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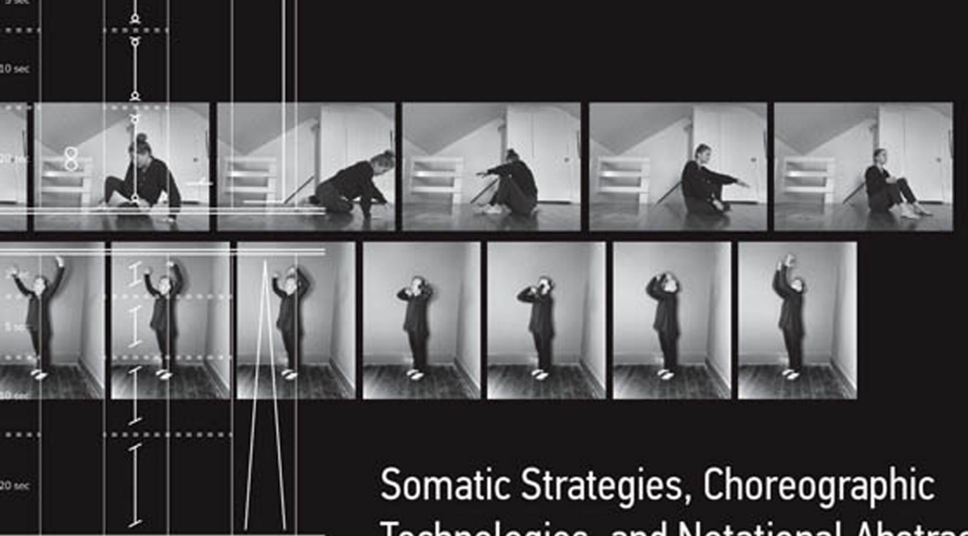

Somatic Strategies, Choreographic Technologies, and Notational Abstractions through a Laban/Bartenieff Lens

Amy LaViers and Catherine Maguire

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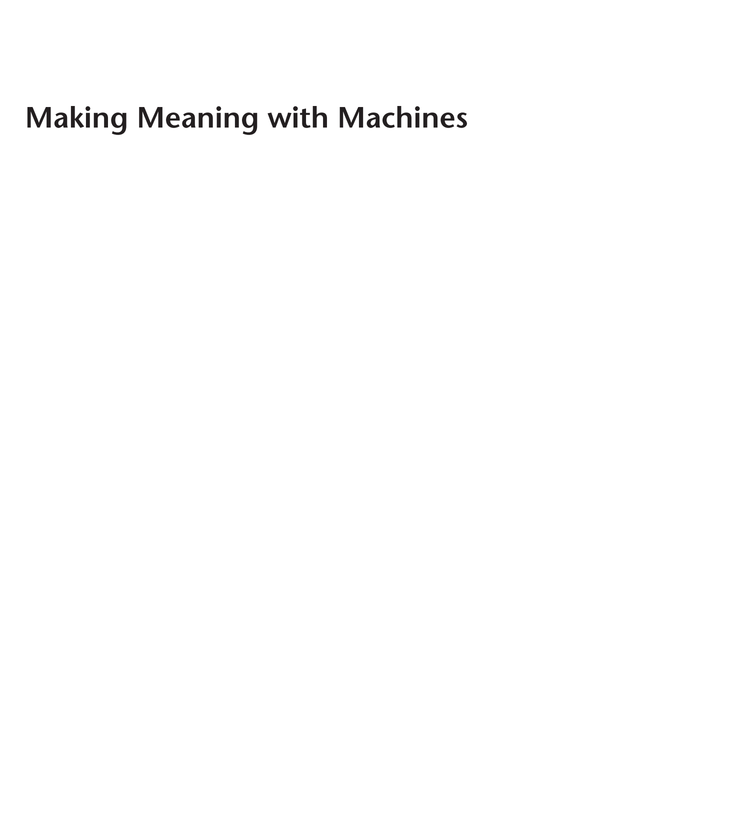

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Making Meaning with Machines

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

Amy LaViers and Catherine Maguire

The MIT Press
Cambridge, Massachusetts
London, England

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

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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

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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

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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

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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

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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

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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.

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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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1701295 from NSF. We also acknowledge the physical spaces where this work developed, including the dance and mechanical science and engineering departments at the University of Illinois Urbana-Champaign; the systems and information engineering department at the University of Virginia; the McGuffey Art Center in Charlottesville, Virginia; AgapeBelgium in Ardooie, Belgium; and the Conference for Research on Choreographic Interfaces at Brown University (where we had our inaugural writing session).

We thank our colleague Elizabeth Jochum for putting us in touch with Doug Sery at the MIT Press, where we were so amazed to have found a simultaneously sympathetic and critical voice. Moreover, our thanks go to our current editor, Noah Springer, whose guidance has greatly helped our work. Both Doug and Noah recruited amazingly thoughtful reviewers who lent significant time and intellect to reviewing the first early chapters, and then an entire manuscript. The book has shifted and changed with each round of their feedback, for which we are incredibly grateful. Jonathan Pearce's wonderful symbol designs are featured throughout the book; we are so grateful to his talent and energy in working with us on these illustrations (and allowing us 1.1 pt linewidth; that extra 0.1 is everything!). Our colleague Penny Chang reviewed an early draft and has been very helpful in creating clarity in our thinking and writing, and Kate Ladenheim reviewed a final draft, giving us important feedback from someone teaching and working right at the intersection of technology and dance. We also owe a great thank-you to Nicholas Osborne as well as the production teams at MITP and Westchester Publishing Services, who proofread, formatted, and copyedited this manuscript with a detailed, discerning eye. Finally, we thank the very first readers of our work, family members who also supported us through an intense experience: David Campanelli, Keegan Campanelli, Bryce Campanelli, Margaret LaViers, and Eric Minnick.

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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.

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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

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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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Introduction: Inviting Engineers into Movement Studies

This book was written by two dance artists: the student in the prelude (Amy), employed as a roboticist, and the teacher in the prelude (Cat), focusing on inner awareness of physical expression in her approach to movement instruction. This text results from the application of our shared training to the development of robotic and automated systems. The biggest shared component of that training is a particular, comprehensive system for analyzing movement that this book is grounded in, but we also bring broader training in dance, artmaking, engineering, and research.

On our journey to understand the phenomenon of human movement, we have established a rich collaboration spanning disciplines that has left us with more questions than concrete answers. How should a gestural interface react to a “flick” versus a “dab” versus a “punch”? Should robots reach out to a human counterpart with a direct, telescoping action or through a circuitous arc in space? How many distinct actions does a person perceive in a given robotic behavior? How do we know whether (and how) to yield to a colleague walking in the hallway? How will we know whether (and how) to yield to a twelve-armed robot “walking” in the hallway?

Patterns in movement seem to advertise internal states of human movers, and engineered systems increasingly aim to reflect and accommodate this idea. To help achieve this goal, this book is a primer for seeing, describing, and creating a wide array of movement patterns with both natural and artificial bodies, facilitating broader and better design choices for roboticists, technologists, designers, and artists. The main topics of the book are a descriptive and symbolic taxonomy for postural and gestural bodily movement and a theory for understanding how people create and perceive meaningful patterns in such movement. The book does not offer many

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equations, programs, or algorithms (although it cites many texts that do), but its material is grounded in examples and terminology that are relevant to roboticists, computer scientists, and technology designers.

Delving into Somatics, Choreography, Notation, and Machines

Among formalized systems of somatic practice, choreographic design, and notation is a broad suite of body-based theories and practices—a body of knowledge that we broadly term "movement studies," which includes movement analysis. Whereas most domains in this field focus on either inner experience (e.g., Body-Mind Centering/BMC) or outer expression (e.g., ballet technique), Laban/Bartenieff Movement Studies (LBMS)—a contemporary term meant to describe both Laban Movement Analysis (LMA) and Bartenieff Fundamentals (BF), along with advancements since the passing of the work's founders and namesakes Rudolf Laban and Irmgard Bartenieff—sits at the nexus of interior, body-based experience, where the somatic practice of movers is at the forefront of movement investigation, and the exterior, performative pursuit, where choreographic principles for creating observable changes in bodily motion serve the goal of presenting ideas on stage. Thus, this field of movement studies has implications not only for how we might design the movement of machines, but also why and how human movers experience that motion. In this book, we are not simply interested in cataloging this body of knowledge, but in exploring how this work has implications for designers, researchers, and technologists—namely, how new use cases for these relatively old tools will affect everyday life. That is, what will people think of robots in new, emerging contexts? Thus, we invoke more active language, and throughout this book, we refer to the *application* of somatic practices and choreographic principles in technology design as the use of somatic strategies and choreographic technologies, respectively.

As a new assistant professor, building a research program in robotics at an engineering school, Amy sought a way to train her growing research group, the Robotics, Automation, and Dance (RAD) Lab, which was filled with science and engineering students, as well as designers, dancers, and other artists, who had a variety of movement backgrounds (e.g., soccer, ballet, tai chi, playing the violin, and making bread) but had never used these experiences (at least formally) in technology design. To provide students with the

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tools to better reflect on and subsequently understand those experiences, Cat was invited to create workshops for these students, which translated into involvement in the students' research, growing this teaching relationship into a research collaboration that has investigated and begun to illuminate how first-person, embodied movement is a resource for work in robotics, artificial intelligence, and other technologies.

The workshops were held in dance studios (including the RAD Lab itself, as shown in figure 0.1) and felt more like dance classes than engineering courses (although they were both). Over the years, they were taught by both Cat and Amy, as well as other collaborators in dance and movement studies. The primary participants in the workshops were graduate students conducting research in robotics while enrolled in degree programs in engineering, but robotics is an inherently interdisciplinary field, so the workshops were also attended by artists, computer scientists, dancers, designers, kinesiologists, movement analysts, musicians, and somatic practitioners from the RAD Lab, as well as the broader university communities in which the workshops were held. These workshops were supplementary to typical activities in research on robotics, human-robot interaction (HRI), and engineering, giving students and employees in the RAD Lab experiences that were fully centered around the space of movement studies. These workshops are the basis for this book, and their attendees and content are representative of the audience and topics of the book, described in the next two sections.

In the remainder of this section, we will describe how we began studying gait with a doctoral student named Umer Huzaifa (now an assistant

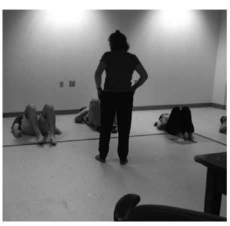

Figure 0.1
Snapshots from the RAD Lab at the University of Virginia, taken from fall 2014 to spring 2015. Left and center-left: Cat teaching movement workshops to graduate and undergraduate engineering students. Center-right and right: Amy conducting research with the team, leveraging choreographic and somatic learnings from these workshops in the development of expressive robots.

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professor at DePaul University in Chicago), when one of these workshops saved Umer's fledgling passion project, setting it on the path to becoming a core research area in the lab that would eventually lead to work published in top robotics venues, including the International Journal of Social Robotics (SORO), the International Conference of Intelligent Robots and Systems (IROS), and the IEEE International Conference on Biomedical Robotics and Biomechatronics (BioRob), and be funded by a grant from one of the most prestigious and competitive sources of research funding in the US: the National Science Foundation (NSF).[1] We will revisit Umer's work later in the book, but it is instructive to share here how it began in order to paint vivid details of the materiality of this kind of interdisciplinary work and, therefore, why we wanted to write a book to capture our workshops.

Umer was a graduate student in robotics with an undergraduate degree in electrical engineering, and he wanted to study gait for bipedal robots. He had read many papers on gait and bipedal walking robots; Russ Tedrake's work was a particular favorite. Amy had never worked on gait, but her training in dance and movement studies described the role of the core in human gait, which she knew was not emphasized in biomechanics or leveraged in robotic walking. This disparity provided a potential opportunity for new work. So, promising that he could work on this project in parallel to other work he was doing in the lab, she gave Umer a book of movement exercises and asked him to try them himself at home. This is not how somatic and choreographic thinking best develops (and yet it is the setting for you, our reader, as well).

After a few meetings, it was clear that there could be some interesting explorations of this topic. Amy found a large group of students willing to come in on the weekends and work on this special side project. The first meeting was a workshop led by Cat in the RAD Lab at the University of Virginia. When Cat entered the lab to work with the students, a division was immediately felt: she was dressed in dance clothes (form-fitting tights and bare feet), while the students were wearing street clothes (shorts, jeans, belts, socks, and shoes). The divide would go beyond fashion: each group valued different epistemological systems.

The first thing that Cat did was to ask the students to take off their shoes and socks and walk around the room, feeling their feet and their shifting weight as they traveled around. An internal sensing of the changes in pelvis as their weight shifted over their bare feet was encouraged with cues

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around feeling the bones, the rotational relationship of the leg and pelvis, and holding their hands on their hips to feel the movement through their own hands as it occurred. The next step was lying on the floor and introducing movements that would further support awareness of the pelvis, legs, and the interactions between them. To get a sense of the scene, imagine a group of students lying on the cold, linoleum-clad concrete floor of the lab, engaging in subtle movements designed to connect them to the internal space of their moving bodies.

While there was definitely some awkwardness, these students embraced the experience and were willing to do more in this vein of body research. Umer lingered at the end of this workshop to share his ideas with Cat about his research on gait and how this embodied experience supported his creative design process. This began the collaborative research relationship between Cat and the RAD Lab. Now, using Umer's work as a concrete, connecting example, we would like to illustrate how knowledge from somatics, choreography, and notation affected our work on gait design for robots.

First, how *somatics* has influenced our work with machines: Instead of approaching the parameterization of gait from external measurements, where ankle, knee, and hip displacement is the most salient feature of the movement, we considered an internal, somatic experience of gait (Huzaifa et al., 2016), as parameterized by concepts from Bartenieff Fundamentals, in particular "lateral pelvic shift," "sagittal pelvic shift," and "thigh lift," which describe the action of the pelvis side to side and front to back and the flexion at the hip joints, respectively. These exercises are typically used to retrain patients in physical therapy or students in a dance class, enlivening their pelvic core and enriching their access to weight shift from it. Thus, our parameterization focused on these three concepts—notably ignoring the action of the most distal joints in favor of proximal and core-based actions. This shift led to innovations in hardware design that have been applauded for their ability to mimic the natural dynamics of human walking, which is notably energy efficient: consider the difference between shifting the center of mass of a system directly, allowing gravity to power a fall (our approach), versus wrenching that center of mass through space via distant, distal actuators (the traditional approaches).

We were interested in developing a system with many, many styles of gait. To do this, we turned to *choreography*. Rather than working to create a single, energy-efficient gait, or even to categorize running versus walking (gaits

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distinguished by differences in footfall ground contacts) as many researchers do, we wanted to design many varieties, with subtle variations among them. We settled on searching the space of walking (gait defined by continuous contact with one of two bipedal lower appendages and the ground), such as skittering, sauntering, ambling, and dragging. These descriptors come from synonyms in the English language for "walking" (of which there are over sixty). We ended up validating six distinct walking gait styles in studies with human subjects, broadening the palette of options for machine movement designers (Huzaifa et al., 2020). None of these gaits use minimal energy (the mere presence of six valid gaits hints that we were not minimizing energy usage), but they offer a way of thinking about how distinct internal states may be communicated—or context may be reflected—through external, observable movement styles that are salient for human viewers.

The movement of the pelvis is almost imperceptible to most sensors that quantitatively measure and digitally map movement: one team of prior researchers had to surgically implant reflective markers to document its motion using infrared cameras (Crosbie et al., 1997). Thus, instead of by external measurement alone, it was through direct engagement with movement analysis that we leveraged somatic strategy and choreographic technology in robotic design. Or, as we wrote with a larger team of dance experts and engineering researchers:

> Our approach is pragmatic: we want to understand the phenomenon of how people create such vastly varied motion profiles that communicate complex intent. This knowledge, we believe, is contained inside body-based movement training and somatic practice where practitioners hone their own movement capabilities by expanding their array of choices. External methods, typically employed in the sciences and in engineering such as motion capture, photography, force plates, and the like, can work to document the result of a movement pattern but do not have access to choices made by a human in focus, motivation, sensation, memory, prior muscle patterning (and re-patterning), etc. The practice of honing these choices is one of embodiment—a body of knowledge that cannot be known but only moved. (LaViers et al., 2018, p. 3)

Unlike the computational simulation of gait, where we determined the pattern of forces necessary to produce forward locomotion in various styles on a particular, simple model of a given mass, the human labeling of these gaits is not universal across subjects and will change over time. In 1,000 years, the forces used to generate these gaits will measure the same, but culture, lifestyle, and conventions will have changed dramatically, creating

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new contexts for observing, naming, and interpreting the very same patterns in movement. If the pace of life increases over this time, what is today a hurried gait that transmits urgency and expediency (or means "I am in a hurry") may seem normative or neutral (or means "I am not in a hurry") in this distant future. Indeed, this future world is sure to have new styles of walking altogether. To grapple with the complexity of meaning-making, the book will often return to and emphasize the idea that meaning is specific to a given context (and therefore is not always shared between the mover and observer).

In addition, the representation of the gaits we designed affects how they are understood. Umer's simulation used vectors discretized in time to represent these gaits. Among the research team, we tried the gaits with our own bodies, moving them physically; we riffed on each one, varying it a bit, then a bit more, and so on, in order to come up with new varieties that we tried to name, notice, and codify; we displayed these gaits to subjects as rough cartoons; we came up with representative labels in English; and, in the future, we could use a symbolic system of *notation* to represent the gaits. Broadly, we can think of these alternative methods of representation as various abstractions—notational abstractions—that influence what is observed, experienced, interpreted, and saved for translation to other bodies. The interdependence of mover, context, and observer becomes especially poignant when notating movement. Notating movement is personal and embodied, and a form of meaning-making that can help clarify our design goals for machines.

A Growing Community at the Intersection of Robotics and Dance (Whom This Book Is For)

Researchers with significant formal training in somatics, choreography, and notation are rare in traditional engineering programs, and it is hard to study this material through books and archival publications. Most movement practitioners come from dance, therapeutics, and somatic practice, so the medium of their work is not primarily academic writing; rather, knowledge is passed through physical, bodily practice in studios, therapy rooms, and gyms. Nevertheless, the use of movement studies, especially in the Laban/Bartenieff tradition, is growing in engineering and computer science research.

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A search conducted on the term "Laban" in June 2020 showed 383 papers in the Association for Computing Machinery (ACM) database and 105 papers in the Institute of Electrical and Electronics Engineers (IEEE) database, with 268 (70 percent) and 80 (76 percent) of these results published in the prior ten years. Searching "Bartenieff" yielded 23 papers at ACM and 8 papers at IEEE, with 15 (65 percent) and 6[2] (75 percent) published since 2012. Relatedly, a published data set using the query "dancer" in the ACM database returned 194 papers since 2019 (Rajko, 2021). While these papers represent a very small portion of the overall publication activity in these large professional societies, they represent a segment that is growing—and will grow much more in the coming years as robots, computers, and machine interfaces increase in daily human experience.

And so, in writing this book, we are targeting roboticists, technologists, designers, and artists who seek to utilize technology as a means of expressing and/or recognizing human movement, promoting the widespread idea that a deeper understanding of human movement will help us build better tools in an increasingly technology-based world. We imagine our primary audience as graduate students, technical researchers, and product designers who are working in areas of human-robot, human-computer, and human-machine interaction and need better background knowledge about choreography, somatics, and notation. In parallel, dancers, physical therapists, and movement coaches may use this book to better understand the potential of their expertise in technology development and of the use of technology in their creative process. Further, other movement analysts may enjoy this book as a reference for themselves, as well as a road map to the impact of this work in technology. Increasingly, this hybrid field drawing on movement studies (including dance, theater, and digital media) and robotics (including human factors, control theory, and mechanism design) is referred to as "expressive robotics," or even "choreobotics."

University courses in human factors, arts and engineering, HRI, affective computing, animation, human subject research, and other increasingly offered programming at the intersection of design, the arts, and engineering, may use this book as a primary reference. For example, Amy's graduate-level course in mechanical engineering "High-Level Movement Representation and Robotic Control,"[3] taught in 2017 and 2019 at the University of Illinois at Urbana-Champaign, is the kind of interdisciplinary course that could use this book to supplement traditional engineering texts

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with vital knowledge from movement studies. Similar courses are increasingly offered in higher education. They often feature faculty and lecturers from both engineering and performing arts, some of whom—especially those working in performance studies, dance, and kinesiology—may have specific training in choreography, somatics, and notation. Movement analysis certification programs (like the ones that Amy and Cat participated in) tend to bridge all three of these domains and also may find this text useful in demonstrating application areas for the work, as well as a reasonable reference source featuring symbols and their corresponding concepts identified in one place. In addition, traditional courses in HRI, design, and human factors may increasingly find this textbook useful as these disciplines continue to be enriched and broadened through interdisciplinary exchange, evidenced by the growing body of work that employs movement studies in technology development.

Industrial technology designers are increasingly thinking about embodied interactions between humans and artificial agents. Roboticists are working on the problem of “social robots,” such as the Amazon Astro, that can seamlessly integrate into human-facing social situations. Software designers are using new off-the-shelf tools like Microsoft’s Azure Kinect depth camera and software suite to create immersive experiences that react to users’ bodily actions and gestures. Engineering programs are widening the scope of their course offerings to include physical, human-centered design to better prepare students to create devices for the Internet of Things. Yet how should such experts think about the body and its patterns in motion? It is not practical for every technologist to have extensive training in body-based design taxonomies and theory as well, and so our goal has been to write a book that makes this body of knowledge, accrued through physically taxing hours spent in a studio setting, more accessible to this community.

Finally, machines are already personal. As our tools increase in number and complexity, it is worth spending time grappling with how these devices change the narratives of and experiences in our daily lives. So, while this book is primarily written for professionals working at the intersection of the body and machines, it is also for anyone interested in interrogating their own relationship with machines. After reading this book, users who interact with a device such as a Fitbit may be better able to interpret the measures provided by that device inside their own personal contexts and bodies.

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Meaning-Making with Machines (What This Book Is About)

In this book, we aim to create a broad reference on movement studies (theory and practice) appropriate for engineers, designers, and researchers designing new tools that either produce or interpret movement styles and patterns. Primarily, we identify LBMS as a useful framework for organizing, producing, and explicating somatic strategies, choreographic technologies, and notational abstractions. We are presenting an edited and expanded version of the system stemming from our ever-evolving work with machines, adding new and refined terminology, analysis, and notation.

We even suggest that working with machines is essential to developing a systematic understanding of perceived movement, drawing a parallel to how the piano and other instruments were essential to figuring out perceived patterns in sound. Thanks to comprehensive music notation, we have access to playing the same song on different instruments, algorithmic readability of music, music copyrights, and many more technologies that rely on this systematic, abstract understanding. We are not there yet with movement and dance, but such understanding is growing with the explication and expansion of the tacit, embodied research that goes on in dance studios, physical therapy rooms, gyms, and outdoor fields, where the passage of knowledge is person-to-person and body-to-body, rather than from person-to-book or book-to-person. This book aims to add another flow to that exchange, and while holding fast to the tenet that *not everything can be written down*, we provide notational abstractions to support the process of writing down movement.

This book tries to scale the experience of in-person events that we have conducted for interdisciplinary audiences, like the workshop that kicked off our work with gait, to an introductory text for researchers, developers, designers, and artists interested in understanding principles of somatics and choreography (what we term more broadly as "movement studies") and their application to the design of new systems and interfaces. In our workshops, we expose graduate and undergraduate students to different aspects of choreography, improvisation, somatics, meditation, notation, and observation through the lens of movement studies as tools for meaning-making through recognizing patterns, contexting, and gaining insight into the complexity of human movement. We approach these ideas through experiences that frame the body's movement as the basis for our understanding

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of the world. In measuring, analyzing, and noticing bodily movement, it is critical to consider both *qualitative* and *quantitative* analyses from *subjective* and *objective* perspectives. As such, this book will not feel like a typical text on developing novel robots. Furthermore, we do not imagine that one could develop a novel robot with only this book as a guide. It is instead meant to supplement the many existing works on computational programming, mathematical modeling, and empirical validation of machines.

For the purpose of sharing physical experiences through words on a page, the book uses “embodied exercises,” where we make the somewhat unusual request that readers get up and move in their own environment. Often, these exercises will be supported through observation, writing, video recording (of yourself and others) and rewatching, and engaging other moving bodies. We know that many readers will not have access to the requisite tools, space, and time to complete such exercises in every reading of the book, so while we implore the dedicated readers to make time and space to experiment with these exercises, we have worked to create stand-alone text that explicates the physical, embodied knowledge that these exercises are aimed at transmitting. These exercises are the native format of the knowledge that this book presents, and being able to learn in this format will require practice. Perform the exercises, come back after some time, and try them again; film yourself and watch the playback; take notes; and use your body as a place for observation. Over time, you will perceive more from these exercises and thus be able to experience them with more nuance—a cyclic pair of reinforcing processes. As such, these exercises will not immediately impart physical wisdom, but trying them is a necessary step. Physical experiences will always be distinct from written text or derived equations, so we implore readers to take on these exercises with rigor and energy.

Chapter Road Map

Chapter 1 reviews prior literature that grapples with how to understand humans’ embodied experience and expression. We review the philosophy of meaning-making, as well as methods of measuring and describing movement. We draw on a broad set of fields ranging from philosophy, mathematics, the social sciences, physics, and biology, which we cannot fully cover in depth. Instead, our aim is to share important references that have shaped our thinking, with an emphasis on scholars who are considering an internal,

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first-person point of view, as they are likely to be less familiar to our primary audience of technology designers. We expect these readers to be more familiar with concepts traditionally presented in robotics textbooks, so such material is less developed in this book. Moreover, the concepts in LBMS have historically been underpinned more directly by this body of thinking than by technical designs for machines. This chapter is meant to broadly inform and point readers to deeper references on these complex topics.

