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Wood, Timothy R

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Embodied Worldmaking

A Dissertation submitted in partial satisfaction
of the requirements for the degree of

Doctor of Philosophy

in

Media Arts & Technology

by

Timothy R. Wood

Committee in Charge:

Dr. JoAnn Kuchera-Morin, Co-Chair

Marcos Novak, Co-Chair

Marko Peljhan

March 2021

The Dissertation of
Timothy R. Wood is approved:

Marko Peljhan

Marcos Novak, Committee Co-Chairperson

Dr. JoAnn Kuchera-Morin, Committee Co-Chairperson

March 2021

Embodied Worldmaking

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by

Timothy R. Wood

*To the wild ones the strong ones the soft
ones – to bodies and to the healing of their
pain – to the warm dreams you feel floating
in your bodymind waiting to find a place in
the world – to the earth and to the sky – to
indigenous peoples everywhere – may we
begin to understand true just embodied
coexistence and collaboration.
May your breath now be a gift to the world
and to you.*

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I would like bring your attention to the lands beneath your feet, and to acknowledge the indigenous peoples of the land where you are now. I am lucky to be in Goleta, California, home of the Chumash people, and I would like to extend my respect and gratitude to the Chumash community, past, present, and future for their care of this land. My work at its heart is a collaboration with this land and I feel truly grateful to witness it knowing that the care, life, and beauty of the Chumash people is reflected in my experience of the land today – and I feel a responsibility to connect with, listen to, and love the land and all of its creatures as a members of my own family.

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Curriculum Vitæ

Timothy R. Wood

Education

- | | |
|------|--|
| 2021 | Doctor of Philosophy in Media Arts and Technology, University of California, Santa Barbara (Expected). |
| 2018 | M.S. in Multimedia Engineering, Media Arts and Technology, University of California, Santa Barbara |
| 2009 | B.S. in Computer Science, College of Creative Studies, University of California, Santa Barbara |

Professional Experience

- | | |
|-------------|--|
| 2013 – 2021 | Graduate Student Researcher, Allosphere Research Group, University of California, Santa Barbara. |
| 2009 – 2013 | Software Engineer, Zentopy Inc., Santa Barbara. |

Awards

- | | |
|-------------|--|
| 2015 – 2016 | Robert W Deutsch Foundation Fellow. |
| 2015 | Interdisciplinary Humanities Center for the Visual, Performing and Media Arts Award. |

Selected Publications

- Kodama: Reconnecting the Body to Nature through Immersive Performance and Technology. (Jan 2018). UCSB Master's Thesis
- Wan Rosli, M.H., Yerkes, K., Wright, M., Wood, T., Wolfe, H., Roberts, C., Haron, A., Estrada, F.R. (2015). Ensemble feedback instruments. In Proceedings of the international conference on New Interfaces for Musical Expression (pp. 144-149).
- Wakefield, G., Roberts, C., Wright, M., Wood, T., Yerkes, K. (2014). Collaborative live-coding virtual worlds with an immersive instrument. In Proceedings of the 14th International Conference on New Interfaces for Musical Expression.

Abstract

Embodied Worldmaking

Timothy R. Wood

Embodied worldmaking explores the transdisciplinary creative intersection of embodied movement practice, known in the field of somatics, with virtual world-making performance and media arts practice. This research integrates diverse methods into a framework for creating immersive media performative artworks inspired from the body and the natural world that aim to create spaces of refuge for reconnecting to the whole body and sharing embodied stories of interconnectivity with land. This framework takes the form of the embodied worldmaking process, a set of integration methods prioritizing the body in relationship with creative expression, media arts practice, and interactive technology. Specific methods are shared for connecting embodied movement practice, embodied interaction design, performative virtual worldmaking practice, and creative coding system design.

This practice-based arts research is conducted through the iterated processes of creating poetic virtual worlds and instruments inspired by living ecologies, designing interaction mappings between whole-body sensing systems and virtual ecosystems, and exploring improvisational performance and embodiment practices within these systems. This performance research practice provides the grounding

motivation for designing the creative coding system, seer, and the four integrative media artworks of this dissertation.

The audiovisual creative coding system, seer, was created to empower the process of embodied worldmaking. Autobiographical design methods were used to grow the expressivity of the system to support the media artworks of this dissertation. The system enables expressive and rapid production of instruments and virtual ecologies intended for use in immersive installations and improvisational performance environments. Seer provides useful tools for designing audiovisual worlds for performance, as well as new methods for the iterative design of full-body interaction mappings and composition.

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1

Introduction

1.1 Motivation

“As electric media proliferate, whole societies at a time become discarnate, detached from mere bodily or physical ‘reality’ and relieved of any allegiance to or a sense of responsibility for it. The alteration of human identity by new service environments of information has left whole populations without personal or community values.” (McLuhan and Watson, 1970)

Although McLuhan wrote these words in a different era of electric media early in the emergence of personal computers, its sentiments still hold true today with a clear poignancy. McLuhan suggests disembodiment as a symptom of an underlying design flaw in how we create and use technology, and ultimately how it leads to a disconnection from personal and shared values.

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Our usage of technology and our immersion in environments shaped by humans grows more and more prevalent. At the same time, the effects of the anthropocene on the whole planet are undeniable as we witness human driven changes and global warming radically shift the face of the Earth and its stability as a living organism. In my opinion, it is clear that these disconnections are a reflection of each other across scales, and perhaps it is indeed the missing personal and communal values that initiate the issue.

It is time to ask difficult questions deeply and persistently: what values are present in a given environment, system, or structure and how do we create space for new choices in order to greater reflect the values revealed in our whole and diverse bodies, our whole and diverse communities, and the whole and diverse Earth all as living ecosystems?

This dissertation, motivated by these large questions, is about the practice based media arts research process I call *embodied worldmaking*, and the creative coding framework, *seer*, developed to empower the process of exploring embodied interaction alongside virtual worldmaking. The practice of embodied worldmaking is a creative media arts practice combining interactive audiovisual instruments, virtual reality environments, and somatic movement performance. This research, situated within and between the fields of media arts, somatics, dance improvisation, human-computer interaction, virtual worldmaking, and creative coding,

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explores immersive media performance spaces and how they can shape us and be shaped by us through our movement and our stories. Embodied worldmaking prioritizes the process of embodiment, the process of engaging with living presence experienced within and unique to each body, and posits that this place of being and knowing offers a unique and critical perspective to root in, learn from, and share experiences and knowledge from. Embodied worldmaking aims to create space for bodies to listen to the meeting place of internal and external sensation and movement resonated through interaction in immersive poetic worlds. Embodied worldmaking employs biomimetic visualization and simulation techniques to create virtual ecologies as reflections of internal qualities and processes that connect us deeply to the living world. This practice is a practice of making space. Can we make space to support feeling, moving, learning, and engaging with our bodies in new ways? Can we make space to support a deep connection with the living world and the land that supports us, even through technologies which often separate us from this connection?

The practice of embodied worldmaking is intended to be an integrated trans-disciplinary process that traverses and navigates diverse ways of knowing and ways of expressing, and like a strange attractor's chaotic path, follows the pull of different fields in order to find and share a space of wholeness, balance, and empowerment. Embodied worldmaking is a media arts practice that utilizes cre-

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ative technologies to bridge and expand two primary fields, both extremely rich and diverse on their own: embodiment and worldmaking.

Taken at face value the term embodiment can be interpreted as simply to exist or take physical form, to have a body. However, in this dissertation I assimilate the term to reflect its richness including its explorations in philosophy and phenomenology, its description in HCI embodied interaction research, as well as its expression in somatic movement practice based research such as Body-Mind Centering. This dissertation will explore the meaning of embodiment and why it is a critical method for discovering new perspectives of our relationship to knowledge, self, technology, society, and the Earth.

The body, in its living presence, does not exist separate from the space of a world that gives it ground to grow within. The world is a necessary precursor for the body to exist in the process of living: sensing, moving, nourishing, creating, and evolving. Worldmaking explores the process of creating worlds, and also how witnessing and perceiving the world is a part of this creative act. In this dissertation, the term worldmaking encompasses the complex and intertwined nature of how living systems and experiences can be expressed, shared, and enframed through poetic narratives, guided movement exploration, and the technical crafting of space and sensory experiences. I rely on this complexity to integrate the diverse arts practices of this dissertation, and examine the meaning of world-

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making through the lenses of embodied experience, poetry, performance, ritual, mythology, evolutionary biology, virtual reality, and artificial life.

Embodied worldmaking is the practice of making space for what is human and what is more-than-human to exist in reciprocal relationship through movement, performance, and story telling.

To engage with the body in these types of mediated space-making experiences requires both a technical engagement through sensor systems that read movement and touch, measuring the body from the outside, as well as a fundamental engagement with the body through movement practice and interoceptive phenomena, becoming aware of the body from the inside.

The relationship of body and technology has changed a great deal from the early days of computers up until today, however the widespread adoption of personal technologies that prioritize the visual sense and have a limited capacity for embodied agency still maintain a pattern of dislocation in experiencing our whole body in relationship with technology. Many new sensors and interfaces have been developed integrating a wide range of methods of interacting with computers using the body, motion, touch, breath, heart rate, and brain signals. Motion tracking systems and devices provide methods of detecting bodies in motion and connecting movement and physiological data to computational systems. Sensors found in consumer technologies like the Kinect, the Leap Motion, and the HTC Vive

provide accessible and low cost technologies for incorporating motion tracking and gestural interaction into any application. However, there is still much to be desired in the software tools and design practices for working with these technologies to create meaningful, empowering, and embodied experiences.

1.2 Problem Context

If McLuhan's words point towards disembodiment as a symptom of a design flaw in how we create and use technology, how did this separation form and what can be done to bring balance and reconnect these gaps in conscious relationship with technology?

I believe this separation has evolved over the history of civilization through repeated instances of cultural trauma and colonization, where limited perspectives and privileged powers impose value systems and structures on other living cultures. Adopted, accepted, oppressive, and learned patterns continue unless challenged and these histories and limited perspectives are embedded in the foundations of modern society in fragmented and extractive philosophical, economic, and political structures and ideologies.

The processes of division and dissection are an important foundation of scientific learning, however these same processes become dangerous when we lose sight

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of the whole and indivisible nature of living systems. One such division which helped in the foundation of scientific thought, can be seen in Rene Descartes debate on the nature of consciousness resulting in Cartesian Dualism, a line of thinking which has brought separation between the wholeness of body and mind. The body's innate intelligence and complexity is dissected, fragmented, and de-valued when the paradigm of objective thinking is prioritized beyond a point of balance.

Another prevalent disconnect can be seen in the economic system of capitalism. The word economics, from its Greek roots, is formed from *eco*, meaning home, and *nomos*, meaning accounts. Together the word represents the art of managing the home. Given the implications of this meaning and a recognition of the Earth as our home, it is not difficult to see how an economics driven off of the principle of unending growth does not pose a promising future in relationship with the sustainability of planetary limits. Our system of caring for the home is disconnected from the home itself, the economy is disconnected from the ecology of living Earth.

Kate Raworth, a renegade economist, describes a piece of the solution: "we need to shift the idea that success lies in endless growth to success lies in balance, meeting human needs within planetary boundaries...the big metaphorical opportunity of our time, if we are are going to thrive with and as part of this planet, is to

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connect what we understand about bodily health to planetary health” (Raworth, 2017). The human body is a connecting metaphor to all life and the planet; health lies in balance and systems have limits.

Technology empowers the creative impulse of its purpose, transforming what is possible, while maintaining embedded patterns and value systems. For example, as seen in *The Social Dilemma*, a documentary film about the effects of social networking, the social networking platforms intended to provide meaningful service with positive impact on people, evolve into an extractive attention economy ultimately promoting addictive and unhealthy behavior. Given a foundation and purpose of capitalist values prioritizing financial growth, the system grows beyond the boundaries of healthy human limits and values.

This is exactly why we must challenge the foundations of structures, systems, and patterns and to prioritize the dissemination of value systems that support living balance and equity across scales of body, society, technology, culture, and ecology.

In the words of Donna Haraway: “how can we think in times of urgencies without the self-indulgent and self-fulfilling myths of apocalypse, when every fiber of our being is interlaced, even complicit, in the webs of processes that must somehow be engaged and re-patterned...it matters what ideas we use to think other ideas with. It matters what matters we use to think other matters with.

It matters what knots knot knots...It matters what thoughts think thoughts. It matters what worlds world worlds” (Haraway, 2016).

This leads to the problem of integration this dissertation explores. How can we build bridges within ourselves, our practices, and our technology, to challenge fragmentation and to resonate the innate truths of integration, of wholeness of body-mind, of human society as a part of nature, and of virtual worlds that tell regenerative stories of integration and balance?

1.3 Problem Focus

Specifically, this dissertation seeks new methods of integrating embodied movement and ecological listening practices with media arts worldmaking practices to create regenerative narratives and spaces of refuge that prioritize the connection of body and Earth.

Additionally, this dissertation searches within this space and how to design the creative computational tools to support these processes. Creative coding tools aim to support creative use of programming languages and digital media to create a wide range of expression and aesthetic experience. What aspects of creative coding can be focused to support the processes of integrating diverse methods of embodied performance and media art practices through embodied worldmaking?

1.4 Research Questions

My primary research questions are:

1. How can embodiment and somatic practices integrate with media arts creative practices in order to inform, empower, and prioritize whole body experiences?
2. How can ecological listening practices integrate with media arts worldmaking practices to create spaces for valuing the connection between body and Earth?
3. How can creative coding systems be designed to empower the practice of embodied worldmaking, using programming languages to create embodied interaction with virtual worlds inspired by ecological experiences?

1.5 Contributions

The primary contributions of this dissertation include:

1. Four embodied worldmaking works and performances exploring an embodied connection to biomimetic computational processes and virtual worlds, and a qualitative analysis evaluating and contextualizing these works.

2. The novel creative coding framework *seer* which offers a unique and expressive textual live-coding interface for creating immersive audiovisual ecologies and embodied interaction mappings.
3. The Embodied Worldmaking methodology: an ecology of taxonomies, heuristics, and generative methods for navigating embodiment practices in relationship with virtual worldmaking, gathered from the process connecting the works of this dissertation.

1.6 Overview of this Dissertation

This dissertation is an in depth look at the transdisciplinary research process I have called *Embodied Worldmaking*.

In this chapter, I have outlined the motivation for this research as a means to practice instilling human and more-than-human values into our interaction with technology. This is made possible through the intersection of improvisational somatic movement practice with ecological listening and storytelling practices shared through the mediated enframing of immersive virtual worldmaking. I have also shared the primary research question which focus this work, as well as the concrete contributions delivered in this process.

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In chapter 2, I will provide the background and history of the fields which ground this work, as well as how they interconnect and lead to the embodied worldmaking process.

Chapter 3 describes the prototype works which evolve and develop both the novel creative coding framework *Seer*, as well as the *embodied worldmaking* process and methodology.

In chapter 5, I share the *embodied worldmaking* process, methodologies, and taxonomies of guiding metaphors. It is in this chapter where the process developed from the practice-based works is clarified and evaluated in relationship with the research questions of this dissertation.

Chapter 4 describes in detail the design and implementation of the creative coding framework, *seer*, and its contributions to the field of media art as a supportive tool for creating embodied interactions and biomimetic worlds.

Finally, I provide a concluding overview of shared contributions and limitations of this work, and I also outline what possible future directions should be pursued to continue this research and build upon this work.

2

Background and Related Work

This research builds on the evolution of a diversity of fields intersecting embodiment, virtual worldmaking, and creative technology. In this chapter I will highlight the research, histories, methods, and works of these related fields and their intersections important to the foundation of this dissertation.

2.1 Embodiment

A standard definition of embodiment, found through an online search, is as follows: "a tangible or visible form of an idea, quality, or feeling" or an "investment in or manifestation through a physical body; a bringing into or presentation in or through a form."

In this dissertation, the term embodiment points to the phenomenological and encompasses the rich experiential processes of being a living body. I would define the term in this dissertation along the lines of: "the participatory process of

2. *Background and Related Work*

existing as a living body, awareness of the body, and awareness through the body, engagement with meaning, and agency in relationship to self and other.”

