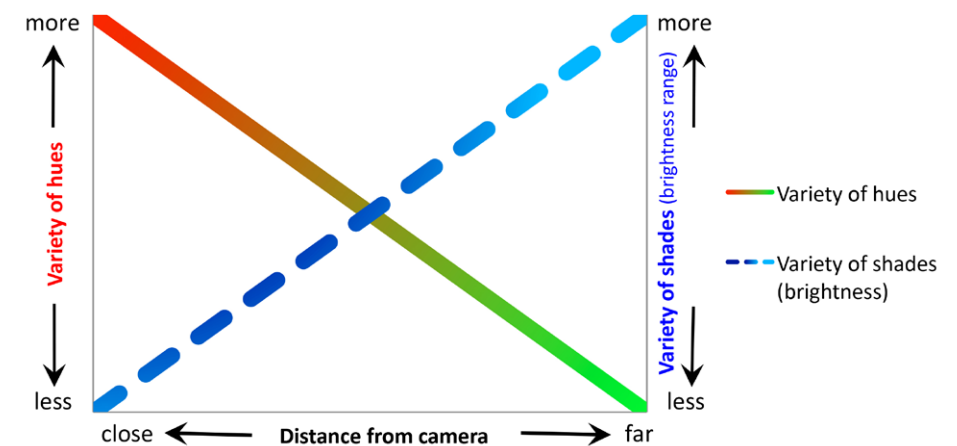
Figure 13. Inverse relation between variety of hues and variety of shades, effected by varying distance from the camera. © Joshua B. Mailman, 2012. Used with permission.

COMPROVISATION AS THE IMPROVISATION OF MACRO-FEATURES, EMERGENT PROPERTIES

It's important to stress that comprovisational technology such as *Fluxations* enables a different kind of expressive control than usual musical instruments offer. For instance, enabling an improvising performer to use smooth flux of degrees of variety of color to visually project *dynamic form* over time (*temporal dynamic form,* form from flux of intensity, narrative form, asynchronic form) is not something an ordinary musical instrument does. It's not even analogous to an ordinary musical instrument. *Fluxations* also lets the performer smoothly increase and decrease the variety of ellipse height and width in the foreground layer and the variety of note durations in the musical texture, by moving his or her feet closer together or farther apart, an effect heard (and briefly seen as well) in *Firefly Fury* at 11:35–12:55, a passage that starts 40 seconds into the following clip. Yet there is more. In addition to showing trajectories of durational variety and ellipse height and width variety, this video excerpt also has flux of syncopation (controlled by the left wrist) and flux of pitch variety and hue variety, in the direct layer and the foreground layer. (The passage is shown here: http://vimeo.com/fluxations/vid13.)

The feet don't just dance; they also steer the music and graphics. The correlation of feet distance to durational and size variety thus enables yet another kind of expressive trajectory in improvised performance. To the viewer-listener such degrees of variety (of color, size, shape, and duration) are not features of individual events but rather *emerge* over some duration of time; they also relate to various aesthetic-perceptual situations that emerged in the viewer-listener's past experience. In these respects, such qualities are *emergent*. Through such technology as *Fluxations*, for the first time a number of such *emergent* features of music and animated graphics are brought within the realm of spontaneous expression. These are features that previously could be manipulated only through non-real-time composition, which is where I learned them from, mostly through *cybernetic phenomenological* analysis of works I admire.

DIALOGIC INTERACTION IN IMPROVISATION (INTRA-MODAL)

As I suggested above, *Fluxations* is a *comprovisational* system because it embeds some compositional aesthetic decisions into its algorithms. Nevertheless, it being an interactive system, much of what is heard and seen through it is determined by the dancer-musician during performance and thus is not determined in advance – indeed many aspects decided by the algorithms are also not determined in advance, but rather are decided during the flow of performance. (None of the video clips presented here were pre-choreographed or otherwise predetermined.) For these reasons, it's most pertinent to discuss *Fluxations* performance as improvisation, and consider how the performer's decisions come about.

In discussing improvisation, Benson remarks that sometimes intentions evolve during the act of creation. [97] More than anything, this characterizes the spontaneity of improvisation. An improvisation implies that the decisions about what sounds or sights are to be enacted are not all decided in advance. Thus improvisation is a recursive feedback process, in which decisions are made in response to what was seen or heard in previous moments of the improvisation. As Smith and Dean describe it, "this process involves a dialogue within the medium, so that each gesture becomes a 'response' to the 'call' of a previous one." [98] This includes the seeming "landing on a wrong note," [99] if such a thing exists, for no improviser who is truly challenging himself is fully in control of every nuance of sound; unexpected details crop up when interacting with any technology, whether it be a saxophone or a Max patch. Adventurous improvisers embrace such uncertainty. [100] [101] "In an improvisation, each gesture can imaginably produce significant modifications in the total sound and musical development." [102] [103] In Figure 14a, I diagram this dialogic aspect of improvisation in a somewhat simplistic way, for the case of the solo improviser. [104] In simplest terms, each sound the improviser makes through her action influences what her next sound-producing action will be, so that improvisation is an indeterminate chain of events. [105]