Chapter 2 zooms in on movement studies, the particular body of knowledge that we employ here, broadly describing types of somatic practice, choreographic process, and notation. Chapter 3 then focuses most directly on the book's intellectual center, LBMS, presenting a vocabulary of terms dealing with the creative generation of movement design (the process more generally identified as "choreography") and the interpretation of movement experience (the practice more generally identified as "somatics"). That chapter ends with the introduction of embodied exercises, which provide an opportunity for crucial investigation outside the pages of this book.

Thus, part I begins broadly, reviewing the literature on meaning-making, and ends with the specific goal of this book: the introduction of a taxonomy that drives a notation scheme for describing movement. The organization of the next five chapters, forming part II, is created by five components used as lenses to analyze movement, including a component that has emerged from our work with machines: Body, Space, Time, Shape, and Effort. In each associated chapter, we look broadly, congealing around questions often used to describe these categories and bringing our broader experiences in dance and dance-making to bear on these topics. These chapters form the bulk of the reference material of this book, and each contains a section describing the application of that chapter's content to machines.

In chapter 4, we introduce the *Body* component and ask "*What* is moving?" answering with the role of the form or container of a moving body and the somatic, internal experience of movement. In chapter 5, we introduce the *Space* component and ask "*Where* is the movement?" articulating broad spatial categories that help organize the happenings of a moving body and begin to relate this action to the environment. In chapter 6, we introduce the *Time* component and ask "*When* is the movement happening?" explaining how rhythm and phrasing help human movers come to fairly precise notions about timing of movement. In chapter 7, we introduce the *Shape* component and ask "*For whom* is the movement?" delineating the

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types of connection—with self, with another, or with a group—that help name the spatial patterns of movement in its environment. In chapter 8, we introduce the *Effort* component and ask "*How* is the movement executed?" providing options for the texture and tonality of movement that help name the temporal pattern of movement in its environment. This chapter outlines and extends Rudolf Laban's famous Effort System, which explicates categories of motion quality. (There are already numerous endeavors in the emerging field of expressive robotics that have tried to incorporate this system in machine design, including our own attempts, but we don't think that any of these works are mature enough yet to be called a complete success.) It also introduces the "affinities" between each of the components of the system, which interact to bolster the richness of human motion.

Any coherent movement phenomenon of a body provides answers to these five questions (what, where, when, for whom, and how) and indeed many others, expressing something meaningful to an intelligent observer. The categories that comprise part II, therefore, offer a limited picture of movement that needs to be resolved with synthesis and integration inside of applications. To that end, part III of the book makes the work specific to applications in human-machine interaction and design. In particular, it introduces a guiding framework for seeing and notating bodily motion, with an emphasis on postural changes and gait (but also including gesture, facial expressions, and vocalization), as means for communication. Combined with this information-theoretic model, the taxonomy introduced in part II, and a notational scheme introduced in part III, part III answers the "*Why*?" question about movement, illustrating how humans make sense of movement in personal and individual ways—and thus how they make sense of machines.

In chapter 9, we analyze a variety of important applications with machines that have been—or could be—affected by this work. Further, we outline a process for engineers and designers, not only calling attention to how movement affects technology design, but pulling apart the process of observation, context, and prior experience and identifying how each affects how and what we see. The chapter also connects this analysis to examples of HRI research in this area.

With context and fodder from these application areas, chapter 10 delves into the complexity of notating movement, applying the symbology and principles from parts I and II in a series of examples that also highlight the relationship between a particular taxonomy and what can be observed (and

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thus notated), offering engaged readers more opportunities for practice. Finally, the conclusion of this book broadens our scope to consider numerous somatic and choreographic lenses from a collection of movement traditions and practices across the experiences of many bodies.

We end with a nod to the ongoing explorations in movement practice and theory that allow the kind of design process that has been used to produce pleasant physical spaces—like the Downtown Mall in Charlottesville, Virginia, where the perspectives in the prelude took place—and that will be crucial to creating harmonious environments that contain both natural and artificial movement for both humans and robots. Such facile design is enabled by systematic understanding of the medium of movement. We establish a particular approach that we are calling "the BESST System" as our primary tool, but we also offer glances toward other movement practices, including the design of movement-based algorithms, machines, and devices, as a key source of such knowledge. As humans that successfully navigate a wildly dynamic and complex planet, this knowledge is in all of us, and our book aims to write some of it down.

"Dancing, Happy Robots" (What This Book Is *Not* About)

Throughout this introduction, we have stressed the malleable, unfixed nature of movement and the meaning made through it. Consider the first version of the Nest Protect smoke detector, which was silenced by the wave of a hand. Its designers' intention was to create a system that could be easily turned off for errant cooking activities that annoyingly trigger smoke alarms, but because these designers had little training in how humans make meaning from postural and gestural shifts in movement, they failed to consider that waving arms can also, in the right context, indicate the need for help. This oversight led to the device's recall (Skybetter, 2016). A wave is an action that means different things in different contexts; moreover, a hand extending from side to side in an arcing, repetitive pattern is a movement that can be identified as many things: a wave, a wipe, a shoo, a stir. This is even true of language and stereotyped gestures like a "thumbs up" sign, which can be used rhetorically or sarcastically, drastically changing the meaning of a common symbol employed by some cultures in some time periods.

Words (and other symbols) change their meaning in new contexts and when spoken by particular speakers. Movement is the medium for all these

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symbols, which must be recognized, repeated, and understood on distinct bodies across distinct contexts. Thus, this book will not provide a lexicon[4] for *what movements mean*. We are passionate about this point. While it is possible to construct scientific experiments that measure similar responses to the same stimuli across a particular population, this is not the process of movement analysis, and it creates a quagmire for automation, which may be deployed as a diagnostic tool in medicine, surveillance, advertising, and finance. Already, tools in these spaces that attempt to automatically determine the meaning of human behavior (like the Nest Protect) have been identified as biased and faulty. Such effects are magnified for marginalized communities that are underrepresented in the design process, not well represented in data sets, and more vulnerable to the repercussions of misidentification.

Making a robot with motion that is meaningful to its users may have as much in common with the process of writing a best-selling novel as designing a structurally sound bridge. Dictionaries of languages, which are specific to time, place, and culture, include multiple meanings created, edited, and refined on an ongoing basis by human experts; experts of language debate the meaning of important texts for decades; and automated speech recognition is limited to low-stakes, simple applications in narrow contexts (e.g., automated call centers). This is the approach that we motivate in this book. Every movement of a machine must involve a painstaking degree of user and designer input, refinement, reconsideration, and adjustment from human experts—and must be tightly coupled to a particular user and use case.

We will briefly share research[5] that highlights how affective and valued judgments of movement, such as "happy" and "beautiful," break down across contexts. This does not mean that we cannot make artificial motion that is read by a large pool of human subjects within a particular experimental setup as "happy" or "sad"; indeed, we will also discuss research showing that such a feat is possible too. Instead, we aim to illuminate for readers that creating a successful piece of technology is much more similar to creating a work of art than they may realize—especially when that piece of technology moves. Instead of encoding meaning into motion, we impart the practice of considering *when*, *where*, and *for whom* a particular meaning may manifest. Moreover, these meanings need not be limited to topics of affect, mood, or emotion; sometimes a movement is just about scratching an itch.

This is counter to the approach of many research groups, including some of our own collaborators (e.g., Knight & Simmons, 2014; Zhou & Dragan,

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2018; Luo et al., 2020), and we hope for spirited academic debate to continue on this point. Such debate has lived within the RAD Lab, creating important research insights. For example, Umer's work on gait grew out of his ongoing insistence (despite resistance from Amy) that it would be an interesting domain. And a debate about the viability of labeling a motion pattern as "happy" inspired a series of studies that reveal the benefit of explicitly modeling context in predicting human labeling of motion style (Heimerdinger & LaViers, 2019).

Likewise, the ultimate end of this book is not to design "dancing robots." In fact, we hope that the book will broaden and complicate your notion of what "dance" and "robots" are. Although you can certainly look up formalized taxonomies of movement, like ballet and tai chi, that proffer certain steps as being part of a tradition, often with associated meaning, in this book, we use the field of dance as an intellectual pursuit, a form of research, not a categorization of movement. As such, there will not be a section of the book that lists movements that are dance and movements that are not (as we are most interested in the *field* of dance, a knowledge base that helps understand all movement, instead of the social *activity* of dancing).

We will not be specifying how to manufacture machines that do what humans do; rather, we hope to teach you why you think that machines, which are still vastly dissimilar from any human form, do anything vaguely similar to what you do at all. Namely, that is, *the dance is in you*, so you observe it with other entities. Likewise, this perspective and the detailed focus on sensing and feeling our human anatomy motivated in this book—which especially emphasizes the human spine and viscera, which are often overlooked in favor of the function of distal joints in robotics and biomechanics—put into question the notion of what constitutes a "humanoid." In fact, in some contexts, a well-designed expanding and contracting faceless orb may have more in common with human motion, as it captures an abstract notion of breath, than does a back-flipping humanoid.[6]

Moreover, we want to challenge the idea that a "step" is ever performed the same way, instead emphasizing the wide variety of shapes and sizes that bodies (both natural and artificial) come in and the unique experience and variability that seem to be inherent in human movement. The point of this book is to provide readers with a descriptive (rather than an evaluative) taxonomy with which to describe your inherently personal observations of movement. Such a conversation is especially important as we look toward

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creating systems that function correctly across populations in an inclusive manner. As two people with particular bodies authoring this book, the way that we see movement (and, likewise, the way our movement is seen) are not universal. Becoming aware of this individuality is an awakening that can be dealt with only by including anecdotal, first-person experience (often through qualitative and subjective methods).

This relationship between one's experience of moving and one's perception of it extends to our approach to defining machines. We do not spend much time differentiating among models to describe human movement (e.g., an algorithm that detects and labels distinct styles of human gait from motion-capture data) and models to execute complex movement phrases (e.g., a bipedal device that creates various styles of gait recognizable by humans). The former example concerns sensing and interpretation, and the latter example concerns actuation and generation. But these are two sides of the same coin: both will depend on how we define, construct, and deconstruct gait. We have to contend with that interdependence, especially in gross body movement like posture, gesture, or gait. Typically, we will discuss movement in the context of human bodies because that is the source of how we see patterns in movement, but we will do so with a taxonomy that is amenable to abstraction, and thus translation to artificial bodies.

An Introduction to the Bodies That Wrote This Book

On a rainy day in the fall of 2013, the two of us met over pastries at a coffee shop under the vague pretext of "this is someone you should know"—connected through mutual acquaintances who noticed two professionals for whom the daily movement practices of their youth had grown into professional obsessions with embodied research. Many young children engage in such practices daily or weekly through sports, dance, and recreation, but as two adults who thrived on dissecting movement into parts and synthesizing those parts as a primary mode of meaning-making, we stood out as kindred spirits in the small community of Charlottesville, Virginia. Upon meeting, we found other shared aspects of our experience: our training in ballet, contemporary dance, and yoga. Moreover, we share privileges: we are both petite, white, cisgendered, heterosexual, able-bodied married women with sufficient economic security to allow us to engage in work that often does not pay.

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We came into a deeper relationship when one of us (Amy) began studying with the other (Cat) at the Laban/Bartenieff Institute of Movement Studies (LIMS) to become a certified movement analyst. Cat was an affiliate faculty member and coordinator of movement analysis certification programs with the institute and has used the material in her work in dance (both in the classroom and in her artistic practice) for nearly four decades. Amy was just starting her own robotics lab at the University of Virginia—one that, from its outset, was designed to combine her experience in dance and engineering to create more expressive robotic systems. Movement studies was something that Amy had been leveraging during her doctoral studies, like a growing number of roboticists, searching for a way to study movement such that she could program machines to move in ways that could be salient for humans. The motivation for this emerging intersection of work is that such profiles will be a critical component of interactions between robots and humans as robots move into human-facing scenarios. Thus, completing the two-year modular training program, which Amy would soon begin in Cat's studio, was at the top of her agenda as a new professor.

The studio settings in which much of the field of movement studies has developed inform challenges in disseminating knowledge to academic communities and are inherited from the system's founders: Rudolf Laban (1879–1958), a choreographer and artist, and Irmgard Bartenieff (1900–1981), a dancer and physical therapist. Likewise, the practice of movement techniques heavily used in the performing arts, like those of F. Matthias Alexander (1869–1955), Martha Graham (1894–1991), Merce Cunningham (1919–2009), and William Forsythe (b. 1949), find the primary site of their transmission inside the studio—and theater—rather than in a book.

Laban's interest in movement came from a life in the arts, mysticism, and choreographic practice. He studied the movement of his dancers and worked to create a system for organizing and describing it. His most famous contribution is the invention of Labanotation, a system for movement notation that is still used today, including for the practice of copyrighting choreography. He is also well known for his creation of harmonic movement scales (analogous to musical scales in different keys), and his studies of factory workers during the Industrial Revolution (where he used his dance-inspired principles to improve the functional efficiency of their workday).

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Bartenieff's introduction to the system came first as a dancer and a student of Laban. She then developed a successful practice as a physical therapist, working with both polio patients and professional dancers. One of her key innovations was in developing exercises that helped both seemingly disparate groups improve their access to effective movement patterns. These bodily exercises came from a more sensorial, interior place than Laban's work in stagecraft and performance, and her most prominent contribution to the system was in growing the somatic, body-based aspect of the work.

The work of Laban and Bartenieff in developing theory occurred in parallel to a shift in the practice of Western dance. Traditional classical ballet tightly coupled itself to a rigid bodily vocabulary but was challenged in the twentieth century by expressive pioneers like Cunningham, Graham, Loie Fuller, Isadora Duncan, Katherine Dunham, Doris Humphrey, José Limón, Alvin Ailey, Yvonne Rainer, and, more recently, by Forsythe, Bill T. Jones, Twyla Tharp, Mark Morris, and Ohad Naharin. Their work formed modern, postmodern, and then contemporary dance, each of which came with their own forms of physical training and modes of expression. We, Amy and Cat, are products of that evolution, centered in these particular, Western ways of thinking about movement and using it to express oneself.

Like many other dance artists and teachers, Cat was drawn to the Laban and Bartenieff work in the 1980s as a way to formalize her practice in teaching dance to university students (she founded the dance program at Drew University around the same time) and in creating work with her professional dance company in New York (Offspring Dance Company), while also completing the Certification in Movement Analysis (CMA) program at LIMS in 1984. Amy was attracted to Laban's and Bartenieff's ideas as part of her research in the late 2000s (at Princeton University) and early 2010s (at Georgia Tech and Emory University). As many dance students do, Amy encountered them throughout her dance training, often informally, in classes designed around Laban's taxonomy of body actions or in warm-up routines incorporating Bartenieff's famous exercises. As a researcher, she studied their work from books and papers aimed at quantifying elements of it for application. After completing the CMA program at LIMS in 2016, her understanding of this work became rooted in her own unique physical experience, complicating what was an initially straightforward idea: translating movement to machines.

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Parallel to her studies in engineering, Amy bolstered years of dance training through exposure to physical, bodily rigor that had a new emphasis: description through systematic, symbolic notation. Although she had spent years in the studio—like many soon-to-be movement analysts—beginning as a young child, it was not until college that she was asked to critically reflect on dance as a practice and medium for communication. In graduate school, she participated in the Fieldwork program, hosted by the New York-based arts organization The Field, where artists use a particular, structured style of peer-to-peer feedback that eschews valued judgments for reflective descriptions to better help artists find their own desired expressions. Her training at LIMS further deepened these approaches to movement, providing her with new terminology to describe human movement and a more rigorous framework for examining the process of making meaning from it. The training also helped express intuitive ideas about movement into something that could be written and reasoned about with others in the process of developing new technology.

The Value of Personal, Bodily Experience

Although this book is one of the first to address the application of movement studies to machines, we are one of many to include an experiential perspective of movement in the design process. Designers of products from vegetable peelers to furniture, and environments from the interior of private homes to public parks, have also employed this approach. In fact, the outdoor promenade in Charlottesville, Virginia, where the personal perspectives in the prelude were written and our collaboration began, is a perfect example of a space shaped by the influence of a dancer's expertise.

The downtown mall was designed by the acclaimed landscape architect Lawrence Halprin, who also created Ghirardelli Square in San Francisco, in concert with a technique for observing movement developed with his wife, the renowned dance artist Anna Halprin (Worth & Poynor, 2018). This process, which included the creation of movement scores (Halprin, 1975) and participation from many community stakeholders (Halprin, 2014), resulted in many distinctive features of this mall (Hirsch, 2011). For example, rather than dotting the space in linear, predictable lines, irregularly placed trees cause walkers to dodge and weave along the mall, encouraging more meandering pathways of travel for occupants of the space. In the context of this

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promenade, such patterns of motion may be associated with relaxation and recuperation, whereas linear, direct pathways might have been associated with expediency and exertion. It creates a pleasant and distinctive space that offers views of the Blue Ridge Mountains and facilitates successful businesses, public events, and community-building in the downtown area.

Such a process is not so different from the one that we encourage in this book, paying explicit attention to experience, movement, and human perception of them. If Lawrence Halprin merely noted the kind of experience he wanted to create and not distinct pathways for walking in the space, or if he had merely written the options of the distinct pathways for occupants and not what these two choices might mean in the context of a pedestrian promenade, he would not have ended up connecting mechanisms of movement to the experience of particular architectural features, likely failing to make the same successful design. Collaboration with dance artist Anna Halprin and the use of movement scores (notation) facilitated this needed connection.

Technology designers are increasingly thinking about physical interaction between humans and artificial agents in shared spaces. At the 2019 US National Robotics Roadmapping Workshop in Chicago, Illinois, employees from Amazon and FedEx described their challenges with warehouse robots. An anecdote from one employee, who rearranged her path of travel to avoid the autonomous robots because she feared them, saying that she could never tell what they would do next, paints a vivid picture. Even while the safety systems on these devices ensured that the machines did not pose a real physical threat, workers faced confusing path-planning choices of their own when faced with opaque, monolithic devices for which designers did not create conventions in observable changes to help employees understand the internal state of those devices. These particular robotic challenges are choreographic and require nuanced observation of humans' somatic experience to resolve.

A key difficulty in design problems like the ones formulated by the Halprins, Amazon, and FedEx is the ubiquity of movement. Just like air, or the blue of the sky, or unconscious bias, movement, through its ever-presence, becomes hard to notice—and often even harder to define. What constitutes a "movement"? How is it measured?

In this book, we will posit that the answers to these questions are not yet known, but what is clear is that the answers comprise a perceptual

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phenomenon. All matter is constantly in motion; it is the salient moments where a "movement," or several "movements," are *consciously perceived* that interest us in this book. Somatic strategies—the application and development of somatic practices for producing and observing one's own bodily movement—help illuminate our personal experience of movement. Choreographic technologies—tools that emerge from the practice of making and sharing dances—provide design methods that align with the perception of human audiences. Notational abstractions—specific systems for representing movement—connect these perspectives in forcing concrete observation and creating opportunities for reinterpretation and translation. And so, just as we were able to sing before we could notate music and tell stories before we could write books, the best way to formalize the knowledge that comes from embodiment is to look within, move, and dance.

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I Making Meaning through Movement

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1 Noticing Movement: Meaning, Measurement, and Experience

This chapter provides a wide overview of meaning-making and movement. **Movement studies,** including **movement analysis,** discussed in chapter 2, provide an intellectual landscape with which to understand how humans construct (and likewise deconstruct) movement. In chapter 1, we take a broader focus, reviewing many disparate fields to better situate chapter 2: philosophy helps us understand how movement translates into meaning; engineering provides quantitative models and empirical measurements of bodily movement; and phenomenology gives us a framework for understanding how the felt experience of the body relates to movement perception. Crucially, these fields create a picture of how humans perceive themselves in their own observations about the world. This is not so different from machines: the same movement model used to generate robotic behavior through actuation can also be used to interpret the behavior of counterparts through sensing. For humans, since our perception depends on our own unique bodily experience, the meaning that we make from our sensations is unique, personal, cultural, contextual, and tied to the human form, casting anthropomorphism—and any sense of shared meaning with a foreign body—as a property of the observer as much as (if not more than) the observed.

1.1 Meaning-making

The personal process of constructing salience from elements in our environment

Phenomenology brings an intellectual framework to conscious experience. Maurice Merleau-Ponty studied experience and perception in the process of making meaning. He centered the subjective, qualitative nature inherent to

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human attention and information processing after noting how his ability to perceive (or overlook) detailed features about an event or object changed the meanings of these observations. For example, Merleau-Ponty (1945, p. 5) contended that the meaning of a red carpet changes if it is noted that it is a thick, wooly carpet as opposed to a smooth carpet with low pile. His work grapples with how to disentangle ourselves from the world in which we are constantly interpreting our sensations—making meaning—in order to understand the very thing that we are trying to perceive. In other words, our subjective experience is embedded in everything we think we understand; we are constantly imperfectly perceiving, and in doing so, changing both our access to the world and our experience of it.

We see this in the body very literally: an exercise in finding a centered, neutral posture will often engage participants in a bouncing and shifting of their mass to feel different distributions of weight (say, in the feet). Each bounce and shift changes what the mover is sensing and what the body's internal state is; thus, when returning to a previous posture, that posture feels different. Coming to a resolution about where one is centered and neutral in posture is then an ever-shifting compromise and estimation, changing moment to moment and day to day. On a day when the feet are cold and stiff, "center" may feel like a narrow regime of tenuous balance, whereas on a day when the feet are warm and pliable, "center" may feel like a wide space of play and activity because the bandwidth of perception and action in the feet is greater when they are enlivened and "awake." You can experience this by grabbing one foot and giving it a thorough massage, heating your foot with the action of your hands; then try balancing on that foot and the other, unmassaged foot in turn.

The interconnection with training and perception is also observed in scientific studies of human perception. For example, olfaction and the human ability to evaluate and describe olfactory sensations are found to differ distinctly across cultures. In a study comparing Jahai hunter-gatherers from the Malay Peninsula and Dutch participants from the Netherlands, Majid et al. (2018) discovered that the Jahai are more adept in expressing their experience of odors in language. The researchers noted faster response times and the use of more dedicated, abstract language in Jahai participants compared to their Dutch counterparts, confirming previous studies that showed that other hunter-gatherer cultures are better at describing odors (Majid & Kruspe, 2018). Just as wine sommeliers distinguish among subtle variations in wines,

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even noting the differences in taste between vintages, this research suggests more broadly that prior training affects what we can externalize about our experience and that language is a nonunique abstraction that can be better or worse at describing our sensations. We experience similarities in working with movement: the dedicated taxonomy presented in part II equips movement analysts to more easily, accurately, and rapidly describe movement.

The philosopher Maxine Sheets-Johnstone (2011, p. 438) writes that "the primacy of movement" makes it hard to examine directly, and language is "post-kinetic," or a behavior that is a result of our movement. Language is movement, and many other things that are not language are also movement. Thus, it can be confounding to compare meaning-making with written language to meaning-making with movement. The notion of a movement dictionary relies on limited contexts and formalizations of movement. For example, Raindel et al. (2021) study movement associated with "dramatic action and emotion" in order to develop such a lexicon to link body postures and their meanings, finding that descriptive verbs were stronger labels than emotional states.

Emotion is one way that we assign meaning to movement, and trained actors use many cultural conventions in communicating such states through their movement (Goodman, 1976). But it is easy to imagine moments where the same posture takes on entirely different meanings: a clenched fist thrust into the air can indicate anger, victory, or having just successfully squashed a mosquito. Likewise, the notion of what a word "means" (in the sense of the elements contained in that word's entry in a dictionary) is distinct from what an actual, situated utterance of a word *means*. As such, this book will not codify stereotyped expressive actions—a thumbs-up, for example—and list their meanings; it is instead concerned with the embodied process of coming to meaning with foreign bodies.

In studying language, linguists deal with meaning through the notion of symbols, and the process of symbolic representation is often linked to language and language formation by psychologists who study language acquisition and development. Scholars Alex Gillespie and Tania Zittoun (2013) heighten the role of the body and its movement (instead of emphasizing language) in meaning-making. They use the example of a family with an infant and a toddler to describe how symbols form, explaining that when the baby cries, the older sibling does not know the meaning of this bodily action or what will come from employing it. But the older sibling observes

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the reaction of the parents to the baby's cries and learns to associate meaning with it. The older sibling sees the parents jumping to give attention and care to the newborn—and is even herself drawn into the act, creating a relationship between the baby and the rest of the family. In fact, the next time the older sibling cries, she does so with this new knowledge that crying will elicit a caregiving response from her parents. This example highlights how meaning is created and reinforced through lived experience that is specific to one individual.

Consider a similar example with technology: computer developers trying out a new device may poke at a button that they do not know the purpose of, developing a sense of meaning through their observations of the device's reaction, whereas lay users might be socially conditioned away from pressing unfamiliar buttons. Gillespie and Zittoun (2013, p. 528) assert this idea of meaning's mutability and contextual nature explicitly:

> Symbols arise at the points where internal, personal, embodied and emotional experiences meet an external social or semiotic structure. Meaning is where personal sense and shared meaning meet. The personal sense comes from our own unique embodied trajectories. Although our experiences are socially determined, that determination works on our own individual bodies, stirring individual emotions, creating personal sense. This personal sense finds expression, or resonance, in social settings and semiotic structures. Equally, these institutional settings and semiotic structures need to find the relevant personal sense, the relevant past experiences and embodied memories in their participants, to function.