The purpose of this usage is to breathe life into the language of speaking about living bodies, and to breath life into the language of speaking about living bodies in relationship with technology. In actuality, we are always existing, sensing, and acting through our bodies, however we aren’t always attending to them with prioritization of value. By accentuating the term embodiment, there is an aim to bring our attention to the reclaiming of valuation for the body and all bodies, including the earth as body. The embodiment I refer to in this work is most accurately reflected through the field of somatics, however embodiment is becoming a more and more important aspect in the field of human computer interaction (HCI) as well.

2.1.1 **Embodiment and Somatics**

Somatics, coined by Thomas Hanna in 1970, is the field which studies the *soma* or “body as perceived from within” (Hanna, 2004). Somatics is a recent field within the west, however it encompasses a wide range of practices, methods, and research communities with diverse origins and histories, including ancient movement practice and martial arts such as yoga, tai chi, Qigong, and Aikido. Many modern somatic practices have ties to modern dance and performance practices,

2. Background and Related Work

or have been influenced by pioneers in the field, such as Francois Delsarte, Emile Jacques-Dalcroze, Rudolf Laban, Isadora Duncan, Mary Wigman, and Anna Halprin.

Somatic researcher Martha Eddy identifies that in somatics, “the goal of the somatic movement professional is to heighten both sensory and motor awareness to facilitate a student-client’s own self-organization, self-healing, or self-knowing” (Eddy, 2009). Eddy provides a history of somatic practices and their connections to dance, as well as a categorization of somatic subfields including: somatic psychology, somatic bodywork, and somatic movement.

Body-Mind Centering

Body-Mind Centering (BMC), started by Bonnie Bainbridge Cohen, is one of many somatic movement and embodiment research communities. BMC offers a comprehensive structural organization of information around embodied anatomy, embryological and developmental movement as the scientific ground to map and connect somatic experiential knowledge in relationship. BMC’s organization of information and experiential qualities around body systems and developmental movement patterns provide a grounding framework for experiencing and connecting body and Earth.

2. Background and Related Work

Engaging with the systems of the body provide one method of learning and experiencing the body from an anatomical perspective. By getting to know the qualities, functions, and interconnections of each system of the body through experiencing them within one’s own body, BMC provides a way of connecting to anatomical knowledge directly in an embodied way. Here one can experience the qualities of connection between systems such as respiratory and circulatory systems through guided experiences of breath, heart, lungs, and fluids. These qualitative investigations use the embodiment process as methodology, where guided movement called *somatization* or guided imagery as *visualization* directs ones attention within their own body towards what is being explored.

BMC investigates developmental movement patterns both pertaining to “ontogenetic (human infant development) and phylogenetic (the evolutionary progression through the animal kingdom) development” (Cohen, L. Nelson, and Smith, 2012). One method of connecting to developmental movement is through embodiment of the *Basic Neurocellular Patterns (BNPs)*, or repeated patterns of movement that exist across many forms of life from prevertebrate to vertebrate lifeforms. These movement patterns include prevertebrate processes such as: vibration, cellular breathing, sponging, and pulsation, as well as vertebrate processes such as: navel radiation, mouthing, spinal movement, homologous movement, homolateral movement, and contralateral movement. These patterns show up at

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different stages of evolution and development and reflect resonating qualities of Ernst Haeckel's biogenetic law, or how "ontogeny recapitulates phylogeny" (G. Nelson, 1978). Another aspect of developmental movement is embodied in the qualities of the relational movement cycle consisting of the verbs: yield, push, reach, and pull.

All of these tools give the body-mind experiential mappings between qualities of experience to specific aspects of their body's development as tools of agency and interconnectivity.

"Aligning inner cellular awareness and movement with outer awareness and movement through space within the context of the developmental process can facilitate the evolution of our consciousness and alleviate body-mind problems at their root level. As we are more able to experience our consciousness at the cellular and the tissue level, we are better able to understand ourselves. As we increase our knowledge of ourselves, we increase in understanding and compassion for others. As we experience the uniqueness of cells within the context of tissue harmony, we learn about individuality within the context of community. As we gain awareness of our diverse tissues and the nature of their expression in the outer world, we expand our understanding of other cultures within the context of the Earth as a whole and the awareness of our planet within the expanded consciousness of the Universe" (Cohen, L. Nelson, and Smith, 2012).

Anna Halprin and RSVP Cycles

Anna Halprin is a pioneer in the field of post-modern dance, and is also considered a pioneer within the field of somatic movement practices as well. Her dance, performance, and artistic practices utilize improvisational movement methods and

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connect strongly with the idea of the body and the natural world as teacher. Her work is community oriented and connects performance scores to myth and ritual. Halprin's work evolved through dance and investigates the creative process in relationship to the process of healing.

Along with her husband, Lawrence Halprin, the creative method of RSVP cycles was created to organize and integrate the creative process of developing performances and rituals. The method represents four interconnected aspects of process including: resources, scores, valuation, and performance. Resources represent materials and ideas used in the process. Scores are the instructions for carrying out a process. Valuation represents the dynamic process of response to take action in developing the work based on underlying values. Performance is setting the work in motion. These phases are repeated and reordered throughout the creative process and reflect a dynamic iterative evolution.

Authentic Movement

Authentic Movement is an improvisational movement practice started by Mary Starks Whitehouse in the 1950s (Lovell et al., 1999). The practice holds connections to Jungian philosophy and somatics as a form of dance therapy. The movement practice takes a simple form, where a witness holds a container of focused attention in support of a mover. The practice recognizes the powerful quality

that emerges in the context of being witnessed within a space of safety and trust. The mover is tasked with following the movement impulses that come forward and want to be expressed. This space is a space for conscious processes to meet, dance, and communicate, with unconscious processes.

2.1.2 Embodiment and Human Computer Interaction

The field of human computer interaction has evolved greatly since the early era of computers. The field has gone through a number of transformations and paradigm shifts reflecting the values and needs as the sphere of computational influence has increased. HCI has evolved from prioritizing evaluation metrics that compare efficiency and mechanistic ideals towards metrics that value human-centric experiential qualities.

Third-wave HCI represent this shift in thinking as the prevalence of technology has made visible the need to humanize our relationship with it as a means of meaning making.

Embodied Interaction

Paul Dourish’s *Embodied Interaction* design philosophy connects embodiment to HCI through phenomenology, tangible computing, and social computing. Dourish defines embodiment as “the property of our engagement with the world that

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allows us to make it meaningful” and embodied interactions as “the creation, manipulation and sharing of meaning through engaged interaction with artifacts” (Dourish, 2004). This connecting philosophy is a move towards understanding and valuing the qualities of whole body lived experience as an important criterion in interaction design, recognizing that “you cannot separate the individual from the world in which that individual lives and acts” (ibid.). Although this work was a great shift towards embodied design, the philosophy had little to say about actual knowledge of the body or movement.

Kinaesthetic Creativity

Kinaesthetic creativity is defined by Svanaes as the “body’s ability to enact alternate future possibilities via movement” (Svanaes, 2013). In the context of HCI, digital performance environments, and embodied instruments, kinaesthetic creativity reflects the possibilities of creating spaces of movement in relationship to technology and interactive virtual worlds. Research by Hsueh et al. on modes of kinaesthetic creativity in relationship with interactive visual systems outlines a taxonomy of creative movement relationships that highlights important qualitative distinctions important to this work. Their taxonomy represent creative kinaesthetic relationships with an interactive visualization through a two axis relationship to the system and to the self. One may be engaged with the visual-

ization as either an instrument, a partner, or a medium; and one may be engaged with the self through either a reactive, or a self-reflexive relationship. These two axes make up a taxonomy of six distinct engagement modes (Hsueh, Alaoui, and Mackay, 2019).

Somaesthetic Appreciation Design

Somaesthetics provides a philosophy integrating somatic principles with aesthetic principles and pragmatic philosophy (Shusterman, 1999). Shusterman aims to create a structured framework for a pragmatic approach to using the values and methods of somatics to create and improve experiential qualities of body and life.

Kristina Hook integrates Somaesthetics into interaction design, through a series of autobiographical designs to create specific design principles for creating objects and experiences that reflect somaesthetic principles. Hook’s Somaesthetic Appreciation Design offers four general principles taken from their design work including: subtle guidance, making space, intimate correspondences, and articulating experiences (Höök et al., 2016).

Subtle guidance points to the delicate qualities of guidance necessary for directing people into experiencing their internal body sensations. Because the intention in this case is for people to experience what is uniquely occurring within their

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own bodies, information that is too direct, specific, suggestive, or embedded with agenda may influence or limit the body's safety to feel itself.

Making space represent the strong influence of the environment on the body's sense of safety and comfort. Creating spaces of refuge allow the body space to listen.

Intimate correspondences represent the qualities of interconnection between the experience of the body and the experience of the environment. In the case of an interactive design that aims to resonate with a particular quality of internal experience, making sure that this mapping of qualities closely reflects the rhythms and states of the body.

Finally, articulating experiences reflects the importance of communicating and tracking the embodied experience within the design process and in receiving feedback.

2.2 Worldmaking

The idea of worldmaking is not singular in origin. What is a world and how is it made? We can look to the greek word *cosmopoiesis* for clues. *Cosmos* literally means an orderly systematic whole or world, however its meaning is multi-faceted and layered. *Cosmos* is seen in the *cosmos* as the universe, the whole of everything

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in existence. Cosmos is found in the order of ornamentation or the cosmetic. Cosmos is also found in the cosmopolitan, or the people of the city as ornament. Worlds are made of worlds.

As philosopher Nelson Goodman describes worlds: “the many stuffs—matter, energy, waves, phenomena—that worlds are made of are made along with the worlds. But made from what? Not from nothing, after all, but from other worlds. World making as we know it always starts from worlds already on hand; the making is a remaking” (Goodman, 1978).

Our world, the Earth, is a living system of living systems; a world made of worlds. As a living system it houses all the rich and interconnected processes of transformation within its boundaries. Plants, animals, humanity, geothermal and chemical activity are all integrated organ systems of the living Earth, fed externally by the energy of the Sun. Each interconnected whole, a world amongst worlds. Vladimir Vernadsky described the interconnection of complex processes that shape and stabilize the Earth, connecting the geosphere and the biosphere to the integrative sciences of ecology (Vernadsky, 1998). He recognizes that it is not the living systems that depend on the non-living processes, but in fact the living shape and integrate with the non-living processes changing them drastically and in a way, bring them to life, enfolding them into the kinship of living process.

“No chemical force on Earth is more constant than living organisms taken in aggregate, none is more powerful in the long run. The more

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we learn, the more convinced we become that biospheric chemical phenomena never occur independent of life” (Vernadsky, 1998).

The biosphere lives with and through the geosphere and creates new conditions of stability for life to continue; both are alive together.

The term autopoiesis, or self-making, points to the unique quality of living systems to create themselves. The term, coined by Maturana and Varela, is a systems based description used to help define the nature of living systems:

Autonomy is the distinctive phenomenology resulting from an autopoietic organization: the realization of the autopoietic organization is the product of its operation. As long as an autopoietic system exists, its organization is invariant; if the network of productions of components which define the organization is disrupted, the unity disintegrates. Thus an autopoietic system has a domain in which it can compensate for perturbations through the realization of its autopoiesis, and in this domain it remains a unity.

The concept of autopoiesis is useful for recognizing boundaries of organization, however no living entity can be separated from the web of interconnections that it lives within and through. When reasoning about anything in isolation, it is always useful to be reminded of this reality. Dona Haraway uses the term sympoiesis to bring light to the inherent complexity and interconnection of living relationships.

Sympoiesis is a simple word: it means ‘making with.’ Nothing makes itself; nothing is really autopoietic or self-organizing... Sympoiesis is a word proper to complex, dynamic, responsive, situated, historical systems... Sympoiesis enfolds autopoiesis and generatively unfurls and extends it (Haraway, 2016).

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This practice of seeing beyond boundaries of isolated systems is a necessary practice in integrating and bridging dislocated worlds, in the context of economic and technological systems, external factors become internal factors over time. The practice of worldmaking is never in isolation from other worlds, it is both a world-seeing and a world-changing – worlds are in relationship with the ecology of its place of influence and sphere of kinship. In this way, the worlds that are accessible to human beings are both realities and fictions, futures and pasts. We witness the potency of human influence on the living biosphere and geosphere, and the potency and role that human thought, science, technology, story, and myth have to play in the agency over this cumulative worldmaking through the cultural worlds of the arts, sciences, and technology.

Timothy Morton recognizes this interconnection and influence: “The ecological crisis we face is so obvious that it becomes easy – for some, strangely or frighteningly easy – to join the dots and see that everything is interconnected. This is the ecological thought. And the more we consider it, the more our world opens up” (Morton, 2010).

Worldmaking is then a creative practice of integration and of acknowledging interconnection and the ecological thought, acknowledging what is made as a world within and amongst worlds. Bringing together and making connections between worlds; choosing new relationships, choosing new stories, and choosing new values

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within our bodies. Morton recognizes the reflection of body and Earth: “We are all burnt by ultraviolet rays. We all contain water in about the same ratio as Earth does, and salt water in the same ratio that the oceans do. We are poems about the hyperobject Earth.” (Morton, 2013).

There is an implication beyond ecological thinking and towards ecological being and embodiment. Embodiment is an inhabiting of the body that precedes thought and includes thought, it is the bigger world of the bodies’ intelligence that makes thinking possible and connects us innately to the geosphere and the biosphere through languages of resonance. To be a poem about the Earth illuminates a radical identity shift for some on what it means to be human.

This language of resonance is the qualitative and the vibrational. It is the music of living pattern and we are all indigenous to its origins within us and around us. What is the space of listening to this voice? This language is the language of the poetic and includes Bachelard’s *Poetics of Space*, a phenomenology of architectural space and an archetype of spaces felt and remembered within the living experiential body. The qualities of space are the world we feel and inhabit and express through, they ground our experiences and map our memories of being and creating. The spaces we make are a reflection of both our bodies and the foundational spaces of land that house the spaces of made spaces. We recognize in space and in ornamentation the small fascination of living attention

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drawn into creative interplay with worlds of sensation, movement, and imagination. Bachelard's use of *resonance* and *reverberation* provide a poetic method of bridging the worlds of body and Earth through the made spaces of architecture and technology (Bachelard, 2014). The resonance Bachelard speaks to is a form of knowing within the body. It is a recognition of qualitative experience within the present, connected to memory, experience, information, emotion, trauma, thought, or imagined worlds held within the body. A resonant experiences is how knowledge as a connection between experience and information communicates within the body and is drawn forward into the bodies' capacity of attention. What does this imply about the importance of embedded values and living pattern within everything we encounter and learn, within every world of our attention and creation.

The idea of restorative environments points to both this importance of valuing living pattern and its deficit in modern society. Studies by Korpela et al reflect the interconnection of self and environment and effects of inhabiting spaces of refuge that draw particular bodies (Korpela et al., 2001). Other research shows there is a recognition on the innate capacity of immersion in living and growing environments that restore the bodies ability to function as seen in Hartig, Mang, and Evans, 1991. The qualities of modern life, especially when overworked within urban environments, lead to directed attention fatigue which is balanced

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through effortless attention depending on environments with an abundance of the resonating subtle guidance of living pattern to draw sensorial fascination. The qualities of resonance extend beyond direct immersion and include transmission through other media. Studies show how experiences that resonate qualities of living environments through different technological mediums can also create similar restorative benefits as seen in Valtchanov, Barton, and Ellard, 2010.

Stories, ritual, and mythology hold a similar role at the larger scales of culture and society, according to Joseph Campbell, “it has always been the prime function of mythology and rite to supply the symbols that carry the human spirit forward, in counteraction to those that tend to tie it back” (Campbell, 2008). Living systems work to continuously rebuild and heal themselves to a state of balance in response to entropic forces. In the case of living cultural bodies, there is a cultural organ of myth, ritual, and storytelling that plays a critical role in remaking, evolving, and stabilizing the collective cultural body-world. Stories and mythology inhabit a poetic space of collective dreaming and bring the value of living pattern to the imagination. It is a way of creating shared experiences of resonance within the bodymind that guide both individual and collective bodies towards life.

“People say that what we’re all seeking is a meaning for life. I don’t think that’s what we’re really seeking. I think that what we’re seeking is an experience of being alive, so that our life experiences on the purely physical plane will have resonances within our own innermost being and reality, so that we actually feel the rapture of being alive. That’s what it’s all finally about, and that’s what these clues help us

to find within ourselves...We're so engaged in doing things to achieve purposes of outer value that we forget that the inner value, the rapture that is associated with being alive, is what it's all about" (Campbell and Moyers, 2011).

