Ensemble, Entrainment, and Movement in the Mess of the Matter: Non-anthropocentric Design of Responsive-Media Environments

Garrett Laroy Johnson, Todd Ingalls, Britta Joy Peterson and Xin Wei Sha

Abstract: *In this paper, we describe an experimental approach to the study of coordinated group activity (ensemble) through the development of a responsive media system and enacted movement-based research. Interested in how ensembles emerge, we take into account the material conditions of phenomena associated with coordination and entrainment. To this end we share about the development of a responsive media system and as well as a series of movement experiments with the system. As a unframing tactic, we suspend ontological assumptions which occlude, mask, or ignore relation and event as emergent and unprestateable. This tactic belies both our observations of event as well as the design of responsive behaviors in the media environment apparatus. Our investigations yielded insights for us about embodied experience with respect to technicity.*

> Als das Kind Kind war,
> ging es mit hängenden Armen,
> wollte der Bach sei ein Fluß,
> der Fluß sei ein Strom,
> und diese Pfütze das Meer.
> Als das Kind Kind war,
> wußte es nicht, daß es Kind war,
> alles war ihm beseelt,
> und alle Seelen waren eins.[1]
>> -Peter Handke, from "Lied vom Kindsein," featured in *Der Himmel über Berlin* (1987), directed by Wim Wenders

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[1] From Peter Handke's "Song of Childhood," featured in the 1987 film by Wim Wenders *Wings of Desire*: "When the child was a child / it walked with its arms swinging, / wanted the brook to be a river, / the river to be a torrent, / and this puddle to be the sea. / When the child was a child, / it didn't know that it was a child, / to it, everything had a soul, / and all souls were one."

1. The Problematic of Ensemble, Entrainment, And Material Creativity

A small table found in a 2014 blog post by Adrian Freed[2] enumerates words beginning with prefixes co-, sym-, and syn-. In this "semblance typology of entrainments," as he titled it, each word is complete with a short definition, and many words are attached to examples: "Morris dance", "twisting together," "three-legged race", "melting together." Freed's typology unfurls the term entrainment from traditional understandings bounded by discipline. Semblance here can be read here as uniting these disparate notions by what Wittgenstein called their "family resemblence" (this unity Wittgenstein might also approvingly label "true enough"). Freed's list invites us to unfurl notions of togetherness bound together as corporeal gesture coordinated across messy assemblages of bodies and stuff: a group preparing a meal, a crowd's distributed movements through urban spaces, or children playing tag, holding a conversation while walking downtown. We call these notions of togetherness "ensemble".[3]

Like ensemble, the term entrainment seems to have never belonged solely to any one context. Christian Huygens found that pendulums would synchronize their phase when connected by a single medium (harmonicity in classical physics). In musicology, to entrain to a beat is to fall into a groove (or at least to play in tempo). Biological entrainment describes the syncing of an organism's circadian rhythms with an environmental rhythm. Prosodic entrainment is the mimetic matching of patterns of speech in group conversation. Perhaps the most poetic notion of entrainment comes from the morphology of physical and geological systems: solids or liquids perturbed by flow. Aeolian or fluvial flows lift sediment from the seafloor or the sands of a desert, creating patterns of ripples and waves.

In these examples, the temptation may be to understand entrainment as the assimilation or adaptation of one system to another. The preposition *to* is important sign post of the kinds of relationalities we're interested in. It's not so simple as tuning a guitar *to* an electronic tuner, or playing along "to" a drum machine. It is not a relation of pure identity but rather of *summing*; the better pronoun for entrainment is to entrain *with*.