In group improvisation, this indeterminate action-response chain exemplified in Figure 14a becomes more explicit, as one player is not privy to the future actions or thoughts of other players. The open-ended nature of improvisation allows that previous input from each player thus potentially stimulates the decision of the other players: an open musical dialog between people, "mutual interaction... [as a] basis of group flow." [106] In a simplistic way, Figure 14b diagrams the dialogic interaction of two improvisers reacting to each other. [107]

As Benson describes it, "genuine dialogue is characterized by openness." [108] This aspect of improvisation – responding to the unforeseen or even unorthodox – is rightly elevated to a coherent ethical stance by Gilbert Ryle, Arnold Davidson, and George Lewis; [109] [110] [111] [112] and aspects of it are replicated in Lewis's *Voyager* interactive improvisational software system, as is the case more generally with interactive composition and comprovisation. [113] [114] Improvisation presents the opportunity to respond to the unforeseen particulars of a situation as they come up, and such algorithmic systems as Lewis's *Voyager* and Rowe's *Cypher* provide the opportunity for the technologist-programmer/musician to explore the possibilities of such dialogic interaction in ways beyond typical human-human improvisation. [115] [116] Pursuing dialogic interactivity in a new way is part of the purpose of George Lewis's *Voyager* interactive system.

In such systems, typically the improvising algorithm is responding to sounds or individual notes played by the human improviser, as diagrammed in Figure 14c. In an interactive composition system, by contrast, such as Chadabe's or a comprovisational system such as
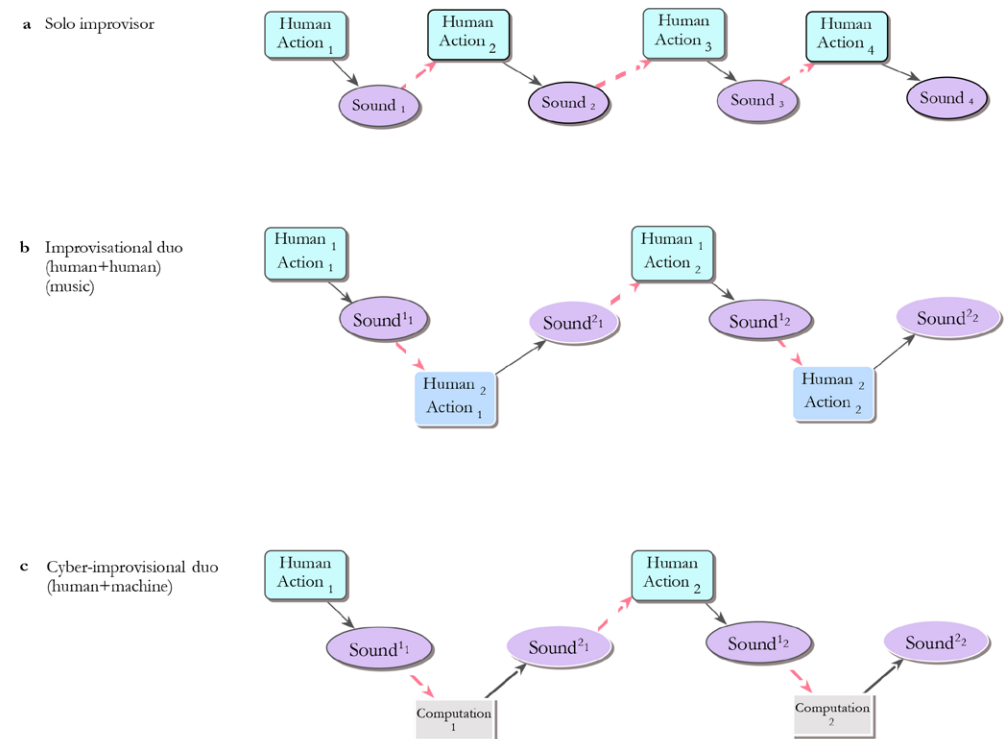
Figure 14. Call-and-response flow diagrams depicting the dialogic intentional aspects of improvisational interaction. Seven contexts are shown: (a) Solo improvisor; (b) improvisational music duo (human+human); (c) Cyber-improvisational duo (human+machine); (d) Solo comprovisation or interactive composing, of audio only; (e) Solo comprovisation or interactive composing, of visuals; (f) Improvisational visuals duo (human+human); (g) Solo comprovisation or interactive composing, of audio and visuals. © Joshua B. Mailman, 2012. Used with permission.

d   Solo comprovisation or interactive composing, of audio only

e   Solo comprovisation or interactive composing, of visuals

f   Improvisational duo (human+human) (visuals)

g   Solo comprovisation or interactive composing, of audio and visuals

Figure 14 (Continued.)

