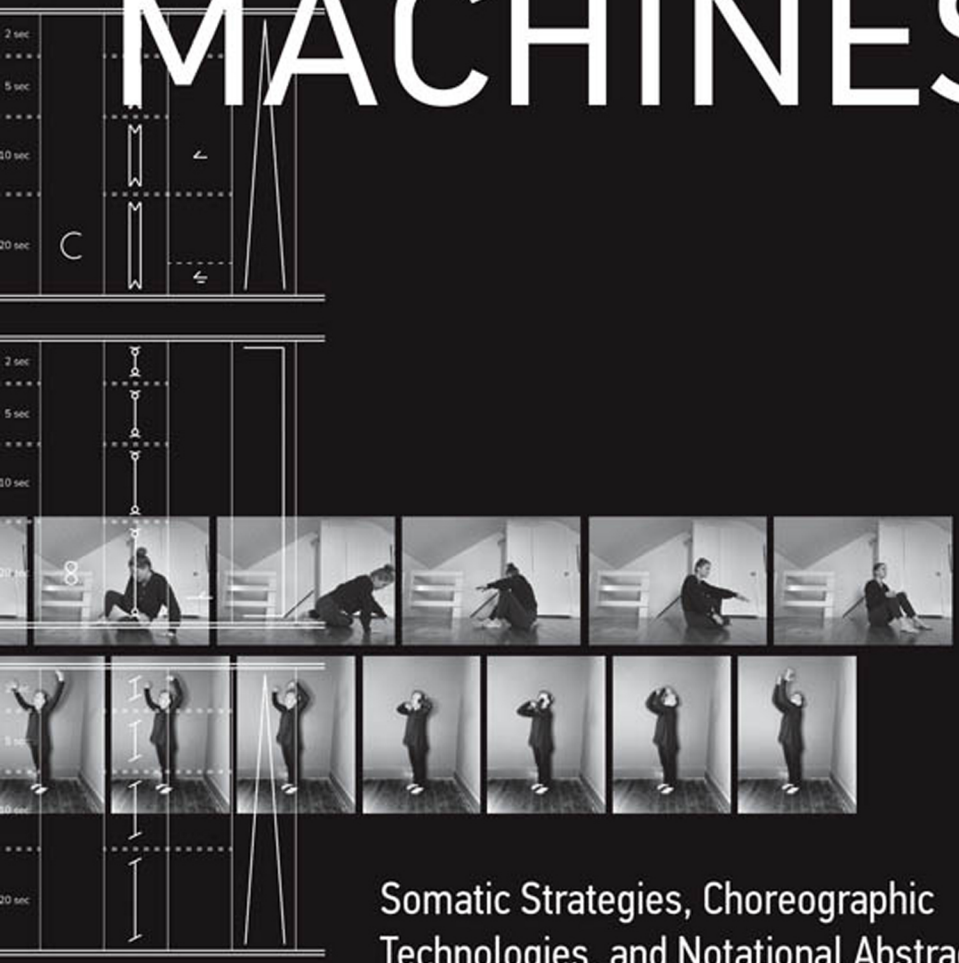
Making Meaning with MACHINES



Somatic Strategies, Choreographic Technologies, and Notational Abstractions through a Laban/Bartenieff Lens

Amy LaViers and Catherine Maguire

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To our teachers and our students, who are one and the same

Contents

Preface

When I was a PhD student in electrical engineering at Georgia Tech, I was given the most incredible opportunity: to study movement. I found myself surrounded by roboticists excited by the opportunity to learn something from a dancer. They seemed to say: Explain it to us. Help us make it. Now help us make it cool. Despite the many challenges of graduate school, I often found myself marveling at the immense privilege of getting paid to learn about my favorite subject.

First, I turned to my practice. The first paper core to my dissertation was inspired in a ballet class at the Atlanta Ballet School. The work developed an idea about smaller snippets of movement combining to form longer more complex phrases (LaViers & Egerstedt, 2011). One shortfall of the work is that it only specified a sequence of static poses, leaving the movements between poses to the imagination. So, the natural next step that I needed to address was: what happens between poses? Naturally, I turned to Rudolf Laban.