Because we will say more about media systems, we'll provide the aeolian harp here as an example. Traditionally this was a stringed instrument installed outdoors. Gusts of wind blow through the instrument, and if the frequency of the vortex turbulence on either side of the string matches the frequency of the string or one of its harmonics, the string will vibrate. (Other "environmental" instrument variations use pipes, bells, or chimes.) Some contemporary engagements with this atmospheric instrumentality are found in Harry Bertoia's sonambient steel-rod instruments. The wind is replaced by the sea in Eduardo Chillida's *Peine del Viento* in San Sebastian or the Sea Organ by Nikola Bašić in Zadar, Croatia. These seaside plazas are built with pipes that lead out to the ocean, through which the surf rushes up to create a roaring, noisy yet pitch-resonant sound. In these examples, the material configuration constitutes a potentiality which are activated in irreducibly complex ways by energetic forces. What's more, the instruments *do not care* where the forces come from; they may be coupled with atmospheric, non-human material, or anthropogenic energies.

As mentioned above, we don't need to include the human to speak of entrainment or

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2 https://adrianfreed.com/content/semblance-typology-entrainments Last accessed [2019-02-19]

3 What we call ensemble could also readily be encapsulated by other philosophical concepts such as the Deleuzoguattarian *assemblage* or the Whiteheadian *societies of actual entities*. No doubt the power of these process theoretical notions are behind the inspiration for this project and the reader may expect more appearances by such figures in the final part of this essay. Rather than get deep into the metaphysical architecture of Deleuze or Whitehead, we take notice of those resonances and return to the problematic of ensemble, "attending to the phenomena" per Husserl's injunction, via empirical experiment. To venture to risk being too open-ended and shrouded in naivety, to ask without embarrassment like the child in the poem from *Wings over Berlin,* "warum bin Ich Ich, und nicht Du?"

ensemble. To this end our project begins in the mess of the matter of ensemble—and ends there too—there is always more to be unpacked from cultural, physical, chemical, and affective strata, novel vectors to pursue. Accordingly, we do not set out to create a definitive account of what we mean by ensemble, but for us a foothold. It acts for us as a problematic in the style of Gaston Bachelard[4] propelling forth a question: How can we condition enacted experience for ensemble to emerge? At least to the extent that creation must be considered technical (in the sense of ancient Greek techne), we hold that this is a fundamentally sociotechnical question.

Agent-based simulations in computational media try to get at complex systems and movement, whether in the case of architecture and the built environment and the movement of cars and pedestrians, economies and the flows of capital, flocking of birds and so on. All of the various movements are described as the activities of so-called autonomous agents.[5] These computational agents are autonomous in the sense that they plan their movement based on local conditions and according to pre-given rules which dictate speed, proximity to other avatars, avoidance etc.

It should be said that on behalf of these algorithmic descriptions of complex behaviors that there are quite good reasons for applying them to various domains, namely that they adequately approximate ensemble and crowd behavior. What's more, they afford many practical advantages over enacted experiment, notably w.r.t. scale. Media artists have been using these techniques for almost half a century to produce impressive eye-candy.[6] But, how can we say that processes afforded by subjectivity (in this case, movement planning, spatial awareness) may be contained within discretized human bodies? And how can we venture to represent these worldly processes by digital logical operators?

On the side of pragmatics, an enacted approach leverages embodied knowledges as well as the physics of the world without collapsing relations into topological graphs. In other words, we do not need to train avatars to walk in order to understand the dynamics of a crowd moving through an airport, we look to in-situ examples of people moving through an airport.

In what follows, we share a project in speculative engineering, experimental movement research, and artistic creation which seeks to clear away presuppositions about what we think we know about ensemble and group coordination, to dispense with the notion of the agent (no more than an ontological bracketing of subjectivity and corporeality), to sidestep reductive accounts of relationality as interacting sets of coded logical behaviors. What follows is a concretized proposition, which points to embodiment as processually constructed and thus conceive of the body which doesn't necessarily end at the skin.

2. *Lanterns*: Development of an Apparatus and Experimental Ensemble Practice

The *lanterns* system is a sandbox for exploring a variety of interest areas, including human interaction in physical-digital systems, experiential approaches to dynamical systems, and corporeal entrainment between matter and biology. The Lanterns are tangible pendant objects with responsive sound and lighting behaviors. The lamps are suspended from hacked GameTrak

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4 Patrice Maniglier, "What is a Problematic?"