This work extends prior semiotic theory on how meaning is made through symbols and how symbols are acquired through *context* (Werner and Kaplan, 1984). It is possible to see this idea in terms of how art becomes meaningful as well, noting especially that the meaning of any particular piece of art requires contextual cues and cultural context; changes over time; differs for each viewer; and may wildly differ from the intention of the artist. For example, one could fall in love with a painting and buy it in their twenties and ten years later—after accruing new lived experience and shifts in societal and cultural norms—see the painting in a new light, maybe even feeling the need to get rid of it.

The phenomenon of shifting meaning motivated postmodern philosophers and artists as well. A philosophy developed by Jacques Derrida (1974), *deconstruction*, purports that a text (or work of art) cannot have a fixed meaning, and indeed whatever meaning is made also changes over

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time. This speaks to our understanding of meaning-making as contextual, based on prior experience, personal, and unique, yet able to be *constructed* by recognizing this mutability and making one's own choices. We invite the reader to consider movement, the body, and the practice of embodiment as a process similar to construction and deconstruction that will support and inform design and making meaning with machines in motion (through exercises introduced in chapter 3 and used throughout part II). You have to move your body to understand what you perceive, but this movement (this observation) also changes what you perceive, as seen in the exercise for finding centered posture described at the beginning of this section.

Because meaning is individual and unique to each of us, each observer of the same moment can arrive at a wholly different meaning. This is most simply because each of us is a unique body brought to that moment by a unique series of movements and making sense of it through the movements available to us. These prior movements form every individual's experience, comprising training, culture, personality, and other characteristics, as well as a unique physical form created through innate biological composition and a series of interactions with the environment during development. The meaning that any individual perceives in the moment is a direct function of that prior corpus of exposure and bodily experience.

1.2 Movement as Quantitative, Objective Events

Measuring movement events, often with technology

If meaning comes from movement, what is movement? Can we measure it? And, if so, what are the units of measure? Can two distinct bodies, perhaps with different physical dimensions, perform the same movement? How do we record a movement event? And what do such records leave out? What does it mean to perform a movement again? What is *not* a movement? In the context of considering meaning-making as a process achieved through motion that was set up in section 1.1, questions like these complicate the notion of measuring and recording movement events and reveal the subjectivity inherent to such an act.

1.2.1 Quantitative Movement Records

Recording movement has been a subject of interest since the first cave paintings, in which early humans scrawled static snapshots of themselves

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and animals performing activities in their environment. And while movement must be inferred in these renderings, the drawings do convey a sense of the dynamic actions and interactions with the environment. During the Renaissance, artists developed a new understanding of the relationship between a two-dimensional canvas and the three-dimensional world. Thus, although they remain inherently subjective renderings that reflect a particular artist's experience, drawings use different innovations for capturing the detail of such an interaction with both concrete and abstract visual representations of the world (Dickerman & Affron, 2012).

Early experiments at quantifying human movement as objective events often employed photography, as re-created in figure 1.1, using long exposures to illuminate the pathways of various body parts, particularly during work. In the early twentieth century, Nikolai Bernstein (1926/1967) studied movement during manual labor, postulating that acts like the one shown at left in figure 1.1 are composed of many smaller movements. He thought that understanding these smaller movements could optimize movement's efficiency during manual labor. Frank and Lillian Gilbreth's (1919) applied motion studies used similar techniques around the same time as Bernstein's original work, although their approach—attaching lighted elements to human appendages—seems to emphasize more variability and chaos in the revealed motion than Bernstein's neat cyclograms. Eventually, Eadweard Muybridge's (1887) studies taking rapid-fire sets of sequential images of horse gaits would initiate the development of motion pictures and reveal

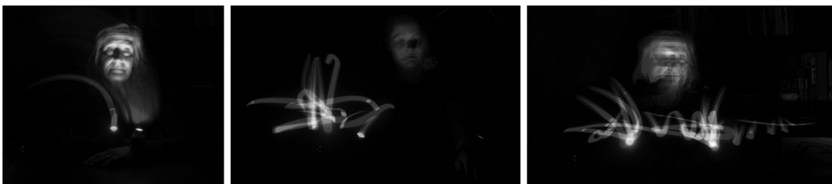

Figure 1.1
Author recreation of early measurements of human behavior offering an externalized view of movement. Left (Cat): Similar to Bernstein's (1926) cyclograms, this two-second exposure shows the motion of one arm in a single action, revealing the smooth coordination of human motion. Center and right: Similar to Gilbreth and Gilbreth's (1919) motion studies, these eight-second exposures show the motion of a longer phrase, revealing the chaotic variability of human motion. The image in the center (Amy) shows one arm, and the image at the right (Cat) shows the action of two arms.

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much about natural motion (specifically, he was interested in whether all four hooves of the horse left the ground at the same time), as discussed further in section 10.1 of chapter 10.

Video opened up new realms for movement analysis, as well as archival records of movement, and probably facilitated a shift from experiencing movement as only a fleeting dynamic process that is felt inside the body to one that can be captured in another medium, documented, and shared. Eventually, the quest for richer external data sets of movement and advances in pattern detection algorithms led to three-dimensional capture techniques. Today, researchers have access to both optical motion-capture systems that detect reflective markers or other vision-based landmarks, as well as accelerometer-based active systems that detect the physical movement of limbs. Software can then approximate rigid skeletal models to explain those sensor readings as postures with associated time stamps. Typically, for full-body motion studies, researchers use skeletons with around 50 degrees of freedom—points of movement (or "joints") between rigid bodies (or "bones")—to model human motion, but filmmakers often use more detailed models to capture the nuanced facial and muscular expressions of movement actors and translate this action into animated characters through a labor-intensive process.

These developments reflect a massive progression of machinery and technology to detect human motion, which we do not aim to detail here. However, it is instructive to consider an example of the kind of motion record that motion-capture technologies extract. Figure 1.2 shows an example of a three-dimensional, room-sized capture space, and figure 10.2 in chapter 10 outlines one of the original data formats that emerged for documenting motion capture data. This is given to provide the reader with a mental image of motion capture, which is often used as a form of ground truth for human motion and is even leveraged in dance performances sometimes (Dils, 2002). This data captures quite a lot of individualism and recognizability. It harkens to motion studies with points of light that occlude most of the human form, which is nonetheless surprisingly recognizable to subjects (Vanrie & Verfaillie, 2004), including when using high-level, emotive labels (Clarke et al., 2005). We see a similar phenomenon in motion-capture data: it can include the distal edges of a body's motion while typically not detecting the motion of the fleshy torso, face, and musculature; nevertheless, the systems record recognizable motion.

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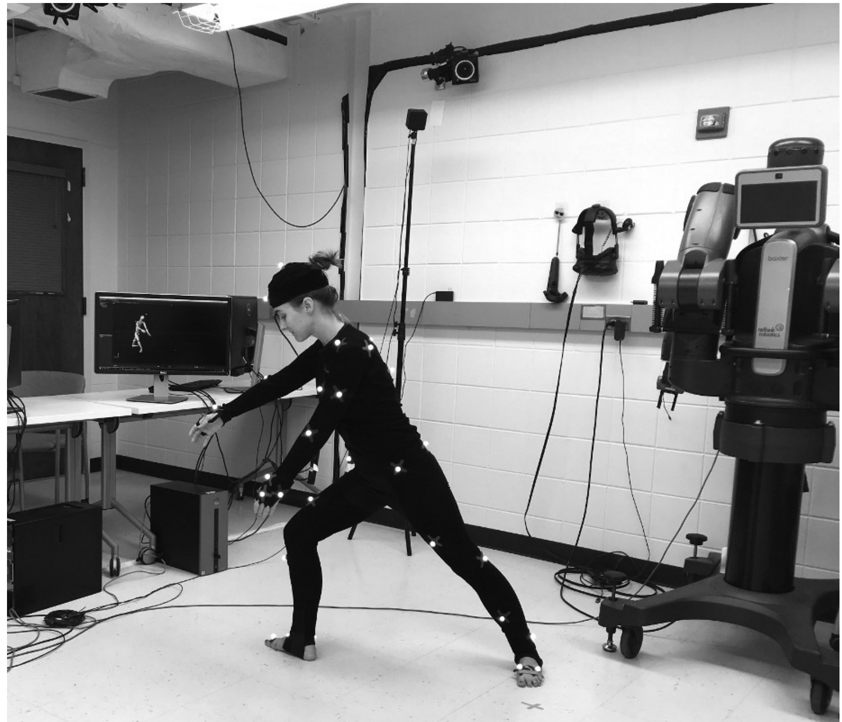

Figure 1.2
Motion capture with passive, reflective markers in the RAD Lab at the University of Illinois Urbana-Champaign. The computer screen displays the three-dimensional model of movement extracted by specialized software from data collected by the overhead cameras that record infrared reflections from the wearable markers on the subject (Amy). Even this motion model lacks many essential details of human movement. An example of a resulting data structure is shown in figure 10.2 in chapter 10.

We are especially interested in noting the shift that machines have caused in how we study and conceive of the process of moving. Being able to see one's own movement *outside* the containers of our bodies is a marked intellectual and experiential shift. In some ways, it afforded researchers in labs like that of the Gilbreths the kind of perspective that a rehearsal director might have with a dance company: watching bodies from an external standpoint for analysis. But it also goes deeper than that—first, by offering options such as rewind, which allow movement phenomena to be viewed in great detail; and second, by suggesting that movement is a measurable,

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objective event. In another sense, however, these recording techniques may be seen simply as an extension of cave drawings, still relying on the subjective perspective of the operator.

1.2.2 Trajectory-Based Modeling

Early measurements drove the development of mathematical models designed to capture and predict how humans moved. In most cases of motion capture, energetic measures of force such as acceleration, velocity, and displacement are employed, which focus specifically on distal bodily limbs. This is evident even in the first studies shown in figure 1.1, where Bernstein was working to optimize human labor under funding from the Soviet Union, establishing a trend that continued in subsequent research, such as Flash and Hogan's (1985) seminal study. Measuring the trajectory of human arm movements, they postulated a quantitative model purporting that humans were selecting minimum jerk pathways, or pathways that minimized changes in acceleration. Like Bernstein, Flash and Hogan used optimization to explain their observations and measurements of the distal joints of the human form in motion.

Trajectory-based metrics are often the basis for comparisons between robots and humans, as well as forming the architecture for *producing* robot motion. Thus, it should perhaps come as little surprise that robots have outpaced human counterparts in the range of magnitudes of acceleration, velocity, and displacement that can be achieved on these platforms. Moreover, robots excel at repetition and repeatability of action, something that Bernstein was also very interested in: he wanted workers who could strike a hammer evenly and repeatedly. A similar idea of ideal workers was used in Karel Čapek's play *Rossum's Universal Robots* (1923). The Czech playwright imagined workers that did not get distracted or need to take breaks, coining the term "robot."

What robots *still* do not do well, however, is create complex patterns that solve tasks or express meanings in dynamic environments. This kind of behavior is common in humans and has been studied extensively. For example, Del Vecchio et al. (2003) examined humans drawing simple figures in a computer program (Microsoft Paint) where users drew lines using a handheld mouse. In their setup, the researchers monitored the resultant actions of the subjects—how the cursor evolved on the screen—and worked to classify the types of drawing tasks that emerged over time. Using

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second-order ordinary differential equations, which captured the patterns of acceleration and velocity in the resulting lines deposited on screen by their human subjects, the researchers identified distinctions like "pickups," when subjects stopped drawing to move to another area on the screen, as well as "straight" and "curved" lines, distinguishing when subjects drew the two line styles. Related and follow-on work has explored this idea in similar ways as Del Vecchio et al. (2003): through the notion of *movemes* (Bregler, 1997) or *movement primitives* (Fanti, 2008). Further discussion of using motion primitives, particularly in the context of robotics and human-robot interactions, appears in chapter 9.

Studying movement in humans by fitting empirical models to external measurement is one way to try to understand the categories of our actions, and subsequently build models for robotic systems. However, we could also imagine abstractions that are not quantitative and objective, but instead are qualitative and subjective. Such a categorization—one that centers on the physical experience of the body—is how pitches came to take a central role in the notation of music, which we will discuss further in chapter 2. However, the quantitative structure of these ideas (i.e., frequencies corresponding to each note) was figured out only many years later.

1.2.3 Informatic-Based Modeling

Another way to look at movement is through the lens of *entropic* measures, a way of modeling that attempts to consider how much information movement contains. Ofli et al. (2014) attempted to parameterize joint angles that are "most informative" using statistical notions; the team used the fact that joint angles with more variance in a given activity are more informative than others, which led to improvements in human activity recognition. Berrueta et al. (2018) similarly approached the topic through the lens of functional tasks. In line with a notion of dynamical movement primitives used in Del Vecchio et al. (2003), this team considered the relative entropy between two constructions of a task, leading to an assistive device that better aids humans in physical collaboration.

At the same time, research influenced by our collaboration has suggested that all movements, in the right context, can be equally informative (LaViers, 2019a). This approach creates instead an information-theoretic measure of distinct **movement platforms.** In this model, different platforms are more or less expressive based on their morphologies (because larger or

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smaller numbers of postural shapes are available to each combination of hardware and software). By counting the number of possible postures based on the physical characteristics of the robot design, looking at the range and resolution of its actuation and sensing systems, this work assigns a number of *bits*, modeling the capacity of each platform as an information source (a concept discussed further in chapters 7 and 9).

In addition to objective measures of information content, researchers have examined subjective measures. Famously, Heider and Simmel's (1944) work with simple abstract shapes (such as triangles, squares, and circles) moving around on a blank surface showed that human subjects can read consistent and similar narratives from the movements of foreign bodies. Reeves and Nass (1996) proposed the "media equation" to describe how people across a wide variety of experiments that they conducted in the 1990s treated artificial representations as real-world entities (e.g., thinking that popcorn shown on a television screen would fall out if the set were rotated upside down and exhibiting politeness toward computers). Similar results have been produced more recently through direct surveys of human observants; for instance, in Darling et al. (2015), the subjects were less likely to be willing to smash robots for which they demonstrated empathy, which was especially heightened through shared narratives. Gielniak et al. (2011) showed the benefit in human perception of robot motion when random noise (highly entropic movement) is added to the motion, causing human viewers to imitate the action more easily. We say that this kind of research looks through the lens of *expression* rather than *function*,[1] as it explicitly considers human perception of moving bodies.

1.2.4 Language-Based Modeling

Language is a key part of culture and communication, and movement is the medium that allows each body to form symbols from this shared corpus through vocalization (and written word). Thus, it is not intellectually rigorous to say that movement is a language; rather, movement subsumes language (Sheets-Johnstone, 2011). In fact, all language is created through bodily movement, both languages that utilize vocalization (e.g., spoken English) and those that do not (e.g., American Sign Language). This is one reason why the concept of "body language" is misleading. Researchers dividing a human subject's posture and gesture from facial expression showed that "body cues" are better than facial expressions at predicting how

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a person's movement will be understood, in terms of positive or negative valence of emotion, by a human observer (Aviezer et al., 2012). The system for movement analysis presented in this book will also focus on gross bodily movement, but the theory driving it, like that of Sheets-Johnstone (2011), presumes that body movement is a broad activity that includes vocalization, facial expression, postural shifts, patterns in breathing, and other elements. Moreover, we will emphasize the crucial role of context and the environment in understanding the varieties of possible meanings in bodily motion, especially when looking beyond the relatively narrow set of movement behavior that produces verbal or written language or facial expression.

Nevertheless, prior work bridging movement studies and quantitative modeling has used transition systems like those that describe the structure of languages (both natural and computer programming languages), as shown in figure 1.3, to model artificial and natural motion. Modeling the behavior of actors portraying a sentry or guard, Gillies (2009) chopped up bits of motion-capture data and described its structure in a finite state machine, which could be used to create novel sequences in the same role. LaViers and Egerstedt (2011) used a similar structure to explain how ballet barre exercises, which are relatively short actions that are thought of as

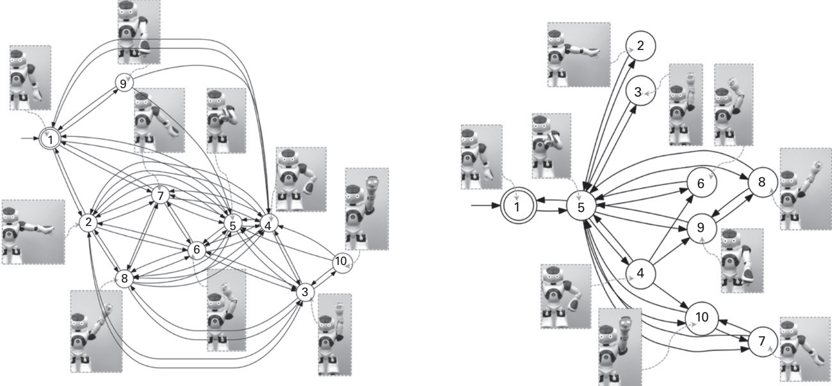

Figure 1.3
Using finite state machines to represent movement. Each state (numbered circles) corresponds to a body pose; each transition (arrows) indicates the possibility of moving between such poses. The structure on the left describes a "disco" style of motion, while the structure on the right describes a "cheerleading" style of motion. However, the trajectory between postures is not specified. From LaViers (2013).

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single movements, describe longer, more fluent phrases of ballet technique, proposing a model of motion that captured only sequences of key poses, not fluid trajectories of continuous action.

Such formulations do a good job of discretizing base movement behavior and generating variations—or styles—of it through recombination. More recent work has explored trajectory-based formulations for capturing continuous aspects of style and generating varieties of motion through optimization frameworks (see LaViers & Egerstedt, 2012; Zhou & Dragan, 2018). Variations in movement execution, in both spoken language and bodily movement, create the capacity for differentiation and communication (LaViers, 2019a).

1.2.5 Subjective Validation of Events

Del Vecchio et al. (2003)'s work with drawing tasks, described in section 1.2.2, highlights an important idea: classification and segmentation go hand in hand. With a different set of template actions, the researchers would have chopped up the subjects' motion at different points in time, creating a different set of movements. Something *feels* "right" about their resultant classification, but it can be difficult to objectively justify why. For example, a trivial classification and segmentation of the activity would be "drawing" and "not drawing," lumping all of the observed activities into one type of task. Or perhaps we divide the "circle" line style into smaller parts or quadrants: north-to-east arcs, east-to-south arcs, south-to-west arcs, and west-to-north arcs. This labeling also explains the data accurately. The possibilities are truly endless; thus, subjectivity is inherent in the evaluation of their work.

Consequently, we need to address in the remainder of this chapter the issue of how subjectivity comes into play when explaining movement and meaning. For example, the model of minimum jerk proposed by Flash and Hogan (1985) has broken down across a wider variety of activities and human subjects. The classifications of Del Vechicco et al. (2003) were acceptably presented, but there is little quantitative justification for why they would be (and it is easy to propose additional models of activity that perform just as well objectively). Moreover, the information content of movement also varies based on context (in some contexts, a given body action is salient; in others, it is not). In other words, human perception plays a role in forming and validating these models, measurements, and records that is unaccounted for in our discussion so far.

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There is much about movement, such as the feeling of viscera bouncing along as we jog, that is not captured by external measurement, so these measurements may have derailed our ability to understand how we experience movement, constructing and deconstructing meaning through our actions and perceptions. Moreover, the notion that video-based records capture movement is imbued with an ableist bias that privileges the *viewing* of motion. In this book, we want to explore movement from a broader perspective, leveraging all of our possible sensing modalities. Thus, we will reexamine the question "What is movement?" and, in doing so, shift from external measurement to internal experience.

1.3 Movement as a Qualitative, Subjective Experience

Describing movement experiences, often with personal reflections

The attempts to define and measure movement quantitatively and objectively presented so far have ended with a wide range of models with a large degree of subjectivity used in validating them. When is a functional task done *well*? When is an expressive action *salient*? The answers to these questions depend on the perspective of the observer and the context of the measurement. With this in mind, let us revisit the question of "what is movement?"

- <u>move·ment</u>: /ˈmo͞ovmənt/ noun
  - an act of *changing* physical location or position or of having this *changed*.
- <u>mo·tion</u>: /ˈmōSH(ə)n/ noun
  - the action or process of **moving** or being **moved**.
- <u>mo·tion</u>: /ˈmōSH(ə)n/ verb
  - direct or command (someone) with a **movement** of the hand or head.
- <u>move</u>: /mo͞ov/ verb
  - go in a specified direction or manner; *change* position.
  - *influence* or prompt (someone) to do something.
- <u>mov·ing</u>: /ˈmo͞oviNG/ adjective
  - in **motion**.
  - producing strong *emotion*, especially sadness or sympathy.

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These definitions[2] have us chasing our tail, so to speak, as many are defined in terms of each other (see the bolded elements of the definitions in the list). What is left (see the italicized key words in the list) amounts to descriptions of change, emotion, and influence. This mirrors an idea that is often quoted in the movement studies community but can feel like an anemic truism: "Movement is change." In science and engineering, many variables change—some that seem to produce movement and some that do not. For example, changing concentrations in a chemical reaction would not prompt descriptions of motion, and certainly not of salient gestures, which is often how the term "movement" is used when describing the human body.

Many things that are not the human body also undergo movement, such as automobiles, steel I-beams, and robotic manipulators. In these cases, where relatively rigid bodies are undergoing transformations in three-dimensional space, we can more easily specify concrete ideas of movement (and stillness): change in posture, change in velocity, change in acceleration, and so on. Moreover, given our understanding of planetary science, quantum physics, and human physiology, we—and everything that we can experience—are always moving. Planets and galaxies rotate and revolve; molecules vibrate to form matter; and living organisms constantly pump blood, move chemicals, digest, respirate, and use tiny movements called "saccades" to observe the world around them.

Certainly, in human bodies, "stillness" is simply an abstraction—or a description of our experience. In this book, we are not concerned with the movement of planets or molecules or diffusion in human cells. Instead, we are curious about moments of movement that are perceived by humans, occurring at particular temporal and spatial scales (not too quick or small or slow or big to perceive), that would be described by an observer as a "movement" or a "series of movements." In this context, we contend that "movement," like "stillness," is not an empirically measurable quantity, but rather a description of our experience. In other words, **movement** is *perceived* change, which frames the process of understanding movement as a choreographic challenge.

Many notable dance scholars have grappled with how choreography, dance, and performance come to have meaning for both performer and viewer, drawing on various philosophical positions, as well as lived practice. In *Reading Dancing: Bodies and Subjects in Contemporary American Dance*, Susan

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Foster (1986) examines the various ways that choreography (and movement) come to have meaning through differing contexts, intentions, representations, and cultural norms. Many of her subsequent works continue this critical examination of understanding corporeality (see Foster, 2002, 2010). Sally Banes (2011), a historian and theorist of contemporary dance, writes extensively about postmodern dance in 1960s and 1970s America, highlighting active collaboration across disciplines and the shift in performance attitudes that changed how the choreography of this era resonated with audiences.

Other scholars writing about philosophical concerns, processes of making dances, cultural contexts, and choreographic relationships with technology also emphasize the personal and contextual nature of understanding movement (e.g., see Butterworth & Wildschut, 2009). Working with digital technology in performance, Susan Kozel (2007) emphasizes the role of technology in human experience as a way to understand bodily movement, using methodologies developed through a vigorous practice using machines in performance to delve into human experience with extant technologies, reframing this relationship through the lens of performance and phenomenology. In doing so, she casts a wide net around who and what might be receptive bodies for affect and performance, addressing future-looking notions of self through our relationship with machines.

These writings also represent a philosophical shift that runs counter to the idea of measurement. Nicolás Salazar Sutil (2015, p. 237) works to resolve the quantitative, objective models of movement used in machines with the qualitative, subjective expression of movement in humans in his treatise on movement representation, writing that “we move in order to know our inner selves from the outside.” Kozel (2007, p. 269) expands the definition of a body in describing her lived experience, asserting that “my data is not radically discontinuous from myself.” While digital records of movement measurement (or data) have facilitated enormous insights about the body as viewed through an external lens, scholars like Sheets-Johnstone, Kozel, and Sutil recenter the experience *from within the body* in their attempts to understand it.

Despite the focus on connecting inside to outside that is described here, this book does not explicitly deal with affect, and the taxonomy presented does not use affective terms. Rather than presenting an extension of affect theory (e.g., Russell, 1980), we encourage the development of the associated images and feelings personal to each mover. Movement can be about

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emotion (Shafir et al., 2016), but our inner (and outer) experiences are not always laden with affect—and, even more, we often work to hide our feelings through choreographic choices in movement.

This shift prepares us to accept some anecdotes presented in chapter 2 that highlight how much of the material in this book was not learned by reading a book—but instead was developed by moving a body. This bolsters a notion of **artificial embodiment** in machines, a description of physical capabilities for machines that are complementary to, and inspired by, human (natural) embodiment. This term uses the modifier "artificial" in the same way that it is used in the term "artificial intelligence," and it encourages the idea that the materiality of external movement in the human body has dimensions, textures, and capacities that are distinct from machines. A better appreciation for the expansiveness of the human experience of movement may better guide investment in machine development as well, avoiding underestimates of technology readiness. For example, the development of self-driving cars has not played out as expected, with many companies failing to deliver on full autonomy as promised (Mims, 2021). Thus, there are a number of objective impacts of experiential analysis.