Fluxations, things works a bit differently, since the performer is not actually producing individual sounds or playing individual notes on an instrument. Instead, actions of the performer feed directly into computations which produce sound (or visuals) without passing th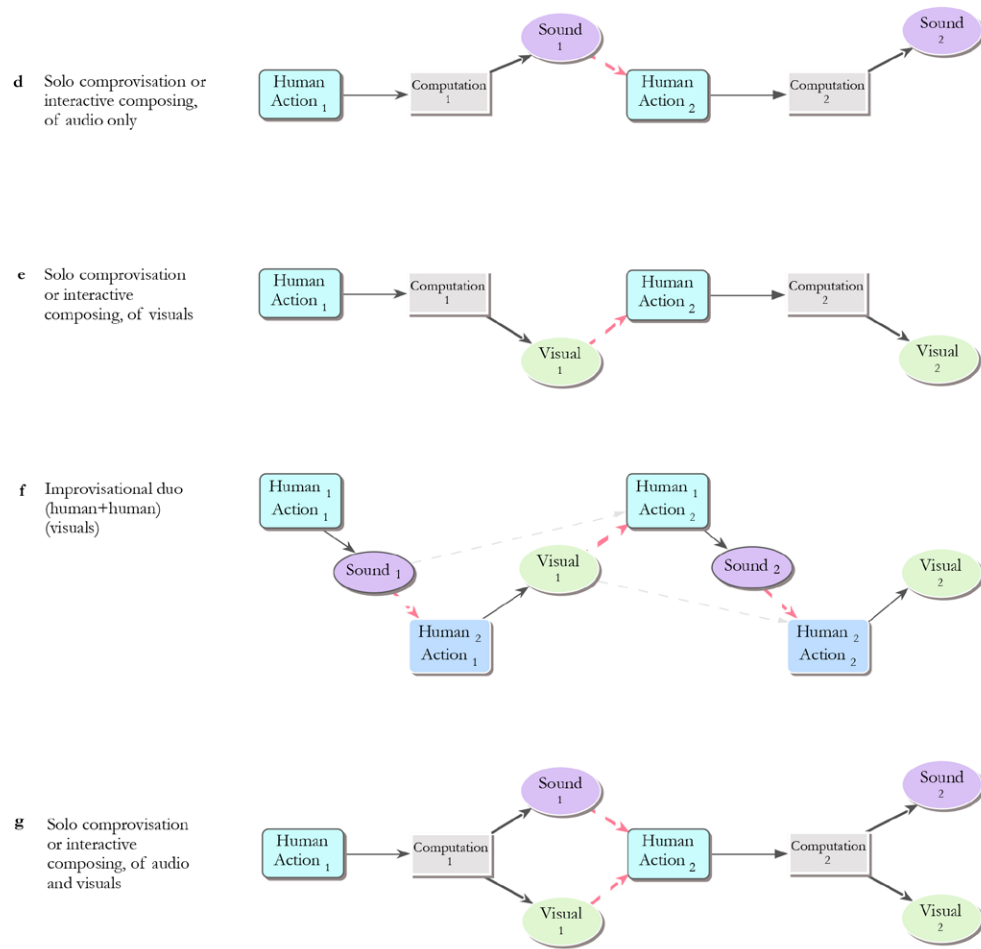rough an intermediate stage that might be heard or seen by an observer. Figure 14d and 14e diagram this situation, the situation of interactive composing or comprovisation (of music or visuals). Indeed it is this very aspect that enables such systems to give the direct expressive control of emergent flux. Since all actions are mediated by the system, none of their side effects can distract from or interfere with the performer's expressive projection of emergent flux trajectories. Rather than using source sounds (or source images) from the performer, the system lets

the performer directly steer many qualitative trajectories of the complexity it produces purely through its algorithms.

Nevertheless, although trajectories of flux are under the performer's control, the details are not; the details that comprise the complexity are stochastically "improvised" by the algorithms as affected dynamically by the performer's interaction. [117] There is the adventurous uncertainty again – opportunities to respond to the unforeseen. Although comprovisation tends to focus on expression, its details are not fully controlled, and thus may present partly unforeseen situations, to which one responds in the moment. Thus, as with interactive systems of Lewis, Rowe, and others, *Fluxations* is not only interactive in the sense of interacting

with a machine acting as an expressive instrument of sorts, but is also interactive in the sense of enabling a dialog between human and machine, presenting cybernetically situated opportunities to react to an ongoing stream of uncertainty.