5 Craig Reynolds, "Flocks, Herds, and Schools: A Distributed Behavioral Model"

6 Gary William Flake, *The Computational Beauty of Nature: Computer Explorations of Fractals, Chaos, Complex Systems, and Adaptation*; Przemyslaw Prusinkiewicz et al., *The Algorithmic Beauty of Plants*; Daniel Shiffman, *The Nature of Code: Simulating Natural Systems with Processing*.

joysticks tracking the lamps' movements. Each lantern consists of six dimmable LED with plastic diffuser,[7] sockets, and a bundle of six cloth-covered electrical wires. Suspended from a theatrical grid, the cluster of bulbs and sockets hovers only a few feet above the ground (Figure 1).

Theatrical hardware yields computational control over the brightness of each individual light bulb. We employ some simple mappings for sonification and animating the lights, which can be seen in documentation videos.[8] We will discuss how we arrived at these mappings and their implications after we have given some background on how we arrived at this configuration for our system.
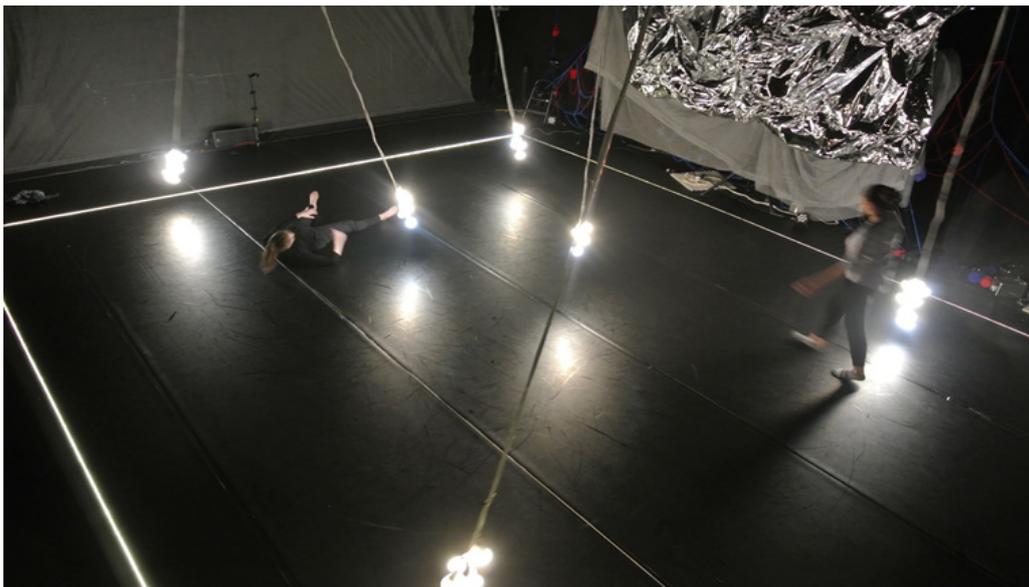

Figure 1: Interaction with the Lanterns system

Through the free interplay of movement-based experimentation (Figure 2), design iteration, and artistic creation, we developed aestheticized movement practices *alongside* our experimental engagements with the system. As we went along, artistic creation informed research questions and experimental design. In turn, both of these activities informed the development of the *lanterns* system (Figure 1). This meant the design of the hardware (on the scale of months) and responsive media software (on the scale of minutes, hours) was retooled as we went along. Below, we will give some background on the process of developing the system and the influence of the co-developing experimental practice, and the aesthetic achievements (dance works and an installation environment) and the way in which our work always refracted back through the questions we were asking about ensemble.

The system developed iteratively alongside in-situ experimentation about rhythm and ensemble. In preliminary experiments, we began not with lanterns, but balloons. We created an on-the-fly system for ensemble coordination using some cheap latex balloons which we worked together to keep above the ground.

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7   The plastic diffuser and LED technology make the pendants extremely durable.

8   Three Lanterns videos: Movement games with early prototype https://vimeo.com/193831344; dance performance https://vimeo.com/216553103; group etudes (experimental performances) https://www.youtube.com/watch?v=Evm1z-Kjllg.