1.4 Kinesthetic Attunement through the Act of Recording

Discerning new aspects of movement through informal notation

Most of the scholars mentioned in this chapter are interested in understanding human experience, which they approach through a wide variety of intellectual frameworks ranging from philosophy to experimental methods. But what does Kozel mean when she describes intercorporeality between bodies? And what, exactly, is the bodily movement that Sheetz-Johnstone refers to, which exists before language, before we write down ideas? This is a physical, lived practice in the body, which we must find a way to access through the pages of this text. A concept that may help is something called **kinesthetic attunement.** This term is used in multiple communities of studio-based dance practice, but it shows up occasionally in published academic writings, particularly in the context of dance (Gray, 2015), therapy (Samaritter & Payne, 2017), and especially Dance/Movement Therapy (DMT) (Young, 2017).

We can choose to come into a deeper noticing of the movement of ourselves and others through kinesthetic attunement. In this process, we take the

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movement of an observed body into our own. It can be as simple as mimicking someone else's gait (an exercise that we invite the reader to try at the end of chapter 3) or as elaborate as rewatching the same piece of choreography over and over in order to learn each step and imitate the dancer's style with high fidelity through repetition and rehearsal. In both acts, we learn something about how we move, how another body moves, and how we perceive that movement—three phenomena that are fundamentally interlinked.

The act of recording our observations creates engagement that requires closer scrutiny, analysis, selection, and refinement of our experience. Activities like writing, drawing, painting, photographing, or filming our experience help save elements from the current moment to revisit them at another time and place—and even by another body. We can even view this practice of recording as a type of embodied, or physical, exercise. Not only does the mover have to engage in movement to record (as a finger depresses a camera shutter or as a hand holding a pen moves across the page, say), but also the recording becomes a basis of reflection.

We record our impressions of movement every time we take a photograph. Watching the subject in motion, we time when to capture the image based on their actions (often, this is as simple as waiting for the subject to become still with a smile, but sometimes it is more free-form than this convention). In this case, many of the choices made in capturing the impression of the moment are functions of the device's inner workings: the array of RGB (red, green, blue) values created by a digital camera is set by the device makers; the reflection of light on the device's sensors establishes what gets recorded into this format. On the other hand, Chapter 10 will introduce a movement notation system. However, we do not need complex technology or formalism to begin to translate the patterns we notice in movement to an archival format. A useful inroad is to record impressions in less structured formats, allowing us to discover more about the process of choice-making required in documenting our experience of movement.

For example, by using a pen and paper, we can watch a movement phenomenon and attempt to record what we see in real time. Forgoing any attempts to capture the details of the environment (i.e., features of the space where the movement happens) or the mover (i.e., height, clothing, or age), we can allow ourselves to focus on the changes in the scene, which can be roughly sketched through an ordinary writing implement. The examples in figure 1.4 show the results of such a process. These free-form sketches do not reveal any identifiable details about the observed event, and yet

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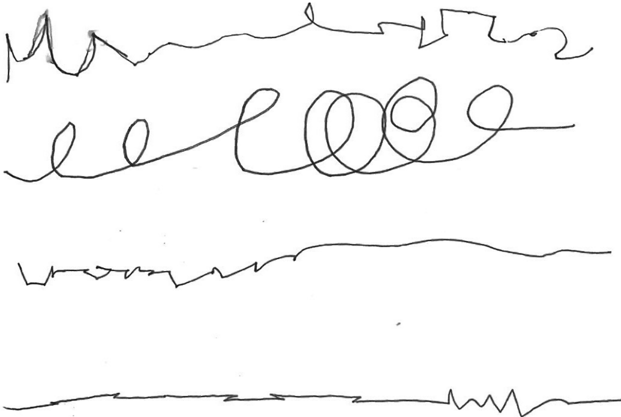

Figure 1.4
Simple movement notation of four distinct observations of human movement. Here, time progresses left to right, and each line reflects impressions created by bodily movement over time. Each line break indicates a new body being observed in a new activity. The observation is of people working in a kitchen.

there is a sense of meaning: repeated loops suggest a repetitive movement; curved lines suggest softer, gentler actions than rigid, straight ones; and sharp changes in writing style suggest that the same may have been true in the observed movement.

The methodology is mostly known only to the notator—as is the value of the exercise, which is simply in *noticing* the choices made and the movement that inspired them more deeply. Rather than a perfect record of the event, this exercise is useful for observers to learn what they perceive. For example, here we could compare the same four observations by multiple observers watching the same event, noting similarities and differences in what is noted by each. This allows us to recognize other ways of observing the movement and, maybe most important, what the pattern is in our own observations. Just like a photograph or any other recording method, these scribbles are imperfect records of the event and represent (consciously or not) a value system in the choices made to create them. This is one of the central purposes of written symbolic representation (notation) of movement.

A second use of notation is to transfer movement from one body to another. Another exercise that we could perform with such scribbles is to share the record with a partner, asking them to move the script. This task could come with—or without—instructions of how the record was made.

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For example, in the caption of figure 1.4, we are told quite a lot about how the observer used the paper to record impressions. But we might not have such instructions, so we could instead suppose that the impression is of a static pose, with one limb described by each line. Still, we would need to translate the design on the page into our body. And it will be instructive for the original observer to see how another person creates an interpretation.

As we add structure to our ability to describe movement, first through the taxonomy and associated symbology presented in part II and then through the notation system described in chapter 10, we hope that you will gain some bandwidth in how specific you can be in describing movement. To do so, you will add to your bank of terms for describing, and thus for noticing. However, this pure, free-form exercise of designing lines on a page amid live observation is one that can always be returned to for new discovery about, deeper kinesthetic attunement to, and richer noticing of any subject of interest.

Chapter Summary

In the act of making meaning with machines, we are wholly and fully consumed by thinking about how humans move, how machines move, and how, based on those respective models for movement, both entities interpret or perceive movement. We invite readers to explore this idea through creating a recording of their own kinesthetic attunement to some movement phenomenon in their own environments, as demonstrated in figure 1.4. This act will involve subjective choice and objective observation, producing a record that is both qualitative and quantitative and that reveals your own tendencies toward and styles of pattern making.

In reviewing prior scholarship from philosophy, dance, and engineering, we have opened this book by asserting that movement and first-person, subjective experience described through qualitative analysis are key to meaning-making; this book will deal with these topics with application to machines. Further, we have cast empirical measurement (often thought of as quantitative and objective) as a form of meaning-making, noting that when you set up an instrument to take a recording, you have made many subjective choices and need qualitative analysis to understand the result. Meaning relies on objective facts and quantitative measures as much as subjective perspective and qualitative description.[3]

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2 Studying Movement: Somatics, Choreography, and Notation

Chapter 1 has set up the importance of the first-person subjective qualitative perspective in understanding movement, as well as how there are quantitative, objective, and measurable events that build to meaning in the eyes of human viewers. The goal of this chapter is to provide a background review of movement studies. The chapter will discuss three foundational parts of movement studies: **somatics, choreography,** and **notation.** While chapter 1 focused on a host of published academic studies, here we review some published work but also add more ethereal and personal outputs: performances, classes, and therapies. Thus, we use the term “movement studies” to comprise both movement *theory* and *practice*. To the former, principles and academic writing about somatics, choreography, and notation provide intellectual grounding for the specific taxonomies and principles employed in fields like dance, kinesiology, and physical therapy. To the latter, practical examples and anecdotes from embodied experiences in studios (see figure 2.1) and onstage situate this work inside a pragmatic, practice-oriented landscape for investigation and research.

2.1 Strategies from Somatics

Learning from the embodied, human experience

Somatics is a broad term used to describe movement methodologies that center around the experience of the human mover, inviting dualistic investigations into the mind-body connection through conscious physical practice honed through technique, principles, and repetition. The work of Irmgard Bartenieff, often termed “Bartenieff Fundamentals (BF),” is an example of such a method. Her work as a physical therapist and dancer

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Figure 2.1
The setting for this chapter. Pictured here are examples of workshops in choreography, somatics, and notation, led by the authors alongside other movement analysts and movement artists from 2014 to 2020 at the University of Virginia (UVA) and the University of Illinois Urbana-Champaign (UIUC) inside the context of research in robotics. Unlike earlier workshops, which were held in a robotics lab in an engineering school (see figure 0.1 in the introduction), these workshops in dance department studios at UIUC had ample room for movement and incorporated special "sprung" flooring to safely support large weight shifts, including jumping.

helped her develop theories that supported a set of exercises used in her practice and meant as investigatory tools for others as well. Chapter 3 offers a longer discussion of this work, which is key to Laban/Bartenieff Movement Studies (LBMS) and the other information presented in this book.

Many other such **somatic practices** exist, including Alexander Technique, the Feldenkrais Method, as well as traditional forms of yoga and meditation. F. Matthias Alexander was a stage actor who developed a somatic method to improve physical performance; his work shares the approach of many somatic practices by encouraging the mover not to find "correct" patterns, but to notice habits and unconscious choices in order to find more possibilities. Likewise, Moshé Feldenkrais developed a physical practice to help refine, remove, or redefine habits. This work has been associated with alternative medicine and therapies. Thus, the form of these physical practices overlaps with the writings of Maurice Merleau-Ponty and Maxine Sheets-Johnstone, who were grappling with how to resolve the physical situation of their own bodies with their understanding of the world.

There is significant overlap and exchange among different traditions, and practitioners of one method are often trained in others as well. Moreover, credentials such as a Certification in Movement Analysis (CMA), Registered Dance/Movement Therapist (R-DMT), and Certified Feldenkrais Teacher

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(CFT) attest to their holders' proficiency with aspects of the bodily knowledge represented in these practices. A professional association, the International Somatic Movement Education and Therapy Association (ISMETA), tracks expertise in somatics and offers its own credentialing. Much of the work in this community is passed down not through books or other writings (although those exist as well) but through physical, felt practice, as such, much of ISMETA credentialing is based on hours of experience and practice.

The authors of this book are both CMAs, and Cat is also a Registered Somatic Movement Educator (RSME) through ISMETA. However, the book reflects the totality of the authors' own background, which includes substantial training in dance more broadly. Much of this training occurred inside the paradigms of physical practice learned through studio-based, embodied transmission. This education is harder to track and cite, but we provide a few examples here (and in section 2.2) to give the reader a sense of the native environment of this type of knowledge. The following first-person excerpts describe somatic experience that transmitted physical embodiment inside a studio, led by movement experts.

Amy, in undergraduate studies at Princeton with Rebecca Lazier, 2006:

> *One task that might be set to a dancer is to roll from a supine position (lying on the floor on one's back) to a prone position (contacting the floor through the front side of one's body, such as kneeling on the shins). Babies do this action with relative ease but adult movers, like me at twentysomething, often develop difficulty in completing this action smoothly and efficiently. We'd been doing an exercise that involved such an action for a few weeks, as I remember, and Rebecca, in her characteristic exasperation, stopped us all to implore us to use our "head-tail" connection to ease this transition. I will never forget her rubbing her hand over the upper part of her spine, emphasizing the weight of her head at the end, a mechanical advantage, showing us the part of our bodies we were forgetting. Nor will I ever tire of the smooth feeling of rolling over my entire integrated spine to switch from supine to prone as I contracted my side and shifted my weight, supported by my heavy head, to roll over.*

Cat, in undergraduate studies at Wesleyan with Mona Daleo, 1981:

> *We began class just recognizing our patterns of inhale/exhale. We then tried changing the ratio of the durations of the inhale/exhale, first creating longer inhales with short exhales, and vice versa, then balancing the duration of each. Then Mona directed us to use the inhale to expand and the exhale to contract. This was a modern dance class and up to then, after years of countless classes, I had never had breathing focused on as a "warm-up" to connect to my body. I was amazed to discover my inhale was*

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much longer than my exhale—which, when exacerbated, created almost a "panting" that was limiting my movement capacity. As I linked my breath to movement—for example, by reaching my arms to the sides and then up over my head while inhaling and pressing my palms together to travel down the front surface of my body to rest in front of my chest on the exhale—I was stunned to discover a sense of my own inner space and contents as integral to my moving body; there was a sense that as the breath flowed in and out of my body, I could link that flow to support and clarify my movement execution.

We can never feel these experiences in the same way again. Our bodies have changed—we have learned new skills, we have aged, and new stimuli entreat us to move—but the knowledge created in those moments is more than a tacit, implicit coordination. It is a reasoned, articulated plan of action that comes from integrating sensations of one's own container into generalizable knowledge. When applying this knowledge to the design and analysis of a new tool (see, for example, section 4.5 of chapter 4), we say that we are employing a **somatic strategy.**

Such strategies, developed through the pursuit of full-fledged embodiment, have been present at pivotal moments of machine design. For example, in imagining how people could learn to use the power of computers for broad creative ends, designers at Xerox PARC utilized the metaphor of a "desktop," creating a digital space with a familiar embodied analog (Isaacson, 2014). At Apple, designers carve prototypes from foam and attach precise weights to simulate how the products will feel in consumers' hands (Isaacson, 2011). Such a practice better engages the body in the design process. Paul Dourish (2001, p. 126) defines such embodied interaction as "the creation, manipulation, and sharing of meaning through engaged interaction with artifacts." Zhang and Wakkary (2014) push further, highlighting how personal experience can and should influence industrial design.

Newer fields of human-machine design are emerging in robotics, the Internet of Things, and artificial intelligence. The field of human-robot interaction (HRI) inherits much from Dourish's and Zhang and Wakkary's approaches, merging design and phenomenology with engineering and science. Likewise, HRI is openly acknowledged as an interdisciplinary field. In a recent survey, Bartneck et al. (2020) describe the field as comprising engineering, science, and design, noting (as we do in this book) the difficulty in overcoming the barrier between working in science and engineering,

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where external, explicit models of knowledge prevail; and in design, where internal and implicit knowledge are often more celebrated. These researchers list many fields of contribution to HRI, although they do not mention any domains of the arts. However, they do acknowledge the challenge of embodiment and working with embodied agents as being a distinguishing aspect of the field, suggesting, in our view, that studio-based arts will have an increasingly important role in this field.

This studio approach that emphasizes *physical investigation situated through designers' own bodies* is a way to include somatic strategies in machine design, including in dance (Akerly, 2015). In this vein, the scholar Kristina Höök developed products with IKEA that featured lighted and heated elements designed for meditation and relaxation. She writes about her approach to product design as being explicitly informed by somatic practices, as well as the writings of phenomenologists. Emphasizing the importance of first-person experience, Höök promotes the need for physical attunement, embodied practice, and contextuality in design, eschewing the notion of "natural" interfaces for those that are designed with the full intelligence of the body, creating conventions that befit the context. Discussing Sheets-Johnstone's theory on the primacy of movement, Höök (2018, p. 35) describes the relationship between movement and meaning as well as the inextricability of our own movement experience from creating that meaning:

> As we move, meaning arises and is communicated; for example, you can see where I am heading by watching my gait and by knowing your own gait and movement. On that basis, it is easy to see how gestures, eye directions, or facial expressions can develop to become meaningful communication. It is with a basis in these prelinguistic, meaning-making practices that language can be invented and be filled with meaning. In that sense, language is post kinetic. It is through movement that we understand and act in the world. Our bodies move. Our thinking is movement.

This echoes Gillespie and Zittoun (2013)'s description of symbol formation in chapter 1: we create meaning through movement observed in context. Moreover, it adds an extremely important idea that we inherit from somatic practice: what we see in movement is based on our own containers, forms, and patterns for movement. And, as noted by Merleau-Ponty, our perceptions—our observations about the world—limit, shape, and form the meaning that we extract. Research in technology development has made similar points in the context of interviewing designers (Fdili Alaoui et al., 2015b).

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When we think of the process of how people anthropomorphize machines, which is often explained as seeing things that have an inherent "humanlike" shape moving in a "humanlike" way, we must note our own role in that. That is, we tend to anthropomorphize what we see *based on our own experience* because our human forms are our bases for knowing and making meaning in the world (Varella, 2018). This phenomenon is as much, if not more, about our own experience as any measurable feature of design or action we see on the machine.

Petra Gemeinboeck collaborates with choreographers and dancers who then embody simple, abstract shapes to kinesthetically probe the movement potential of nonhumanlike robot morphologies. This method, referred to as "Performative Body Mapping (PBM)," aims to "exploit one of the most interesting characteristics of robots from an embodied meaning-making perspective, that we can bodily resonate, kinesthetically extend into, and relationally make meaning with their spatial, embodied dynamics and the relations they spawn" (Gemeinboeck, 2021, p. 7). In this process, these researchers are including, in a direct way, nonanthropomorphic shapes (Gemeinboeck & Saunders, 2017), embodying the very real process of interpretation that other bodies go through when seeing unusual movement.

For example, as a dancer twists her elbow to enliven the corner of an abstract, three-dimensional form she is wearing, her body creates a map to meaning that gets filled in by the sensations of force, torque, and pressure on her musculoskeletal system and her own interpretations of sensing the resultant motion. While lay viewers will not know about this dancer's particular experience, they will find their own bodily maps to reinterpret the gesture. Perhaps it reminds them of a paper bag they saw blowing in the wind earlier in the day, or the time they got stuck pulling an intricate dress or shirt over their head. In either case, their prior and ongoing bodily experiences form their basis for reading the motion.

This example is leading from the somatic, internal perspective of a dancer to the external perception of the choices she makes—to her choreography. Acknowledging the embodied experience is an important advance that has created products that interact with our movement at increasingly high bandwidths and humanistic sensitivities (Höök et al., 2018). To consider the consequences of a machine that moves or otherwise exhibits agency in its environment, we must look to the crafting of movement in time and space—or *choreography*.

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2.2 Tools (Technologies) from Choreography

Learning from the theory and practice of dance making

At first glance, "dance" as a concept can be seen as a prescribed list of movements that divides the world of movement between dance and nondance: either movers are dancing or they are not. Throughout this book, we utilize dance not as a set of allowable movements or instructions, but rather as a body of knowledge of **choreographic principles** for understanding, designing, and creating movement. The philosopher Catherine Elgin (2010, p. 81) describes the evolution of dance, across choreographer and genre, that crystalizes the process and body of knowledge that is choreography:

> *Swan Lake* is beautiful. It is delicate, graceful, enchanting. Martha Graham's *Night Journey* is not. It is riveting, harrowing, horrifying, often ugly. Yvonne Rainer's *Trio A* isn't even that. Being utterly pedestrian, it does not play on the emotions at all. But it is intriguing. Taken together these three dances raise questions: What is dance up to? What does it do and how does it do it? *Night Journey* discredits the thesis that the end of dance is beauty. *Trio A* discredits the thesis that the end is affective engagement. Possibly dance as such has no end. Different works and different genres pursue different ends. But whether or not dance has a telos, questions arise: "What does this particular dance do? How does it do it? And why?" My thesis is that dance embodies and conveys understanding.

Thus, dance (at least as we use the term) is not a list of movements, but rather the ongoing quest for new movements and new ways of expressing new ideas through movement. Dance equips us to break down, understand, and intentionally design movement (LaViers et al., 2018). Further, even within a given genre of codified dance, like ballet, flamenco, or break dancing, or of movement practice more broadly, like tai chi, gymnastics, or pole vaulting, there is a natural evolution of what its practitioners consider acceptable movements allowed by its teaching, practice, execution, and design as its cultural, scientific, and institutional setting changes. For example, the evolution from ballet to contemporary dance can be seen through a lineage of notable choreographers, such as Loie Fuller, Isadora Duncan, Katherine Dunham, Martha Graham, Doris Humphrey, José Limón, Merce Cunningham, Alvin Ailey, Yvonne Rainer, Bill T. Jones, Twyla Tharp, William Forsythe, Mark Morris, Ohad Naharin, and Elizabeth Streb.

Dance highlights the problem of trying to create a single movement "dictionary." Within dance, loosely speaking, there are many dictionaries:

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one specific to each genre of dance, to each choreographer within a genre, and even to each dance within a given choreographer's body of work. Outside of dance, we will see many of the same movements used for very different purposes, with less formalization and codification of the taxonomies used. The wipe of a hand across the brow may be used in a particular Mark Morris piece, crafted with careful similarity across the myriad of bodies in his company to be performed "in unison"[1] and recalls his penchant for applying pedestrian-seeming gestures in precise relationship to complex classical music scores to convey a sense of humor. A similar wipe may be used inside a sweaty Southern church at the tragic funeral of a child; here, the gesture it is not used as an implement of artistic expression, but as a salve to soothe the internal needs of a particular mourner. A dictionary that claims to decode movement or enumerate a universal "body language," therefore, has limited intellectual merit and valid use cases because the number of such possible dictionaries is at least as large as the number of practicing choreographers (and probably closer to the number of distinct contexts and people using movement all over the world right now, in the past, or in the future). Moreover, "choreography," as we use the term, is a complex process, not just a lexicon.

The early postmodern choreographers of the Judson Church Group (1960–1964) used ideas from Jacques Derrida about deconstruction, rejecting prior forms and formalization, and in so doing offered a way to make meaning with movement that relied on the movement as being meaningful in itself rather than simply representing another idea. Merce Cunningham, with his randomization practices—for example, tossing a die before a performance to determine the order of movements just moments before the dance was performed—played with this notion too. While a work was created by deconstructing movement, separating prior forms into their gestural and postural component parts, a whole was in fact constructed that an audience experienced and interpreted as meaningful. This was a new way of creating dance and making meaning with and of movement.

As we grapple with defining movement and inviting the reader to engage in an embodied practice to support and inform construction of artificial embodiment, we give nod to this duality of deconstruction/construction and the use of the body as a site of knowledge and a tool for research (Cancienne & Snowber, 2003). In doing so, we hope to dispel the idea, which often permeates engineering and scientific communities, that

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choreography is useful only for making robots dance. As Elgin's writing (2010) helps explain, all movement can be dance and all movement can be not dance—it is the application, intention, and context that determine movement's purpose. Elgin's description of choreography as the pursuit of expression through novel movement that is not currently considered dance, along with the descriptions of the body as a site of information and choreography as a place of inquiry by Cancienne and Snowber (2003), reinforce this point of view. In other words, dance is not an isolated domain, and choreography is an intellectual pursuit for new knowledge that emphasizes the physical body.

As we will see in chapter 3, Rudolf Laban's work emerged from this viewpoint, formalizing principles of movement discovered in his work as a choreographer. Much of that work occurs through embodied transmission in a studio. Examples of such embodied absorption of the foundations of choreography include the following excerpts from our own studies.

Cat, in undergraduate studies at Wesleyan with Susan Foster, 1982:

> *I took what was essentially a "dance history" class with Susan my junior year. She renamed this class "Anthropology of Dance" and taught us history from a perspective of choreographic taxonomies situated in different times and places. Typically, this type of class is taught from text, but we learned by trying on the movements of the choreographers from the different time periods we were studying. We also had to create movement compositions of our own using different choreographic techniques, or ways of making meaning, that the various choreographers we were studying had used. It had never occurred to me that different approaches to choreographing could create different meanings all together even when using the same set of movements. So, this was my first understanding of both the context-dependent nature of making meaning in movement, as well as the idea that making meaning from movement to express certain ideas can be accomplished in myriad ways that will all have an impact on both the performer and the audience (often in different ways).*

Amy, in undergraduate studies at Princeton with Ze'eva Cohen, 2007:

> *Ze'eva and I had a difficult relationship at times; something which cannot be separated from this embodied transmission (on the other hand, it is harder not to get along with the author of a textbook that you're reading). She (rightly) berated me for failing to account in my writing for the cultural conditions choreographers were working within. This "teaching moment," combined with my own contrarianism, cultivated an argumentative relationship between us. So in composition class, working with a fellow student, when Ze'eva was happy with our (in her words) "nice little dance" that was "almost finished," I felt inspired to push against the grain and shake up the entire piece. I suggested to my collaborator that we make a change to our work, which at that point used*

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contrasting movement profiles to represent successful, if difficultly achieved, communication. "What if I killed you at the end?" I asked her. In so many ways it was the polar opposite of what Ze'eva expected from us, and it gave her the shock I'd hoped for. When we showed the piece the next week, she gasped aloud. It was something I'd have never tried on my own without the context Ze'eva and my collaborator created, which taught me how countering the audience's expectations can work, how effective it can be at creating drama and communicating ideas. Instead of a piece about two beautiful women learning to get along, we created a piece about female violence, dominance, and cunning.

Contemporaries of our teachers also explicated their knowledge in writing—often in nontraditional formats. For example, William Forsythe produced videos on DVD that explained his "improvisational technologies" (Haffner et al., 1999/2012) from which we derive our concept of **choreographic technologies.** This DVD set used visual annotations along with Forsythe's own nuanced embodiment (video of his movement was featured prominently in the work) to explain shapes, figures, and techniques for creating expression through the body (Haffner et al., 1999/2012). Additionally, Forsythe and his company collaborated with a team of technologists led by Norah Zuniga Shaw to document their embodied work in the piece *One Flat Thing, Reproduced* as a so-called choreographic resource (Delahunta & Shaw, 2006) in an online, interactive product entitled *Synchronous Objects* (Palazzi et al., 2009; Shaw, 2016).

Rebecca Lazier and the musician Dan Trueman wrote a book documenting her choreographic work, *There Might Be Others* (2016), where the onstage movement was created through live cues that allowed the dancers (and her, in real time) to make decisions about what emerged. The book also documented the process used to create the live improvisational musical score, as well as their collaboration with the engineering professor Naomi Leonard to design algorithmic movement strategies. Leonard also published work studying emergent behavior enabled by this collaboration (Özcimder et al., 2016, 2019). Such products document the knowledge produced through the process of choreography.