AGENT-EFFECT COMBINATORICS OF INTENTION IN MULTI-MODAL INTERACTIVITY

Yet the multimodal (audio-visual) aspect of *Fluxations* brings another twist, one that I did not anticipate until I started interacting with it. This concerns the dialogic nature of improvisation and what can be learned about it through technology-based interactivity, that is, through cybernetic embodied exploration of spontaneous expression. Consider first that the emergent features discussed above are emergent within the listening domain and within the visual domain. But their cross-modal interaction creates yet another higher level of emergence. How does this affect the intentionality of improvisation? To be more specific, I want to consider how the pursuit of new dialogic interactivities indeed advances into new territories when exploiting cross-modal comprovisational technologies such as *Fluxations,* and even moreso in *FluxNoisations.* [118] Consider that bringing new multi-modal vectors of expression within reach of the improviser also brings new forms of spontaneous dialog into improvisation. Notice that Figures 14a-e only depict dialog *within* a modality. For instance each sound-producing action is a response to a previous sound,

thus an intention to produce a result in one modality (sound) in response to an event in the same modality (sound). One can imagine another situation, such as depicted in Figure 14f, where each improviser is responding to events of another modality (for instance a musician reacting to a dancer or other visual artist, and vice versa), though it's hard to imagine he or she isn't also responding previous events in his or her own modality (depicted in pale grey dashed lines). Either way, each improviser's follow-up actions are targeted toward an event in the modality of his instrument. For example the musician's follow-up actions are each directed toward making the next sound, that is, toward some *sonic* result.

Figure 15 organizes the dialogic interactions of Figures14a-f in terms of the modalities in which an initiating event occurs (listed vertically on the left) and the modalities toward which a follow-up action is directed (listed across the top). For instance the dialogic interactivities of Figures 14a-d are depicted in the upper left cell of the table; each is intra-modal: sonic-to-sonic. Figure 14e is also intra-modal: visual-to-visual (the table's center cell). Figure 14f, by contrast, is *cross*-modal: sonic-to-visual and visual-to-sonic, and perhaps also convergent, since an improviser is often responding to the results of her own prior actions. When improvising with *Fluxations*, sometimes I seek a certain sonic result, but as I achieve it, I am seduced by the particular visual configuration that emerges, which then lures me into focusing on improvising the visuals. That is an example of cross-modal dialogic

Modality of stimulus	Sonic	Visual	Sonic/Visual
		Modality targeted by response	
Sonic	Intra-modal	Cross-modal	Divergent (pan-modal)
Visual	Cross-modal	Intra-modal	Divergent (pan-modal)
Sonic/Visual	Convergent	Convergent	Synesthesic (synchresic)

Figure 15. The combinatorics of intention in cross-modal interactivity, in terms of the modality or modalities in which the initiating event occurs (listed vertically on the left) and the modality or modalities toward which a follow-up action is directed (listed across the top). © Joshua B. Mailman, 2012. Used with permission.

interactivity in *Fluxations*. For instance in one passage in *Fully Body Comprovisation No.1* (2:00–4:47) I went back and forth several times, first targeting a certain emergent sonic result, then a visual one, and so forth; often the side effects of one would prompt the other and vice-versa. (The passage is shown here: http://vimeo.com/fluxations/vid14.)

What hasn't been addressed so far is how all these come together in an unprecedented way in *Fluxations* and *FluxNoisations*. Figures 14a-f fail to depict the essence of the dialogic interactivity of these systems. With these systems the performer responds to both sonic *and* visual events (that he and the algorithms effected previously) *and* responds by targeting either visual or sonic results, or both, as diagrammed in Figure 14g.. In this case the situation may approach what Michel Chion calls *synchresis*: an immediate and neceessary relationship arising between what one sees and what one hears. `119` `120` It relates closely to *synesthesia*. In regard to dialogic interactivity, both are denoted in the bottom right cell of Figure 15: a sonic/visual stimulas prompting a sonic/visual aimed action: dialogic interactivity that is *synesthesic,* or *synchresic*.