Figure 2: Dancers in free play with the Lanterns system

We made two important observations in these experiments. First, that the oblong shape of the balloon and its related material constitution introduced indeterminacy into the activity (the initial spark for our interest in *the role of matter* in movement and ensemble). And secondly, that our collective modes of playful engagement *continuously shifted* as we changed variables (adding balloons, people tiring, etc.). We found that most attempts to determine roles ahead of time quickly fell apart. Speech was too slow to coordinate our action, but as we practiced our approach changed in order to accommodate the contingency of the balloon physics.

With these balloon games on the mind, we began to work on a single lantern. The first prototype strongly resembled the final iteration in terms of physical design and the media behaviors were similar but not as refined (and obviously absent any group dynamics).

We made two observations from working with this system. First, one significant difference is that the first prototype used spherical glass bulbs with incandescent filaments. We noticed immediately that interlocutors took a long time to get used to moving the lantern because they regarded it as fragile and delicate (In the end we did break many bulbs, which led us to switch to LEDs with plastic diffusers). Furthermore, we began to find the movement resonances that were composed into the lantern itself. By resonances we mean the patterns of movement which recurred throughout our play, like circling and swinging. Both of these observations point to what we mean by *composing conditions for activity* (instead of determining outcomes or steering behavior).
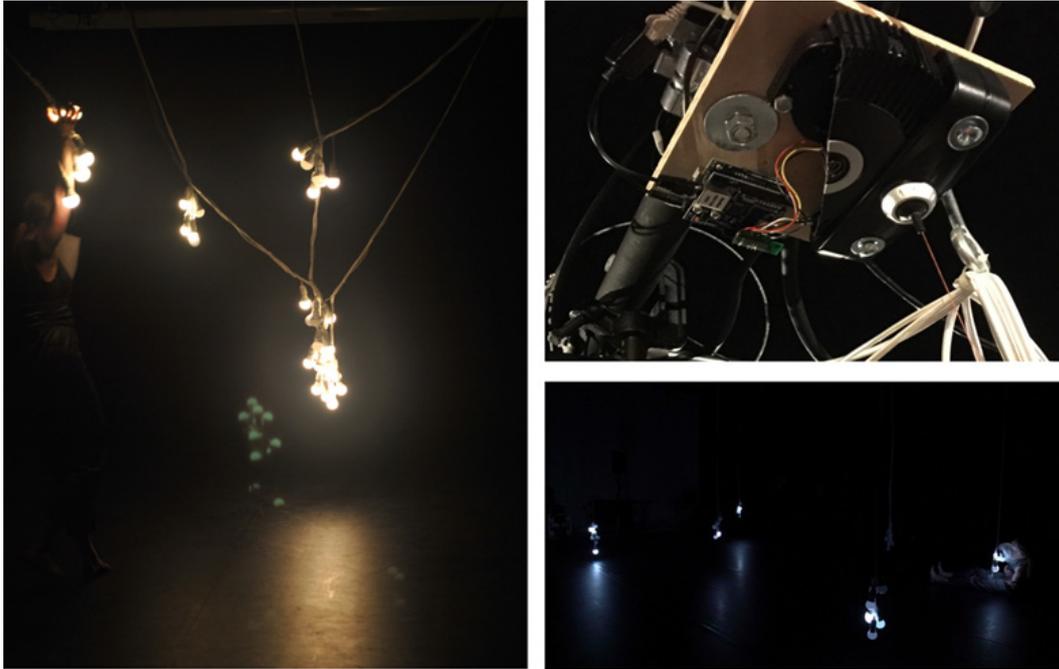
Figure 3: Instances of the final Lanterns system

Like many of the proposals contained here, we advocate a movement away from discrete considerations of media towards continuous ones. The design ethos of responsive media, a particular way of composing systems with media, sensors, and computation, is attuned to processual aspects of experience, such as rhythm, atmosphere, affect, and ensemble.[9] Continuous approaches to computation in digital domains might be said to emulate the analog or the material in some way (consider the aeolian harp example above). In the case of the *lanterns*, much of the computation is *already done by the analog physics of the system*.