In addition to sharing knowledge from these domains for technologists' use, one of the themes of this book will be how working with machines helps develop and push the field of movement studies itself. Likewise, choreographers working with technology, like Margo Apostolos (1991), Thecla Schiphorst (Calvert et al., 1993), Stelarc (Atzori & Woolford, 1997), Susan Kozel (2007), Kate Sicchio (2014), Kate Ladenheim (Ladenheim & LaViers, 2021), and Catie Cuan (2021), are adding to this body of knowledge through

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their practice and corresponding theoretical developments. Lauren Bedal, a member of the Advanced Technology & Projects studio at Google, notes this phenomenon in an interview with *Dance Magazine*:

> Advances in gesture recognition technology require a new choreography of in-air hand gestures to interact with objects such as 'pinch' to select with Oculus Quest; 'swipe' to skip songs on Google's Pixel *4*; and a 'bloom' to open the menu for Microsoft Hololens. Designers in this space are actively defining a new lexicon of movements to create intuitive and playful methods of interaction. (Skybetter, 2020)

Thus, choreography is already part of technology development, largely promoted through designers with niche, specialized interdisciplinary training. We propose that using choreography in a practical pursuit, such as developing machine behavior, is the implementation of choreographic technologies (e.g., see section 5.4 in chapter 5). We distinguish choreographic technologies from somatic strategies in terms of both the bodies of knowledge from which they derive and the impetus of the translation: choreographic technologies engage the environment with an external, expressive point of view, while somatic strategies focus on engagement with the body and germinate from a more internal, functional point of view. These distinctions can blur, however, given the relationship between internal sensations and our expression in the environment.[2]

2.3 Abstractions from Notational Systems

Formalizing many notions of movement

An early, robust form of recording movement comes from a surprising place: music notation. Here, viewing music-making as a subset of human movement activities, we investigate music notation to draw a parallel to it when we investigate notation for movement more broadly.[3]

The very first forms of music notation date back to 2000 BC (Schøyen Collection, 2022), when cuneiform tablets from the period have been found to contain a form of notation called "tablature" (Kelly, 2014, p. 18). This notation was specific to a particular instrument, (e.g., a lute). Rather than detailing notes and rhythms as modern notation does (notes would not be developed for another 3,000 years), this notation instructed the reader about how to play the instrument (e.g., pluck this string, then that string). We therefore say that this is a **platform-specific representation:** the instructions would not make sense when trying to perform the same patterns on

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a different instrument. Most modern programs for robots have this feature as well. That is, the same program, or set of movement instructions, cannot be used interchangeably with most robots.[4]

Another way of thinking of this early notation is that humans did not yet have an abstract understanding of music: it was a concrete thing that emerged from a particular tool when you acted on it in a particular way. In the Middle Ages, people would become curious about the prospect of "[learning] songs which they had never heard" (Kelly, 2014, p. 65). To do so required abstraction—centrally, the invention of the music *note,* which prescribed a sound *pitch*. Thus, this abstraction enabled the development of **platform-invariant representation,** which allowed the same song (or series of pitches) to be played on different instruments and sung by people with different vocal qualities and ranges.

The musical note was identified by a monk, Guido Monaco, around 1030. This advance changed earlier forms of notation that came after tablature, which used *neumes* to preference pitch over timbre, quality, and melodic form. As Kelly (2014, pp. 79–80) writes:

> It was true before Guido, and it remains true after him, that not every aspect of a performance, not everything about a piece of music, gets transferred to the page. You have to choose what's important. When Guido invented the note, as it were, he threw out a lot of other information.

Thus, even the process of notating music, a commonplace and widely used technique, is an act of *subjective* choice and established *convention*. This system of notation has become the basis for the digitization of music, automatic music players, transmission and archiving of songs, and other advances. All of this is enabled by a *particular* abstract understanding of the design space of music. Each distinct form of understanding may be thought of as different **notational abstractions.** Other methods, such as shape note music notation, continue to advance the representation of music with additional convenience, detail, and applicability (Marrocco, 1964; Wong & Danesi, 2015).

Such audible vocalizations and felt rhythms are a subset of what we might try to notate in bodily movement more broadly. That is, the design space for music is much, much lower-dimensional than the space of movement options for the *whole* body. Why was this subset the first to be notated? In Guido's time, music played a central role in religious processions and services, and there were few devices to aid the process of archiving and preserving the structure of these religious implements. However, with the

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dawn of photography, recording movement from an external, quantitative lens became possible before any such comprehensive movement notation akin to that for music was developed. Namely, notes were invented over 800 years before sound recording (Thomas Edison's phonograph), and that was followed closely by video recording a little over a decade later (Edison's kinetograph), which allowed movement instances to be recorded easily. This access to recording devices may have thwarted progress in the broader development of movement notation, leaving the abstract ideas that were required for distinct bodies to perform the same actions relatively unexplicated, embedded in human minds and bodies. There is an urgent contemporary need for understanding movement abstraction.

One pioneer in pushing the commercial use case for this idea is JaQuel Knight, a prolific choreographer of some of the most famous dance routines of popular music artists, including Beyoncé's acclaimed *Single Ladies* music video. While the music that accompanies this work of art is well protected by copyright and intellectual property law, Knight's much-repeated and riffed choreography is not. He was paid a single fee for his work on the video, while the director, songwriters, and singers are entitled to royalties for reusage of the work. Why do these artists get compensated differently from Knight? Because they have the ability to represent their work: the video itself can be saved as a media file, the words of the song are written in language, and the music of the work is notated. Knight, by contrast, faces an uphill battle to say what movement constitutes his choreography (Milzoff, 2020).

It is no surprise, then, that Knight has turned to movement notation to begin to document and copyright his work. Knight has worked with Lynne Weber at the Dance Notation Bureau to use movement notation to file for intellectual protection of his choreography. This notation is much like the early form of music notation, tablature, in that it does not lend itself well to abstraction across bodies. How should a quadruped robot perform his choreography for *Single Ladies*? How should a wheelchair user perform it? These questions are similar to those that tablature writers might have had about how to perform the same song on different instruments, and they are especially pertinent when thinking about alien bodies—for example, machines—creating meaningful movements.

Some attempts have been made to use extant notational schemes for movement to encode, prescribe, and interpret motion for machines (Barakova et al., 2015). Naoko Abe and Jean-Paul Laumond led such an effort,

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collecting the work of many researchers (Laumond & Abe, 2016) and conducting their own work (Abe et al., 2017) in this vein. However, most of these attempts fall victim to the deterministic interpretation of anthropomorphization, assuming that using a robot of the correct morphology allows transmission between human and machine.

For example, in work with a large, hulking "humanoid" (with no malleability in the core), steps encoded in movement notation were transcribed to the robot (Salaris et al., 2017). Since many of the distal joints, which the system of notation they used focuses on prescribing, are to some extent mimicked in the machine, there is a case to be made that the team succeeded. However, the robot is a wildly different mechanical device than the original human performers (and observers), with different ranges of motion and dynamic access. Thus, the re-creation can be thought of as a cartoon-like imitation that does little to unpack the assumptions made in creating the translation. Which part of the machine maps to which part of the movement score is a subjective choice: for example, they reflect assumptions about the human form that include two arms in the upper body and two legs in the lower body.

We lack explicit and consistently used abstractions for notating gross bodily movement and, as such, the translation process is especially brittle; it breaks down for many machines and human bodies that do not share the same distal morphology as able-bodied humans, entirely missing the expressive and functional nature of our core anatomy. Yet there are examples of success: for example, green blobs can be highly effective bodies for re-creating the same movement ideas (Kingston & Egerstedt, 2011). Sara Hendren (2020), in grappling with the intersection between bodies and technology, explains the opportunity presented by diverse bodies, which she views as generative sites of creativity and inspiration for designing a better built world. Likewise, removing our ableist assumptions about bodies can pave the way for deeper understanding about what bodily movement (*perceived* change) is.

Chapter Summary

This chapter has introduced somatic practice and choreography as key bodies of knowledge comprising movement studies. It has also begun to provide fodder for how these foundational bodies of knowledge will be used to

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construct and deconstruct movement in applied settings as *somatic strategies* and *choreographic technologies*. We also introduce the notion that the act of notation explicitly brings the choices of human observers into the process of recording movement. Thus, the problems of both generating and recognizing the "same" motion across bodies require a system that offers a process for uncovering the myriad instances of human experience of movement, as well as offering design tools for generating observable patterns in that movement. Chapter 3 introduces such a system, which involves a particular set of somatic strategies, choreographic technologies, and notational abstractions.

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3 Constructing Movement: Somatic Strategies, Choreographic Technologies, and Notational Abstractions through a Laban/Bartenieff Lens

What are the options in a mover's palette? As we saw in chapter 2, there are many ways of answering this question—contemporary and historical, formal and informal, qualitative and quantitative—and, in our view, all of them fall short. In short, the answer to this question is unknown. New feats of athletic prowess are accomplished; new dance moves are invented; and new technological devices extend our own bodies. This book is centered around one way of describing a mover's palette, using a particular system that we will expand and refine in our presentation. As has been set up in the previous chapters, we care about three aspects of this system: its ability to capture both internal, somatic knowledge and external, choreographic knowledge, as well as its inclusion of a process for notating movement based on capturing essential patterns. This chapter will provide historical context and a contemporary overview of this system and introduce the embodied way of working that is essential to understanding it. Then, in part II of this book, we provide expansive coverage of this body of knowledge that integrates ideas from multiple practices, as well as our work with machines, to provide a primer for movement studies.

We frame the options in a mover's palette as aspects of both their own interpretation and their own ability to move and distinguish elements that come from their own experience (somatics) from those that come from communicating with others (choreography). We describe applying such distilled knowledge to the development of technology as the use of a somatic strategy and choreographic technology, respectively. A "strategy" is a plan of action designed to achieve a major or overall aim, and "embodied" refers to expression in concrete, often corporeal, form. In this book, a "somatic strategy" is an intelligent action taken by a physical body that achieves a goal. A "technology" is the use of knowledge for practical applications,

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and "choreographic" relates to the expertise and knowledge used by choreographers in expressing ideas through performance with moving bodies, creating an event that is meaningful for the human participants. In this book, therefore, a "choreographic technology" is a practical application of choices made about articulated bodies moving in space and time that considers context and audience for a particular expressive end. Notational abstractions developed from this body-based practice of movement are crucial to consider in this text as well, as such systems become the basis of transfer of movement between bodies. An "abstraction" refers to dealing in ideas rather than events, and "notational" refers to the practice of symbolic representation. In this book, consequently, "notational abstraction" refers to the concept that our representation of movement depends on our ideas about it. We are interested in the implications that this work has for designers, researchers, and technologists—namely, by posing the question: how can a given movement idea be perceived as the "same" when performed by distinct bodies?

3.1 Historical Overview

Development of movement studies in the Laban/Bartenieff tradition

This section provides a picture of **Laban/Bartenieff Movement Studies (LBMS),**[1] which has grown from **Laban Movement Analysis (LMA), Bartenieff Fundamentals (BF),** and the contribution of many practitioners who have worked with the material over the past 100 years or so. We begin with a description of the system that has emerged from LBMS as it exists today. We then give a very brief chronology of how the system developed, culminating in the diverse arenas where the work has been applied. Finally, we provide some context about how this book presents extensions to the system that have come from our own work with machines.

3.1.1 Contemporary Snapshot

Training programs in movement analysis[2] do not occur in lecture halls; instead they reside in dance studios, both inside and outside academic institutions. Thus, the work is often not written down—it is often not even articulated in language at all. It is executed live, in person, in the body, with rhythms and gestures, through experiences crafted by experts in choreography and presentation through movement. Transmission often occurs moving body to

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moving body and is disseminated by teachers to students who then go on to utilize, adapt, and craft experiences of their own, which are in turn transmitted to their students—and so on—without being tied to written prose.

This embodiment of the work necessitates an explicit statement about the bodies who originated this work, their historical context, and the limited swath of people who have studied the work since. As Rudolf Laban writes in *Principles of Dance and Movement Notation* (1956), as quoted by Irmgard Bartenieff in *Body Movement: Coping with the Environment* (1980/2013, p. 17):

> We should be able to do every imaginable movement and then select those which seem to be the most suitable and desirable for our own nature. These can be found only by each individual himself. For this reason, practice of the free use of kinetic and dynamic possibilities is of the greatest advantage. We should be acquainted both with the general movement capacities of a healthy body and mind and with the specific restrictions and capacities resulting from the individual and structure of our own bodies and minds.

This quotation first highlights the goal of movement studies: to offer choices to a mover. Further, it points to pitfalls that occur in evaluating such choices when many such evaluations are unrealized and unconscious. Likewise, the history of the development of LBMS contains specific moments that reveal those often ugly unconscious biases.

3.1.2 Historical Development

As a choreographer, Rudolf Laban was interested in human movement, and he approached his work primarily from the perspective of dance and mysticism. He developed a system to "write" movement (Guest, 2013, p. 11) and "map" the space of the mover (Studd & Cox, 2020, p. 139) called **Labanotation.** This work also established broader ideas about the relationship of the mover's space to their expression and relationship to the larger world (Laban & Ullmann, 1950/2011), resulting in what has become known as "space harmony" (Dörr, 2007). Later, he became interested in dynamic aspects of movement and began collaborating with an expert in time-motion studies, F. C. Lawrence (Bradley, 2008). This area of inquiry was further developed and refined into what has now become known as the "Effort component" of movement analysis (Laban & Lawrence, 1959). This work, in whole, became known as Laban Movement Analysis (LMA).

Irmgard Bartenieff was a physical therapist, educator, and dancer who used her training in Laban's work to pioneer the use of dance in a therapeutic

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context. While working with diverse populations, including professional ballet dancers and polio patients, she developed principles that helped her patients find for themselves new (and/or renewed) patterns of motion. For example, both the ballet dancers and polio patients with whom she worked had developed patterns of muscular holding in their pelvises and lumbar spines that prevented coordination between their upper and lower bodies. Thus, she furthered the system by bringing the physical body explicitly into the framework. Through these efforts, she developed her own set of movement methods and exercises that are often referred to as "Bartenieff Fundamentals (BF)." This evolution has continued with today's practitioners further developing Bartenieff's original principles and applying this work to a variety of applications, including hands-on physical therapy, diagnostics for injury, improvement of connectivity within the body, repatterning to avoid reinjury, and improved physical crafts in dance, sports, public speaking, and other activities requiring physical presence and performance. This work is considered an important extension of Laban's original advances in the space of choreography that helps facilitate physical expression by a variety of bodies. This work has become an important, integrated part of the system overall, and thus, although LMA is a better-known acronym to describe this community of work, many prefer the term "Laban/Bartenieff Movement Studies (LBMS)" to acknowledge Bartenieff's contribution.

The system continued to evolve after Laban and Bartenieff, as others contributed to clarifying, explicating, and naming parts of the movement experience. Many of these insights were integrated into four components of LBMS—Body, Effort, Space, and Shape (BESS)—but people also created other systems based on their interests and applications of the material. Notable in this list are Warren Lamb, who developed Action Profiling, seeding what later became its own component of the system, which describes the shape and relationship between posture and gesture (Lamb & Watson, 1979); Judith Kestenberg, whose work with infants and mothers led to the creation of Kestenberg Movement Profiling; Martha Davis, who studied nonverbal communication (Davis, 1983); Bonnie Bainbridge Cohen, who developed the well-known Body-Mind Centering (BMC) somatic practice (Cohen et al., 1993/2012); Peggy Hackney, who created new symbologies and methodologies for connecting breath to body (Hackney, 2003); Colleen Wahl, who added clarity about phrasing's significance in all aspects of the

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system (Wahl, 2019); and Karen Studd and Laura Cox, who have codified and evolved a new modern taxonomy (Studd & Cox, 2013/2020).

Laban's early work began in Germany and partly flourished during the rise of fascism. While he later fled Nazi Germany and ended his days in England, this period working under the Nazi regime was his most prolific and well funded (Bradley, 2008). Moreover, his work was created within the context of Western culture and indeed privileged that culture's art—and the white, able bodies that it exalted—above others. Alan Lomax later used Laban's work to value one way of moving (styles of movement used in Western art) over another (styles of movement used in art from indigenous communities), claiming that certain styles of movement were more advanced, and likewise were the cultures that used them (Williams, 2007). In contemporary times, similar analysis gets applied to political candidates' movement patterns and actions, which often serves to justify the observer's own political leanings. Such applications attempt to measure movement, assigning value to particular choices, instead of valuing all movement options. Moreover, acknowledging the influences of the observer's own bias is essential to moving the work beyond white supremacy, anti-Semitism, colonialism, and patriarchy.

To that end, LBMS has been moving forward, as seen in many arenas where this embodied taxonomy and system for describing movement (Maletic, 2011) have been used to advance human knowledge in a variety of intellectual domains. The system is used today by a heterogeneous group of people working across multiple disciplines, all of which include a component of human movement, including but not limited to health care, the creative and performing arts, education, sports, diplomacy, and conflict resolution. Some notable examples include the following:

- **Creative and performing arts:** Cadence Whittier uses LBMS to examine and enhance ballet pedagogy, including in *Creative Ballet Teaching: Technique and Artistry for the 21st-Century Ballet Dancer,* her 2017 book that explores using LBMS in ballet technique. Dancers working in the theater have also explored exercises based on LBMS to enhance actor training in both the vocal and physical realm to enhance the expressivity of body and voice (Bloom et al., 2017).
- **Social work and social justice:** Martha Eddy (2016) uses LBMS and somatic practices to explore embodied peace education, as well as violence prevention. Her research seeks to understand and explicate the

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role of the body in negotiation. Deborah Heifetz utilizes LBMS to teach international conflict resolution and mediation in culture and community development. She has served as special advisor to the Crisis Management Team of the Israeli police and she supports peacebuilding by utilizing embodiment practices (Fernandes, 2014).

- **Sports and biomechanics:** Many people in the sports and rehabilitation fields use LBMS to enhance athletic performance and help rehabilitate movement (Hamburg, 1995). Janet Hamburg was a leader in this field and is best known for using LBMS to develop a comprehensive seated exercise program for people with Parkinson's disease (Hamburg, 2004). Mark Morris's "Dance for PD Program," led by David Leventhal (McRae et al., 2018), uses Hamburg's work.
- **Psychology and therapy:** Rachelle Tsachor and Tal Shafir (2019) use LBMS in their research to enhance understanding of the connection between body movement and emotion. This work is teasing out the fundamental underpinnings of applied fields like Dance/Movement Therapy (DMT), in which practitioners work with patients in a therapeutic context through embodied and creative movement.
- **Movement theory and technology:** Many people connecting technology to movement have found LBMS to be an apt resource for thinking about movement in a structured manner. For example, in developing forms of movement representation for technological development and interaction, Nicolás Salazar Sutil (2015) studies Laban's work extensively, examining connections to contemporaries in psychology, like Jacques Lacan, and in philosophy, like Maurice Merleau-Ponty.
- **Affective computing and dance:** Thecla Schiphorst has led several studies that examine how computational tools can enhance dance practice, several of which employ LBMS. In one work, sonification is explored as a method to improve dance pedagogy (Françoise et al., 2014); in another, her team examines how experts see movement with greater nuance than those without specialized training (Fdili Alaoui et al., 2015a); and in another, tools for choreographers are developed (Fdili Alaoui et al., 2014).
- **Artificial intelligence:** The computer scientist James Wang is working to model human expression based on bodily movement by creating an annotated data set, the Body Language Dataset (BoLD). They use LMA

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to support their characterization of expression and attempts to automatically recognize bodily expression (Luo et al., 2020). LMA has long been thought of by scientists and engineers as a resource for "decoding body language." However, LMA is not a lexicon for "what movements mean"; instead, it offers a system for resolving salient actions and inactions that is informed by context and the observer's own preferences and bias. Wang and his team are working with produced media (e.g., movies and YouTube videos) from a US-centric view. Such works share expressive strategies—ones that are often not replicated in natural, nonperformative behavior (Gladwell, 2019)—that LMA is useful for describing, allowing the team's algorithm to match raw data and lay impressions from human workers on Amazon Mechanical Turk via LMA-based annotations.

- **Animation:** Just as it is a useful tool for choreographing dances, LMA has been used to design the actions of virtual avatars and animated characters (Badler et al., 2000; Durupinar et al., 2016; Ziegelmaier et al., 2020; Kim et al., 2022). Leslie Bishko (2014), an animator and CMA on the faculty of Emily Carr University, focuses on expression through movement in animation. She uses LMA in her research to support movement visualization in three-dimensional animation, including puppeteering and creating avatars in virtual environments.
- **Robotics and automation:** Likewise, a growing number of roboticists have incorporated the use of movement studies in **expressive robotics,** particularly those working in human-robot interaction (HRI). For example, Heather Knight and Reid Simmons (2014) use Laban's theory of effort, which we describe in chapter 8, to develop movement profiles for robots that observers associate with motivations in the form of emotive states (happy and sad), personality traits (shy and confident), and situational states (rushed and lackadaisical). Similar work has been done in numerous research groups, employing both Laban's theories (Barakova & Lourens, 2010; LaViers & Egerstedt, 2012; Kim et al., 2012; Sharma et al., 2013; Burton et al., 2016; Cui et al., 2019; Bacula & LaViers, 2021) and Bartenieff's later work (Nakata, 2001; Huzaifa et al., 2016). Although associations with machines are not explicitly part of LBMS, these researchers use the system to structure their ideas about movement and then validate the associations for a particular context through empirical studies with human subjects. These research efforts suggest the importance of LBMS for HRI.

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- **Biology and animal behavior:** The Effort component has also been used to refine observations of animal movement (Gladwell, 2009). For example, Robert Fagan et al. (1997) used the system to examine locomotion, social, and even manipulation behaviors in gorillas, canines, goats, and magpies.

Within the LBMS community, Cat, alongside Karen Studd, Laura Cox, and Esther Geiger, has been refining, evolving, and developing the system in both content and pedagogy through ongoing international training programs, working under WholeMovement, as well as with certification programs like the one that Amy completed as a student. The influence of their collective approach is therefore formative for the material presented in this book. In particular, this group is using a taxonomy that includes identifying new basic body actions (e.g., vocalizing); fundamental baselines of the body experience (i.e., weight-sensing and flow-sensing); patterns of body organization that align with motor development (e.g., radial symmetry); recognizing and articulating the Shape component as having primary patterns of change of toward and away from self (i.e., gathering/scattering and concave/convex); and creating the attendant symbols to further clarify notation and its role in understanding movement (e.g., modifying the "forward" and "back" space symbols) (Studd & Cox, 2013/2020). We continue to evolve and refine the system in this book, adding and refining symbols, editing the presentation of topics, developing new approaches to notation, and delineating a new fifth component (Time)—all emerging from our work with machines. The rich and collaborative practice in the community of movement analysts keeps the system vibrant and relevant to multiple fields of application and strengthens the system itself.

3.1.3 How Working with Machines Has Evolved the Material

This book comes most directly from our work and movement experiences with (and as) engineers. We employ LBMS and other theoretical constructs in a way that has proved useful for our field of research. In particular, we add a new component, refine the presentation of certain symbols, and edit concepts for consistency, especially with an eye for translating ideas across natural and artificial bodies. We also end the tradition of associating Laban's and Bartenieff's names with the work, opting for a generic acronym to name the system.

Our evolution repeats an established pattern. In working with patients with differing movement capacities, Bartenieff had to explicate many things

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about the body—ways of describing it, ways of patterning it—that she would not have found if limited to her own bodily experience. Likewise, studying the movement of babies has been useful for understanding the system: adult movers come with many mature patterns of movement that younger, immature movers have yet to develop. This practice is common to other movement theories like those of Moshé Feldenkrais and F. Matthias Alexander, and one of the most popular videos shared across these communities is of a young baby rolling over for one of the first times, through a series of exploratory kicks and weight shifts. This video allows us to see foundational patterns in movement that build to complex, three-dimensional, cross-lateral adult human behaviors. Thus, working with bodies different than one's own has a rich and generative history in somatics as well as choreography (examples of choreographers working with machines are given in section 2.2 of chapter 2).

Likewise, in working with machines and algorithmic descriptions of movement, we have found bodies with novel capacities distinct from our own. While even the most advanced robots do not possess the same intelligence (or embodiment) of adult human movers, machines can be used to create starkly pure action—for example, a movement that is strikingly to the left, void of any sagittal or vertical contributions that exist in a human gesture. This raises new questions about how to describe movement.

The description of LBMS in the next section is a particular instantiation of the system that we find useful for working with machines, and as such, it is an extension of the history described here. This extension is informed by our own particular perspectives, which are centered in Western, proscenium-based forms of movement expression and conditioned by growing up and working in the US in the context of robotics and movement analysis. As a result, in this book we are using and expanding the material in our own applications, as limited by our own cultural and intellectual embeddings.

3.2 Laban/Bartenieff Movement Studies: The BESST System

Presenting a unified framework for movement analysis of natural and artificial bodies

There are many systems that address choreography and/or somatic practice, as described in chapter 2, but we value the lens of LBMS, as we find that it bridges these two approaches to observing, creating, and experiencing

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movement. In other words, both the inner experience and outward manifestation of movement—of both the individual and the individual in relationship to the environment and other movers—are explicated. LBMS does not favor one approach over the other; rather, it constantly engages in an ongoing duality of personal and universal, inner and outer, self and other, and provides explicit connections between the mover and the environment.

Take, for example, ballet technique. It is a specific form of expression, preferencing a particular vocabulary that aims to extend movement potential beyond the "normal" range, characterized by external rotation, extreme flexion and extension, and extraordinary agility, strength, speed, balance, and finesse. All of these aims establish a clear sense of technical expertise, and such virtuosity is measured against an external form relative to an idealized execution. As a result, there is a set of expressions in ballet technique that are judged to be virtuosic, and this privileges an external presentation of self as the larger goal.

Conversely, a somatic practice like BMC preferences the inner or experienced movement of the practitioner and is focused on virtuosity as an achievement of inner connectedness, efficiency of movement, and support of breath—in other words, the experience, sensations, and feelings of the mover. In BMC, practitioners explicate connection to internal body systems, including organs, and sensory experience; this favors an inner approach of self-awareness as the larger goal.