### SPONTANEITY, REACTIVITY, AND UNCERTAINTY

I already discussed some uncertainties inherent to improvisation and algorithmic interactivity. An improviser truly challenging himself is uncertain even of some of the immediate outcomes of his own actions. In an ensemble setting, an improviser is uncertain what other players will do. Performing with an interactive system, the improviser is uncertain what details the algorithms will produce. What I've been suggesting is that yet another uncertainty arises when being able to simultaneously improvise macro-features (emergent properties) of mutually coordinated computer music and graphics through motions of the whole body cybernetically

entangled. This uncertainty is as much retrospective as prospective. It is an uncertainty about one's own expressive intentions: past, present, and future. I find that the more I improvise with *Fluxations*, the more trouble I have disentangling when, and through which actions, I am aiming at a visual emergent effect vs. a sonic emergent effect. (Perhaps it is a little like tap dancing, which is also bodily enacted bi-modal visual and sonic presentation – except the experience I am discussing is much more peculiar, because it is so immersive, intense, and beyond routine.) I am not even sure if such intentions could be distinguished – or should be – if indeed they arise as part of a *synchresic* experience. A kind of synesthesia arises from improvising with the system.

I encounter the same blend of improvisatory bodily intentions working with *FluxNoisations*, a new system involving percussive noise and symmetry-based generative geometries whose configurations and colorings are controlled interactively. Figures 16 and 17 show some color geometries that arose in an improvised demonstration. Demonstrating this more clearly is the 20-minute video compilation FluxNoisations Potpourri shown here: http://vimeo.com/fluxations/fnp. In this video footage I am shifting my hands, shoulders, elbows, and sometimes my whole body, striving to stabilize an interesting geometric configuration or segue between nuanced differences of geometric configurations and carefully cycle back and forth between segments of the rainbow color continuum that are circulated through these symmetries. At the same time however, I am trying to choose certain noise and percussion pulses over others, transition between them, and achieve certain sonic combinations; all these spontaneous intentions intertwine in performing in/with *FluxNoisations*.
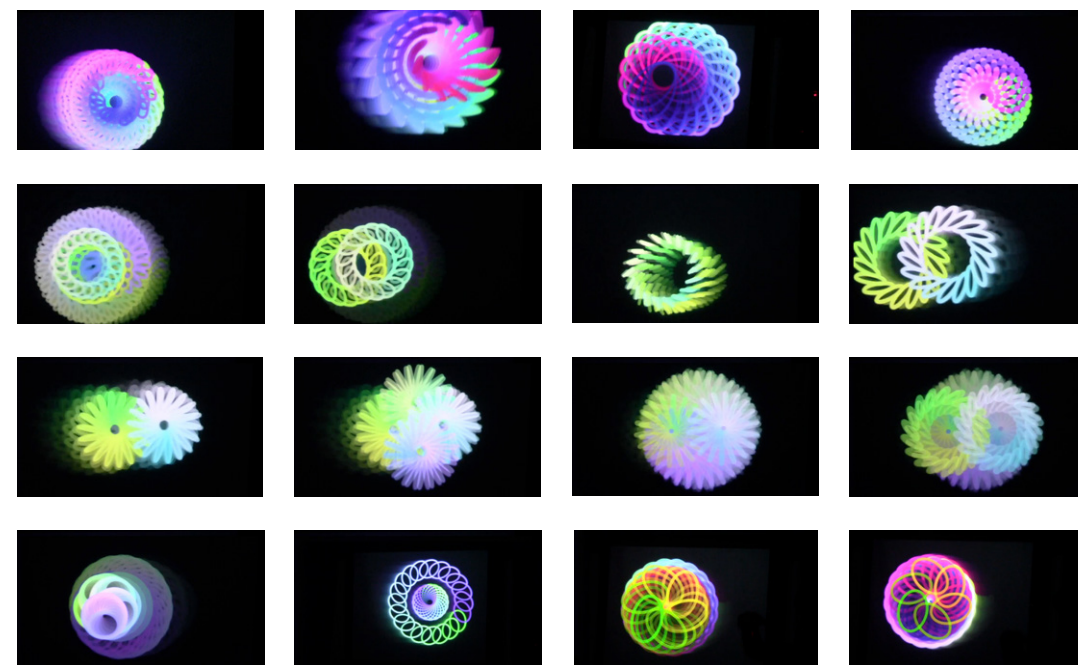
Figure 16. 16 stills (ordered chronologically) from the filming of an improvised demonstration of *FluxNoisations* in September 2012, at the Columbia Computer Music Center. These show fluctuating color geometries arising from various positions and motions of the hands and body. Photos by Danielle Y. Robinson. View the video *FluxNoisations Potpourri* here: http://vimeo.com/fluxations/fnp. © Danielle Y. Robinson, 2012. Used with permission.
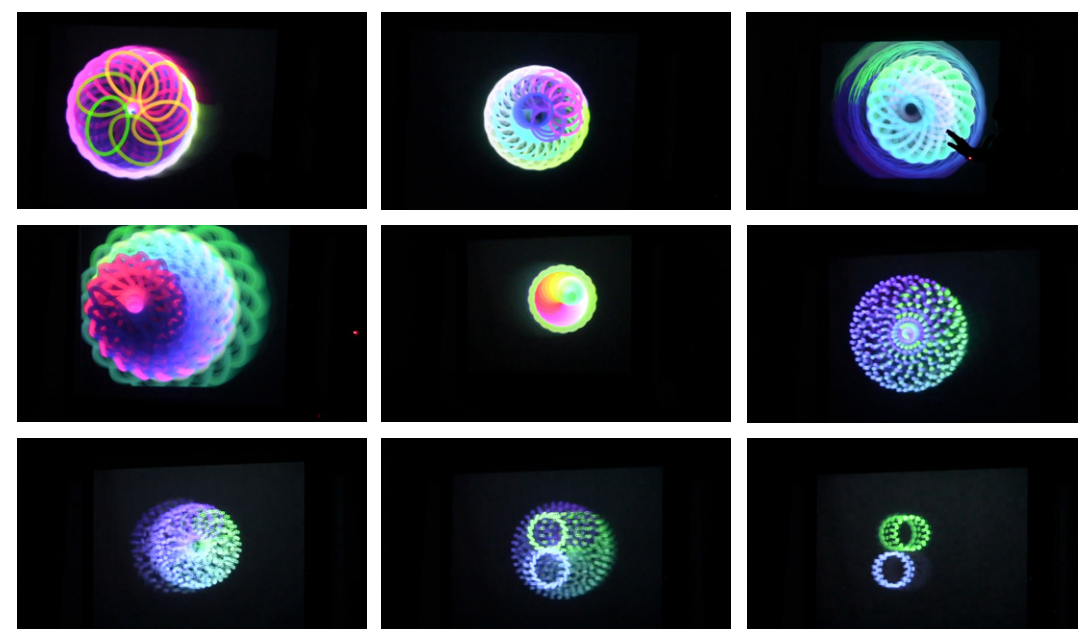
Figure 17. Nine stills (ordered chronologically) from the filming of an improvised demonstration of *FluxNoisations* in September 2012, at the Columbia Computer Music Center. These show fluctuating color geometries arising from various positions and motions of the hands and body. Photos by Danielle Y. Robinson. View the video *FluxNoisations Potpourri* here: http://vimeo.com/fluxations/fnp. © Danielle Y. Robinson, 2012. Used with permission.