My teacher from about 1999–2005 (when I was in middle and high school), Irena Linn, had studied in Germany at a school set up by Mary Wigman (one of Laban's students). Miss Linn, as we called her, taught choreography through the use of taxonomy. She used her taxonomy to help us notice our habits, inspire new ideas, and create balance in our work. I remember the tiny chalkboard in the corner of Dancer's Studio in Knoxville, Tennessee. It was such an unusual feature for a dance studio, but she would have us crowd around it while she wrote the names of (and, I believe, symbols for) different movements on the board: rotation, jump, travel, and so on. She talked to us about changing levels and varying the dynamic quality of our movement (this one was always hard for me!). And

I still remember the first movement I choreographed in this new context: I pressed my hands, fingers spread wide, down on the floor next to my right foot; then, contracting from my core for support and keeping my foot and hands in the plane that had been formed by the smooth wooden planks on the floor, I lifted these distal parts through the air so that the sole of my right foot and the palms of my hands faced my audience. The movement displayed level change as well as forcing a weighty, strong physicality—and associated quality of motion—that did not come naturally to me.

So, it is likely that at some time in those early days, I heard Laban's name. I learned more about his work as I completed my senior thesis at Princeton University, where I took the novel opportunity to participate in a deep, independent, yearlong study to explore how the tools I'd been learning in my studies in mechanical and aerospace engineering (e.g., root locus analysis for understanding how controller gains affected closed-loop system dynamics) could inform the analysis that I was doing in my dance studies (e.g., comparing the styles of various choreographers working across genres and time periods). This is when I first encountered Labanotation and the effort system, feeling simultaneously excited by and dissatisfied with both: I marveled at the idea of a system of notation that could mark down the idea of a movement phrase just as music notation does for pianos, trumpets, and harps, but I wished for a system that would be used as regularly by dancers as music notation is by musicians. In those days, I felt so much optimism that quantitative tools could help create a new, more robust way of representing movement. My thesis was advised by Professor Naomi Leonard, who had so successfully wielded quantitative models in producing robot motion and capturing aspects of fish behaviors with collaborators outside engineering like Professor Iain Couzin. During this work, she introduced me to Professor Magnus Egerstedt, who would become my graduate adviser and whose motion-capture studio I borrowed to complete the work. In the end, I produced strange looping and wiggling plots that perhaps reflected stylistic differences between modern dance and ballet (but more likely just displayed the complex nonlinearity of human motion, a hint that Professor William Bialek gave me at the time, but that I did not understand until many years later).

Naomi's success in working with a biologist like Iain painted a tantalizing mirage about interdisciplinary research and gave me the idea that working with the field of dance as an engineer was possible. Perhaps one day this

will be true, but I do not think it is today. There are a couple of important distinctions between biology and dance that must be highlighted. First, while biology and dance are both rooted in qualitative description (I am thinking of biologists venturing out of the lab into the natural environments of animals to *observe* their behavior and *write* their findings), there is centuries of work in laboratories using quantitative measurements of animal and other natural phenomena that sits comfortably alongside this observational work. Second, and maybe more important, there are lots and lots of books about biology. Of course, there are lots and lots of books about dance, too—there are lots and lots of books, period—but my sense is that there are more books, papers, and archived information about biology. To try to quantify this sense, the search term "fish behavior" currently returns almost four million results on Google Scholar, while "Laban Movement Analysis" returns about 40,000 and "Laban system" returns about 70,000, including a book called *Laban for All* by Jean Newlove and John Dalby (2004).

I opened that exact book in 2010, trying to understand the elusive idea of movement quality as I extended my initial research with Magnus. Newlove had been a student of Laban and worked with both dancers and actors (alongside Dalby) throughout her career. I consumed their book with excitement, and in the margins of my copy, you can see my excitement at quantifying this system. My first note adorns a description of "the whole-step," where I wrote, "An example of how [Laban] gave names to the elements of the cycle we see in joint-space" (Newlove & Dalby 2004, p. 20). In my recently completed undergraduate research, I had performed a linear (and nonlinear) decomposition of motion-capture data about walking, so this description refers to the cycles that appear on two-dimensional plots (projections of higher-dimensional spaces) in those types of analyses. After this description, they invite the reader to move, writing, "Try these time-honored step sequences but don't just do them with your feet. Let the movement flow through your whole body" (p. 20).