We are living bodies immersed in living worlds with the creative capacity to make worlds and to shape the planet. Perhaps in realizing an interconnectivity of worlds we can listen for the worlds and the futures that recognize that moving towards life is a collective effort. To move in isolation at the cost of our kin is to move at odds with the living whole. Every viewpoint is imperfect; nothing can see everything.

2.2.1 Virtual Worlds and Biomimetic Programs

Virtual worldmaking provides an exploration into highly immersive media where resonant experiences can be shared. This is a powerful medium to create full body experiences through computational processes. Engaging with the biomimetic is an opportunity to create experiences that resonate with the qualities of living pattern and living environments.

Three early exemplar works utilize the capacity of virtual reality to create experiences of resonance and exploration of both body and Earth.

Brenda Laurel and Rachel Strickland's *Placeholder* immerses participants in a natural landscape where the body is transformed into a number of animal spirits

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exploring a world of story embedded in the landscape's petroglyphs guided by the voice of a live performer. Laurel conceives of virtual reality as place to "reinvent the sacred spaces where we collaborate with reality in order to transform it and ourselves" (Dixon, 2006).

Char Davies' *Osmose* immerses the participant in a natural world of ethereal beauty, navigable through a full-body interface and breath based intuitive control.

"*Osmose* is about being-in-the-world in its most profound sense, i.e. our subjective experience as sentient, embodied, incarnate, living beings embedded in enveloping flowing space. Osmosis: a biological process involving passage from one side of a membrane to another. Osmosis as metaphor: transcendence of difference through mutual absorption, dissolution of boundaries between inner and outer, intermingling of self and world. *Osmose* as an artwork is motivated by the desire to heal the Cartesian split between mind/body, subject/object, which has shaped our cultural values and contributed to the West's dominating stance towards (and estrangement from) life. In this context, *Osmose* seeks to re-sensitize — reconnecting mind, body and world" (Davies, 1998).

In *Dancing with the Virtual Dervish*, the immersant is the dancer who is moving within and in relationship to virtual organs of the human body. "Literally and figuratively a body of enormous scale, the resultant virtual environment is an incomplete torso comprised of a skeletal spine, pelvis and ribs, along with the viscera of a heart, kidney and liver...These organs can be "entered" to reveal otherworldly chambers. The virtual body thus becomes an immersive, nonlinear book, a text to be read, an architecture to be inhabited" (Gromala and Sharir, 1994).

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The exemplar works show early instances of worlds that engage with immersive full-body interaction and also incorporate resonance with both body and Earth.

More recent advances in computation and artificial life research The processes of biomimetic simulation through computation have been explored within the field of *artificial life* identified by Jean-Claude Heudin as research which “seeks to understand, through synthetic experiments, the organizational principles underlying the dynamics of living organisms” (Heudin, 2006).

One early cellular automata based simulation of this kind, called the *Game of life*, uses a simple rule set to simulate the growth and death of colonies of adjacent living cells. As the simulation run, surprising patterns and evolutions unfold, suggesting a complexity arising out of a seemingly simply set of rules. These processes can be used themselves to create immersive abstract narratives. *Artificial Nature*, by Haru Ji and Graham Wakefield, uses fluid ecosystems containing evolving creatures and morphing fields of chemicals and nutrients to create beautiful artificial life worlds (Wakefield and Ji, 2009).

Inspiration for biomimetic algorithms specific to the works of this dissertation include algorithms for plant growth, spring, and wind simulation, fluid field simulation, and particle simulation.

Plants growth explorations have been based on the previous work of Lindenmayer’s L-systems (Lindenmayer, 1974), Honda’s tree growth visualizations

(Honda, 1971), Oppenheimer’s recursive branching tree growth model (Oppenheimer, 1986), and Runions et al’s space solonization algorithm (Runions, Lane, and Prusinkiewicz, 2007). Animation of trees and associated wind and spring forces have been inspired by the works of Stam, Sakaguchi, and Habel (Habel, Kusternig, and Wimmer, 2009; Sakaguchi and Ohya, 1999; Stam, 1997). Fluid field simulation in this dissertation is based off of Stam’s work on realtime fluid animation (Stam, 2003).

2.3 Creativity Support Tools and Autobiographical Design

Shneiderman’s *Creativity Support Tools* enumerates a number of design principles determined to be crucial in designing technical tools for supporting work within a creative medium. He asks the question: “how can designers of programming interfaces, interactive tools, and rich social environments enable more people to be more creative more often?” (Shneiderman, 2007). The four design principles identified include: supporting exploratory search, supporting collaboration, supporting rich history keeping, and designing with low thresholds, high ceilings, and wide walls.

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The research of this dissertation designs tools for creativity support of the works created in exploration of this integrative research. The design methodology used has taken research on autobiographical design methods as a baseline. Autobiographical design is a method of design research through self-usage practices (Neustaedter and Sengers, 2012). As a research method, autobiographical design supports research that follows a certain heuristic of practice-based requirements. The methods are particularly useful for research needs that require: fast tinkering, development of real applied systems, designed to meet genuine needs of the designer, leveraging long term usage of a system. Through the practice of autobiographical design certain pathways of knowledge are available including the development of experiential understanding, early innovation, revelation of ‘big effects’, and the non-generalizability of the designed system to other domains or designers.

3

Prototypes in Embodied Worldmaking

This story builds upon the explorations of my Master's degree research titled *Kodama: Reconnecting the Body to Nature through Immersive Performance and Technology*. I will briefly summarize the contributions of my Master's work to begin, and follow by describing the trajectories and intentions that led to a series of prototype works exploring the methods of embodied worldmaking and further developing the creative coding system, *seer*.

The embodied worldmaking process explores the transdisciplinary research space connecting embodiment, worldmaking, and creative technologies. Each work explores this space and prioritizes different combinations of focus navigating between body, world, and instrument. The holistic methods I have developed for connecting these fields, called embodied worldmaking, have emerged and become clarified from this process. I will explain these methods of embodiment practice,

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worldmaking practice, and transformation through interactive instruments in detail in chapter 4. It is also through this prototype process that the creative coding framework *seer* was designed and developed as a foundational tool for supporting the development of embodied worlds. The *seer* system will be described in chapter 5.

In Figure 3.1 I have drawn each of the important prototype works within the three dimensional transdisciplinary research space. The visualization is called a trigraph and represents how the focus of the work is balanced between each field. The position of each dot represents the design space of the work and which aspects took primary focus. Works close to the center of the graph focus on balancing each aspect of body, earth, and technological instrument, while works towards the periphery prioritize a deepening of development in one or two dimensions. The size of the dot represent an evaluation of how integrated and fluid the creative process unfolded in relationship to moving between the different roles involved in exploring the design space of the work. Larger dots represent works that I experienced more fluidity in the creative process, moving between my embodiment work, storytelling work, and my technical instrument design work. Smaller dots represent less fluidity and greater creative friction in the process. This friction is associated with experienced limitations and struggles working within the design space in relationship to the creative instruments and technologies in use. This

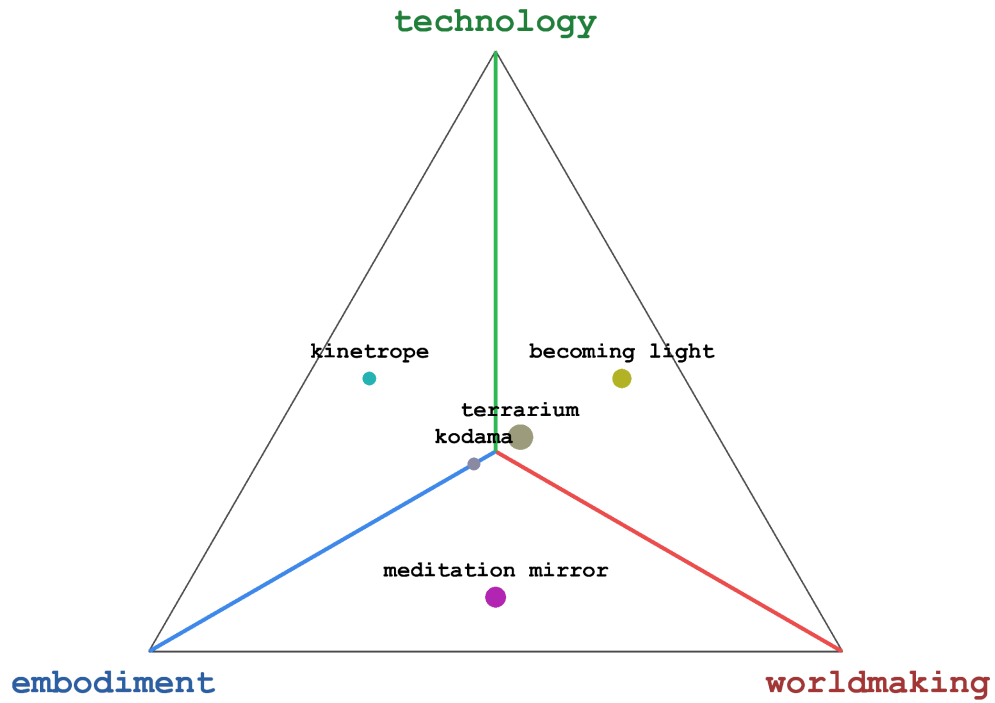


Figure 3.1: This map visualizes the primary focal point of prototype research works within the transdisciplinary research space connecting embodiment, world-making, and creative technologies. The position of each dot represents the design space of the work and which aspects took primary focus. The size of the dot represent an evaluation of how integrated and fluid the creative process unfolded in relationship to moving between the different roles involved in exploring the design space of the work.

map is intended to give an overview of the works and to help orient the reader as to the intended territory of each work as well as to how much perceived flow was experienced working with the tools throughout the process of developing each work.

3.1 Kodama: Prior Work

The culmination of my Master's research resulted in the development and performance of Kodama one of the first attempts at integrating elements from all dimensions of this research space in balance. This performance work includes an embodiment practice exploring evolutionary and developmental movement within a virtual world of trees, simulated chemical pattern formation, and live video feedback. The performance world unfolds in time to tell a story of human and non-human evolution, interdependence, and care. The work includes multiple dance performers, live poetry, and audience participation. The creative coding framework, *seer*, was developed in an initial form to support the development of Kodama, and provided methods for composing the virtual world's processes in space and time.

In 3.1 this performance work is shown as inhabiting the center of the trigraph, signifying an attempt to create a holistic experience where all elements of the



Figure 3.2: Kodama performance in the MAT transLAB, End of Year Show 2014.

research space integrate with and empower each other. Although, in my opinion, Kodama as a performance, successfully created an experience of integrating body, earth, and technology, it is my experience that I had to work incredibly hard as a designer to create this integrated experience as a performer.

The integration was a real struggle, I found myself drawn away from my body, the earth, the other performers, and the meaning of the work when working with developing the supporting technologies.

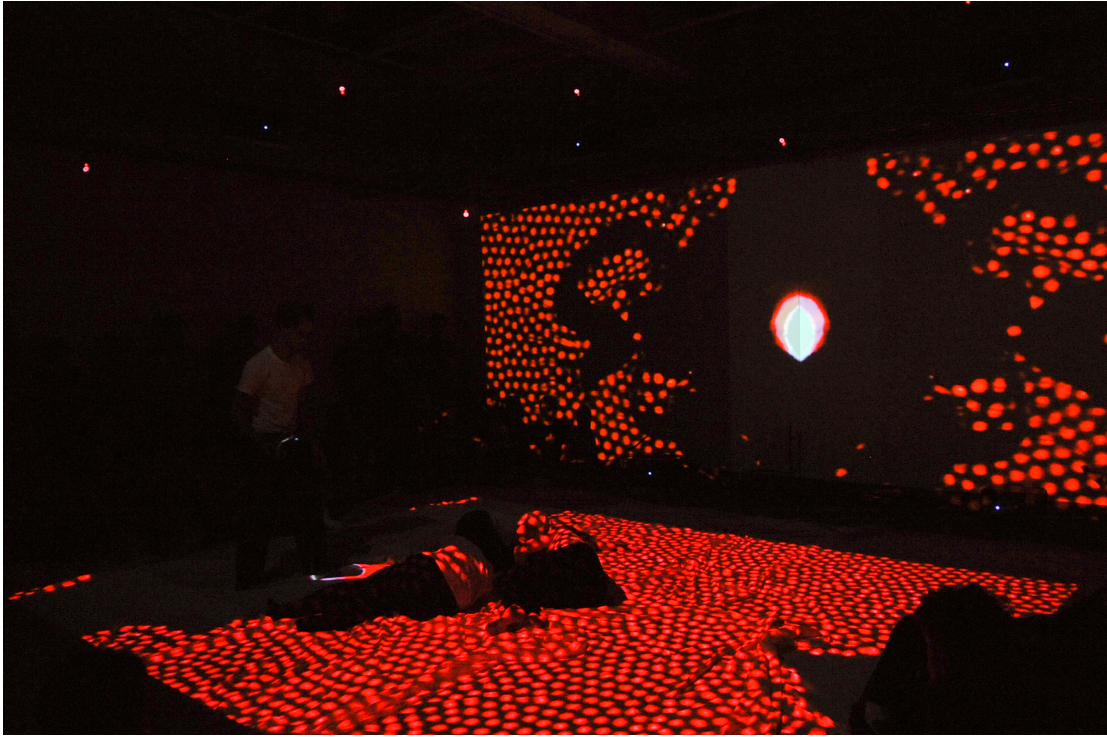


Figure 3.3: Kodama performance showing the interactive pattern formation instrument.

Although I had intended my system to empower the creative process of integrating these elements, it became clear that for my creative process to really flourish I needed to go further with the system in order to create space for greater ease in moving between roles. It wasn't enough to utilize the technology to create an integrated experience of body and earth during performance time. I discovered an underlying motivation to create the experience of this integration deeper throughout the whole design process. How can I create greater flow within my

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tools and workflows to support embodied interaction and expressive worldmaking during each phase of the process: ideation, designing, prototyping, exploring, interacting, composing, choreographing, and performing? My bodymind inhabits very different ways of thinking and working within these different creative spaces and stages, and by exploring ways of making this process more fluid and expressive I aim to integrate these aspects in my work as well as integrate these diverse creative selves within me. From this place, I saw the need to deepen my explorations within each primary research area and explore ways of developing my skills towards this integration within my practice and my tool set.

The experience of designing Kodama led me to pursue new directions and depth in my search including: richer full body motion tracking, making space for emergence and virtual agency, greater ecological interconnectedness within the virtual worlds, improving the design tools and composition methods to support my own embodied experience in transitioning between the roles of designer, programmer, and performer, as well as a deeper engagement in sharing embodiment practices as part of participatory performance.

This is a jumping off point for the exploration into the embodied worldmaking practice of this dissertation. My methods and the Seer system have evolved through the continued exploration and refinement of the practice of designing worlds for embodied performance. In the next section I describe the first proto-

type work of this dissertation *Kinetrope*, an exploration of movement and agency in relationship with virtual growing lifeforms.

3.2 Kinetrope: Full Body Interaction, Virtual Agency, and Embodied Artifact

Kinetrope was created in response to Kodama and was intended to deepen the possibilities of embodied interaction in relationship with virtual generative agency. This process started with the technical pursuits of finding a suitable method of full body motion tracking as well as the implementation of a growing virtual plant-like agent. The work was created in the context of a class exploring 3D fabrication and morphogenesis (the biological growth of form). Kinetrope explores and enables an interactive embodied design process to capture movement and create physical sculptures that are grown in collaboration with the virtual agent. The building blocks of this instrument were incorporated into the *seer* creative coding software, enabling this instrument to be used in the context of live performance and virtual worldmaking. Because the project was primarily an exploration of creating an embodied interaction instrument, you will see it located in the upper left portion of the trigraph in 3.1, however the project also includes many important directions in worldmaking that push it towards the center of the graph.