We employ simple analyses of the position data to create simple media behaviors; we extract the speed of each lantern from the joystick data vector as well as a measure of each lantern's proximity to other lanterns. Their proximity is determined heuristically by calculating the total distance of each lighting pendant to the group's centroid. Each lanterns position data are mapped to banks of filtered noise which are tuned to various pitch collections. Their speed and acceleration control playback speed and tuning of a bank of samples, fluttering the lightbulbs as they sound. Sound is spatialized across a multi-channel sound array to track the lantern's position through the space.

The total distance from the pendants' centroid controls the pitch and amplitude modulation of sub-bass oscillators; as the lanterns gather together, the oscillators pitch into an audible range and pulse more frequently. The amplitude of this synth maps to the amplification of the light's control data.

In the case of the final swarm of swinging lanterns (Figures 1-3), the simplicity of the media behaviors aims to highlight the prebaked, kinematic rhythmic character of each individual lantern as well as their relationships to other lanterns. The spatially diffused sounds, pulsing lights, and moving pendants constitute an experientially rich set of inter-penetrating fields of media and matter. Instead of algorithmically injecting variance into the interaction, we aim for a reproducible sonifications and lighting behaviors which leverage the rhythms, movements, and

9 Sha Xin Wei, *Poiesis and Enchantment in Topological Matter*.

energies directly from moving human bodies and analog matter. In this way, Lanterns' responsive sound and lighting de-emphasize algorithmic virtuosity. Instead virtuosity is always already relational, social, and lived. Tightly coupling sound and light to the movements of the physical system also works to de-center the human's hierarchical footing by destabilizing "interactive" design frameworks in which humans control over media through sensors are not slaved to the human body or extend as prostheses.

A key aspect of our approach to experimental phenomenology is to rely not on models of "psychological" or "cognitive state" but instead to use semantically shallow models to drive the computation,[10] described in [Sha 2013]. This design principle results from an abductive approach to studying rich experience with the least possible commitment to theoretical models of experience. In particular, we have developed rich responsive media systems that leverage the embodied physicality and physics, but eliminate the need for modeling "user" "psychology" in code.[11] *Lanterns* draws on these methods, techniques and design principles. Material computation or natural computing in foundations of computer science and engineering, and new materiality in cultural studies signal a turn to the design of responsive environments and computational media paying as much attention to material qualities like elasticity, density, wear, and tension as to social and cognitive experience. This demands thinking about and designing computation in a non-reductive way that spans formal divides between symbolic-semiotic, social, and physical processes. One radical context for the *lanterns* work is the investigation of hybrid physical-digital models of computation, especially those that blend digital microprocessors instantiating Turing computation with the physics of analog matter. Following Stepney and our own previous work, we generalize computation as the reproducible transition from state to state of a structure (physical, biological, informatic) under some deterministic scheme.[12] Previously we observed that sound computing already exemplifies a rich history of hybrid physical-digital computation, where the processing of sound leverages both the physics of the analog and algorithmic (the code) parts of a computational electronic-musical "instrument." Most importantly, we consider the human to be part of the system, following human-in-the-loop design common in AI research motivated by augmentation rather than automation (replacement) of human activity. *Lanterns* radically simplifies the complexity of the dynamics of the parts to clarify the relation among the physics, the digital computation, and the human performers. We single out temporal (generalized rhythmic) aspects of activity such as cadence in swing, body and sound, as described below. The basic observation is that simple ballistic physics of the lanterns allow the performers to play most creatively to invent ensemble gestures that would be impractical to model and embed into code in advance.[13]

3. Tactics for Engagement: Experimental Results

In this final section, we synthesize insights about ensemble from the experiments with the system itself. The following table summarizes the activities and inventions generated during experimental working sessions led by four professional dancers who have worked together for

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10 Ibid.