Much of the preceding discussion of improvisatory cross-modal (sound and visual) interaction might seem to lead to an application of Gilles Faucon-nier and Mark Turner's *conceptual blend* theory [121], except that this situation I'm discussing is not at all linguistic, and perhaps not even conceptual, but rather pre-conceptually embodied. Because of the role of bodily movements in this multi-sensory intentionality, I am encouraged to consider whether mirror neurons can prompt uncertainty of intention and whether such improvisational intentions fall under the rubric of "material based imagination," which involves "a tight connection between motor-sensor apprehension and imaginative experience." [122] [123] The enigma need not necessarily be unraveled. As Benson explains "Improvisation presents us with something that only comes into being in the moment of its presentation." Perhaps we should include the modality of intention (aural vs. visual) as being determined or created in the moment of presentation, and perhaps lost in that moment as well, or possibly never determined at all! The whole matter is complicated by what Lewis calls the "cyborg inflected double consciousness": [125] the source of spontaneous creativity – in this case both aural and visual – is distributed between human and machine, which are conversing, not-verbally, but through motions enacted by the human body and through sound, music, and image.

Kenny Chow and Fox Harrel also suggest what's appealing about physically enacted animated systems: "We believe animated systems entailing... motor-sensory connection are able to give users an embodied experience of an expanded illusion of life," [126] which is amplified in the exploratory context of improvisation. Even though I didn't originally anticipate the *indeterminacy of improvisational intention* I've been discussing, I now embrace it; it is the kind of adventure I want to have with such systems as *Fluxations* and *FluxNoisations*, and that generally I seek in musical and visual art: I – in this case the dancing audio-visual performer – becoming somewhat lost in a physically enacted alien phenomenology, an embodied form of pragmatic speculative realism, a motor-sensory "what if." The experience has significantly altered my perception of (my relation to) music, visual art, and my own body.

I conclude with a quote from Roy Ascott, which resonates with what I value in working with interactive audio-visual media, as I just explained it: as an embodied adventure of synesthesic (synchresic) spontaneity, reactivity, and uncertainty:

Both individual artworks and cultural clumps can act as behavioral triggers. But the cultural force not only controls a Social Situation it constantly assigns to it fresh goals. This is not a steady state control – it is one affecting a changing, fluid field. This is one kind of value, amongst others,... It requires the New, unfamiliar forms and unprecedented relationships. These come only out of creative behavior – unlearned, non-routine, constantly shaken up. It involves taking risks, stretching the intuition. There is a splendid paradox in Art that often the wildest, most far out, random unprogrammed activity can in the end produce work which may exercise the most profound and fruitful control of the human situation. [127] ∎

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78. Joshua B. Mailman, "Introduction to Temporal Dynamic Form Theory and Analysis," (lecture, Harvard University, Department of Music, Cambridge, MA, April 2009).