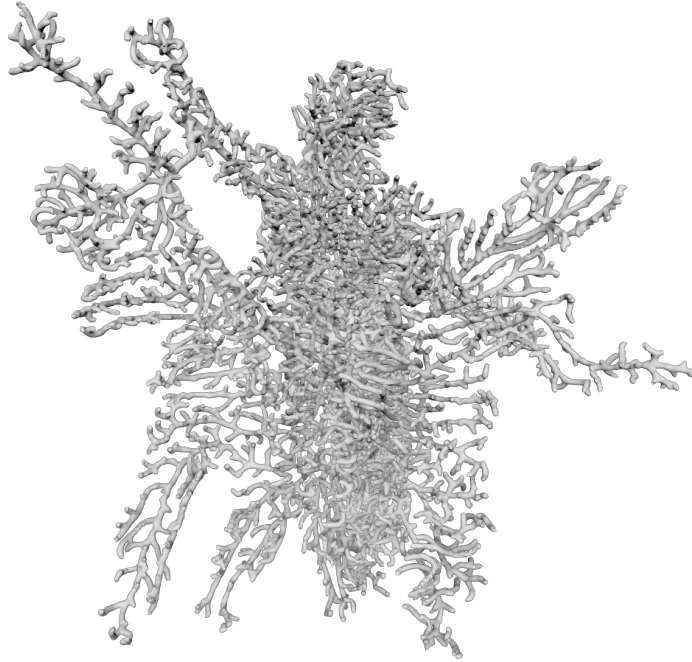


Figure 3.4: Rendering of a kinetrope form grown from an improvisational movement session.

Kinetrope is named after the greek *kinein* (movement) and *tropos* (turning), referring to a new type of tropism or force that a plant grows in conversation with. This force is a translation from the moving body into the virtual world of the kinetrope through the realtime capture of the body's surface as a point cloud. The interactive system that was developed utilizes a Kinect depth camera and skeleton tracking to enable greater full body interaction potential. Realtime point cloud data allows a body to engage directly and spatially with the virtual

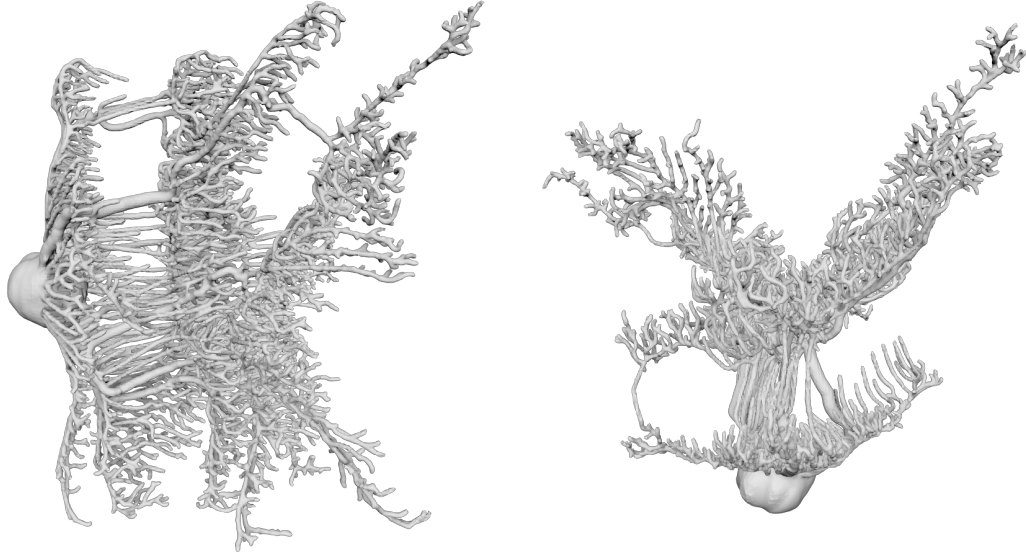


Figure 3.5: Alternate views of kinetrope rendering.

agent through 3D sampling of the body’s surface. The kinetrope seed awaits the presence of moving point cloud data and begins to grow and branch towards the virtual body within a specified threshold. This process is based on the algorithm described by Runions et al. (**Runions:2007wl**), however it uses the realtime point cloud data of the body as the set of attraction points to guide the agent’s growth in an interactive capacity.

3.2.1 Technical Implementation Details

The initial technical system relies on a single Kinect depth camera oriented towards empty space and a projector for realtime visualization. The exploration

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began with implementing the growth algorithm and visualization guided by and woven together with movement explorations with the system.

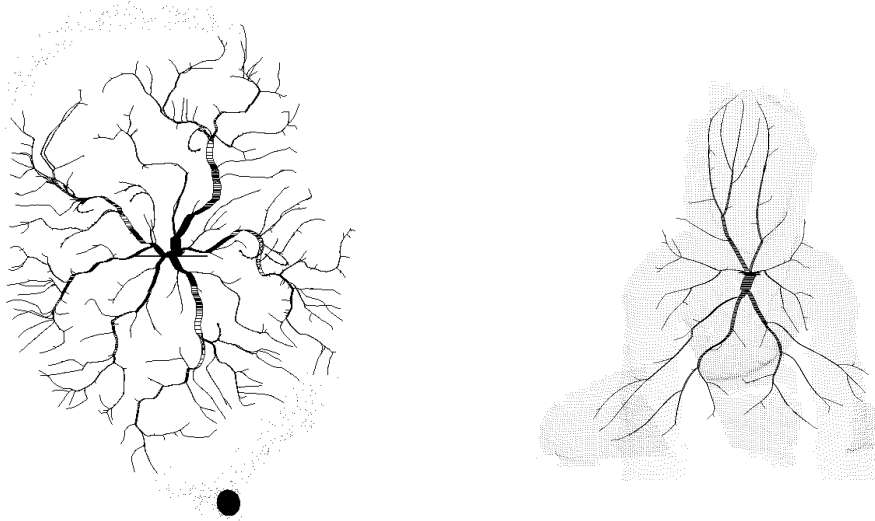


Figure 3.6: Initial implementation of growth algorithm, showing mouse interaction (left) and body interaction using a Kinect (right).

The growth algorithm was implemented within the *seer* framework and initially ran quite slow when given the Kinect point cloud data as input. It was necessary to improve the performance of the algorithm in order to achieve a real-time system to make interaction feasible. The algorithm is required to make distance calculation between each branch of the form and each active leaf in the input set creating an exponential complexity as the form grows. Typically, the leaves are removed from the input as branches grow close enough to them, however since this project is using a live point cloud stream as input, the set of leaves is

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always full of new data to grow towards every input frame. A number of methods were used to solve this issue. Firstly, culling the point cloud data is necessary. To reduce the number of points fed to the growth algorithm, I used the built in user segmentation of the OpenNI software library to separate depth data of the body from any background objects within the space. I also added a decimation method to further reduce the incoming point clouds by filtering out every Nth point from the data. Secondly, I implemented an octree spatial data structure to store branch data, reducing the number of comparisons necessary from $\mathcal{O}(n^2)$ to $\mathcal{O}(n \log n)$ time complexity. Lastly, it was necessary to make the growth simulation asynchronous and move it off the graphics thread to maintain responsiveness even for large growth structures. Example source code is included in the appendix ??.

The initial implementation required interaction via a laptop keyboard to initiate the growth process, to capture the resulting structure, and also to reset the system to a blank slate. This need to move between the computer and the movement space becomes tiresome and is a major limitation of this work and is explored in the next work. This friction can be reduced with a wireless device, or avoided when working with another person. The development process was primarily done alone so to reduce this context switch fatigue, I used a wireless keyboard when prototyping and capturing my movement explorations.

3.2.2 Embodied Movement Explorations

Moving with the system was explored both with visual feedback of the growing kinetrope and motion tracking data, as well as without any feedback at all. The choreography of this form developed directly from the process as an improvisational relationship. The process happens in real time giving the moving body a chance to witness the growth process and respond. The growth process was initially quite slow so the initial movement score used this timing limitation as a basis for exploration. The choreographic potential arises out of this dynamic relationship between physical body and virtual body, an interconnected exchange of motions and impulses. As the mover, I become a growing tree, and the tree grows through me.

My senses respond to the shapes I see and feel as I move. I enter into stillness, letting the growing roots fill my form. In stillness, I am still moving, feeling the growing form in my imagination and my body's energetic response to sustaining the shape I am in. I reach through my legs and arms, grounding into the earth and supporting the feeling of weight as a continuous curvature through me. I lengthen and bring space into my spine, changing subtly, a new presence, supported by the virtual process. The virtual shapes me through my imagination making it a reality.

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If you close your eyes, if you come alive, into the space inside, the sense of space inside your body, the feeling of bone, the feeling of blood, the fluidity and flexibility of organs. When you breathe and feel the sensations of your cells touching each other, moving, vibrating, in connection. What is it like to be alive? What is it like to be you, in your body, all of your cells working together, an orchestra experiencing wide arrays of musical sensation. What is it like to feel it, to see it, to hear it, to touch it, to move it – how does it move you forward, into your own living becoming. What calls you? This is an experience of you. This is an experience of self, of whatever selves arise and speak and are attended to. It is quite a unique attention to be able to give to oneself – to make space to explore what is inside. To return again and again to a witnessing eye, the present moment, and how it is unfolding, your choices of attention and becoming – following the path of consciousness. Listen. How do we grow? How do we grow in relationship? How do stay connected to the self in relationship with the other.

We interact with technology every day as it is. There is a segmentation, a split between our reality and the virtual realities we see on screens and in our devices. How do we become aware of this boundary. How do we become mindful of our own needs in interacting across this boundary. The economy of interaction cannot be balanced as long as part of our selves are not being addressed. We lose our body, or parts are neglected. I explore the possibility of full body interaction

across the boundaries between worlds. In relating to a Kinetrope, a channel is opened. Not only does my body's motion through space affect the growth of these plants, but a relationship is developed. I am moved by the growing tree. And it is moved by me.

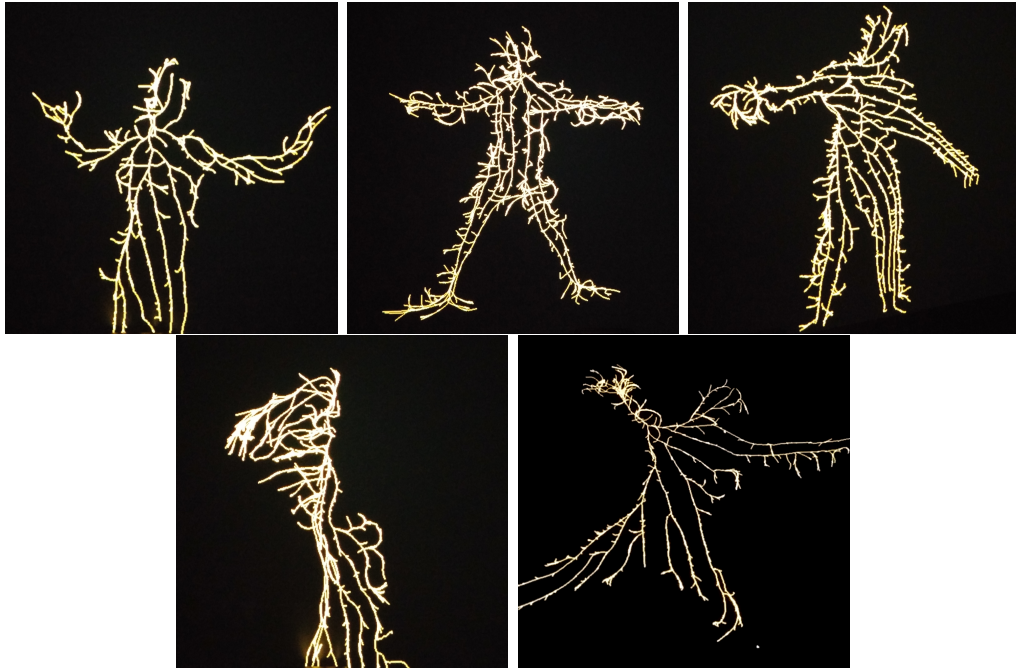


Figure 3.7: Interactive movement explorations with Kinetrope growth algorithm.

3.2.3 Fabrication Process and Embodied Artifacts

The fabrication process requires a translation from the the forgiving and simple 3D geometries of the virtual to the reality of the physical. Geometry must become continuous surfaces and solid form. Any discontinuity or overlapping areas will

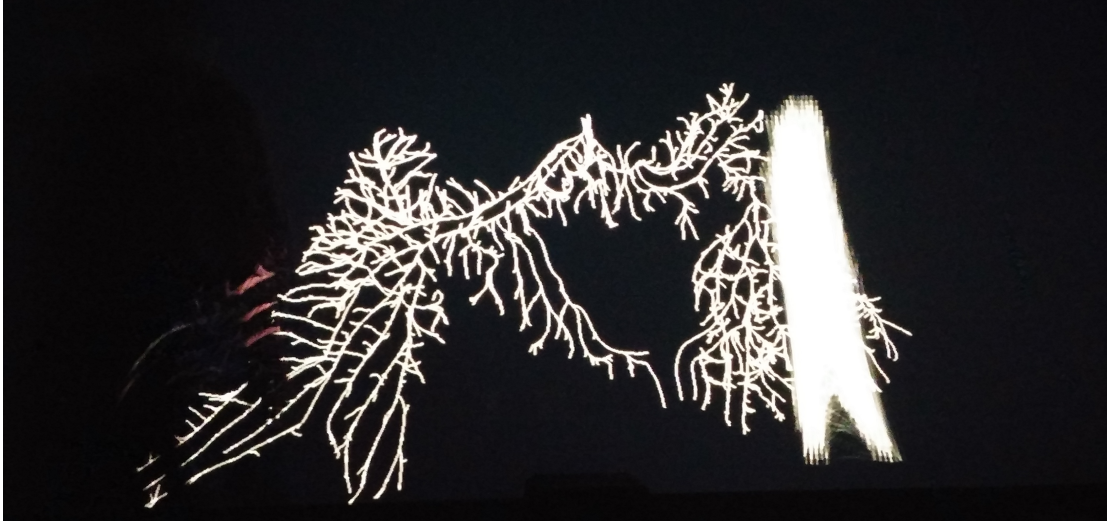


Figure 3.8: Interaction showing growth following movement across the space and the realtime visualization of the body's point cloud rendered as a fuzzy cloud of lines.

cause problems in the fabrication process. Because of this need, I developed a pipeline for processing exported point cloud data and generating 3D models ready for fabrication. To accomplish this I utilized the existing 3D mesh processing software MeshLab (Cignoni et al., 2008).

After a movement and growth session was captured, the generated digital representation of the branching form needed to be exported to a file as a point cloud. Translation from the simple digital form to a densely spaced point cloud required an additional generative step with its own set of configuration parameters. MeshLab provides various tools for reconstructing mesh surfaces from point cloud

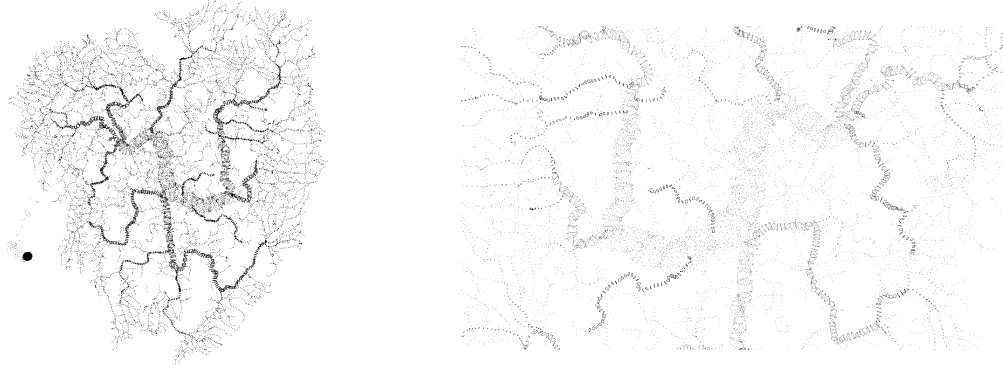


Figure 3.9: Forms are exported as point clouds, where branches are mapped to rings of oriented points with a diameter relative to the age of the branch, as seen in these screenshots.

data, however in order for these algorithms to generate adequate results point cloud data must be constructed that closely represents the desired surface. I found that evenly spaced oriented point clouds with normal data worked well. The export process iterates along each branch and generates rings of points with a radius that tapers based off the age or depth of the branch. Each exported point also includes a normal point away from the branch surface indicating the continuous surface to be generated.