In LBMS, virtuosity is achieved through broadening the palette of movement options in both sensing and action. The goal is not to execute a specific vocabulary of movement (as in ballet), but rather to broaden the range of choices that a mover has. The goal is not about honing a particular inner experience (as in BMC), but rather to develop the ability to make clear choices in movement manifest in the environment. We see LBMS as a process with which to engage our bodies to continue to learn, rather than a fully formed, prescriptive paradigm. Moreover, as the human experience continues to broaden, such as through the use of new tools like robots, this body of knowledge will continue to evolve to accommodate that. Box 3.1 presents the **BESST System,** comprised of five components with overarching themes (each with an associated symbol, shown in figure 3.1) that we use for these ends.[3]

The acronym "BESST" is created through the first letter of each component (Body, Effort, Space, Shape, and Time). The five themes form a description of recurrent patterns of relationship between seemingly opposing or distinct

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Box 3.1
The BESST System

- **The Body component:** Addresses "what" is moving. The body is the basis of our physical and lived experience. (See chapter 4 for more about this component.)
- **The Space component:** Addresses "where" movement is happening. Movement occurs in our internal, personal, and shared environments. (See chapter 5 for more about this component.)
- **The Time component:** Addresses "when" movement happens. Movement occurs over time, giving access to ideas like duration, phrasing, and rhythm. (See chapter 6 for more about this component.)
- **The Shape component:** Addresses "for whom" the movement is happening. This captures the interaction of the body in space, naming higher-order patterns that emerge from this phenomena, such as those of accommodation of and relationship to the environment. The larger idea here is the interaction of our body in space and the bridge of inner to outer and self to the larger environment. (See chapter 7 for more about this component.)
- **The Effort component:** Addresses "how" the movement is happening. This captures the behavior of the body in time, naming higher-order patterns that emerge from this phenomena, such as those that relate to distinction in movement quality. The larger idea here is recognizing the motivation and intent that drives complex movement expression. (See chapter 8 for more about this component.)

In identifying and reconciling patterns, paradoxes emerge. This notion is incorporated in the system through the concept of "duality,"[4] visualized through a lemniscate (or Möbius strip)—a form that expresses two seemingly distinct surfaces actually blending together and moving seamlessly from one to the other. As you trace the inner edge of the surface, it becomes the outer edge and back again, in an endless loop that is at once two surfaces and one form. This physical form is used to describe the overarching themes of the system:

- **Stability/Mobility theme:** Addresses the interrelationship of two primary movement descriptors, acknowledging that to be a stable moving body, one needs access to movement, or mobilization, and to have access to movement, one needs stability. (See section 4.6 in chapter 4 for more about this theme.)
- **Function/Expression theme:** Addresses the interrelationship between practical and aesthetic dimensions, acknowledging that to be efficient, one needs a broad palette of options, and to be expressive, one needs functional support. (See section 5.5 in chapter 5 for more about this theme.)

(*continued*)

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Box 3.1 (continued)

- **Exertion/Recuperation theme:** Addresses the interrelationship between work and relaxation, acknowledging that work requires periods of recuperation, and recuperation becomes exertive without periods of work. (See section 6.5 of chapter 6 for more about this theme.)
- **Self/Other theme:** Addresses the relationship between our personal experience and the broader world, acknowledging that we are a world of connected individuals. (See section 7.5 of chapter 7 for more about this theme.)
- **Inner/Outer theme:** Addresses the relationship between the inner intent and experience and the outer expression and perception of a mover, acknowledging that one's outer expression changes one's internal state and vice versa. This theme is also directly reflected in the topology of the lemniscate where the outer surface becomes inner and vice versa. (See section 8.6 in chapter 8 for more about this theme.)

ideas within the system. Additional dualities relevant to movement studies and engineering are seen in other common pairings (e.g., yin and yang) that may sometimes be presented as a linear spectrum with opposing poles but here are understood as two versions of the same idea; that is, as "two sides of the same coin." Consider the following list for other possible dualities:

- *Explaining methods of analysis*: Quantitative/qualitative, subjective/objective, meaning/measurement, micro/macro, individual/universal, simple/complex, part/whole
  - For example, a whole is made up of parts; each part is its own whole.
- *Explaining design*: Form/function, construction/deconstruction
  - For example, form creates function; function dictates form.
- *Explaining movement*: Condensing/expanding, content/container, constant/change, success/failure
  - For example, when one surface of the body is expanding, another surface is always contracting (and vice versa).
- *Explaining agents*: Mind/body, sense/act, intelligence/embodiment, mechanization/computation
  - For example, mechanization creates computation, and we use computation to generate mechanization.

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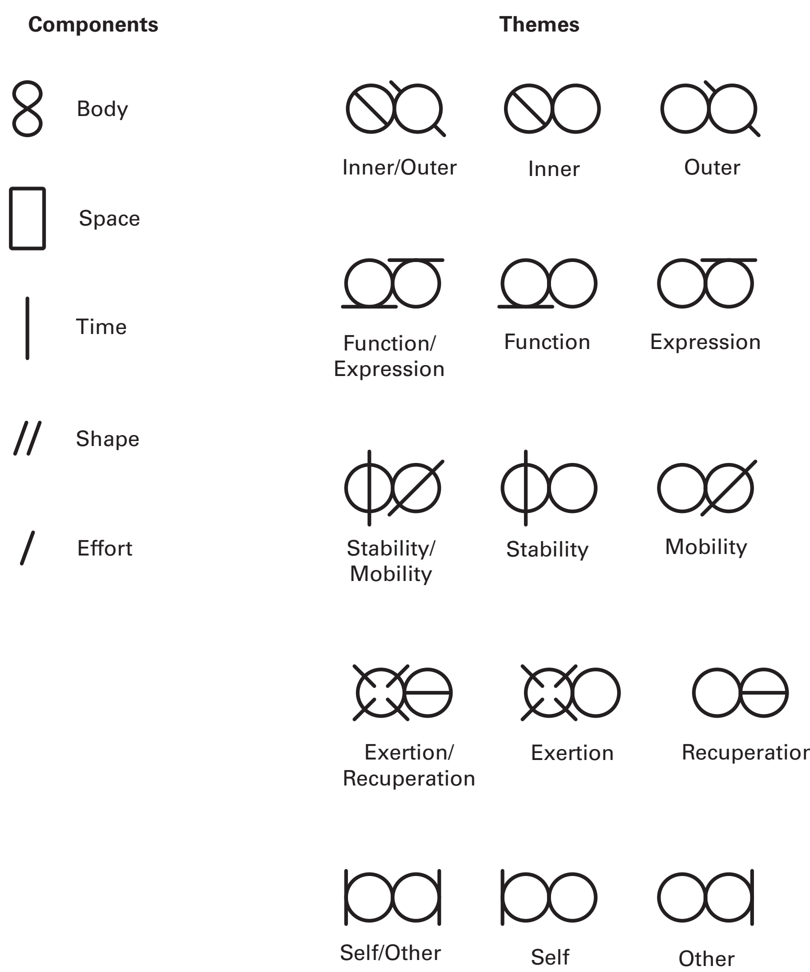

Figure 3.1
Component and theme symbols. The component symbols establish a visual pattern as they are used in many of the symbols for concepts within that component. For example, the same slash used here for Effort is found at the center of the Effort graph in figure 8.2 in chapter 8. The theme symbols also set up a feature of many other symbols in the system; they demonstrate how related concepts are represented with symbols that can aggregate and overlay one another. For example, the symbols for Function and Expression, which can be used on their own, also can be superimposed to create the symbol for the Function/Expression theme.

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The relationships between components in the BESST System are called **affinities.** For example, activities that we often do above our heads share associations, just as activities done close to the ground do. These activities, happening in similar areas of the environment, inherently share features of movement. For example, extended arms and a sense of destabilization are associated with reaching overhead due to our bodily forms, while crouched lower limbs and a sense of connection to the earth (or grounding) are associated with squatting low to the ground. Our experiences create associations between these activities, linked by common geometry and dynamic consequences of similar bodies.

We visualize these affinities in two ways: one that is nonhierarchical and one that is hierarchical. In the nonhierarchical model, these components are not seen as independent features of movement, but instead as a series of interrelated, overlapping, and redundant ways of describing parallel perspectives of movement. This model articulates how in mature adult movers, each component of the system relates equally to all the others. An adult mover can generate movement from our bodies (foregrounding the Body component) or from our inner motivation (foregrounding the Effort component). In the hierarchical model, we recognize the foundational roles of body, space, and time in enabling the movement of both natural and artificial bodies—and thus give primacy to the Body, Space, and Time components. This model recognizes that all bodies can move, and as that movement comes into increasingly complex relationship with the environment, expression—in space, in time, with other bodies, and governed by the mover's own intent—becomes more and more evident. These two models are illustrated in figure 3.2.

In the nonhierarchical model of relationship between components, the components are viewed as equal. In the hierarchical model of relationship between components, we note that we can perceive a body (whether natural or artificial) moving in space over time, but when meaningful choices are made regarding changing our form to accommodate and/or interact with the environment, or changing our expression to broadcast our intention, that is the manifestation of a mature mover/observer (e.g., an adult human). We can assign these things to robots by projecting our own experience (as we do, say, in seeing expression in cartoons) and by recognizing that robots are bodies that move in space and time, so they can reveal shape and expression.

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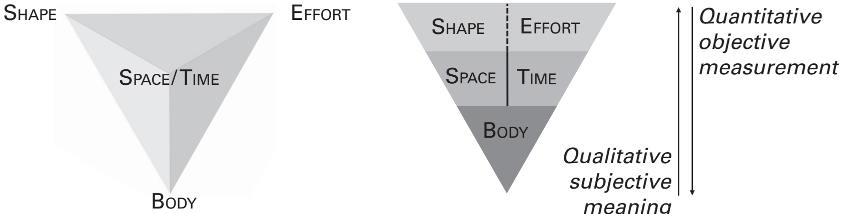

Figure 3.2
Nonhierarchical and hierarchical models of the BESST System components. The nonhierarchical model uses a tetrahedron (left) and the hierarchical model uses a triangle (right). The former model follows the traditional presentation of BESS, where each component is seen as a possible central basis for analyzing movement. The latter model arranges components in an ordered manner that reflects the types of movement concepts that robots (or other simple bodies) can more feasibly embody.

Thus, in this model, Shape is defined as patterns (of form change) in space, and Effort as patterns (of expressive/dynamic change) in time.

In analyzing the movement of machines, we observe richer patterns in the adult mover (natural) and simpler expression in the machine mover (artificial). Yet both of these are bodies that move in space and time. We see this reflected in an often-stated observation in the LBMS community: "Body is basis." Therefore, in this book we point to the primacy of the Body component, followed by Space and Time, which round out a foundational picture of a body moving. As we consider the movement in context, especially that of the mover's environment, higher-order concepts about the mover can be revealed, shading the baseline established through a body moving in space and time with ideas about relationship (via the Shape component) and intent (via the Effort component).

This taxonomy also enables symbolic, visual representation, a notation system called **motif,** which allows us to capture the essential elements of movement events, which in turn can allow us to both perceive larger patterns and overall meaning. The symbols are designed to combine very specific ideas of movement into a larger whole through visual representation. This also allows us to find new patterns and practices, as we can start from motif and then find movement, and/or we can look at movement and then write motif. Chapter 10 introduces several systems of notation and details several ways to use motif.

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Thus, we begin to explicate the idea that movement studies offer a palette of movement choices that in turn, coupled with the ability to make symbolic representation, can support observation and—through both experience and perception—make meaning, find patterns, and engage bodies fully with their knowing, moving selves. That conscious awareness forms a new basis for making design choices regarding the movement of machines and how we can in turn make meaning of machines in motion.

3.3 Using Embodiment as a Process of Inquiry

Developing the physical practice necessary to examine and experience embodiment

Humans are always using movement, both perceived and experienced, to make meaning of our world. We are pattern makers and pattern perceivers, and it is through this constant process that we strive to reconcile paradoxes. Insofar as we "know" anything about movement, this knowledge is constructed inside the containers of our body: *we know because we move*, and *how we move determines what we know*. The BESST System is a way of languaging and experiencing that constructed, inherently personal reality by naming the parts of movement that coalesce to create meaning.

So far, we hope that we have set up a sense of how many people working with many forms of scholarship have grappled with understanding the perceived components of patterns in motion. We hope that you have a sense of how complex and unfinished this conceptual space is—and realize that the tools we offer in this book have grown out of a limited, Western point of view that is structurally and pedagogically distinct from traditional technical disciplines. Most important, we need to communicate the value of moving in your own body to understand this work. The physical knowledge of moving one's body contains a wealth of experiential, qualitative, and subjective information. Though complex and unfinished, this space is concrete, and it is where an emerging articulation of sensational, visceral, embodied, and personal understanding is situated.

Why do you need to move your own body to learn this material? Can't everything be written? In writing about the development of music notation, particularly the switch to notes, which prescribe pitch, over the more qualitative *neumes*, which were used in the further past to indicate emphasis and melodic shape, Kelly (2014, p. 80) writes that "you can't write down

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everything. Whenever you choose one thing, you inevitably omit something else." As notation brings a fuller conscious attention and awareness to specific aspects of the process of moving and interpreting movement, it can enhance aspects of that lived experience—but possibly at the expense of ignoring other aspects. Thus, a personal, lived, *embodied* practice (and repetition of practice) are needed to integrate the concepts we introduce in part II. With this in mind, we pause here to scaffold this suggested practice.

We invite—nay, implore—the reader to participate in the embodied exercises given at the end of key sections of this book, including here. We call these exercises "embodied" to emphasize their physical, corporeal nature, but we could just as easily call them "intelligent," as they are designed to help hone the reader's capacity for understanding. Just as intelligence is a feature of human capacity, we note that embodiment is a similarly important feature that means almost the same thing but foregrounds the physical, lived experience rather than the mental, generalized one. Here, we aim to offer a series of prompts to guide you in developing a somatic practice that you can carry throughout this book.

Embodied Exercises

- **Getting moving and tuning in:** The goal of this exercise is to begin to engage in and learn from a somatic experience, which will require *thinking*, *feeling*, and *sensing* your movement.
  - Start by finding a comfortable standing position. Take a few moments to be intentional about the width of your feet, the balance of your weight, the alignment of your spine, the tension in your arms. Try to find a comfortable, not overly held or overly relaxed posture. In coming to stillness here, notice what you feel in your body. Namely, tune in to all the movement that continues even here, in stillness.
  - Place your hands on your chest to notice the rise and fall of your breath. Place your hands on your heart to feel your pulse. Is there pain or sensation anywhere that draws your attention? Touch that part of your body and rub or tap it. See if that changes the sensation.
  - Notice your stance. How is the weight of your body distributed through your feet? More weight on one foot? Are your feet aligned under your legs or spread out? What is your resting stance?

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  - Now begin walking around the room. Notice the room. Notice yourself moving within the room. What draws your attention?
  - Continue moving around the room while increasing and decreasing the speed of your walk, escalating into a run and cutting through the space. Then freeze. Notice your feet contacting the ground. Has your sense of your stance changed? Take a look. What do you see? What do you sense? Once again, place your hands on your chest. Has the rise and fall of your breath changed?
  - Place your hands on your heart. Has your pulse quickened? What parts of your body are now drawing attention?

Try repeating this process several times, using the following exercises to revisit it through new lenses, noticing each time what changes and how your awareness of your body changes.

- **Synthesizing somatic experience:** Try to synthesize the previous exercise. Consider and welcome both the positive and negative aspects of your experience. Looking through the lenses of thinking, feeling, and sensing is one route to doing this.
  - What did you think about this exercise? Did you gain any new knowledge? Was it familiar or unfamiliar?
  - What did you sense during this exercise? Did you knock into anyone or anything? Did you trip and/or fall?
  - How did this exercise make you feel? What was comfortable or uncomfortable about this exercise? Did you enjoy any specific aspect of it? How did it change the way you feel?
- **Introduction to the interrelated lenses of the BESST System:** Take a video, repeating the event in the “getting moving and tuning in” exercise, for easier viewing and analysis. Then, respond to each prompt, introducing the components of movement studies discussed in the next five chapters.
  - Body: *What* are you sensing? Which parts of your body are involved in the action?
  - Space: *Where* are you moving? What are you thinking about and attending to?
  - Time: *When* is the movement happening? What happens first, second, third, and so on?

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- Shape: What or *whom* are you interacting with?
- Effort: What were you feeling during the movement? What does it look like you were feeling? What is the inner motivation for this action? *How* was that manifested in the way you performed the motion?

- **Gait matching:** Here, you will explore the process of kinesthetic attunement through basic locomotion. If you do not have full use of your legs, translate the task through your own method; while moving from bipedal walking to, say, rolling a wheelchair is a big translation, all individuals will have a mismatch between their bodies and the bodies that they try to imitate. Here, we are interested in more abstract concepts like order, pacing, rhythm, muscular tension, posture, movement quality, and attitude.
  - Fall in step behind someone (perhaps along a corridor in your building, keeping a safe and respectful distance).
  - First, match the order and pace of their legs, moving the left and right sides of your body in step with theirs. Then, look deeper: what kind of weight shift are they using? How are their arms moving? What is the posture of their spine, and how does it change across the gait cycle?
  - Now reflect on how this imitation feels. Is it comfortable? Empowering? Awkward? Which body parts feel as though they are in alien territory? Which feel right at home? How does this inform your relationship (or how you would imagine yourself to be engaged in relationship or activity) with this person?
  - Return to your own natural gait, shaking off the act of watching another person. How does your own body feel now? Are you newly noticing any aspects of your own gait?
  - 🎥 Record yourself inhabiting different gaits and come back a day or two later, when the experience is no longer fresh, to offer yourself an external point of view of your own movement and how (and if) you perceptibly varied it to accomplish the exercise.

Chapter Summary

This chapter has introduced the main influence on the movement studies presented in this book: LBMS. We have worked to provide a brief historical context for how the BESST System came to be. The chapter has also introduced the notion of embodied exercises. These activities allow you to engage

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in your own movement, recognizing your interactions with others, and illuminating the idea that you are already using movement analysis in your daily life. The goal of this book is to help you articulate that expertise and bring it to the point of applying it to technology design through somatic strategies, choreographic technologies, and notational abstractions.

Part I has set up some subtleties of systematically viewing moving bodies—a phenomenon that we are constantly surrounded by and experiencing ourselves—and outlined a path forward. Next, in part II, each chapter will deal with Body, Space, Time, Shape, and Effort in turn. That said, while being useful for the format of a book, such a linear presentation is in tension with the holistic, overlapping, and redundant nature in how these categories are used (particularly in the nonhierarchical model shown at left in figure 3.2). Each component will introduce a set of symbols, utilized to deepen the specificity of ideas that can be notated with motif. In part III, we bring in case studies from technology, introducing systems of notation and highlighting open problems in the field.

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II Describing Movement with an Embodied Taxonomy: The BESST System

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4 What Is Moving? The Interconnection of Body Parts and Action (Body)

Part I of this book introduced the complexities of noticing, studying, and constructing movement, valuing both the subjective experience and the objective event, which combine to create a meaningful pattern. This helps us to notice and describe a moving phenomenon and then make new choreographic choices or interpretations about it as two separate, interacting processes. This chapter will zoom in on one aspect of this picture: the physically moving body. At times, it will seem like an anatomy chapter, but we are concerned much less with the true, scientific anatomy of the body than the *perceived* anatomy. It is through the perception of our own bodies that we are able to craft movement behavior that gets us through the tasks of our day, including communicating and interacting with others around us; it is through our perception of others' bodies that we can work together toward the ends of accomplishing such tasks. In this frame, we present the *Body component* of the BESST System to heighten our understanding of moving bodies.

It is also important to notice how different bodies represent a unique and valuable perspective on the world. We see this idea quite literally in the viewing of any artwork, including in the performing arts. Imagine the distinct, physical perspective that a person who is five feet tall has on a painting like the *Mona Lisa*, hung with its base five feet from the floor, versus someone who is seven feet tall. They will see slightly different shapes on the canvas due to the projection of the painting at their respective heights: the shorter person has to actually look up to view the thirty-inch-high canvas, while the taller person must look down to see it. The two viewers will have different experiences navigating to the painting; the taller person can see the work over the heads of other onlookers as she approaches, while the shorter one does not see its features until reaching the front of the viewing line. We know

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that we will have readers who move through the world differently than we do. Whether it be above-average height, an old injury, the use of a wheelchair, uncommon speed, or any number of features that shape and define human bodies, these attributes contribute important and novel access to the environment, shaping unique experiences. Thus, rather than emphasizing a singular view of embodied experience, this chapter aims to equip individual readers to investigate their own bodily experiences and physical intelligence, which, in turn, inform how they view the movement of others.

Machines also have bodies, but their mechanical architectures and their programmed behaviors do not align with the patterning of human bodies (a fact that is often clouded by the naming of robot components and subsystems as “arms” and “legs”, for example). What we are interested in is the way these bodies move in space and time. By first developing a richer taxonomy to describe the patterns of our own container, we can better compare and contrast our actions with machines’ actions. In fact, distinct body architectures (both human and nonhuman) successfully express the same or similar ideas in many contexts and applications. For example, in this chapter, we will see a low-dimensional (simple) robot that successfully expresses distinct styles of walking gaits in a user study. Even though this simulated body does not have “knees”—or even exist in three dimensions—patterning the artificial body in a particular way evokes ideas of “skittering,” “sauntering,” and other gait styles. This example shows how studying the body through a somatic lens can broaden the types of perceptually salient behaviors that robots can perform.

Thus, this chapter explicates features of our conscious experience of our own container (and the contents of that container). It explicates fundamentals, reviews anatomy, and provides physical landmarks from which to reference motion. We will also begin to introduce some associated symbols related to these ideas that can be used both to abstract and to notate larger movement ideas.

4.1 The Body as a Container

How our anatomy affects our experience of and ability to accommodate the environment

The body is a container—not only of our lived experience, but also of bones, muscles, organs, tissues, and fluids. Our perception of movement (and the broader world) is affected by context and our own individual characteristics, including the relative shapes, sizes, and compositions of our bodies. Take,

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for example, the two authors of this book—both are women, white, petite, and have similar experiences, particularly regarding our dance and movement training. However, we are of two different generations (we are twenty-five years apart in age) with limbs of different lengths, ranges of motion, and strength.

Given our commonalities, we share many physical biases; given our differences, we show how even distinct bodies can move in unison, imitating one another via abstraction. For example, a person in a wheelchair has yet another experience of the body as a container, but whether on wheels or on feet, the bipedal moving body and the wheelchairing body both *locomote*. Both bodies can move forward in space from one location to another. The meaning of that locomotion will be understood differently but can in many ways be identified as "the same." The meaning and experience of the movement will always be affected by context, including the body creating and observing it.

Another example of this is height. A tall, sighted performance goer can move through a large crowd, scan the assembled bodies, and see a large field of movement, while a short, sighted performance goer cannot. These two bodies have different physical forms and thus afford different experiences and assimilated intelligences about the world. The short person will see those in front of and around him, but will not be able to see the crowd. This engenders a different experience and creates the need for different strategies for accommodating an environment. For example, in the context of viewing a performance in a theater, a shorter performance goer is more likely to sacrifice a broad view of the whole stage and select a seat in the front, magnifying the detail of the bodies onstage and muting the broader picture, providing a distinct experience (quite literally) of the viewed performance. After the performance, a performance goer seated up close might comment on the sweat of the performers that belied effort that was otherwise well hidden, while a performance goer seated farther away might comment on the affecting distance between the protagonists during a soulful duet. A blind performance goer may have picked up more acutely a particular quality of contrast between the timbres of the performers' voices.

If the performance goers were octopuses, they would have even more different ideas about the world. This kind of thought experiment becomes useful in developing machines because we can (and do) create eight-legged machines that may need to coexist in human-facing settings. What is common between the human form and an octopus? Even without expertise in human or octopus biology, we can list a few rough, obvious commonalities, which form a basis of shared experience and potential understanding,

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noting whether motion occurs at the core or in distal elements, the relationship to gravity, the body's midline, and preferred directions for action and sensing. These concepts are defined in box 4.1 and given symbolic representations in figure 4.1.