Years later, I am still untangling those words. Of course, it is impossible to take a step without moving your whole body, but Newlove and Dalby's point is clear: notice your whole body and make active choices within it. For my part, I was then, as I am now, obsessed with the idea of cataloging the incredible vastness of human motion. I think that at that time, even after decades spent in a dance studio, I had thought that the picture in my mind of a skeleton evolving in a high-dimensional state space (its joints

plus their velocities) was complete, and this domain just needed a little math to sort itself into a satisfyingly simple picture. My thinking was something like: "Sure, the human body is a little more complex than a piano, but computers have lots of transistors and can help us find a basis for human motion that easily explains what we perceive in it." Today, I think that that line of thinking is laughably naive. Today, I think that it is only the richness of the space—and reveling in it—that can be satisfying. Then, guided by the limited texts I could find on Laban's effort system, including *Laban for All*, I happily modeled the quality of a movement with four continuous variables that figured into an optimal control problem, which was the extension that Magnus and I devised to include Laban and expressive quality into robotic motion (LaViers & Egerstedt, 2012).

Fast forward a few years, and I am an assistant professor in charge of my own research funds. My very first investment was going to be to study Laban's work for myself, at the source, in the studio. Professor Lori Teague, a member of the dance faculty at Emory University who collaborated on my graduate work in the effort system (LaViers et al., 2014), had connected me with a training program in movement analysis that I eagerly began. In the program, I was quickly immersed in a world that resisted publishing and regarded my beloved *Laban for All* with annoyance for its simplicity and audacity. Most of the books for the training program were primary sources: Laban and Irmgard Bartenieff's own writing, which was decades old by then. On the other hand, my graduate adviser had proudly displayed his multiple recently published texts that he had authored—which were in open, even joyous, competition with the texts written by his colleagues. He had taught me to see this kind of competition as a productive space for progress. These two worlds could not have been more different.

My time studying Laban's work as an engineering department faculty member led me to a very pessimistic outlook of engineering's capacity. The realities of getting funding, publishing, and advising students ruined the rosy picture of interdisciplinary research that Naomi had painted for me of her collaboration with Iain. Program managers insisted that I extend existing models claiming that Laban's effort system revealed the emotional content of movement (and I lacked a textbook to cite their mistake); reviewers judged my habit of coauthoring with movement experts as unethical (and I fought prior precedents where these collaborators were anonymous); my faculty colleagues told me that art wasn't engineering (leaving me confused

about why I had been hired); and students were more interested in quantitative modeling than they were in qualitative reasoning (often at the expense of quality work). Railing against such simplistic, one-dimensional insistences, I tried to show roboticists how *inexpressive* their machines were (LaViers, 2019a), comparing their capacity to the staggering computing power of microchips and the marvel of natural life (LaViers, 2019c). I showed how important the arts were to robotic development (LaViers et al., 2018; Cuan et al., 2018; Ladenheim & LaViers, 2021) and how expressive *all* motion can be, experimentally demonstrating that emotive labels for movement break down across contexts (Heimerdinger & LaViers, 2019). The chasm between disciplines is fertile, if also turbulent.

It was in this context where I met my coauthor, Catherine Maguire, from whom I began taking classes—both within and outside my movement analysis certification program. Cat quickly introduced me to two books that were central to the process of complicating my relatively simple picture of human movement (a motion-capture body moving through a knowable state space). First, she had me complete coloring exercises from an anatomy book, a task that felt so *silly*, but which was responsible for teaching me, at the ripe age of twenty-six, facts as basic as the following: my stomach is *under* my ribs and my legs start *deep* inside my pelvis (I'm still working to find the extent of that depth today, a process that literally brings free-flowing tears to my eyes). She also gave me *Everybody Is a Body* by Karen Studd and Laura Cox (2013/2020), a book that I read with excitement but that left me aching for a more academic presentation of a system for movement analysis.