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80. Joshua B. Mailman, "Emergent Flux Projecting Form in Ruth Crawford Seeger's Quartet (1931)," (paper presented at the *Seventh International Conference on Music Since 1900 / Society for Music Analysis Conference*, Lancaster, U.K., July 2011 and at the Society for Music Theory Indianapolis, Indiana, November 2010).

81. Joshua B. Mailman, "Dynamic Form (Flux of vertical cellularity in Isaac's Quis Dabit and flux of pitch freshness)," (paper presented at Northeast Music Cognition Group, Yale University, New Haven, CT, May 2010).

82. Joshua B. Mailman, "Duality of metaphor for time and music: applications to computational-phenomenological analysis of musical form and expression," (paper presented at the *Music and Philosophy Conference: Time Theories and Music*, Corfu, Greece, April 2012 and the plenary session roundtable on Metaphor, *Seventh International Conference on Music Since 1900 / Society for Music Analysis Conference*, Lancaster, U.K., July 2011).

83. Joshua B. Mailman, "Temporal Dynamic Form in Music: Atonal, Tonal, and Other," 402-417.

84. Joshua B. Mailman, "Emergent Flux Projecting Form in Ruth Crawford Seeger's Quartet (1931)."

85. Joshua B. Mailman, "Cybernetic Phenomenology and Music Ontology."

86. Joshua B. Mailman, "Seven Metaphors for (Music) Listening: DRAMaTIC."

87. Joshua B. Mailman, "Interactive Computer Simulation for Kinesthetic Learning to Perceive Unconventional Emergent Form-bearing Qualities in Music by Crawford Seeger, Carter, Ligeti, and Others."

88. Joshua B. Mailman, "Temporal Dynamic Form in Music: Atonal, Tonal, and Other," 402-417.

89. Joshua B. Mailman, "Emergent Flux Projecting Form in Ruth Crawford Seeger's Quartet (1931)."

90. Ibid.

91. Joshua B. Mailman, "Temporal Dynamic Form in Music: Atonal, Tonal, and Other," 273-280, 402-17.

92. Because OSCeleton sets the top of the field to 0, the *maxHeadHandsHeight* actually increases as one lowers the body toward the floor.

93. Note that Processing's "background" function does not correlate exactly to what I call the "background layer" of the Fluxations interactive system. The background layer of the interactive system also includes the backdrop behind the particle system, which is painted by a different line of Processing code.

94. Noam Sagiv, Roger Dean, and Freya Bailes,"Algorithmic Synesthesia," in *The Oxford Handbook of Computer Music*, ed. Roger Dean, 294-311 (Oxford: Oxford University Press, 2010).

95. Johannes Itten and Faber Birren, *The Elements of Color: A Treatise on the Color System of Johannes Itten Based on His Book The Art of Color* (New York: Van Nostrand Reinhold, 1970).

96. Josef Albers, *Interactions of Color* (New Haven: Yale University Press, 1963).

97. Bruce E. Benson, *The Improvisation of Musical Dialogue*, 58.

98. Hazel Smith and Roger T. Dean, *Improvisation, Hypermedia and the Arts since 1945*, 106.

99. Ajay Heble, *Landing on the Wrong Note: Jazz, Dissonance and Critical Practice* (London: Routledge, 2000).

100. David Borgo, *Sync or Swarm: Improvising Music in a Complex Age* (New York: Continuum, 2007).

101. David Borgo, "Agency in Coaction: A Material-Semiotic Approach to Understanding Electro-Acoustic Improvisation" *Music: Cognition, Technology, Society,* interdisciplinary conference at Cornell University, Ithaca, NY, May 11-13, 2012).

102. David Borgo, *Sync or Swarm: Improvising Music in a Complex Age*.

103. Marcel Cobussen, Henrik Frisk, and Bart Weijland, "The Field of Musical Improvisation," *Konturen: Interdisciplinary Journal for German Cultural Analysis* 2, May, 2010, http://musicalimprovisation.free.fr/index.php (accessed February 25, 2013).

104. The reader is also referred to Figures 17 and 18 on pp.172-3 of Smith and Dean's *Improvisation, Hypermedia and the Arts since 1945*. Those diagrams explore several other aspects of solo and group improvisational interactivity.