Point cloud data was then imported into MeshLab and poisson surface reconstruction algorithms were used to generate 3D surfaces. It takes some time to configure the parameters of this reconstruction algorithm to generate a continuous

3. Prototypes in Embodied Worldmaking

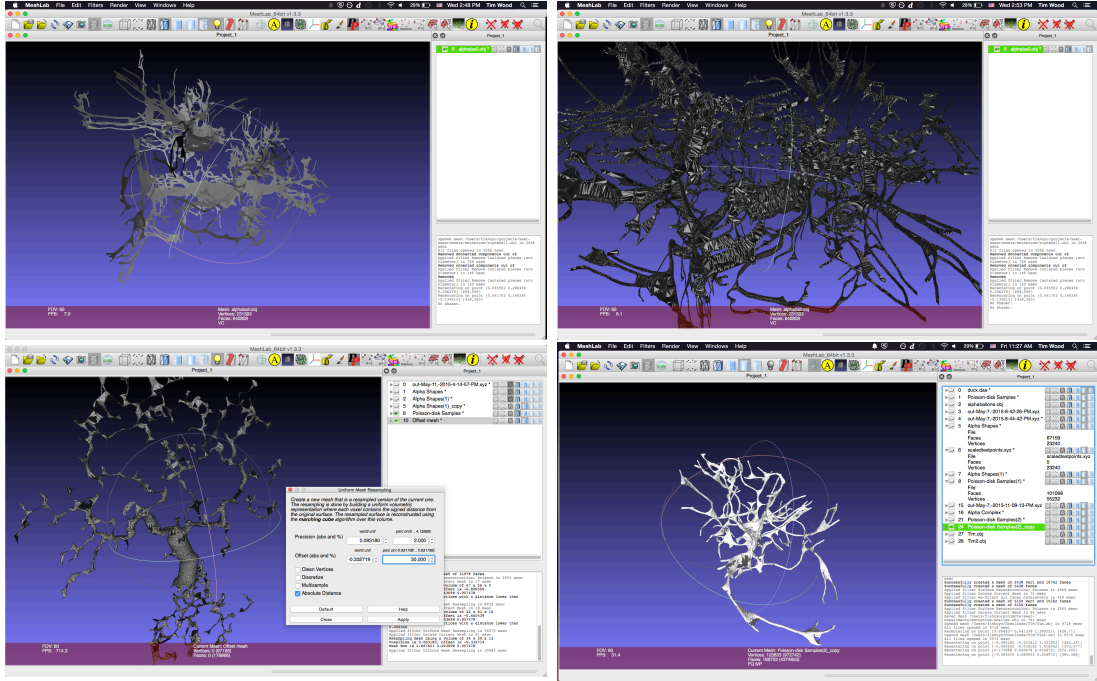


Figure 3.10: Point cloud data was processed in MeshLab using surface reconstruction tools and mesh cleaning tools to generate 3D models for fabrication.

form at a desirable resolution that is not segmented into pieces. Other processing techniques for utilized to clean up the resulting form, such as surface subdivision, surface offsetting, and mesh cleaning tools for removing self intersections and closing holes in the mesh. The resulting mesh was then imported into the MeshMixer application for a final cleaning pass and validation before printing.

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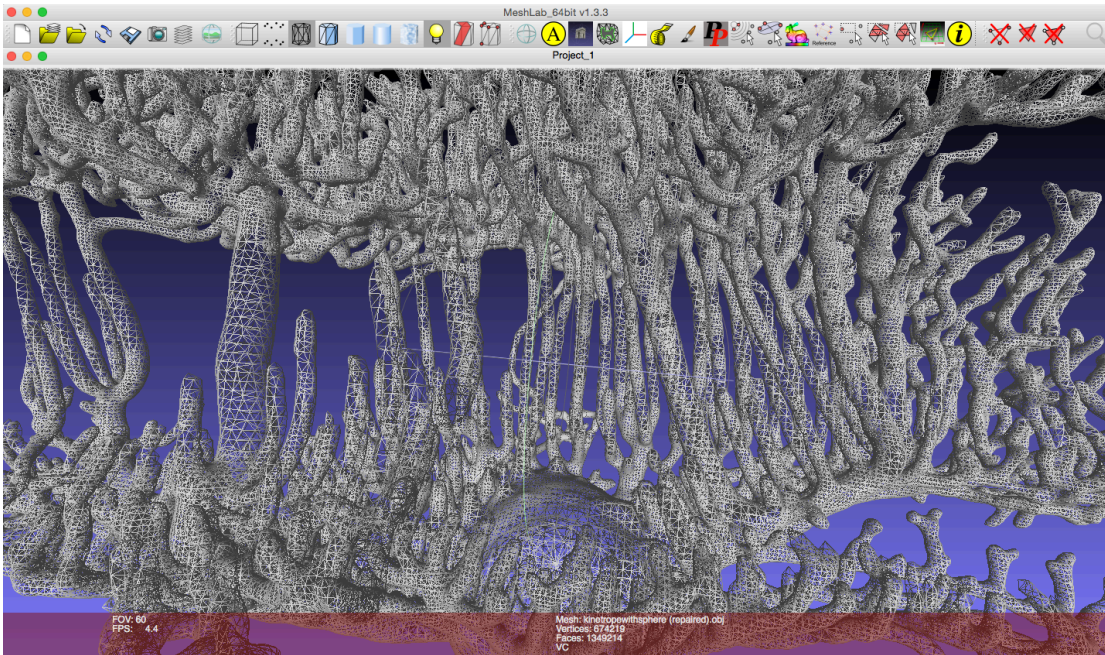


Figure 3.11: Close up of the mesh used for the final print.



Figure 3.12: 3D printed artifact of a kinetropo form fabricated after the interactive process.

3.3 Becoming Light: Worldmaking Composition Technologies



Figure 3.13: Performing *Becoming Light* in the MAT transLAB, here the performer's lean generates a virtual wind that blows the tall grasses behind him.

Becoming Light is the next work of this dissertation, which included the technical focal points of advancing the full body interactive instruments developed in *Kinetrope*, sharpening the expressive potential of the spatial and temporal composition tools of *seer*, and adding new worldmaking tools for visualizing point cloud avatars and interacting with particle simulations. The embodied interac-

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tion instrument of the previous work added new possibilities of movement based storytelling in these works, and required new ways of programming relationships between interaction events, virtual agents, and composition events, ultimately making it easier to move between roles in the development process.

Becoming Light is an embodied performance world and consists of an interactive virtual environment for improvisational movement performance. The scores developed for the piece involve embodying and inhabiting the communication between heart and lungs as a metaphor for the liminal space of transitions, the membrane between worlds, inner and outer, physical and virtual, life and death. As design research, the focus was on integrating new composition methods for worldmaking and so I have placed it in the upper right portion of the trigraph in figure 3.1.

3.3.1 Composition Interface and Gestural Events

Technically, the challenge was to create a new programming interface to enable rapid prototyping of interaction gestures and composition events, while making it easy to create mappings between gestures and events. To accomplish this, I turned to the expressive potential of reactive programming methods, which provide a way to create representations of reusable data streams (Maier, Rompf, and Odersky, 2010).



Figure 3.14: Performing *Becoming Light* in the MAT transLAB, here the performer’s movement navigates the virtual space and modulates parameters of the motion blur visualization effect.

In developing an interactive world as a performance composition, there is a need to handle different kinds of events including discrete one time events and continuous events, both as incoming data streams from interactive devices and as user created composition events over time. In this work, I initially implemented reactive data streams through the *scala.rx* library. This allowed wrapping incoming interaction data as reusable and composable event streams. This made it possible to more easily create gestural events based off of the composition and integration of layers of lower level tracking data.

3.3.2 Movement Sampler Expressive Instrument Design

The performance world was intended to reflect a sense of empowerment to the performer in interacting and navigating the performance with the whole body. These interactions encompass both dynamic improvisations with continuous simulation instruments as well as pre-composed gestures that are mapped to discrete composition events, making space for the improvisational movement impulse to progress the world.

As a method for rapid experimentation with and iterating on gestural interaction mappings, I built a sampling instrument for recording movement point cloud and skeleton tracking data. This sampler allowed me to record gestures in space as a sort of movement scaffolding with which I could design gestural mappings to create the intended qualities for that movement. I could then test the mapping with my body and record new samples to continue to refine the interaction.

This piece included gestural events for navigating the performance world, through spatial and body shape triggers. Using the composable data streams to detect simple gestures of relative joint positions in space, new events were generated when certain choreographed shapes were performed in specific regions of the performance space. These embodied portals provided a mechanism for navigating the performance space, and creating an embodied agency in choosing the path and timing of the performance.

3.3.3 Designing the Worlds

Poetically, the performance world speaks to a space of transitions and a space of dreams, on the edge and in between. How do we navigate these transitions, where is the agency within us, and where in our bodymind must we allow movement to position our perception? This is a place that moves between states of consciousness, between ways of knowing, and between worlds; dreams and deaths, selves and others, seeing beyond the boundaries, and perhaps finding a power of inhabiting multiple worlds at once and connecting them.

Inspired by the practice of Authentic Movement and the realms of subtle movements between the conscious bodymind and the unconscious bodymind, this piece navigates a space of dreams. It was my intention to create a very high contrast environment focusing on darkness and light and a process of orienting oneself on and within boundaries. The embodied movement language of this piece focused on the lungs and the breath as a transitory space between internal and external, conscious and unconscious. Our lungs hold this intense fractal contact with the air we breath, allowing oxygen and carbon dioxide to diffuse directly into and out of our blood through the many balloon like alveoli air sacs within the lungs.



Figure 3.15: Performing *Becoming Light* in the MAT transLAB, here the performer's movement through space navigates the 3D virtual environment.



Figure 3.16: Particle system based visualization of the movement looper instrument.

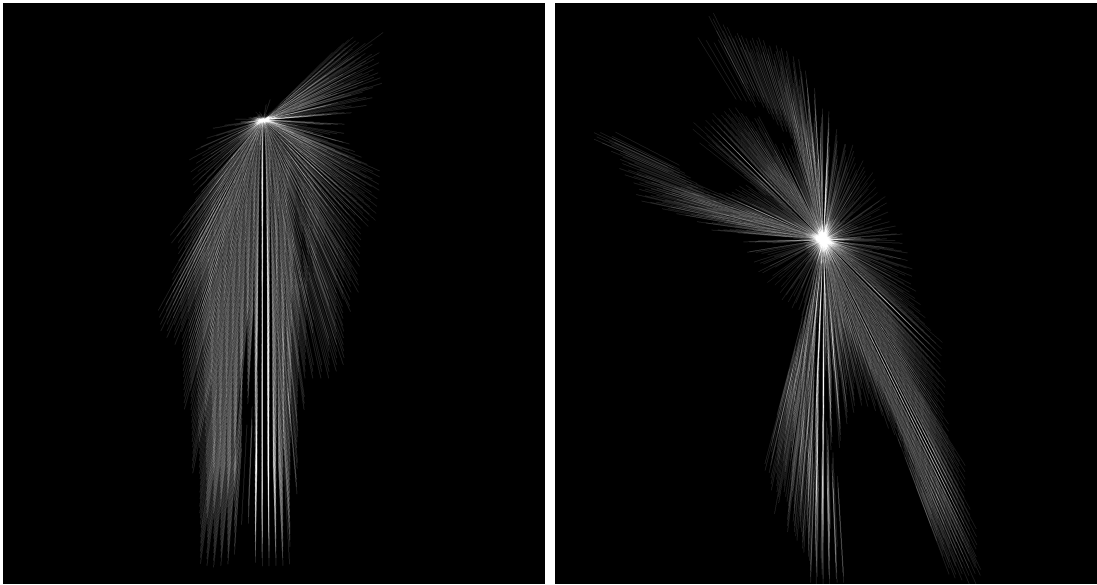


Figure 3.17: Line based visualization of the performer's depth tracking point cloud, using different detected skeletal tracking locations for focal points of visualization.

3.4 Meditation Mirror: Guiding Embodied Experiences

Meditation Mirror is a participatory performance environment and virtual world which explores offering guided embodiment visualization as a key component of the performance. This exploration is a continuation of similar processes and instruments as developed in previous works, however this work shares a hybrid virtual reality performance environment which offers an asymmetric experience with one participant immersed through a head mounted display and the rest of the audience experiencing the immersive projection environment and the bodies in the space. The work aims to use a reflective visualization of the immersant to help facilitate and guide attention within the body. The primary focus of this work was integrating more direct usage of guided embodiment methods in relationship with a participating audience immersed in the performance world, as such I have placed it in the bottom segment of the trigraph in figure 3.1.

3.4.1 Designing the World

Meditation Mirror began with the inspiration to share an embodiment meditation where the attention is guided within the body focused on growing a vertical connectivity of the energy centers of the body, or *chakras*, as described in Vedic

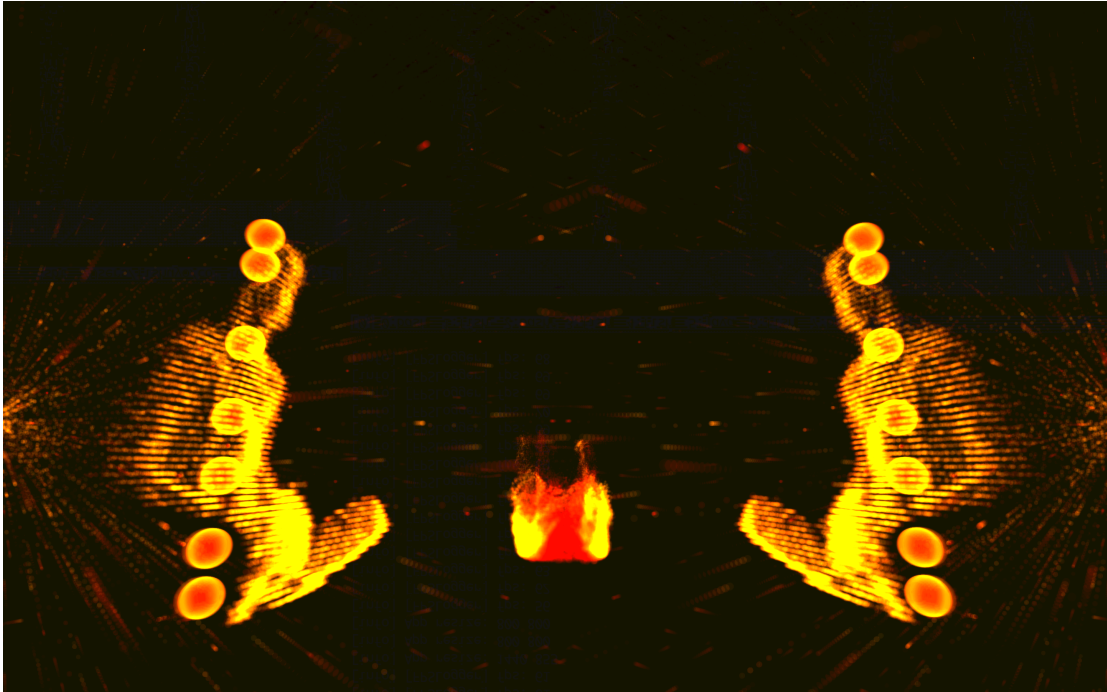


Figure 3.18: Screenshot from projected imagery of reflected meditation visualization.

philosophy. This practice is also associated with the notion of *hara*, or energetic intentionality, as seen in Barbara Brennan's energetic healing method (Brennan, 2011). The idea was to create a virtual reality experience and visualization of the body, and to guide a meditation on this process in combination with the virtual visualization of the vertical alignment.