11 Brandon Mechtley, Julian Stein, Christopher Roberts, and Sha Xin Wei "Rich State Transitions in a Media Choreography Framework Using an Idealized Model of Cloud Dynamics". For more examples, visit www.synthesiscenter.net.

12 Susan Stepney, "The Neglected Pillar of Material Computation," Navid Navab, Doug Van Nort, Sha Xin Wei, "A Material Computation Perspective on Audio Mosaicing and Gestural Conditioning".

13 As Stuart Kauffman argues, this is always the case with living systems because living systems have open rather than closed configuration spaces, but at the very least, this is a practical insight for building rich media systems for improvisatory activity. Stuart Kauffman, *Humanity in a Creative Universe*.

years. The first column describes various recurrent pendant movements which we discovered through improvised and unstructured play (the resonances to which we referred in the previous section). We made these patterns objectives for some playful exercises which were repeatable which could be varied (column two). An important methodological point was then not to instruct each other how to make this happen. Instead unexpected coordinations emerged as a collectively and processually, transforming the relation between dancers, between the moving pendants, and between humans and pendants (column three).

From a systems perspective, the first column corresponds with different *perturbed states* of the media system (whereas the unperturbed, equilibrium state would be the pendants resting at a standstill) and in the second column variations of these states are permuted. The final column lists the variations of the human ensemble's movement state space when the media system's state is farthest from equilibrium. By far from equilibrium we mean for instance when the lanterns all swing together the inertia of the system will slowly dissipate until reaching equilibrium. This phase space is similar for states "circling" and "twisting." (This is also true for "gathering", but the system seems to enter a different state of equilibrium if the lanterns are knotted together as shown in the image above).

LANTERNS STATE	DESCRIPTION and VARIATIONS	COUPLINGS
Swinging	Lanterns swing like a pendulum; In phase/anti-phase, etc.	Run alongside swinging bulbs; Catch and release (using sight, using hearing); Grouping people w. lanterns, number of humans/lanterns
Circling	Lanterns swing like a circular pendulum; In phase/anti-phase; Moving in the same or opposite direction	Run alongside swinging bulbs; Catch and release (using sight, using hearing); Grouping people w. lanterns, number of humans/lanterns
Twisting	Lanterns wrap around each other; Number of lanterns to group; How many may be touched	Throw a pendant around another; thread them together
Gathering	Bring all the lanterns together	Gather and release (seated); Twisting or wrapping them to hold them together.

Table 1: Lanterns experiments and etudes

Our movement experiments with the *Lanterns* system points to insights about the relationality between coordinating human bodies and the material counterparts via fields of media. What's notable about these tactics is that we changed our relation to the *lanterns*, and in turn their relation to each other, to us, shifted. This suggests a looping relation between the humans and *lanterns*, but there is a lingering slippage in positing a relation between humans and the material system; clearly the humans are coordinating with each other to work with the lanterns, but the pendants do not coordinate back in a way that is familiar to us. This impetus

to collaborate is one-way; as far as we can say, the media system does not wish or desire to participate. The indifference of the system's non-living matter seems obvious. This was quite apparent to the dancers, who, despite their training to navigate complex spatial pathways and anticipate movements, frequently caught a stray lantern to the face, or were scraped by the zip ties which bundled the threads together.

It is tempting to conclude with this indifference as evidence of the intrinsic asymmetry between living and non-living systems (difference in kind). Andrew Culp has proposed asymmetry as a generative diagram for mapping this difference which can be applied to this situation if we replace "terms" with "systems": "asymmetry works to impede reciprocal relations and prevent reversibility. It diagrammatically starts by constituting two formally distinct terms as contrary asymmetry. It is maintained by concretely establishing a relationship of incommensurability between their sets of forces."[14] Culp juxtaposes asymmetry to complexity, which he calls "flattening," and an "equalization of inequality," which amounts to a kind of reductive scientific mysticism. It seems that by reviving Deleuze's concept of the irreducible inequality (here a productive operator generative of difference), Culp's gesture would lead us to space in which the non-human system could speak for itself on its own terms, even if there's no sense to be made of its speech act.