Where my knowledge is broad, Cat's is deep, and her forty years of experience in dance and movement studies create the depth of this book. Where I crave a sentence written with clarity, Cat craves a body moving with clarity (after all, her weekly class in Charlottesville, Virginia, is called "The Articulate Body"). Where I need a system with parallel elements, Cat wants to know what it *means* to an audience—especially her students. I do not know how to describe so much of what Cat has offered me: it is that kind of deep, nonverbal, maternal love that words fail to capture. Writing this book with her has been a true joy.

Cat and I began conceiving of this book at the end of 2019 and began writing in earnest during the peak of the COVID-19 pandemic. Our process consisted of biweekly, hours-long Zoom calls and lots of arguments. I remember one of the first arguments, which would continue over and

over during our writing, about notation—specifically, the form of notation discussed in this book: motif. I often struggled to communicate the value and nature of movement analysis to an engineering audience—especially in funding applications, where space limitations frequently required brief, oversimplified, cartoonlike surveys of wide, broad fields. In such applications, I often described motif as something like a "shorthand" of Labanotation. This immediately connected motif to an idea that engineers could grasp ("movement notation") without entirely conflating it with Labanotation (a subtlety that was important to me). Cat rejected that term strongly, insisting motif was about "essence." Well, despite almost a decade of training with and working alongside her, I barely knew what she meant by that—and I certainly couldn't communicate it to a funding body or in a book proposal (and nor could she).

We returned to this argument often, and it shaped the book, which was not meant to be about movement notation (our initial plan was simply to have one chapter briefly dedicated to the mechanics of it), but we discovered a deeper connection between naming and notating movement ideas than even we had anticipated. As such, we have produced a book that culminates in a chapter on notation, building the entire time toward motif as a final goal, rather than a technical aside. Right now, I feel like the next book will go further into that forest and be entirely focused on the topic of notation. It is how we will solve the segmentation problem (LaViers & Egerstedt, 2014; Sheng & LaViers, 2014). It is how we will make safer autonomous vehicles, mend our relationships with our smartphones, and otherwise better incorporate machines into human experience. It is how we will talk to aliens.

And so, it was while standing on the edge of that forest that we heightened our goals for presenting the symbols used in the book. I first met Jonathan Pearce working on an online automation design tool, where I learned of his ability to weather robust argument to clarify ideas. Asking him to help create some of our more complex illustrations, as well as design a consistent symbol set for motif, was a wonderful decision. Jon's artistry and expertise in graphic design have helped Cat and me sift through many iterations of the visual cues and conventions that each symbol should be composed of, in order to best relate to other existing systems as well as prior renderings of that symbol—a process which has interestingly revealed many oversights in our thinking.

As we go to press, we have found a funding source to enable the open-access publication of this book, part of a National Science Foundation (NSF) infrastructure grant that will create a shared resource of video clips of human motion labeled by expert annotators. The grant, a collaborative effort between Penn State University, University of Illinois Chicago, and my lab, is aimed at facilitating the creation of new tools in computer vision, human-robot interaction (HRI), and the study of human movement more broadly. With each iteration of developing the proposal, we have adjusted it to grapple with the personal nature of meaning and to dive deeper into the nuance of the annotation process. I remain hopeful that in this team, we have a match like Naomi and Iain, and I am grateful to be bringing a true textbook on movement studies into the collaboration—and to share with a community of engineers interested in the expressive dimensions of human motion more broadly.

Researchers rely on the richness of their internal movement model to inform the questions they ask and the answers they are willing to accept. In my doctoral work, I thought that four continuous variables might capture some of the distinct qualities of human movement. Since then, I have suggested that the 3,240,000 static, discrete poses that can be measured by a typical motion-capture recording of a human body are not enough to encompass the incredible phenomenon of our bodies in motion. Today, I feel that even this book barely scratches the surface in cataloging human movement; but somewhere out there, I know that a dancer is being asked by an engineer to explain herself; and I hope this book moves her answer farther than mine and deepens her own questions.

Amy LaViers

Philadelphia, Pennsylvania
June 30, 2022

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Electronic Resources

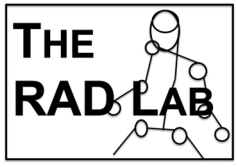
Electronic resources are available at www.makingmeaningwithmachines.com.