To begin, I implemented a method for visualizing the body within virtual reality. Through aligning the depth camera tracking system with the coordinate system of the virtual reality space, I was able to place the point cloud of the

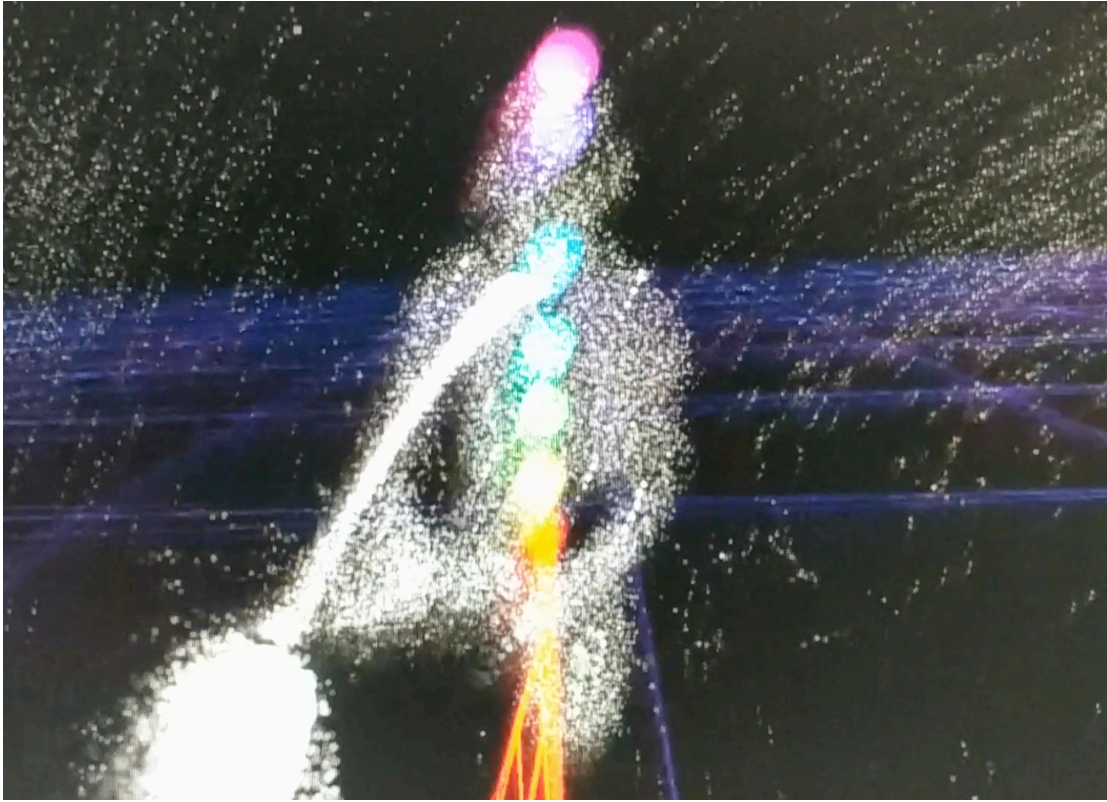


Figure 3.19: Screenshot from view inside the headset where the immersant sees their own point cloud silhouette and interacts with a gravitational particle system.

detected body on top of the physical body so that as one looks down within the VR headset they see their own body as points. This a unique type of avatar that is a sampled version of the real body, giving it a quality and living breathing surface that helps ground the VR immersant in their body.

This point cloud representation of the body is then reflected in front of the immersant creating a virtual mirror and approximate locations for the energy centers of the body are positioned within the point cloud. The immersive experience

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uses particle systems to represent energy flow and the immersant can direct and guide these flowing particles with their hands. My experience of virtual reality within head mounted display has always included an awkward missing presence of my own body in the visual field. This exploration really explores how this point cloud based avatar can be used to ground presence in the body and direct immersants towards exploring their own movement. When seeing their reflection in front of themselves, immersants tended to test the system and orient themselves through moving their body from feedback of the mirrored avatar. After guiding immersants to look down at their own body, they often responded with movement that took on a more self-reflexive quality.

3.4.2 Movement Meditation Score

The score was guided through the virtual world and through my own voice during the performance. The world was composed to progress through different stages, which began with an introductory phase, followed by a growing roots, and then a growing vertical alignment through each chakra. As the world progressed, I guided the audiences attention through a visualization of tree roots growing from their own feet, and then through colors and systems of the body at each stage of the alignment process. The virtual world reflected this process through visualizing virtual roots growth and a virtual tree growing vertically on top of the mirrored

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visualization of the body. As time progressed, particles flowed around different energy centers of the body, where each one was sequentially accented in color and attraction of particles.

A number of participants were captivated by the process of being inside the headset and the experience of witnessing from the room. I remember a comment from participants that reflected how they typically had trouble participating in meditations, but really found this performance experience helpful in allowing them to participate in the meditation and visualization. Participants within the VR headset had a entirely different experience where the meditation was more of a background experience as they inhabited the world and interacted with the particle system.

3.5 Terrarium: Embodied Interaction Ecologies

The final work of this dissertation, Terrarium, is an interactive room scale ecology of movement, virtual plants, and bacteria. The work was an installation designed for the immersive media theater at the MOXI museum of exploration and innovation in Santa Barbara. This work was a durational installation that included a performative element, but was primarily experienced as an interactive installation. Four projectors cover three walls with a three dimensional virtual

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Figure 3.20: Terrarium installation immersive environment at the MOXI children's museum.

landscape, where trees and bacteria inhabit a shifting geography. Room scale tracking was built within the space using multiple depth cameras and custom calibration and alignment software.

As viewers enter the space, their silhouettes are reflected across each wall and their motion creates traces of chemical agents in the fluid atmosphere of the world. Movement effects the fluid through redirecting its flow and through creating

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carbon and nitrogen chemical agents that are consumed by the plant and bacteria life forms. The project aims to reflect the dynamic power of interconnection between our bodies and the ecologies around us; everything is always giving and receiving energy and information, and the quality of attention we give to ourselves we also give to the world around us.

3.5.1 Immersive System Design and Worldmaking

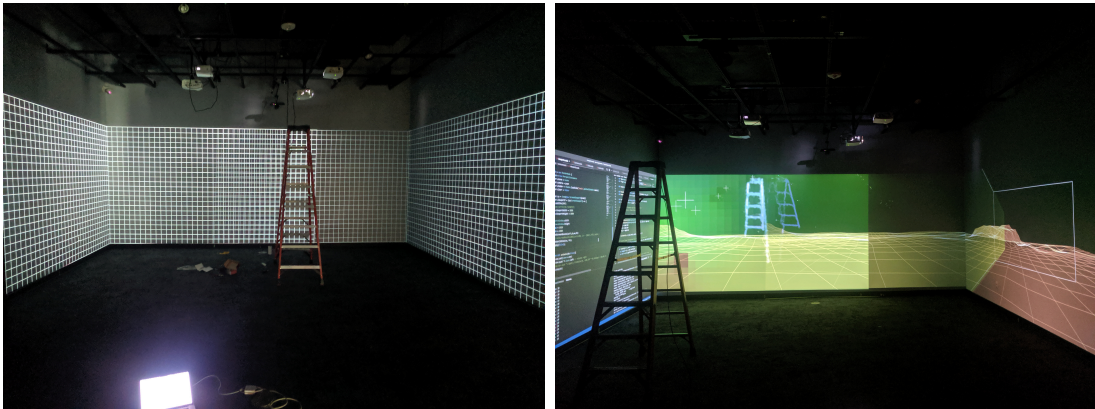


Figure 3.21: Calibration of projectors and iterative development of the installation environment.

Although I had designed the software system before hand because of limited time for installing the work in the theater, a lot of design had to be quickly modified within the space to meet the reality of the space. The system utilized four projectors aligned to cover three walls of the room. My intention was to create a immersive 3D experience where the wall opened into the virtual land-

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scape. Calibrating and aligning the projectors relied on a combination of physical manipulation as well as software viewport calibrations.

The tracking system consisted of three Kinect depth cameras oriented to cover the entire space of the projection area. These cameras were calibrated through a custom iterative alignment algorithm that used user feedback as a means to minimize calibration error. The tracking system allowed multiple point clouds to be integrated, so that groups of users could interact with the ecosystem. Point cloud data and skeleton tracking data was streamed from a distributed tracking cluster to the main simulation machines which handled the simulation and rendering of the virtual world. A separate machine was just for rendering audio.

3.5.2 Embodied Interaction Design

The interaction design aimed to reflect how different qualities of relationship emerge when we are active and when we are still and how our movement qualities can resonate with different parts of the ecosystem. To accomplish this I detected the two simplest qualities to begin movements and stillness. All of the interaction with this piece happens through movement and through the atmospheric field of Terrarium. The atmosphere is made up of a vector field fluid simulation and scalar fields representing three chemical nutrients: carbon (red), oxygen (green), and nitrogen (blue).

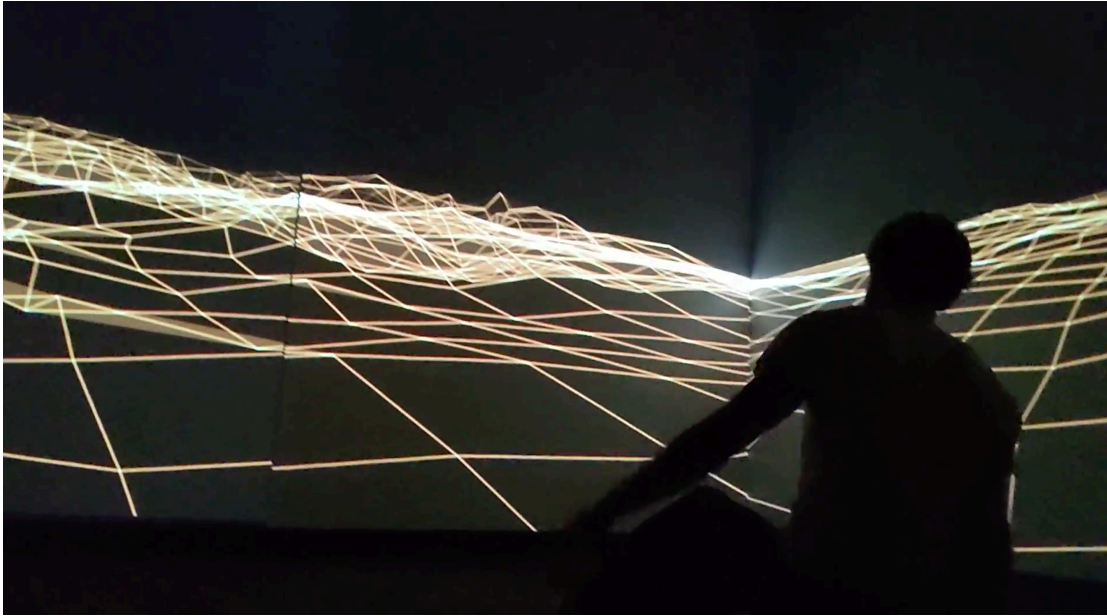


Figure 3.22

Rays are cast from the body's physical location in the room through the atmosphere of the 3D environment. The surface of the atmosphere represented by the walls of the room contain a chemical fluid simulation of the three elements. Movement velocities through space change the vector field of this atmosphere and move creatures, particles, and chemicals through this force field. In addition, dynamic movements add carbon into the atmosphere where the movement occurs. The more dynamic and the more sustained the movements are the more and more carbon is deposited in the atmosphere. In the absence of movement, but the presence of the physical body, nitrogen is slowly emitted from the body's location.

The longer the body remains still the more dramatic the amount of nitrogen is deposited. Oxygen is removed from the atmosphere wherever the body is present.

3.5.3 Virtual Ecosystem

Each nutrient of the atmosphere connects the various processes of the ecosystem. The virtual trees soak up carbon from the atmosphere and transform it into oxygen. The more carbon the trees have absorbed the larger they grow and begin to flower and generate new seeds for new trees. Bacteria also roam the atmosphere and move towards high concentrations of nitrogen, which they consume and chirp. On its own, the system stabilizes to a neutral atmosphere with minimal tree growth and roaming bacteria. As participants interact dynamically, the atmosphere drastically changes colors in mixes of carbon and oxygen, and slowly larger trees begin to grow and the forest becomes more dense. As participants slow down, blue patches of nitrogen emerge and bacteria agents swarm the body's silhouette creating a cacophony of chirping sounds.

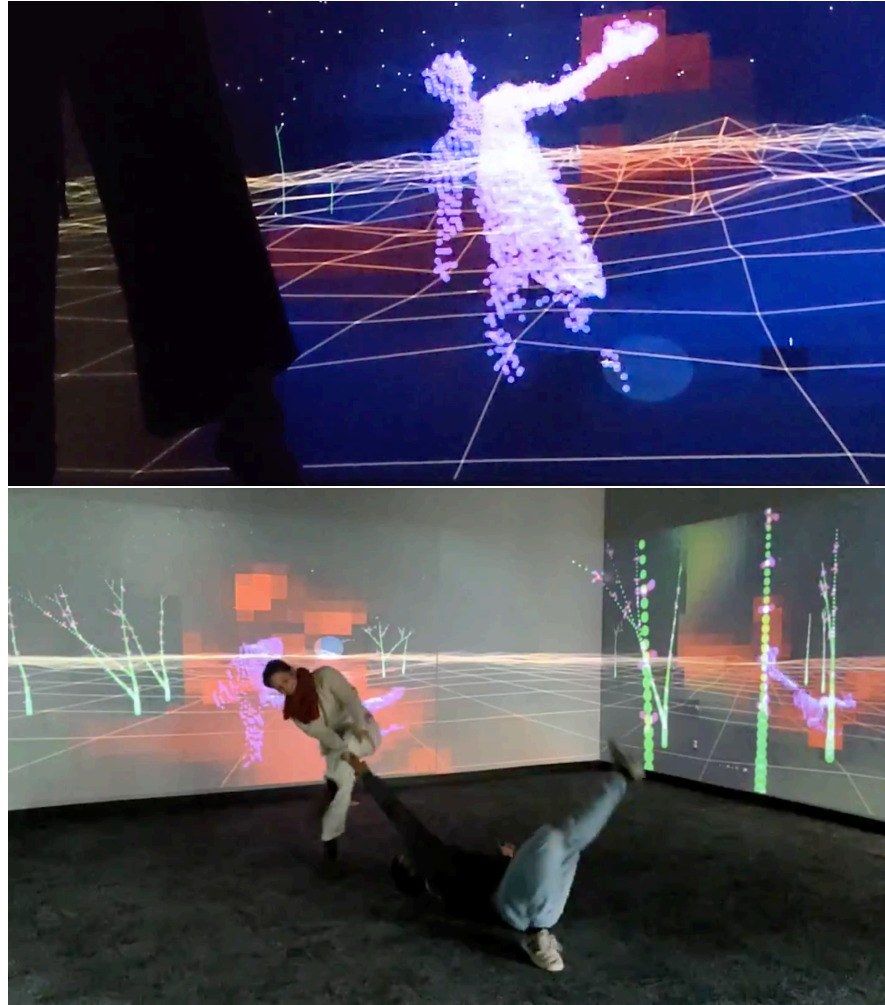


Figure 3.23

4

Embodied Worldmaking Process and Methodologies

In this chapter I will reflect on and describe the methodologies used throughout the processes of this practice based research. I describe these methods in the framework of the embodied worldmaking process, a term I will use to denote the novel contribution of this particular integrative ecology of creative practices. The embodied worldmaking process is a multi-layered creative practice that includes methods integrating embodied movement, ecological listening, and performative virtual worldmaking. I will start by outlining some grounding principles that are key to describing the integrative nature of embodied worldmaking, as well as the novel metaphors used for integrating the combination of practices as a creative ecology that maintains a focus and intention towards balance in prioritizing body and Earth. I will then describe the specific methods and considerations within each phase of the process. It is in this chapter that I have assimilated and generalized

the research and experiences of the previously described works, and it is here where answers to the first two questions of the research will be discussed.

4.1 Key Principles of Integration

As can be seen through the example works discussed in Chapter 3, there is a process of navigation required in the context of transdisciplinary creative making practices to decide where one's focus lies and through which creative pathways and mediums a work is explored. In the case of the works through which I developed this process, it is my experience that having guiding metaphors was especially important in regards to maintaining a balanced creative equity between the different methods of search necessary in creating embodied worlds, such as transitioning between roles of programmer, designer, and performer. These metaphors are a sort of meta-method, or a process of organizing my own process and directing my focus to orient myself within the creative process.

The embodied worldmaking process integrates existing methods of diverse creative practice, design, and embodiment including Halprin's *RSVP cycles*, Höök's *Somaesthetic appreciation design*, Hsueh et al's taxonomy of kinaesthetic creativity, Cohen's *Body-Mind Centering*, Olsen's *Body and Earth*, and Bachelard's *Poetics of Space*. These methods guide a multi-layered making process of designing

experiences, instruments, and performances from the ground of body and Earth. In the practice of weaving these methods together, a novel guiding metaphor pointing to a number of integrative practices has emerged that I call *becoming-tree*.

4.1.1 Integrating Metaphor: Becoming-Tree

As a metaphor, becoming-tree reflects an ecology of metaphors, relationships, and processes within the body and the world. To become tree is to feel the potential of seed, to feel the belonging within earth, to feel gravity, the emergence of roots, nourishment, support, and growth. This living ecology of metaphors serves as a guiding framework for staying connected to and sustaining one's internal creative power. The primary principles that becoming-tree points to includes: slowing down and presence, attention and senses, intention and direction, as well as agency in relationship with needs. The metaphor of tree as a whole points to the nature of a verticality of support, where the process of growth depends on a foundation from below. Becoming-tree calls for a cyclical process of returning to ground, a score for focusing back to a re-growing of the primary principles of becoming-tree to support the creative process unfolding.