In this book, we present the list in box 4.1 (and figure 4.1) as a basis for the mechanisms of anthropomorphism. Puppeteers and animators explicate

Box 4.1

Features of Expressive Bodies

- **Core versus distal motion:** One way to look at moving bodies is to assess and assign centrally located moving elements as opposed to distal/edge elements. Often, the **core** houses ongoing life processes in animals (e.g., heartbeat and breathing) and critical functions in machines (e.g., clock processors and cooling fans), while distal body parts that are considered **limb** deal with more direct interaction with the environment, making this division particularly meaningful in many contexts.
- **Relationship to gravity:** A consistent relationship to gravity is a defining factor in experiencing a body, as all of the bodies considered in this book interact inside a gravity field that immediately affords a "top" versus a "bottom"—or an "axis of length," as discussed more thoroughly in section 4.4—for each moving agent.
- **Midline:** Bilateral symmetry is a common feature of complex, active bodies (defined as bodies that exhibit complex interactions with the environment, e.g., through manipulation, and displayed in members of the chordate and cephalopod phyla) and establishes a sense of "right" and "left." This sense can be imagined as the line of symmetry of our bilateral forms; this is often termed the "midline" of the body. In dance, the midline is often used to reference the notion of having one side and the other side. "Crossing the midline" occurs when a body part breaks across this imaginary boundary.
- **Preferred directions for action and sensing:** We experience the world as bodies that have a preferential direction for locomotion, establishing a clear notion of "front" and "back" (on the body) or "forward" and "backward" (in motion). This establishment of up/down, left/right, and front/back, immediately suggests a location for a "face," which may be understood both as a central location of sensory organs and a set of movement features that do not severely affect the stability of the body. They can consequently be used to express something about the internal state in a wide variety of physical engagements (e.g., with arms full, locomoting across a gravelly environment, etc.).[1]

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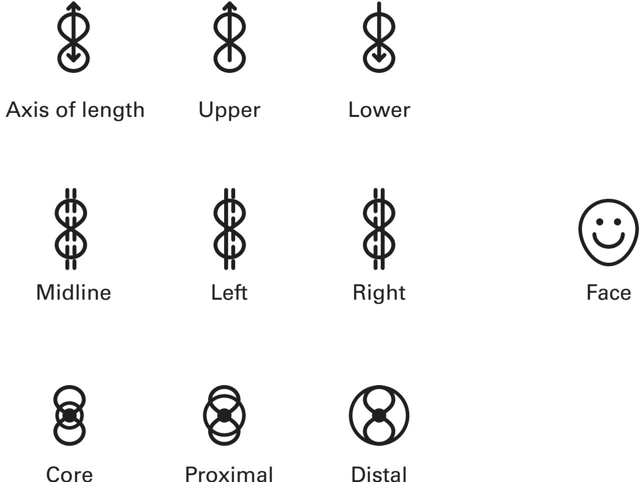

Figure 4.1
Symbols for features of expressive bodies. These symbols correspond to the concepts listed in box 4.1. Symbols for core, proximal, and distal help distinguish between core versus distal motion. A symbol for axis of length, which can be modified to indicate upper versus lower, represents a body's relationship to gravity. A symbol for midline, which can be modified to indicate the right versus left side, represents a body's bilateral symmetry. Face is a general symbol meant to represent a body's preferred sensory center, which in humans is also a highly expressive bodily feature.

similar principles in their process of animating inanimate forms (even simple strips of foam) into lively characters with personality that can express a narrative story, and this list describes features common to many (if not all) fictional cartoon characters (Thomas et al., 1995). Examples of this vast array of bodies, all of which can be expressive for human viewers at varying levels of abstraction—from simple, cartoon figures to detailed, real bodies—are illustrated in figure 4.2.

Several specific features are common to many (but not all) humans and are worth noting and naming explicitly as well. There are: geometric relationships that commonly arise in dealing with the human form, including **patterns of body organization;** bony landmarks, often palpable areas of the body (where bone protrusions can be felt through the skin) that form waypoints in experiencing our form; connections between bony landmarks called **kinetic chains;** muscular landmarks, often referred to as "diaphragms" (a thin sheet of material forming a partition), which delineate key areas of

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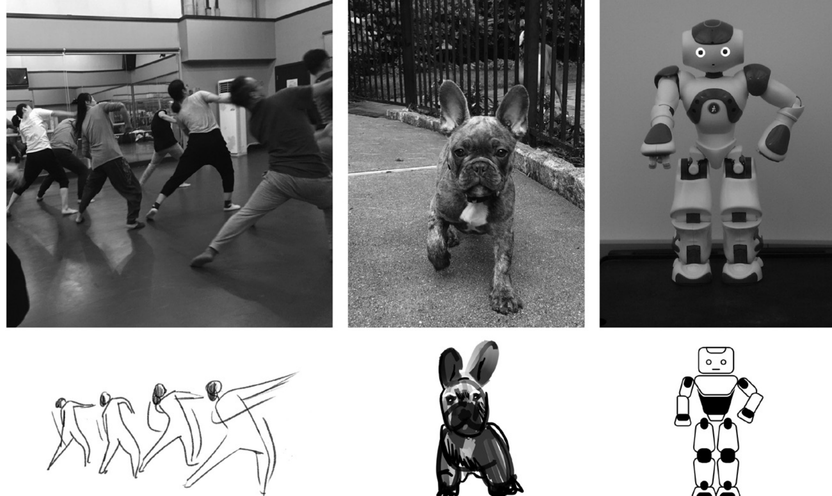

Figure 4.2
Examples of bodies and simplified, yet still expressive correlates. Even though each cartoon (bottom row) is simpler than the original body that it represents (top row), it obeys the principles listed in box 4.1.

action; and aggregate anatomical terminology aimed at describing our *perceived* anatomy (rather than detailing it formally).

The lists in box 4.2 are just a start, as any geometric relationship, muscular pattern, and bony landmark can be used to facilitate a sense of connection based on the goal of the mover. However, these terms have become commonly used in movement studies because they arise frequently in physical practice that focuses on the gross shape change of the whole body (e.g., dance, yoga, and rehabilitation). Likewise, a symbol set of body parts and patterns of body organization that are commonly referred to is given in figure 4.3.

Embodied Exercises

- **Finding bony landmarks:** Go through the list of bony landmarks and see if you can feel each one through palpation and weight shifts. Pay special attention to the complex structure of each joint. For example, the pelvis is not of a homogeneous weight, nor is it a static "bowl"; it allows subtle shifts of bone to accommodate weight.

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Box 4.2
Features Common to Many Human Forms

- **Geometric relationships:**
  - *Six limbs*: We count the two arms, two legs, head (the upper part of the spine), and tail (the lower part of the spine), to create a starfish image that captures our ability to locomote and have complex interactions with the environment. (Even for bodies missing an arm or leg, this image captures the access to movement afforded through the proximal region of the missing limb.)
  - *Patterns of body organization*: These relationships result from our six-limbedness and our preference for two of them (head and tail).
    - **Radial symmetry:** A primal pattern that recognizes six limbs (head, tail, arms, legs), as well as internal content (such as bones, muscles, and viscera), as equal, either moving in toward the self or out toward the environment as one whole (like a jellyfish ambiently floating or swimming).
    - **Spinal:** A primal pattern that emphasizes the spine as the body's core, with the movement relationship between the two ends of the spine a central organizing feature that supports the throu–ghline of our form, particularly in our length (like a fish swimming).
    - **Core/distal:** Recognizes all limbs as equal, moving toward or away from the core (like a hanging pull-string wooden puppet toy whose arms and legs move relative to the stable core of the puppet when the string is pulled).
    - **Head/tail:** Recognizes the primacy of the spine from head to tail in organizing movement, emphasizing the weighted ends of the head and pelvis (like a cheetah running, using the head and tail in oscillation to propel its action).
    - **Upper/lower halves:** Recognizes the upper unit (e.g., arms and head as one) as separate and equal to the oneness of the lower unit (e.g., tail and legs), like a frog hopping.
    - **Right/left halves:** Recognizes the whole right side as one unit and the whole left side as another unit and defines a clear sense of midline and bilateral symmetry, like a lizard bending left or right.
    - **Cross-lateral:** Recognizes the connection of the upper to the lower from right to left through the core and crossing the midline, like an upright human walking with their arms swinging gently in opposition to the legs.

(*continued*)

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Box 4.2 (continued)

- **Bony landmarks:**
  - Spine
    - Cervical (7 vertebrae, C1–C7, with C1 being closest to the skull)
    - Thoracic (12 vertebrae, T1–T12)
    - Lumbar (5 vertebrae, L1–L5)
    - Sacrum (5 fused vertebrae)
    - Coccyx (4 fused vertebrae)
  - Pelvic girdle
    - Sit bones
    - Pubic bone
    - Tailbone
    - Sacrum
    - Iliac crests
  - Hands
    - Wrists
    - Heels of the hands
    - Balls of the hands
    - Fingertips
  - Feet
    - Ankles
    - Heels of the feet
    - Balls of the feet
    - Toes
- **Kinetic chains:**
  - Head/tail
  - Heels of the feet/tail
  - Scapula/fingertips
  - Scapula/head
  - Scapula/sternum
  - Hand/other hand
  - Head/heels of the hands
  - Heels of the feet/sit bones
  - Sit bones/sternum

(*continued*)

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Box 4.2 (continued)

- Head/hands
- Hand/scapula
- Trochanter/other trochanter

- **Muscular landmarks:**
  - *The throat (partition between the upper core and the head)*: This esophageal muscle group, near the occipital joint at the peak of the spine, creates the basis for vocalization.
  - *The diaphragm (partition between the upper and lower body)*: This layer of muscle bisects the human form around the T12 vertebrae and is the key mechanism of breath, pressing down on an inhale (creating a larger volume of relatively lower pressure around the lungs) and pressing up on an exhale.
  - *The pelvic floor (partition between the lower limbs and the core)*: The pelvic floor is a group of muscles and the associated connective tissue that interweave to form support for the organs of the pelvis and for shifting weight near the center of mass (located between the pubic bone and the tail bone in the bowl of the pelvis).
  - *The psoas (connection between the lower and upper body)*: The iliopsoas muscle begins at T12 and spirals through the pelvis to insert at the head of the femur (thigh bone). It is one of the deepest muscles, and primary hip flexors, that connects our upper and lower halves and is critical to our ability to stand upright and locomote efficiently.
  - *The palms of the hands (partition between the environment and the body, frequently)*: The surface of the skin on the underside of the hand that runs between the tips of the five fingers to the wrist; it provides a surface for object manipulation, gesture, and weight bearing.
  - *The soles of the feet (partition between the floor and the body, frequently)*: The surface of skin on the bottom of the feet that runs from the tips of the toes to the heel and is what is in contact with the floor (both sensing and applying forces) when we walk.
- **Aggregate anatomical terminology:**
  - *Core*: Also referred to as the "torso," the core is generally recognized as the area between both shoulders and both hip joints. It includes the spine, with the crucial meeting place of T12–L1 (the 12th thoracic vertebrae and the 1st lumbar vertebrae, where the diaphragm is attached and further delineates two volumes) marking the link of upper core to lower core—also referred to as the **center of levity** (approximately the

(*continued*)

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Box 4.2 (continued)

centroid of the skull, collarbone, sternum, and associated abdominal muscles and vital organs) and **center of gravity** (approximately the centroid of the pelvic girdle, iliac crest, sacrum, and associated abdominal muscles and vital organs). The skull and pelvic girdle are often described as the 5th and 6th limbs.

- *Proximal joints*: Forming the basis of the "limbs," the proximal joints are considered to be the shoulders and hips, but if the head and tail are experienced as limbs, then the sacroiliac joint (where the bottom of the spine meets the pelvis) and occipital joint (where the top of the spine meets the skull) are also proximal.[2]
- *Distal joints*: The distal joints are considered to be joints associated with the hands and feet.[3]
- *Prone/supine*: Refer to two different surfaces of the body, often clarifying the relationship to the ground (prone is belly and face down, and supine is belly and face up).

- **Heel rock:** This exercise is analogous to a frequency response test in systems analysis, where unknown systems are probed with sinusoidal inputs to characterize their features. We will similarly use an oscillatory input to the body to explore, experience, and edify its connections. This exercise can be practiced in many positions and is classically experienced while lying supine on the ground with extended limbs. To begin, we recommend trying it in "supine hook," lying supine with the knees bent, allowing for full contact with the floor through the bottoms of the feet. Then move on to the other "neutral" postures suggested in section 4.2.
  - Lie supine on the floor, grounding your connection, especially through the heels of your feet; this forms a "neutral" starting state.
  - Notice each point of contact that your body has with the floor: heels, pelvic girdle, chest girdle, back of head, arms.
  - Pushing into the connection of your feet to the ground, give yourself a "rock," pushing into this point, increasing the reaction force with the floor, and then release, relaxing back to "neutral."
  - Repeat, playing with different rhythms, arrhythms, and tempos. Notice the connection between bodily parts—in particular, how the

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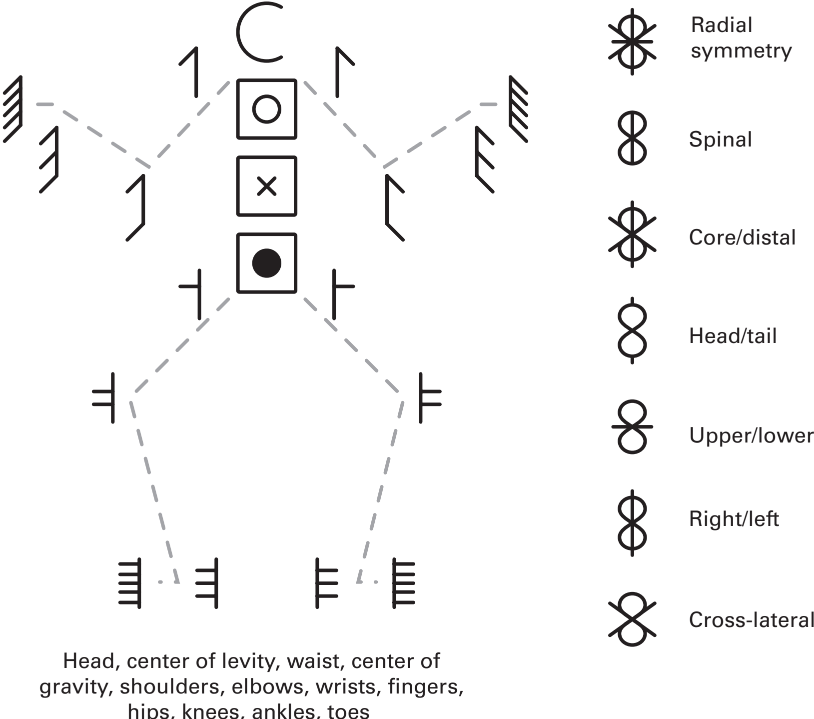

Figure 4.3
Symbols for body parts and patterns of body organization. The symbols for body parts (left) are arranged along a stick figure to roughly show their anatomical positioning on the human form. The symbols for patterns of body organization (right) leverage the Body component symbol to abstract the human form.

push you give with your heels ripples through to your head. How does that feel? Is there anywhere that ripple gets stuck? Use the bony connections listed previously, like heel/tail and sacrum/scapula, and as each part contacts the floor, pay attention to what order and in what timing these sensations occur, to notice this experience in more detail.

It is a learned skill to increase the sensations and physical actions that your body allows in this exercise. As adults, we develop all sorts of patterns of "stiffness" and "holding" in our bodies. We resist the relaxed undulation that this exercise is promoting, especially when it is unfamiliar. You can return to this foundational exercise many times throughout the book, using it as a

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preparation for other exercises, revisiting it with breath and other bodily sensations. Always work to increase your ability to notice and experience this gentle rocking and the successive action of each body part rocking into another and transmitting that pulse from the heel up to the head—and, paradoxically, you will need to do less to facilitate that increased motion.

4.2 Finding a Neutral Baseline

Investigation with weight-sensing and flow-sensing

The body is constantly in motion. Maintaining any given position or state requires sustained action guided by sensory feedback loops. Even what feels like "sitting still" is not actual stillness: the human body is constantly filled with micro-movements and -adjustments. Dancers and performance artists, like mimes, train for years to achieve the appearance of total stillness; yet, for example, they cannot eliminate the beat of the heart that is constantly filling the body with subtle reverberations. So, then, if everything is in constant motion, how is it possible to recognize that a new coherent movement, such as a particular gesture, posture, or action, has occurred?

One way that such changes become salient is in contrast to a neutral point of reference—or **baseline.** It is hard to find a true, universal neutral baseline because this idea is contextual, personal, and adaptive: the answer differs between a ballet and tai chi class and is different for people of different flexibilities or with different numbers of limbs. A different baseline should be established for a study of movement of office workers sitting at their desks than one used for studying basketball players shooting free throws. There are several body positions that are common choices for finding and establishing a neutral baseline in the LBMS tradition: lying on the ground in an *I* position, an *X* position, supine hook, and standing with parallel legs. These positions are described in box 4.3.

There is a perceived experience of our body, which these neutral positions help us observe and is distinct from its physical truth. For example, we do not perceive the exact weight (as measured in pounds or kilograms) of our body or its parts; however, we do have a sense of *having* weight, an idea that is affected by the mood, emotion, preoccupations, and goals of the moment. Lying in a familiar posture on the floor helps us check in with how our weight feels *today, right now*. It is difficult to estimate exactly how fast or with what acceleration any one of our body parts is moving at a given moment,

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Box 4.3
Body Positions for Establishing a Neutral Baseline

- **Lying on the ground in an *I:*** Lying supine with limbs extended down (the form typically used for Savasana in yogic traditions).
- **Lying in an *X:*** Lying supine with the arms overhead and away from the body at approximately 45 degrees, with the legs extended away from the body in the same manner.
- **Supine hook:** Lying supine, the arms by the side, with the soles of the feet on the floor, and the knees bent and pointing toward the ceiling. The legs are parallel to each other and the heels are in line with the sit bones.
- **Standing:** Standing with the arms relaxed by the side and the feet under the hips roughly parallel to one another.

Each of these will offer different experiences depending on whether the body is passively or actively engaged (or somewhere in between).

but our sense of its relative motion may be described in some moments as free and ongoing or more rigid and controlled in other moments.

To describe these ideas about experience, the Body component of the BESST System distinguishes broader, perceptual ideas of **weight** and **flow** that are related to but distinct from the quantities of the same names that are measured by scales and meters. There is an entwined relationship between these ideas of weight (both active and passive) and flow (both release and control). Flow foregrounds the connection to the environment and others in it; weight foregrounds the connection to our body/container. Practically, these ideas are very useful in generating different styles of movement and intention within movement through greater attunement to our own bodily state.

Weight (as differentiated from the expression of "weight effort" described in chapter 8) emerges from our experience of our mass in relationship with gravity. This is the process of **weight-sensing.** This sensation allows us to differentiate ourselves from the world, noticing the "other" and finding "me," as opposed to "you" and/or the environment. The ability to activate our agency through the sensation of our weight gives us the ability to act separately from others. Flow (as differentiated from the expression of "flow effort" described in chapter 8) arises from our experience of our contents in ongoing motion and from connecting to the ongoingness of our

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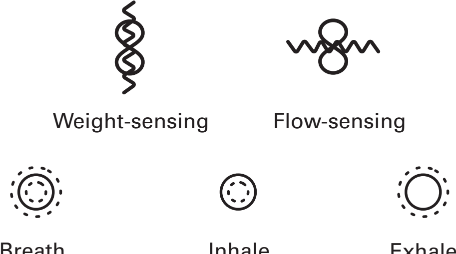

Figure 4.4
Symbols for weight-sensing, flow-sensing, and breath. Top: symbols for weight-sensing and flow-sensing[4] use the Body component symbol and a wiggly line (less sharply undulating than the vibratory phrasing bow in figure 6.1 in chapter 6) along the weight and flow effort axes in the Effort graph (shown in figure 8.2 in chapter 8). Bottom: symbols for breath,[5] including inhale and exhale.

environment. For example, ongoing processes like heartbeat and breath[6] can be viewed most broadly as modulations of control and release. Noticing and partaking in this process is called **flow-sensing.**[7] Symbols for these concepts are shown in figure 4.4.

Another way of understanding weight- and flow-sensing is to draw parallels to the ideas of “doing” and “being,” respectively. When we activate our weight, there is a consciousness of doing something, but when we connect to our flow, there is a consciousness of being something. In this way, weight-sensing[8] begins to allow an experience of differentiation between self and environment, and flow-sensing facilitates an experience of undifferentiation and connection to the broader environment. It is from this experience of weight and flow that we come into awareness of our body and its neutral, baseline state, from which we can perceive distinct movements occurring. As our movement becomes differentiated from such a baseline, we make qualitative and dynamic movement choices to express that intent.

As we find ourselves in increasingly frequent and close relationship with machines, we want to predict and be able to “know” the state of the machine. If we perceive its “readiness” and “presence” from subtle shifts in posture that simulate these ideas of weight- and flow-sensing identified in human movers, we may better understand the machine as part of our environment. Thus, we endeavor to find a way to make machines indicate readiness. Such an idea is exhibited in software updates to the SoftBank

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NAO robot, which now features an Autonomous Life setting that introduces subtle, seemingly random shifts and built-in "animacy" that simulates these ideas in the machine. Seeing the action of the robot gives people an ongoing signal that the machine is on and available for function. In a similar way, we signal readiness to other humans by returning to our baseline. The experience of baseline weight and flow, which is implicit most of the time in humans, therefore becomes critical to explicate in order for machines to express that same engagement to us.

Embodied Exercises

The following sequence of movement experiences is designed to take the mover from a place of "being" to a place of "doing"—in other words, from a state of undifferentiation from the whole of the environment to one of differentiation between individual agency and the environment. We call this weight-sensing/flow-sensing in the BESST System.

- **Breathing exercise to connect with flow:** Begin by lying on the floor and allowing your weight to release into the floor and your breath to flow freely and easily through your body. As you inhale, imagine the breath flowing like water inside your body and bathing your inner space. As you exhale, release the flow into the environment. Allow the inhale/exhale phrase to move easily and evenly.
- **Sloshing of internals to connect with flow:** Begin to allow this flowing breath to move you—pouring your breath and sloshing your internal contents to allow different parts of your body to come in contact with the floor. As different surfaces come in contact with the floor, use that sensation to begin to identify the container of your body.
- **Bouncing to connect with weight:** Begin to activate pushing against the floor and shifting your weight to a level change (i.e., sitting, kneeling, and standing), and finding different places of support for your weight. As you do this, add movements of pulsing, jiggling, and bouncing to find your weight, activating it in relationship to gravity.
- **Mobilizing in space through level change and locomotion and checking in on contacts with floor to connect weight:** Clarify your movement intention now to include changing levels, going to different places in the room, making different pathways, and using different forms of locomotion (e.g.,

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rolling, crawling, and walking) to experience agency. Continue to notice your relationship to the floor and the different surfaces of your body.

- **Repeat:** Start the process from the beginning to find more connections, sensations, and experiences that increase nuance and range of expression.

4.3 Basic Body Actions

Naming changes in the container

Now that we have established useful patterns in the form of the body—largely reviewing selected elements of established anatomy, albeit through a lens for embodiment and somatic experience—and clarified a notion of baseline from which changes may be more salient, we can move to establishing a taxonomy for describing patterns in the body's motion.

In this section, we align with a commonly recognized idea in computer vision, robotics, and animation: the movement primitive discussed in section 1.2 of chapter 1. This idea has been posed to extract coherent movements from two-dimensional video and three-dimensional motion capture—the so-called *motion segmentation* problem. While it is not clear what quantitative formulation will become dominant for this purpose, the plethora of papers pursuing this analysis confirms what experience suggests: there are moments in time that make sense to chop up movements, and other moments that do not. Listing out types of possible movements is one step—which has been used by engineers as well—that helps better formulate this problem. But how do we choose these types? How much do these choices bias our resulting analysis? This is a step where added nuance in sensation, observation, and intuition provides formal guides and tools for explaining results—both in individual experience and in the output of computer algorithms.

At its core, any movement is a shift in the center of mass of the body. Changing the position of a hand—outstretching a palm toward an object in the environment, say, or even just fidgeting slightly as one sits alone waiting for a bus—changes how gravity is acting on a body. Whether this outstretched hand represents the intent to pick up an object or this fidget indicates nervousness or relaxation is a result of inference about objective changes in the body container. Thus, we would like a set of terms that allow us to describe *without assigning a meaning* to such changes in center of mass or **change of support.** To this end, we suggest a list of movement concepts that offer more descriptive power, called **basic body actions,** organized into **axial movements,** which do not cause the body to travel through the environment

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in a significant way, and **locomotor movements,** which are aimed at moving a body to a new location in the environment. These basic actions (shown in box 4.4 and figure 4.5) can occur on any body part and can often occur in temporal clusters that are important to resolve with one another.

One possibly surprising omission from this list is “facial expression”; and this reflects the descriptive emphasis of the BESST System. While we might typically or more consciously notice the absence or presence of a smile, what is often more important to consider is the postures and gestures of the rest of the body that accommodate the smile. We need to consider questions like “Was the action of the mouth (expand) accommodated by a slackening (expand) of the face overall and a stiffening (condense) of the spine?” as the answers are usually key to resolving why the change in bodily container could be classified as a “smile” in a particular context. Moreover, this list gives us a new language with which to analyze a given smile. Was the smile a gesture, condensing in a temporal moment to communicate something to the environment, or a posture, part of a longer phrase that was about the internal support of the mover? By not jumping to a limited list of possible expressions or other coherent, stereotyped actions, like “wash,” “dry,” or “paint,” which are limited in their application to a particular task—or even the names of movement from codified systems of expression, like “pirouette,” “triplet turn,” or “rock step,” which are refined combinations of these basic actions—we can resolve full bodily expression in more detail across many more contexts.

Embodied Exercises

- **Basic body action scavenger hunt:** Look for each of the distinct body actions over the course of the artist Robyn’s *Call Your Girlfriend* music video (https://www.youtube.com/watch?v=Nv644ipg2Ss). (Most of them appear.) Where do you find them? How much of the performer’s body do you need to see in order to identify them? Which actions do not appear for you?
- **Choreography with basic body actions:** Create a floor pattern map using the symbols provided in this section to create a movement design; enact this design in your own space using your informal notation. (See the example provided in figure 4.6.) How does moving this phrase bring new nuance and more complexity to the task of notating it? What movements did you need to add to connect the ideas you sketched out? Did your floor pattern accommodate the actions you drew?