Materials for the **symbol set** presented in chapters 5–8 and appendix A include digital renderings and editable files of each symbol, as well as additional symbols.

Materials for the **notation** presented in chapter 10 include digital renderings and editable files of the scores in key figures, as well as video footage of the authors performing the notated movement phrases.

Materials for the **embodied exercises** introduced in chapter 3 and used throughout chapters 5–8 and 10 include video footage of the authors demonstrating several key exercises.

These materials are hosted online by the Robotics, Automation, and Dance (RAD) Lab.



Prelude: Opening with Embodied Perspectives

A butterfly floats erratically past my view. It seems to flit around chaotically, perhaps being eddied around by the slight breeze that moves the leaves of a nearby tree. Yet as I look more closely, its two large, wide wings flap down with clear control and intent, breaking the chaos with order and organized movement. A car approaches, slowing as it comes to a crosswalk. The path of the car follows the outline of the one-way street, and its linear path is a stark contrast to the butterfly: stable, orderly, bleak, clear. The car cuts through a large, brick pedestrian promenade at the heart of downtown Charlottesville, Virginia, where I sit on a shaded bench. Trees dot the space in irregular intervals, causing pedestrians to weave and wind as they are forced to make choices on how to accommodate the irregularly spaced obstacles. It's Wednesday around lunchtime, and I can see clusters of people heading in and out of the various restaurants along the sides. This is an undeniably pleasant and restful moment. Looking inward, I stretch out my legs, feel my knee crack and pop, a slight sensation of burning, a sore muscle surrounding an old injury; moving will be both annoying and replenishing today. Standing, I begin to walk to the nearby McGuffey Art Center.

During my walk, I notice my experience of movement. There is a fuzzy line between what is and what I perceive: I don't notice the reason for a sudden tweak in my ankle until I look back and see the substantial rock I accommodated without conscious awareness. And yet I perceive so much. So many details. The sore hamstring that groans as I overtake a hill. The pinching in my left toes as I hurry to make class on time. The rhythm between my scapula and hands as they swing back and forth, in and out of pace with my feet. Arguably, these details comprise more than the handful of commands I design for robots, like the NAO humanoid with its fourteen movable degrees of freedom, where a known, countable set of motors creates the opportunity for actable movement. I'm here to take a dance

class, in which a plethora of details from my own experience must be whittled down and simplified to help me choreograph motion—both for my own body and the artificial bodies I design.

Amy

As I enter my studio at McGuffey Art Center, I am struck by the golden sunlight streaming in through the windows and warming the floor. Cleaning the floor for my class, I push the mop along the parallel lines of hardwood planks, delineating the space. I feel my feet settling into the floor against the pressure of the mop and notice the changes in temperature of the floor surface as I move in and out of the areas warmed by the sunlight. I use this set of spatial pathways and my own body weight to activate a sense of my own agency in interacting with and changing the space where I am about to teach.

Today's lesson is on resiliency and the body's physical "core." I will explain how the spine is the key to adapt the body to new movement tasks and recover balance from a fall. To teach this concept, I will use movement sequences that activate an awareness of the vertebrae, illustrating how the spine is critically, although sometimes subtly, involved in every movement. Vertebrae can be sensed through a myriad of methods, such as direct palpation with the hand, descriptive imagery of our anatomy, and the weight shift that occurs during contact with the floor. Soon, I will ask my students to stand and begin to engage their sense of self by bouncing, jiggling, and breathing in order to better feel the viscera surrounding their spines and to understand how this relationship between stable bony elements and mobile soft tissue evolves in movement. Through this kind of attuning to inner sensation, the class will shift from inner awareness to outer awareness as the movement becomes more complex: from the floor to standing, from standing to traveling through space, from traveling through space to partnering with another dancer, from partnering back to stillness. The class will progress from an inner sense of self to a relationship to the outer environment, relating sensation of internal body parts to actionable changes in the environment. The goal of this work is to offer my students opportunities to make choices in how they engage with their environment and relate their own moving containers to the larger world.

Cat

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