Principles of Becoming-Tree

The first duet of principles that becoming-tree points to is slowing down and presence. To slow down is to consciously choose to do less and to bring more attention to the qualities of what you are doing, making space to come into presence. Presence is a quality of emergence and sensitivity that arises in inhabiting the here and the now. As human beings, our bodies are our fundamental connection to the world, existence, and being alive. We are always in relationship through our bodies, however we are not always attending to them. Thinking and doing is typically in relationship with our ideas and memories of the past and the future. Slowing down into the presence of being reconnects us to the ground of our existence in the body which is the root of all our abilities to sense, to feel, to think, to imagine, and to act.

From presence grows the second principle of becoming-tree, our attention and senses. Being present brings us into relationship with the lived-experiential qualities of what is happening here and now. This information is received through the senses, which tell us both what is happening within our bodies, through interoceptors, and what is happening within our environment, through exteroceptors. Our ability to focus and move our attention determines what sensory information we experience and how we experience it. An example of where one might start is to consciously move one's attention throughout their whole body, experiencing

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any sensations within the body and noticing what is present. This is called a body scan, and is often a part of mindful meditation practices. This is a good way to get a more in depth sense of what you are experiencing throughout your entire body. One might also bring their attention to the space around them, noticing the qualities and textures of sounds, light, space, and other bodies noticing any tendency to analyze, think, or judge the environment and choosing to focus on experiencing them as they are as qualities. In this process we are naturally drawn towards and away different sensory qualities, and noticing attraction, repulsion, pleasure, and pain are important guiding messages of one's ability to navigate attention and intention.

Returning to Ground: Cyclical Score of Valuation

Stand under the oak tree, the old oak tree. It is its own world, its canopy reaches and twists in a gnarly path creating a full dome, covering sky to ground. One can only imagine the dome of roots spread out beneath, combined with this reflection the oak spreads its reach at home in a sphere.

How does one even begin to speak, to tell a story about what it is like to be here with the old oak tree? Or to be this old oak tree? The crunches of leaves and acorns, the atmosphere of moths, the hidden bark spiders, the patches of sky between twisted arms, the peace in feeling held in its presence of spherical home.

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To spend time here, one may consider what it is like to grow their relationship with this tree. To come to know the ins and outs of the smells, the light, the qualities sensed outside and the qualities reflected inside. It is as if it speaks to me through my own thoughts and memories, the way I am transported and drawn to particular pathways of my mind and body. Drawn to touch the bark, I am called to a dinner with my family, traveling through time in which a feeling came deep in my stomach, which I feel again now, now connected to a spider's gaze, being seen and I can't back away. In its eyes I claim my feeling of purpose with a new perspective and truth. It is as if in this moment, the spider speaks to me directly and teaches me a new quality to choose in relationship with this place I inhabit within my past, present, and future. Myself, the spider, the oak, the earth and sky – we are reflected in and between each other and in our presence together create each other as worlds growing.

What is this process of being, seeing, and becoming-with? What is this process of interconnection and resonance, where each delicate move leads me right where I need to be to encounter my world growing?

4.2 Embodied Worldmaking Process

Embodied worldmaking is a multi-layered process of exploration and integration, which begins where you are and engages first with the body and the land. This process builds upon the ideas of RSVP cycles and I will especially use the terms of *resources* and *scores* to help disseminate my methodologies. The process has a number of phases through which resources, scores, poetry, systems, instruments, and worlds emerge, are explored, experienced, and performed. The integrative layering practices provide ways of mapping resources and scores between paradigms and stages of the worldmaking process. For example, an embodied experience out in the field generating internal imagery and movement scores can be returned to in the context of exploring interaction with a digital system, instrument, or world. The intention behind this is to create doorways of resonance bridging direct experiences of the natural world with poetic virtual spaces and immersive mimetic representations.

In this section, I will describe the six interconnected phases of this creative process: ideation and inspiration, virtual sketching and biomimicry, embodied instrument design, bridging worlds, performance composition, and performance. I will explain the specific methods, resources, and scores explored within each phase.

4.2.1 Phase 1: Ideation and Inspiration

The first phase is where the seed and soil of the work to come is encountered and experienced directly in the body in relationship with the natural world. Embodied experiences of moving with the land are the foundation, the roots, and the grounding practice of Embodied Worldmaking. Through making myself available to the flow of information between my body and the natural environment I encounter and I choose to listen to small but powerful events and relationships unfolding in the ecology I am immersed within. These events form stories through their interactions with synchronous events and their resonances with my body's movement and memories. I participate in their meaning as images, emotions, and visceral experiential qualities come forward in response.

The methods I use in this process are captured in a duet of scores I call, meeting place and poetic mapping. I will describe these scores here, as well as the resources the scores produce. I will then illustrate this process with a trace captured through a piece of phenomenological writing created from practicing meeting place and poetic mapping.

Meeting Place

Meeting Place is a score for practicing a form of embodied ecological listening, where space is made for internal sensation and external sensations to support one

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another in finding expression and restorative resonance. This practice is inspired both by Whithouse's *Authentic Movement* as well as Olsen's *Body and Earth* practices. Through experiencing the world and our bodies as interconnected phenomena, and focusing our attention of our experiences of the natural world to be reflections of qualities within our own bodies, much can be discovered in the resonating teachings that surround us, enfold us, and move us. Meeting Place, like *Authentic Movement*, is a practice of moving and witnessing. Here there is a dynamic exchange of mover and witness as the body navigates the draw of fascination with the land. As a form of wandering, the practice follows the authentic impulse to move through a landscape, to allow the landscape to hold a container to move within, as well as to strengthen ones ability to witness both the landscape and the self. As the body meets the land, encounters with animals, plants, and elemental forces are experienced through the resonating qualities that connect them to our own bodies. As in Olsen's *Body and Earth*, natural processes and elements can be experienced through how they resonate with the internal processes and systems of the body, and our external senses of these natural processes can direct our attention inward to specific body systems and movements that are called to come forward.

Poetic Mapping

Poetic Mapping is the process of tracking and making traces of the ephemeral qualities, images, sensations, movements, stories, and experiences that emerge in Meeting Place. The experiences themselves are valuable resources that stay with us, however it is necessary to create traces of these experiences as tangible expressions to take a step towards multi-modal expression and worldmaking. Mapping also grounds the experience into spatiotemporal relationships with other experiences, locations, memories, land, and creatures. The poetic map records pathways and traces of resonance from real embodied experiences to emergent and interconnected dreaming. These traces can take the form of poetry, phenomenological writings, embodied drawings, representational drawings, or field recordings.

As this score is practiced, there is a growing of the inner witness. A place of being able to see oneself within an experience without disrupting the experience. This isn't always possible, but this witness plays a large role in tracking and connecting important experiences while within *Meeting Place*. From this place of self witnessing, I sometimes find myself able to compose poetic lines of connecting imagery between experiences. These lines along with the pathways traveled through the environment become key resources in constructing traces for the practice of *Poetic Mapping*.

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I have included an example of a phenomenological writing tracing an experience with Grey Heron below. This example would be a node within a larger map of experiences within the spatiotemporal landscape of the Meeting Place practice.

I stand and watch the heron walk, there is such a patience in her steps. An intense grounded patience and presence. The quality of her movement is captivating and intelligent. I follow in her lead mimicking her quality in my own shift of weight, and noticing my whole body change. My presence drops into the earth and the texture of the earth under my foot. In this quality and in bringing it into my own body, I feel closer. I feel an intimate sense of kinship and respect. To move with such presence requires great skill and dedication, and in seeing this I encounter not just a bird to admire as other, but a teacher a curiosity a spirit and a becoming-with in myself. I am drawn to the long history of becoming that this movement has become-with and from. It is to be respected deeply, the intelligence in the life we are together. I imagine grey wispy feathers growing down my back and along the back edge of my arms, my skin vibrates and tingles with this image. I feel a sense of contentment, ease, and power in standing still with weighted legs and wispy feathering arms. A new sense of patience grows within me and a feeling of power in staying in one place as a choice – a dynamic stillness.

4.2.2 Phase 2: Virtual Sketching and Biomimicry

In the second phase of Embodied Worldmaking, the grounding resource of the poetic map guides the creation of virtual biomimetic sketches. Through the practice of improvisational live-coding and creative coding methods developed through *Seer*, I aim to create digital sketches that resonate with qualities from the poetic map. The poetic map represents both the ground from which the body enters and the world as communicated through dream-like imagery. This phase is a jump upward towards the otherness of dream and searches in how to create virtual processes as reflections of both the nature that inspired the vision and also the qualities and imagery that has emerged from embodied experience.

It is my experience that in working with the computational medium and its idiosyncrasies I find the balance of presence in my body shifted and drawn off center and upward. It is as if my energy relocates to and holds itself in a brain centered orientation of agency. This is a default pattern that emerges for me in the process of programming and designing on the computer, and it is here that *becoming-tree* and the *Return to Ground* score become important tools to redirect my attention, and to continuously choose balance in relationship with computational tools and immersive systems.

Figure 4.1 shows a small selection of example biomimetic sketches.

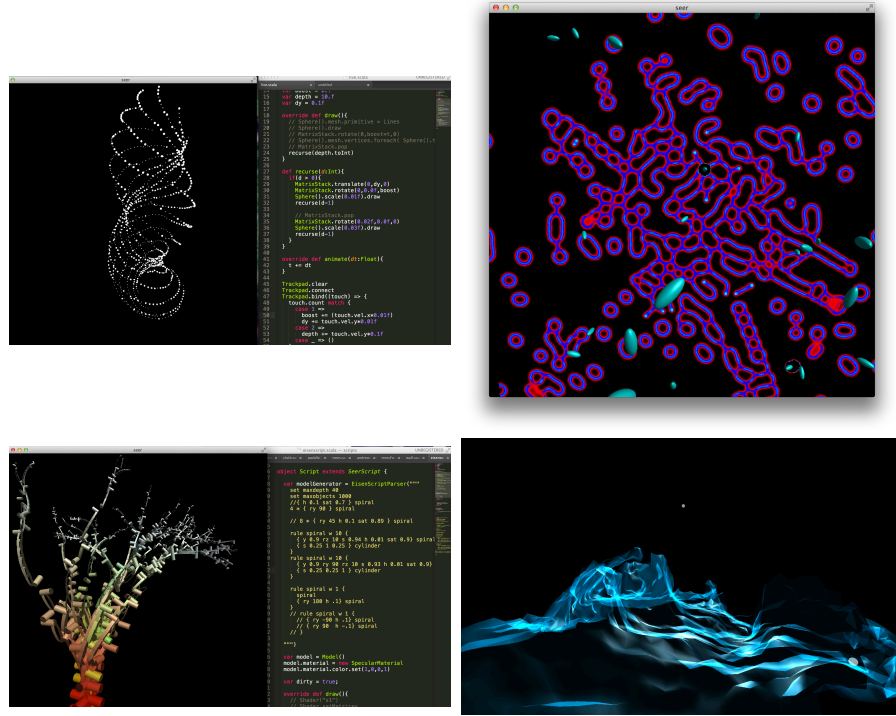


Figure 4.1: Examples of biomimetic sketches.

4.2.3 Phase 3: Embodied Instrument Design

In the third phase, I work to extend the virtual sketches into the physical world through interactive devices that communicate with the body. The goal is to build the possibility of bridging movement and embodied experiences with computational instruments that embody qualities of poetic resonances from the poetic map. This is achieved through iterative mapping design and rapid-prototyping methods from sensing systems to the virtual sketches. In the works of this dissertation I primarily used the Kinect depth camera for whole-body motion tracking. I also

use handheld devices, joysticks, trackpads, and other types of motion tracking devices in exploring embodied instrument design. This phase consists of identifying and exposing key simulation parameters, making space to engage with the body through motion tracking systems and device data streams, sampling interactive data streams, iterative mapping explorations, along with movement explorations that transition from reactive engagement to self-reflexive engagement.

Identifying and exposing key simulation parameters of a sketch is the first step to making it into an instrument. Simulation parameters determine the behavior and expressed qualities of a biomimetic system and when modulated can generate a wide range of outputs. Depending on the type of simulation, parameters can be as simple as individual floating point numbers, or more complex like images, entire point clouds, or multi-dimensional arrays of data.

Simple floating point numbers can easily be mapped to graphical user interfaces as a first step of parameter exploration, while more complicated parameters requires specific mappings from compatible data streams or devices such as camera systems, or spatial tracking systems. Parameters can represent mathematical aspects of the simulation, spatiotemporal behavior, or audiovisual representation.

Figure 4.2 shows a small selection of embodied interaction mappings.

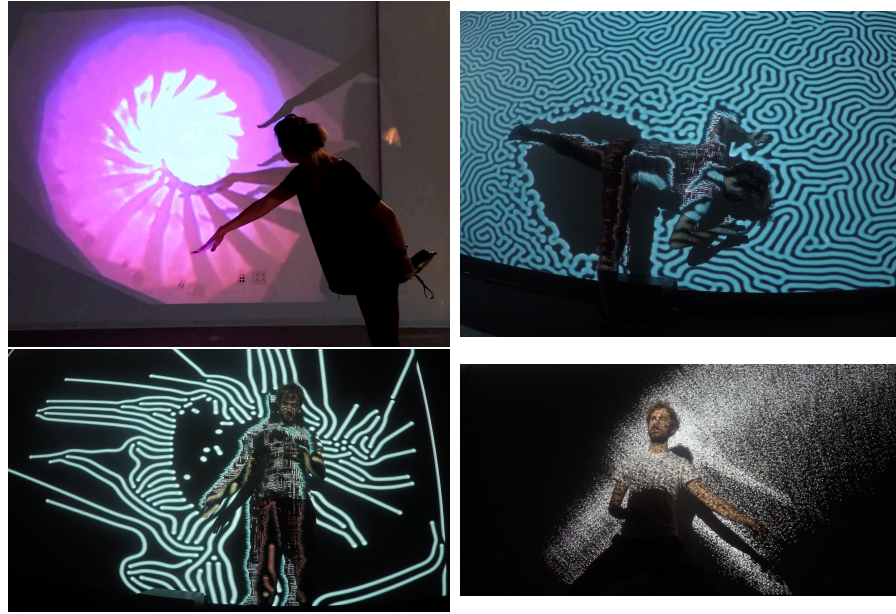


Figure 4.2: Examples of embodied interaction mappings.

4.2.4 Phase 4: Bridging Worlds

Phase four of the Embodied Worldmaking process is where experiential bridges are forged. This is the most difficult and chaotic part of the creative process which involves the most agility and flexibility in moving between expressive roles. Bridging worlds is the phase in which the scores and resources of connecting with land are revisited within the context of the new virtual sketches and instruments. There is an effort to connect embodied experience from the land through the interactive systems, which must be approached from the place of inhabiting land and met by an iterative flexibility of the technological systems.

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This starts with a returning to the ground of the initial experiences of inspiration and movement, and exploring ways of revisiting experiences through memory, the poetic map, and movement scores. There is an idea of carrying the land within the body. How to keep the experiences alive within the moving body, and to bring this fresh oxygenated body into relationship with the technological systems in a way that clearly delineates the gaps and short comings of technology to reflect the aliveness of this body. This is a type of directed self-reflexive exploration which aims to move from virtual sketches as instrument to virtual environments and mediums, in relationship to Hsueh et al's taxonomy of kinaesthetic creativity (Hsueh, Alaoui, and Mackay, 2019).

This is often a painful process for me, as there is so much mental energy and effort put into programming and the living and moving world is so much more fluid. What is easy in the body can be quite challenging in computation. In this pain is a letting go, a softening into and releasing expectation. There is an acceptance of what is and a re-evaluation of possibility into how the oxygenated body wants to play with the systems that are present, both in their affordances and limiting gaps.

Through this improvisational and iterative perspiration of moving from the land and shaping and combining virtual sketches and instruments, distinct environmental qualities and movements begin to form as an ecology from which a new

map of embodied poetic experience is recorded. How does my body resonate with what is happening in relationship to both the technology, the virtual visualizations, and the traces of memory from the land? What allows the voice of my body and the land to inhabit this new space with a stronger resonance? These questions guide my evaluating action of this iterative practice, and distinct resonating qualities of the virtual world and movement are identified and recorded.