105. There are many other responsive aspects of improvisational interaction besides such a series of discrete call-and-response pairs. For instance, the more ongoing feeling of groove may be created, as explained by Vincent Meelberg, "a sense of propulsive rhythmic feel," which can induce one's body to move (or "vibrate"). Groove is induced both through sound (physical vibration) and through visual observation – since "performing actions and observing actions activate the same brain areas." When performing Fluxations my body often feels propelled into kinetic pulsation because of the rhythmic groove created by the algorithm, which I am also manipulating. This is apparent in *Montreal Comprovisation No. 2*. On the subject of groove, see Vincent Meelberg, "Moving to Become Better: The Embodied Performance of Musical Groove," *Journal of Artistic Research* 1 (2011) http://www.researchcatalogue.net/view/?weave=16068 (accessed February 25, 2013)

106. Hazel Smith and Roger T. Dean, *Improvisation, Hypermedia and the Arts since 1945*, 37.

107. The reactive aspects of improvisation such as these are discussed in a number of studies including Pat G.T. Healey, Joe Leach, and Nick Bryan-Kinns, "Inter-play: Understanding Group Music Improvisation as a Form of Everyday Interaction," in Proceedings of Less is More – Simple Computing in an Age of Complexity. Microsoft Research Cambridge, 2005 and David Bastien and Todd Hostager, "Cooperation as Communicative Accomplishment: A Symbolic Interaction Analysis of an improvised

Jazz Concert," *Communication Studies* 23 (1992): 92-104.

108. Bruce E. Benson, *The Improvisation of Musical Dialogue*, 15.

109. Gilbert Ryle, "Improvisation," *Mind*, New Series 85/337 (1976): 69-83.

110. Arnold Davidson and George Lewis "Improvisation as a Way of Life," (2011) http://www.youtube.com/watch?v=NYPlPllQzyc and http://www.youtube.com/watch?v=9r2JrwsGXFY (accessed January 31, 2013).

111. George Lewis, "Improvising Tomorrow's Bodies: The Politics of Transduction," *E-misférica* 4, no. 2 (2007) http://hemisphericinstitute.org/journal/4.2/eng/en42_pg_lewis.html (accessed January 31, 2013).

112. George Lewis, "Improvisation as a Way Of Life," (Lecture, Columbia University, March 7, 2011), http://www.youtube.com/watch?v=3cswYCMQnl4 (accessed January 31, 2013).

113. George Lewis, "Voyager" for Improvising Soloist and Interactive "Virtual Orchestra," (1987).

114. George Lewis, Program note for *Voyager*(1993), Ubuweb: Sound, http://www.ubu.com/sound.lewis.html (accessed January 31, 2013).

115. Robert Rowe, *Interactive Music Systems: Machine Listening and Composing* (Cambridge, MA: The MIT Press, 1993).

116. George Lewis, "Interactivity and Improvisation," in *The Oxford Handbook of Computer Music*, ed. Roger Dean, 457-66 (Oxford: Oxford University Press, 2009).

117. Saint-Germier addresses the issue of whether machines, or algorithms, can be said to improvise. Pierre Saint-Germier, "Can computers improvise?," (paper presented at *ImproTech Paris-New York 2012: Improvisation & Technology*, New York University, May 17, 2012).

118. As compared to *Fluxations*, *FluxNoisations* is as yet at an less mature stage of development.

119. Michel Chion, *Audio Vision* (New York: Columbia University Press: 1990).

120. Wayne Siegel, "Dancing the Music: Interactive Dance and Music," in *The Oxford Handbook of Computer Music* ed. Roger Dean, 193 (Oxford: Oxford University Press, 2009).

121. Gilles Fauconnier and Mark Turner, *The Way We Think: Conceptual Blending and the Mind's Hidden Complexitie*s (New York: Basic Books: 2002).

122. Regarding mirror neurons, Giacomo Rizzolatti and Corrado Sinigaglia, *Mirrors in the Brain: How Our Minds Share Actions and Emotions* (Oxford: Oxford University Press, 2008), 94–98, 124–125.

123. The relevance of mirror neurons to this context is discussed by Kenny K. N. Chow and D. Fox Harrell, "Understanding Material-Based Imagination: Cognitive Coupling of Animation and User Action in Interactive Digital Artworks," *Leonardo Electronic Almanac* 17, no. 2 (2012): 52.

124. Bruce E. Benson, *The Improvisation of Musical Dialogue*, 25.

125. George Lewis, "Interactivity and Improvisation," 460.

126. Kenny K. N. Chow and D. Fox Harrell, "Understanding Material-Based Imagination: Cognitive Coupling of Animation and User Action in Interactive Digital Artworks," 52.

127. Roy Ascott, "Statement from Control," (1966) reprinted in *The Telematic Embrace:Visionary Theories of Art, Technology, and Consciousness*, ed. Edward Shanken, 108 (Berkeley: University of California Press, 2003).

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