Figure 4: Instances of the final Lanterns system

While Culp's provocation inoculates us against the flattening of difference, his reading of Deleuzian metaphysics furnishes no system by which we can account for the lived experience of ensemble. This is not surprising given the nature of Culp's shadow work, imploring us to dispense with Deleuzoguattarian concepts adjacent to ensemble such as assemblage, becoming, and even experience for their affirmative, joyous, and connective connotations. Asymmetry only takes us as far as understanding difference as the continuous substrate and irreducible inequality as a primordial mechanism of creation. Humans and non-living systems are organized *differently*. We can understand this non-human/human ensemble as asymmetrical; forces such as desire,

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14   Andrew Culp, *Dark Deleuze* (Minneapolis: University of Minnesota Press, 2016): 33-37.

intention, anticipation are incommensurate with the physical forces acting upon the material of the lanterns.

To speak to our lived experience of ensemble with lanterns, to describe the encounter between a human and a non-human system, why and how this ensemble falls apart, we come to the question of organization. and indulge a traditionally affirmative reading of the relation of metallurgy to music in Gilles Deleuze and Felix Guattari's a Thousand Plateaus. They write:

> *Matter and form have never seemed more rigid than in metallurgy; yet the succession of forms tends to be replaced by the form of a continuous development, and the variability of matters tends to be replaced by the matter of a continuous variation. If metallurgy has an essential relation with music, it is by virtue not only of the sounds of the forge but also of the tendency within both arts to bring into its own, beyond separate forms, a continuous development of form, and beyond variable matters, a continuous variation of matter: a widened chromaticism sustains both music and metallurgy.*[15]

There are affinities between the lanterns' physical system and the molten metal as a physical system, just as there are affinities between the media behaviors of the lanterns system and musical texturality. This is not just because the lantern pendants are made of copper threading at its core, or that their movements are sonified, but because they are constructed in a manner which accords with both the *continuous* variation of matter *entangled* with media. This entanglement is a function of digital-physical computation strategies mentioned in Section 2.

Given the asymmetry of the lanterns systems and human beings, how then can we speak about ensemble? Or entrainment *with*?

In his essay "Nonorganic Life," Manuel Delanda writes that: "a centuries-old devotion to 'conservative systems' (physical systems that, for all practical purposes, are isolated from their surroundings) are giving way to the realization that most systems in nature are subject to flows of matter and energy that continually move through them."[16] So while we can understand the biological organism of the human as a organizationally closed autopoietic system, and the group of humans speaking, gesturing and walking together as a closed semiotic system, **we need not draw thick lines around humans** when considering the *lanterns* experiments as a movement system. So, "warum bin Ich Ich und nicht Du?" No doubt the humans retain their biologically organized boundaries, but when these systems become coupled in this way, maybe words like "I" and "You" and "It" lose their meaning. In the spirit of Simondon, it may simply be less interesting or enlightening to speak in terms of biological organizations or subjects.

Deleuze and Guattari write that "the musical smith was the first 'transformer'" but no doubt the musical smith was also *transformed* just as the movers in these experiments adjusted their relation to the *lanterns* in order to point the media system towards a state of perturbation. That some of the examples we've cited produce static concretized artifacts may also occlude what is interesting about the *lanterns*. The canal, the arrangement of metal filings, the wave patterns in the seafloor sediment—what is interesting about these is not the result of course by the process. As a movement system, the lanterns don't produce durational artifacts, but rather produce *gesture*. These gestures are co-produced by the physical system of the pendants, the energetic,

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15 Gilles Deleuze and Felix Guattari, *A Thousand Plateaus*, translated by Brian Massumi (Minneapolis, MN: University of Minnesota Press, 1987): 441.

16 Manuel Delanda, "Nonorganic Life," in *Zone 6*, eds. Jonathan Crary and Sanford Kwitner (New York: Urzone, 1992): 128-167.

somatic system of the human movers, *and* the computational media schema continuously driving spatialized sound and the electric flows to the light bulbs. Like music, gesture is ephemeral, mechanical reproduction notwithstanding. Per experimental jazz saxophonist Eric Dolphy: "When you hear music, after it's over, it's gone in the air; you can never recapture it again."