From this process, clear channels of communication between the poetic map of embodied experience with land and this new virtual environment are opened and available to inhabit more vibrantly. It is as if a living confidence has grown and evolved through this integration – an acceptance of the limitations of technology, without the inhibitions of its resistance; a freedom to move with the affordances, and to shine from the deeper connection with the land supporting the exploration.

4.2.5 Phase 5: Performance Composition

With this new channel opened, composition is the next phase of the process which involves selection and organization of material for a specific performance opportunity. The composition process takes the map of experiences discovered from the previous phase and selects and orders distinct resonance qualities and combinations of visualizations and movement in time and space.

4. Embodied Worldmaking Process and Methodologies

I will often start by drawing a story board of a particularly compelling arc of exploration that mimics a pathway through the landscape of inspiration and imagination. The available resources which now consists of virtual sketches in combination as interactive ecologies, each a multiplicity of resonant qualities through specific explored parameter spaces, and movement explorations within those environments. There is a simultaneous growing of the composition through an integration and selection process, ordering these sets of qualities through specific spatial and temporal relationships. The relationships are selected and iterated through experiencing their quality of resonance with performing bodies in motion. Each affordance of the performance space is considered in parallel, integrating spatial audio components with visual components arranged on different surfaces of the environment, and how the body is framed and focused both internally and externally through movement scores.

As the performance world begins to take shape, there is a continual process of inhabiting and shaping the world for a continuity and flow of my own embodied experience as a performer. Particular details of transitioning between segments need to maintain the principles of making space and subtle guidance. In addition, I often ask myself what is missing from this experience that is an important part of the poetic map. Often missing qualities will be incorporated through recording poetry and material from the poetic map and using it as narrative elements within

the world. Also, revisiting the land and practicing more extensive field recordings provide additional resonate sounds or imagery that can be integrated into the world.

4.2.6 Phase 6: Performance and Exhibition

The final phase is the dissemination of the work through performance and exhibition. In performance there is a letting go into a spaciousness of silence and stillness. In accepting the work where it is and inhabiting the space with an intention of sharing the work as spaciousness itself, I aim to give the space to the audience. Through the structure of the world and the qualities of the voices of land embedded within the work, I inhabit the world and listen.

I am listening most attentively to the unique space of the bodies in the room. I encounter the world as if for the first time as it has never met the worlds of each person in the room. I see faces, I speak words, I aim to bring space to those present, and to share an invitation to see and feel in new ways.

I am open to the possibility of radical events to occur and transform, and I have no attachment to a particular experience to be communicated. Performance is an entirely wild place, where I discover new possibilities emerging.

In this experience there is a reflection and a return to the quality of exploring natural environments in phase one of the process. It is as if the creation of the

performance world is the creation of a new opportunity to connect to the fascination of wild synchronicities and interconnected ecologies of beings and presence. I acknowledge the radical importance of the audience as witness and participant to this process, and I experience this feeling of responsibility of guidance as If I was inviting everyone for a walk in the woods.

4.3 Evaluation: Value of Integrative Practices in Embodiment, Ecological Listening, and Virtual Worldmaking

The embodied worldmaking process serves as an integrated design process that reflects the types of qualities and creative processes possible in combining these diverse practices. Two of the primary research questions of this dissertation aim to understand the beneficial qualities and heuristics of interconnection and integration between embodiment practice, ecological listening practice, and media arts worldmaking practice.

Embodied worldmaking integrates embodiment practice and ecological listening through the grounding metaphor of *becoming-tree* and the practice based scores of *returning to ground*. By including these practices as a grounding principle that

4. Embodied Worldmaking Process and Methodologies

is continuously revisited in connection with every aspect of the diverse transdisciplinary processes, embodiment and embodied experience in relationship with land becomes a core value to the creative process.

In relationship to media arts practice, this value creates the opportunity of prioritizing the body in relationship with developed technologies and systems. Through the return to the ground of body and Earth, we are reminded that both are primary and that in prioritizing conditions that create space for a thriving body and Earth the work we make may receive this grounded nourishment to grow stronger, as is reflected in Maslow's hierarchy of needs (Mathes, 1981).

Through the process of resonance and reverberation, connections can be made between the body, the Earth, and virtual worlds. Qualities of movement, computational living patterns, and poetic image create spaces for connecting living interconnected ecological processes at different scales. Through the shared embodied experience of inhabiting performance environments together, there is space to bring value to these connections through meaningful social interactions, sharing experience, and sharing story. The shared experience within an embodied world can become an experiential myth, where embedded connections resonate and inspire new connections within one's self.

5

Seer System Design

Seer is a creative coding framework designed for the rapid creation of scalable interactive audiovisual instruments and environments especially intended for building embodied performance worlds. Seer is designed to provide a simple and expressive textual programming interface that aims to make simple design tasks easy to express and complex design problems tractable, iterative, and interactive. The primary motivation for such a language is to shorten the gap between inspiration and implementation allowing a dynamic and rapid iteration between inhabiting the role of programmer, designer, musician, dancer, composer, and performer.

5.1 System Motivation

Seer is the creative coding framework built as a proof of concept system to experiment with the methods of prioritizing embodiment in relationship with the

construction of virtual performance worlds. Rather than utilize or extend an existing creative coding framework, Seer was designed to grow and meet the needs of the embodied worldmaking practice and its evolution throughout the many explorations of this dissertation. The aim of this method was not only to create the works, but to allow the works to influence the design of the underlying tools and to track this influencing process as a contribution of this research.

Seer is built on top of the general purpose programming language, Scala. Scala runs on the Java Virtual Machine platform which allows a number of other programming languages to work together within the same runtime environment. Scala provides a flexible and powerful range of programmatic expression, offering both object oriented programming metaphors as well as functional programming metaphors. It is a compiled and typed programming language that make it a good choice for creating efficient and scalable systems. Scala's features including type inference, operator overloading, and implicit functions make it a powerful language for constructing internal domain specific languages (DSLs).

5.1.1 Creativity Support for Embodied Worldmaking

Shneiderman's work on creativity support tools offers a number of design principles that serve as guidance for designing tools that empower work within a creative field. These principles include: supporting exploratory search, enabling

collaboration, providing rich history keeping, and designing with low thresholds, high ceilings, and wide walls (Shneiderman, 2007).

The design of the software framework focuses primarily on two of these principles of creativity support for empowering the processes of embodied worldmaking. Supporting exploratory search has been the most important feature that seer was designed for, in addition to providing a system with low thresholds, high ceilings, and wide walls.

The processes of embodied worldmaking require an agility in moving between expressive mediums and ways of expressing, particularly in moving between embodied interaction with an environment and current methods of programming interactive systems through textual interfaces and keyboard. Methods that support rapid exploratory search while programming and composing interaction mappings and worlds offer a great benefit to this creative flexibility and agility. From the perspective of supporting exploratory search, the system was designed to support both rapid exploration of generative and biomimetic systems as well as rapid exploration of embodied instrument design.

In creating virtual worlds and performance there are many layers of the design process that must intersect. Not only is it necessary to explore algorithmic processes as prototype, but the need to layer these sketches with many other simultaneous processes in order to create interactive virtual ecologies can be-

come cumbersome. How do we organize and structure a programming practice that moves between prototyping and large scale interconnected works and performance that are organized in space and time. Seer aims to support the wide walls of designing interactive biomimetic algorithms and designing performance worlds by offering tools for spatiotemporal composition and scaling system across distributed performance environments.

5.2 System Design

How can a system provide tools for rapid prototyping of interactive systems while also scaling naturally to fit realtime performance situations and long-term artistic installations? Seer solves these design problems by offering a live-codable actor-based system built with the general purpose programming language Scala. Seer provides libraries for generating content through expressive and terse interfaces and domain specific languages covering OpenGL based graphics rendering, digital audio synthesis, interactive data streams and devices, high level worldmaking utility classes, as well as novel composition methods for arranging content in space and time. Seer is designed to scale across multiple computation nodes to fit the technical needs of large scale performances and installations, offering methods

for state synchronization and serialization. Seer is designed to be modular and extendable, so that it may grow as new needs and challenges emerge.

5.2.1 Supporting Rapid Exploration

The foundation of supporting rapid exploration is enabling a live-coding methodology on top of a modular creative coding base. Seer implements a novel actor-based live-coding system. Actors provide a form of asynchronous computation using message passing for communication (Agha, 1985). Actors encompass local private state and expose functionality through sending and receiving messages to other actors within the system. This model itself becomes a kind of ecology of computation which organizes computation and state within a modular architecture.

The system is designed around utilization of the Scala Toolbox API for runtime compilation (Burmako, 2017), and the Akka Actor framework for the underlying actor implementation (Vernon, 2015). Scala script files containing actor code are monitored for changes and when updated are recompiled and reloaded into the running audiovisual system. This process happens fast enough for realtime rapid iteration of ideas and code.

The seer actor provides a base class interface similar to other creative coding languages, where overriding functions for initialization and repeated draw calls

and audio callbacks allow runtime code to create an audiovisual presence. Actors also have a receive function, in which messages from the system and other actors can be handled for communicating with other actors within the computational ecology.

5.2.2 Rapid Exploration of Biomimetic Programs

Seer supports the rapid exploration of biomimetic programs through enabling expressive and high level programming constructs for audiovisual features and worldmaking primitives. Seer provides a modular architecture and includes a growing set of useful features for constructing audiovisual virtual worlds. Useful features for general audiovisual creative coding include: expressive high level render graph abstraction. Important worldmaking primitives that have been generalized for repeated use throughout different works of this dissertation include: particle systems, spring simulations, attractors and gravitation, fields, vector fields, fluid simulations, and recursive branching data structures.

The render graph api abstracts an underlying OpenGL render call through the *RenderNode* class which can be connected to other render nodes to form render graphs. This abstraction provides a high level interface to arranging complex graphics processes and multi-pass rendering methods. The render node wraps a collection of meshes to be drawn, a shader program to draw them with, and po-

tentially a framebuffer to render into. When nodes are connected together, framebuffers are used to connect one node's output to another's input through binding one's framebuffer to a texture input of the other's shader program. Although this could all be written within an actor itself, having a higher level abstraction makes organizing and composing these connections easier to reason about without limiting the functionality possible.

Particle systems are implemented as a base class containing the necessary simulation code for basic particle motion behavior. This class is used through extending this base class and adding any additional simulation and rendering implementation. This separates the basic functionality from particular instances, where it is easy to get started with a system of particles and only focus on the unique behaviors and visualization that is needed for this unique instance. Similarly, with other worldmaking primitives, with each there are basic assumptions of behavior that is needed in most cases. The aim is to provide substrate implementations that must be extended with particulars.

5.2.3 Rapid Exploration of Embodied Instruments

In order to support rapid exploration of embodied instruments, a diverse set of modules for connecting to a wide range of devices is necessary. By default creative coding frameworks cover window based event interactions including keyboard and

5. *Seer System Design*

mouse, which Seer does as well. Additionally, external modules for individual interaction methods enable connecting to device data including: Kinect, OpenCV, HID devices, VRPN tracking systems, multitouch trackpads, Leap Motion and more. Every API to different kinds of devices has its own particular events and callback methods. To make things simple, seer wraps these interfaces in a common interface that also enables a reactive streams based data flow language. Reactive streams provide a more expressive and easier to reason about paradigm of programming interactive data streams (Maier, Rompf, and Odersky, 2010). The module of seer which implements the reactive dataflow language for connecting device data streams to actors and OSC is called *Flow*.

Flow has been implemented as a module of the creative coding system Seer. A browser based live coding interface was also built to run Flow code in a standalone manner for integration with other creative coding frameworks through Open Sound Control (OSC) messages (Wright and Freed, 1997). Flow uses the Akka Streams reactive streams framework (Davis, 2019) to implement a domain specific language (DSL) for connecting device data streams to application parameters both locally and over the network. Flow wraps devices as *IO* objects with uniquely named and typed inputs and output streams. The DSL uses the operator “»” for creating mappings between output streams and input streams in the live-

coding environment. Streams of a previous iteration are shutdown when a script is reloaded, allowing for a framework for rapid iteration of different mappings.

5.2.4 Supporting Rich Spatiotemporal Composition

Supporting spatiotemporal composition involves the ability to scale and integrate many processes simultaneously and to select qualities of these processes in space and in time. To work at different scales takes a method of organization, through which layers of the system can be integrated. The built in actor based organization of seer provides some degree of composable organization. Seer also provides specific programming interfaces for composing parameters and events in time.

Worlds contain worlds and layers of complexity are necessary in building up an intersecting virtual experience. In my experience working with other creative coding languages, such as OpenFrameworks, Processing, and Max/Msp, I have always felt the system reach a point in the process where it becomes unwieldy. Where there is too much code for too many parts of the system and organizing, iterating, and composing interconnected events becomes more and more tricky. In designing Seer, I wanted to avoid this unwieldiness. Through the modular actor-based structure and the expressive syntax of Scala, I have found that it is easier to reason about individual parts of the system when their code is organized

within smaller actor components. Also, the ability to utilize message passing from any other actor enables events to be easily managed as messages as opposed to navigating dependent mutable state transformations.

One additional interface for composing important state parameters of the system is the implementation of a state actor which wraps an internal state variable of an actor, and exposes it as its own actor. This allows this data to become an asynchronous state parameter, persistent across script compilation iterations, and modifiable by other actors. These state actors enable a wide range of potentials. Similar to *Parameters* as implemented in the *allolib* creative coding library, these state actors enable simple methods of snapshotting current values and saving them to disk as repeatable preset values, as well as connecting them to simple graphical user interfaces, or exposing them over the network via OSC.

Temporal events can be scheduled through a global scheduler which accepts callback functions for events in time. The scheduler takes a human readable duration and a callback function to be called when after or over the specified duration. By chaining these temporal callbacks, one can easily script sequences of events and transition state variables over a given duration, allowing for temporal compositions to unfold.

5.2.5 Supporting Scalability for Distributed Performance Systems

Performance systems are often very complex and require multiple computation nodes to run every aspect of the system including audio, projection, lighting, interactive instruments, tracking systems, or distributed embedded systems. Traditional creative coding software prioritize monolithic systems in early development, which can take considerable effort to redesign for distributed computation.

The actor based system of seer enables a built in support for transitioning to run on distributed performance systems. Built on top of the Akka Actors framework, seer's actors are able to utilize the message passing interface both locally and over the network. Actors are independent units of computation and this makes it easy to split up collections of actors across different compute nodes and maintain a functioning system with very little changes. Of course, considerations must be made in regards to latency and network bandwidth as sending large amounts of data over the network does not always scale as it does locally between actors. However, overall the process of distributing the computation is a lot easier to implement and manage.

6

Conclusions

This dissertation describes the Embodied Worldmaking process, an integrative method for bridging embodied natural experiences through immersive media performance. This process, grounded in somatic movement practice, is a dynamic creative method for navigating and prioritizing the body and Earth in relationship with technology.

The practice-based research contributes four performance worlds that have led to the clarification of the Embodied Worldmaking process and the creative coding system, Seer. These works showcase the possibilities of both this creative method and Seer as a creative design tool.

Embodiment practice provides a powerful foundation for re-sensitizing oneself to the capacity of the body's ability to know what it needs and to create space for new choices in taking care and directing ones attention throughout the creative process. In having a grounding practice of embodiment the gaps between what

we think we are making and the reality of the experience we feel become more visible.

6.1 **Future Work**

Much of this work has been an integration of methods within the realm of my own artistic practice, and has taken the form of an autobiographical design process. Autobiographical design has allowed for the rapid exploration of this space in producing real performative artworks, systems, and processes, however because of the nature of autobiographical design, the process has mainly been disseminated through performance exhibitions and research talks. Including more collaborators within the process is an important next step in evolving this practice to a more general creative framework.

The next step for this work is to engage directly with other diverse practices and communities. Practicing this process within a collaborative setting through guided workshops would provide great feedback about the application of this process and the tools in a more general context. Performing and gathering workshop participant feedback through formal experiential studies would provide new avenues of design exploration enabling a more widely reaching creative platform.

6. Conclusions

The software platform itself is available online, however making it more accessible to other creative practitioners would greatly benefit its growth as a generalizable creative platform. By creating an online community with tutorials, examples, and extensive documentation, Seer could benefit from a more diverse range of creative practices.

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