Acknowledgments

References

Culp, Andrew. 2016. *Dark Deleuze*. Forerunners Series: Ideas First. Minneapolis, MN: University of Minnesota Press.

Delanda, Manuel. 1992. "Nonorganic Life," in *Zone 6*, edited by Jonathan Crary and Sanford Kwitner, 128-167. New York: Urzone.

Deleuze, Gilles and Felix Guattari. 1987. *A Thousand Plateaus: Capitalism and Schizophrenia*, translated by Brian Massumi. Minneapolis, MN: University of Minnesota Press.

Heess, Nicolas, Dhruva TB, Srinivasan Sriram, Jay Lemmon, Josh Merel, Greg Wayne, Yuval Tassa, Tom Erez, Ziyu Wang, S. M. Ali Eslami, Martin A. Riedmiller, and David Silver. 2017. "Emergence of Locomotion Behaviours in Rich Environments". CoRR abs/1707.02286. arXiv:1707.02286

William Flake, Gary William. 2000. *The Computational Beauty of Nature: Computer Explorations of Fractals, Chaos, Complex Systems, and Adaptation*. Cambridge MA: MIT Press.

Johnson, Garrett, Britta Joy Peterson, Todd Ingalls, and Sha Xin Wei. 2018. "Lanterns: Towards an Enactive and Material Approach to Ensemble." *Proceedings of MOCO 2018*.

Johnson, Garrett. 2015. "Solo Lanterns examples". Vimeo Video. https://vimeo.com/193831344.

Kauffman, Stuart A. 2016. *Humanity in a Creative Universe*. Oxford: Oxford University Press.

Leonard, Naomi E et al. 2014. "In the Dance Studio: An Art and Engineering Exploration of Human Flocking," in *Controls and Art: Inquiries at the Intersection of the Subjective and the Objective*, edited by Amy LaViers and Magnus Egerstedt: 27-49. New York: Springer International Publishing.

Maniglier, Patrice. 2012. "Bachelard and the Concept of the Problematic: What is a Problematic?" *Radical Philosophy* 173, pp. 21–23.

Mechtley, Brandon, Julian Stein, Christopher Roberts, and Sha Xin Wei. 2017. "Rich State Transitions in a Media Choreography Framework Using an Idealized Model of Cloud Dynamics." *Proceedings of the Thematic Workshops of ACM Multimedia*, pp. 477-484.

Navab, Navid, Doug Van Nort, Sha Xin Wei, 2014. "A Material Computation Perspective on Audio Mosaicing and Gestural Conditioning." *New Instruments in Musical Expression*, pp. 387-390.

Peterson, Britta Joy, Garrett Laroy Johnson, and Evan Anderson. 2016. *Lanterns* solo performance. Vimeo video. *https://vimeo.com/216553103*.

Peterson, Britta Joy, Garrett Laroy Johnson, Evan Anderson, Kim Lusk, Juan Rodriguez, and Lela Groom. 2016. Lantern movement etudes. YouTube video. https://www.youtube.com/watch?v=Evm1z-Kjllg.

Prusinkiewicz, Przemyslaw et al. 1991. *The Algorithmic Beauty of Plants.* New York: Springer.

Reynolds, Craig. 1987. "Flocks, Herds, and Schools: A Distributed Behavioral Model." *Computer Graphics in SIGGRAPH '87 Conference Proceedings* 21, no. 4, pp. 25-34.

Shiffman, Daniel. 2012. *The Nature of Code: Simulating Natural Systems with Processing*. Magical Book Project.

Stepney, Susan. 2008. "The Neglected Pillar of Material Computation." *Physica D* 237, pp. 1157–1164.

Sha, Xin Wei. 2013. *Poiesis and Enchantment in Topological Matter*. Cambridge: MIT Press.