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Box 4.4
Basic Body Actions

- **Axial movements:** These are changes in the container of the body that do not involve translation in space.
  - Change of support (act)[9]
  - Posture[10]
  - Gesture
  - Condense
  - Expand
  - Rotate[11]
  - Vocalize[12]
  - Focus
  - Touch[13]
  - Hold
- **Locomotor movements:** These are complex, often cyclic repetitions of a series of axial movements that support the translation of the body in space. The list here refers to bipeds with two additional limbs (arms) available for weight support. For bodies with more limbs, additional modes of locomotion (e.g., pronking for quadrupeds) are available.
  - Change of support in series (act in series, or travel)[14]
  - Roll
  - Slide
  - Crawl
  - Walk
  - Run
  - Jump
    - 1 to 1 (one foot to the same foot, e.g., a hop, where the change in weight typically, but not always, occurs on the supporting surface of the foot)
    - 1 to 1 (one foot to the other, e.g., a leap or *jeté* in ballet)
    - 1 to 2 (e.g., an *assemblé* in ballet or in the long jump event in track and field)
    - 2 to 1 (e.g., a *sissonne* in ballet)
    - 2 to 2 (both feet to both feet, e.g., as often used when shooting a basketball)

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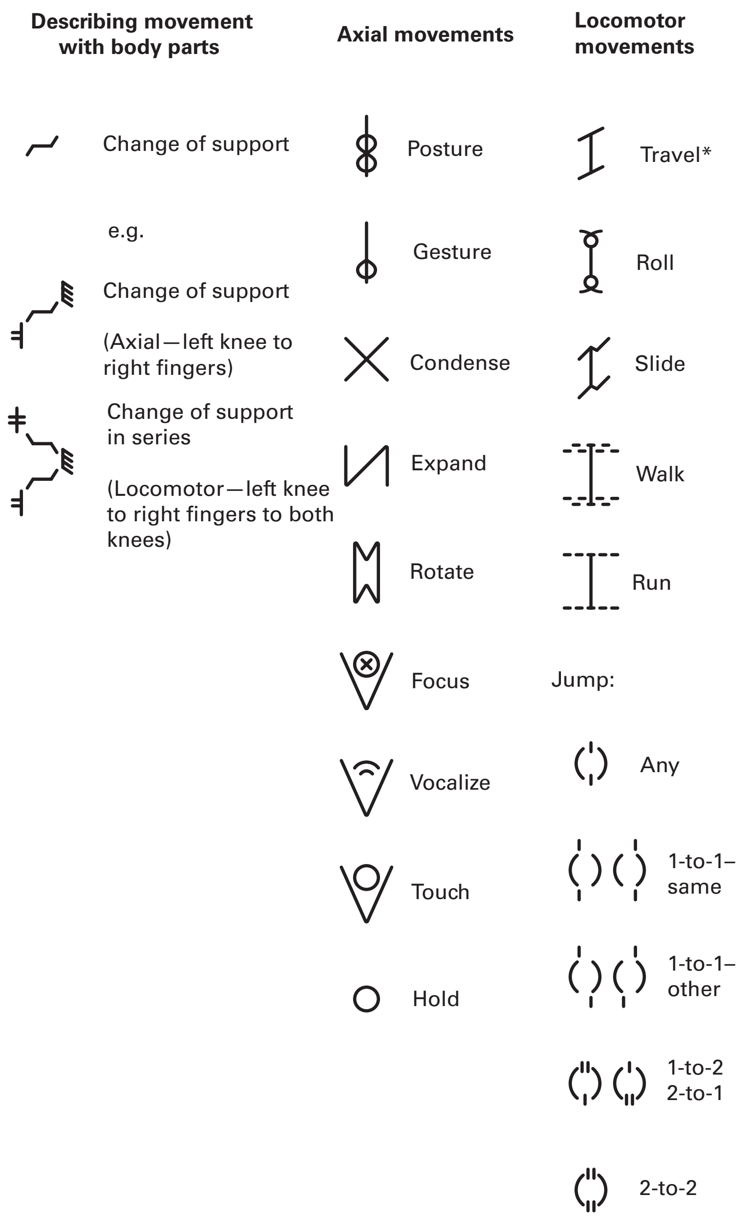

Figure 4.5
Symbology for basic body actions.

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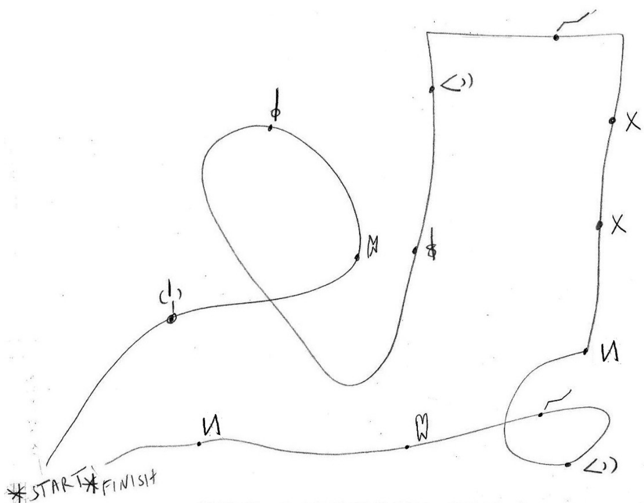

Figure 4.6
Sample floor pattern map with basic body actions along the way. This shorthand allows movement description and arrangement in space and time.

4.4 Body Fundamentals

An outline of somatic support for movement

Body (or **Bartenieff**) **Fundamentals (BF)** include both **BF Principles** and the **Basic Six** (introduced in the embodied exercises at the end of this section). BF Principles are large ideas of connectivity and support for movement intention and experience. These principles, listed in box 4.5, are considered an unordered palette of concepts that help bring individual movers into a better relationship with their own movement patterns. They are interrelated and have a part/whole relationship to both the mover and the mover's intention, as well as to the efficiency and connectedness of the mover's body.

Embodied Exercises

The exercises for this section are a canonical set of patterns established in BF to help demonstrate the principles outlined in this section. The Basic Six is a set of movement ideas, sequences, and patterns developed to get to the

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Box 4.5
BF Principles

Spatial and Temporal Relationships

- **Dynamic alignment:** Our body design is a closed system, and a change to one part will change the whole. This idea of skeletal connections supports access to kinetic chains of movement, framing a key idea that every and any motion in the body affects all of the body.
- **Axis of length:** Our human form is composed primarily of length. We are typically longer (taller) than we are wide or deep. This principle gives us access to that sense of verticality and aligns with the pattern of our bilateral symmetry. Finding thoroughness and connectivity—which is experienced through the center (or midline) of the body (head-tail-heels of the feet) and our relationship to gravity, where the head and tail are simultaneously limbs and core—will support our movement in function (e.g., accessing this idea can help improve stability when attempting to isolate the upper body from the lower limbs) and expression (e.g., taking a more upright posture may signal a sense of power and authority).[15]
- **Body-level phrasing:** This deals with the initiation and sequencing of our movement to help clarify intent. "Initiation" describes where the movement begins (a spatial location signified by body part), and "sequencing" describes how the movements are ordered in time.
    - Initiation
        - Core
        - Proximal
        - Midlimb
        - Distal
    - Sequencing[16]
        - Simultaneous (parts moving at the same time)
        - Nonsimultaneous
            - Successive (adjacent parts moving one after the other)
            - Sequential (nonadjacent parts moving one after the other)

Functional Support

- **Breath support:** Breath is fundamental to our existence and can be either unconscious or conscious. In this principle, we activate volitional breath to support our sense of inner volume in connection to the world.[17]

(*continued*)

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Box 4.5 (continued)

- **Core support:** The trunk of the body, which includes the spine and pelvis, is the place where movement can originate, activate, and support our successful negotiation of our relationship to gravity.
- **Rotary support:** Access to complex, three-dimensional movement is supported by the rotary capacity of our joints, which we can cultivate and articulate.
- **Weight support (and shift):** Mobilization, particularly in our relationship to gravity, enhances our efficient locomotion in space.[18]
- **Developmental pattern support:** There is a predicated, patterned progression of limb/core integration in our human motor development. We can access that progression as a support for our adult movement expression. This progression is the underpinning or building block for our ability to progress from infants primarily resting on the floor to being able to eventually stand upright and locomote. Accessing all of these patterns, as we do as adult movers, as well as returning to and isolating earlier patterns, is a practice that can increase our ability to exhibit complex movement in the environment.

Expressive Intent

- **Spatial intent:** Our spatial goals in our movements, explicitly related to the concepts discussed in detail in chapter 5 but foregrounding the bodily, physical experience that creates these more complex ideas.
- **Temporal intent:** Our temporal goals in our movements, explicitly related to the concepts discussed in detail in chapter 6 but foregrounding the bodily, physical experience that creates these more complex ideas.
- **Shape intent:** The change in our form as we move, both our own form and our form in relationship to the environment, explicitly related to the concepts discussed in detail in chapter 7 but foregrounding the bodily, physical experience that creates these more complex ideas.
- **Effort intent:** Our motivation to move as manifest in movement quality, explicitly related to the concepts discussed in detail in chapter 8 but foregrounding the bodily, physical experience that creates these more complex ideas.

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Box 4.6
The Basic Six

- **Thigh lift:** Focuses on hip flexion and the iliofemoral relationship of the lower limb to the core. This idea is traditionally demonstrated starting in supine hook position and grounding one foot into the floor while lifting the opposite knee toward the nose and then returning it to the ground. This action supports ease and efficiency in locomotion and level change.
- **Sagittal pelvic shift:** Focuses on shifting the pelvis forward and slightly up in a core-to-limb pattern. It is traditionally demonstrated starting in the supine hook and slightly lifting the pelvis off the floor and shifting it toward the heels. This action supports forward and backward locomotion, level change, and centering of the weight over the base of support.
- **Lateral pelvic shift:** Focuses on a sideways mobilization of the pelvis in a core-to-limb pattern. It is traditionally demonstrated from a supine hook position by slightly lifting the pelvis off the floor and shifting through the trochanters from side to side. This action supports efficient lateral weight shifting.
- **Body half:** Focuses on differentiating the right and left sides of the body by connecting the upper and lower halves on each side. Demonstrated by lying on the floor in a big *X* and through lateral spinal flexion, bringing the knee and elbow toward each other on each side. This action supports finding a clear spinal midline through the body.
- **Knee drop:** Focuses on finding a twist of the lower unit in relationship to the upper unit through rotation. Demonstrated from the supine hook position, the knees drop (passive) or reach (active) to one side while the opposite side of the upper body rotates and extends away from the knees. This action supports finding the connection of upper to lower through a cross-lateral patterning.
- **Arm circle:** Focuses on finding the rotational capacity of the shoulder girdle and arm. Demonstrated from the knee drop position, the arm circles up over the head and down across the pelvis, tracing a circle in both directions with the eyes and head tracking the path of the arm. This action supports access to three-dimensional space from the upper limb to the core.

Explore each of these movement patterns with different elements from the list of BF Principles for different experiences to deepen your understanding of how these ideas enact in practice. For example, how does your experience of thigh lift change when you focus on your breath support instead of on your spatial intent of tracing an arcing pathway of the knee toward the face?

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essential level of body connectivity and the mover's conscious awareness of patterns of body-level connections (Bartenieff, 1980/2013). The sequences—listed in box 4.6—can be used for repatterning, diagnosis, full body expression, one-on-one movement work that utilizes touch between client and practitioner (so-called hands-on therapy or practice), among other things. The goal is to facilitate, for the mover, total body integration and connectedness to support efficiency in moving in our uprightness in relation to gravity. For example, Bartenieff used these in her work to reintegrate the upper and lower bodies of both ballet dancers and polio patients. While we present the form in which Bartenieff described these sequences, they are meant to be explored in many configurations, contexts, and relationships to gravity.

4.5 Application to Machines: Generating Artificial Gait

Skittering, sauntering, and staggering

The Basic Six and supporting principles form an embodied basis for thinking about complex movement, including gait. Here, we have focused on gait through three sequences of the Basic Six, sagittal and lateral pelvic shift and thigh lift, as Bartenieff did in her work with polio patients and ballet dancers. This puts the emphasis on the role of the spine in walking, which is downplayed in biomechanical analyses that focus on the large deformation (and corresponding muscle activity) that occurs in the lower limbs during bipedal gait (Cenciarini & Dollar, 2011). The motion of the spine has also been studied in walking, but the motion is so subtle that motion-capture markers have to be surgically implanted (Crosbie et al., 1997). The Basic Six and embodied investigation allows us to sidestep that measurement challenge, instead utilizing a somatic strategy in our design of an artificial walker.

As shown in figure 4.7, working with Umer Huzaifa, we associated these ideas with a planar walker, where a simplified idea of sagittal pelvic shift and thigh lift are mapped to movement parameters (*PS* and *TL*), embedded as variable constraints, along with other fixed constraints required for a walking gait, in a feasibility formulation of an optimal control problem, solved numerically in MATLAB (Huzaifa et al., 2020). This produces hundreds of distinct gaits, six of which have been validated in online user studies in Amazon Mechanical Turk, with users rating the gaits on a scale from 1 to 7 after being trained on these distinct gait terms via selected

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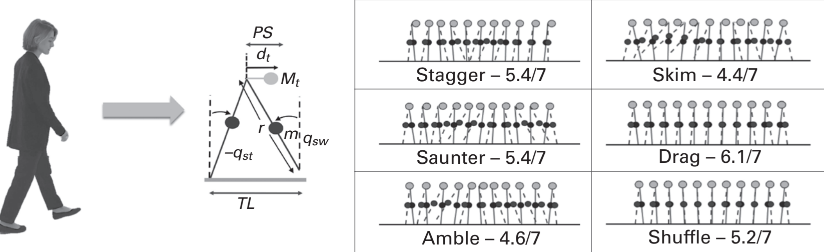

Figure 4.7
Results from robotic gait development. In our research, we have used ideas from embodied movement studies as somatic strategies to generate varied artificial motion and biomimetic platform design. At left, the mapping between the human form and a simplified model (Huzaifa et al., 2016). At right, unpublished results showing ratings by human subjects from Amazon Mechanical Turk experiments (UIUC IRB #17697). Similar results have been published for a simpler bipedal model (Huzaifa et al., 2020). Figure by Umer Huzaifa, used with permission.

definitions. Although about sixty synonyms for “walk” were found in the English language, these six have been validated alongside quantitative planar gait models, using the definitions provided in Huzaifa et al. (2020):

- **Drag:** to trail, to hang with its weight, while moving or being moved; to move with friction on the ground or surface.
  - *I have to drag myself out of bed each day.*
- **Lope:** to run or move with a long, bounding stride.
  - *She put the horse into a lope and headed for the shed.*
- **Saunter:** walk leisurely and with no apparent aim.
  - *In June, some flights were delayed at the airport when about 100 turtles, seeking a place to lay their eggs, sauntered across a runway.*
- **Shuffle:** walk by dragging one’s feet along or without lifting them fully from the ground.
  - *I stepped into my skis and shuffled to the edge of the steep slope.*
- **Skim:** to move, glide, fly, or float lightly and rapidly over or along (the ground, etc.).
  - *The swallows skimmed along the surface of the water.*

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- **Stagger:** to sway involuntarily from side to side when trying to stand or walk erect.
  - *A young woman staggered toward the landlady and fell down in a swoon.*

This research with BF demonstrates how external measurements like displacements do not align with the perceptual landscape contained within embodied frameworks. Moreover, the production of new movement patterns—along with hardware designs (Huzaifa et al., 2016, 2019)—represent an innovation that may improve bipedal walking behavior in future humanoid platforms. Follow-on studies have further explored the efficacy of various label sets across a variety of contexts (Lambert et al., 2019); generally, we find that emotive labels resonate more with lay subjects but vary more across contexts. These variable walking styles, when visibly distinct for human counterparts, may allow an ongoing advertisement of aspects of the robot's internal state to people in parallel with other necessary tasks, creating more expressive robotic systems for more harmonious integration of artificially embodied machines in human-facing environments.

Embodied Exercises

- **Breaking down gait with BF:** Try to see if you can identify a (typically simultaneous) sagittal and lateral pelvic shift, as well as thigh lift, in your own gait. Play with exaggerating and diminishing the magnitude of these components. What kinds of gaits emerge with an exaggerated sagittal (or lateral) shift? Are these useful in certain contexts? How would you modify your shifts if you were walking on ice? If you move differently from the kind of biped we examine here—for example, with a walker or wheelchair—do these concepts map to your experience of moving, or not?
- **Trying an artificial bipedal gait:** Watch a video of artificial gaits from our research (https://www.youtube.com/watch?v=pDTUeP5S2FU) and try them with your own body. What new movements do you have to invent (using your more complex form) to create similar temporal patterns? How well do the verbs assigned in this research fit with your experience?

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4.6 Exploring the Themes: Body through the Lens of Stability/Mobility

Moving to hold still

One way to begin to experience the moving body is to understand the interconnected relationship of stability and mobility. While they may seem to be opposite states of movement, they are simultaneous and ongoing patterns present in all movement. In this context, "stability" is different from "immobility," which implies a holding, stuck and unmovable. Stability supports mobility and vice versa.

Take, for example, a right-handed tennis player executing a backhand shot. The arms are mobilizing but can only be mobilized with the force of the swing by stabilizing the lower body. Likewise, in preparation for the backhand swing, the lower body mobilizes toward the ball while the upper body stabilizes in response to the reaction of the racket against the ball. This relationship—also called the Stability/Mobility theme—can also be seen in more pedestrian actions. To achieve a change of support from one foot to the other as in walking, the right side of the pelvis, right leg, and right foot mobilize, while the left side of the pelvis, left leg, and left foot stabilize to support the push/reach forward into space. This relationship between mobility and stability can also be clearly seen in muscle action: flexion of the elbow requires the contraction or stabilization of the biceps, while the triceps lengthens and mobilizes. The ongoing balance of the two in relationship promotes the ability to move the body.

The idea that you have to move to stabilize and you need underlying stability to move with successful control are principles in feedback control of dynamic systems as well. Feedback control does not offer the topology of duality in highlighting the simultaneity of these ideas, but they are important for human movers, who may overdo the movement in one direction or the other. As Nettl-Fiol and Vanier (2011) write in their book applying Alexander Technique to dancer training, patterns of holding can be counterproductive to increasing the virtuosity of movements like *grand battement*, where dancers need to release the working leg while supporting the standing leg in stability. Clearly, this duality appears in other traditions of movement studies and is useful for embodied practitioners to consider when refining their own movement choices: to perform a complex turn, we need a stable shoulder girdle; to balance on one foot in stillness, we need supple activation of the sole of the foot and the pelvic floor. That is, the body is a dynamic site of perceptual exchange where some movements are called "stable" and

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some "mobile" (and in another context, these labels may be switched), but both contribute to the eventual embodied existence of movement.

Embodied Exercises

- **Exploring mobility and stability in locomotion:** Locomotion is a highly mobile task, moving a body from one place to another, but it cannot be accomplished (especially for bipeds, which are inherently unstable forms) without stabilization.
  - Try walking at an easy pace, and then accelerating into a run.
  - Now freeze and see if you can come to stillness.
  - Balance on one leg, and then the other.
  - What happens when your body is forced in and out of motion? What do you notice about your musculature? Can you notice what parts are mobilizing and what parts are stabilizing in the sequence of movements given here? Can you notice the tiny movements that your body uses to hold "still"?

Chapter Summary

This chapter has described several concepts of embodiment from the Laban/Bartenieff tradition that have been useful in our work, codified as the Body component of the BESST System. We have shared anatomical relationships as perceived in the process of moving that help clarify movement patterns. We have given names to the experiences of *being* and *doing* through the sensations of weight and flow. We have suggested a taxonomy for naming movements that does not belie the purpose or intent of those movements and named principles of bodily support that enable such complex movements. In addition, we have shared how this mode of investigation has affected our own quantitative exploration into variable styles of walking gaits. Finally, we reviewed a common duality named in LBMS (stability/mobility) through the lens of Body. Thus, our physical container and our perception of it alone are not enough to establish our complex ability to move. *Both* body organization (physical/function) and movement intention (mental/expression) combine to create successful movement in an ongoing, fluctuating relationship of stability and mobility of parts that enact a whole.

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5 Where Is the Movement? Spatial Fiducials for Movement (Space)

Just as chapter 4 provided answers to the question of *what* is moving, this chapter examines the *where* of the phenomenon of movement. It can seem an obvious or rather simplistic topic to cover in fields like engineering, animation, and design, where vector spaces and coordinate systems are well established and frequently used, especially with computer-aided design tools. In other words, quantitatively locating objects in space is a well-studied problem that the field of movement studies does not help solve. What this system aims to highlight is *how bodies move through space* and *how that movement creates meaning in a given environment*. We denote then, the Space component as distinct from (but related to) the concept of space as typically used in engineering and design. Engineered systems need to resolve relative approaches and attitudes toward space (the topic of this chapter) as well as measure quantities of distance (a topic well-covered in traditional textbooks in robotics).

For example, objects located four feet from one another can be absolutely measured well by engineering terms, but whether two bodies inhabit the same level of their "kinesphere" (a concept introduced in this section) is not about absolute measurement, but rather about the relative attitude toward each body's approach to the space that the objects inhabit. For a relatively large body, like that of a professional basketball player, to *reach up*, for instance, the distal ends of its fingertips may be eight feet off the ground; for a relatively small body, like that of a child, to take a similar action, the distal ends of the fingertips may be only four feet off the ground. Both bodies can reach and stretch and yearn to move toward the sky as much as they can—creating a similar attitude toward their environment, but with very different physical results. While each body then inhabits a

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different physical space, the movement reveals a similar approach to space and is consequently read as a similar action.

Today, soldiers operating simple mobile manipulators like the PackBot, a robot on two rugged, crawler-style augmented wheels with a four-degree-of-freedom manipulator arm and a two-degree-of-freedom gripper with camera attached, struggle to navigate the robot successfully through situations that the hardware itself can handle. For example, having the base translate at the same time as the arm is not accommodated by current control interfaces but could be accomplished by the set of onboard actuators and sensors. This suggests a breakdown in command architecture and a lack of shared spatial awareness between the human operator and the artificial device.

This forms a fundamental question that sits at the nexus of robotics and movement studies: how can we map one body's understanding of space to another, wildly distinct body? Such translation, between human and robot kinespheres, can be seen as the central task for human robot teleoperators. While it is well understood how to move robot manipulators into different spatial positions (converting between joint space and task space through geometric relationships), it is not yet clear how to efficiently communicate control of a robot body from a human one. Some ideas, like exoskeletons for mapping motion through a wearable armature that aims to capture human movement directly, have shown initial progress, but there persists an inability to improvise and fully utilize the physical capability of the remote robotic device.

5.1 Approach to the Kinesphere

Defining an abstraction to describe the space we can move in

As part of the larger environment of the general space we move in, we each have an amount of personal space around our own bodies—what we call our **kinesphere.** This space is defined by "the sphere around the body whose periphery can be reached by easily extended limbs without stepping away from that place which is the point of support when standing on one foot" (Laban, 1966, p.10). In other words, the kinesphere is delineated by how far we can reach around ourselves. Beyond this physical sense of space, the term "kinesphere" is also discussed as a broader metaphor for the idea that movement from a given body interacts with space in a way that is observable. We also recognize an **innersphere,** or the idea that the body

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has space inside it that, while not visible, can be experienced and accessed in supporting the body expression of space, as well as a **coronasphere,**[1] or the idea that our breath accesses a farther-flung volume of space. That is, we perceive space around familiar moving bodies as capable of being filled with their presence. These terms are listed and further described in box 5.1.

When we move in space, changing our position in the environment, our kinesphere always comes with us. In drawing attention to this volume, the BESST System names a space where a human body can be expressive, where a given human can do functional work. However, purely considered as a volume, the area reachable by a given body is uniquely shaped by that body—and may change over the course of that body's lifetime, or even over the course of a day. We can refine and define our understanding of the volume of the kinesphere by dividing it into parts such as **zones, levels, reach space,** and **pathways** to finesse a greater access and range of motion as a mover. Thus, the lists in boxes 5.2 and 5.3 (and the symbols in figure 5.1) are several ways that we can identify, observe, and interpret this approach to the kinesphere, all of which are understood relative to the body of the mover.

Zones and levels are useful ways to delineate the volume of the kinesphere, with the key idea being that the area in which a movement occurs

Box 5.1
Defining Spatial Spheres of Human Movement

- **Kinesphere (personal space):** Recognizes that our body has contents outside the container of the skin and within our physical reach. Access to experiencing this sphere is often accomplished through the use of varied movement exercises, such as the "movement scales" introduced later in this chapter, which help broaden our repetitive movement patterns in order to find areas of this sphere we may not typically, but still can inhabit.[2]
- **Innersphere (inner space):** Recognizes that our body has contents inside the container of the skin, which include our own inner volume of space. Access to experiencing this sphere is often accomplished through focusing on the internal sensation of breath.
- **Coronasphere (breath space):** Recognizes that our body has contents outside the container of the skin and beyond our physical reach. Access to experiencing this sphere is often accomplished through imagining the external expression of breath.

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Box 5.2
Zones, Levels, and Reach Spaces

- **Zones and levels:** Denote large areas of space relative to the body.[3]
  - Levels of verticality:
    - High level (above the head)
    - Middle level (around the waist)
    - Low level (around the feet)
  - Sidespace (both sides of the body):
    - Right zone (whole right side)
    - Left zone (whole left side)
  - Sagittal dissections:
    - Front zone or frontspace (whole frontal area)
    - Back zone or backspace (whole back area)
- **Reach spaces:** Where movement occurs relative to the core of the body.
  - Near-reach (close to the body)
  - Mid-reach (between the body and the edge of the kinesphere)[4]
  - Far-reach (at the edge of the kinesphere)

Box 5.3
Pathways

- **Central pathways:** Follow a trajectory toward and away from the center of the body in a somewhat linear fashion.
- **Peripheral pathways:** Trace along the edge of the kinesphere, maintaining a constant distance between the center and the articulated edge in any reach space.
- **Transverse pathways:** Modulate between the center and the edge of the kinesphere, negotiating the in-between space.

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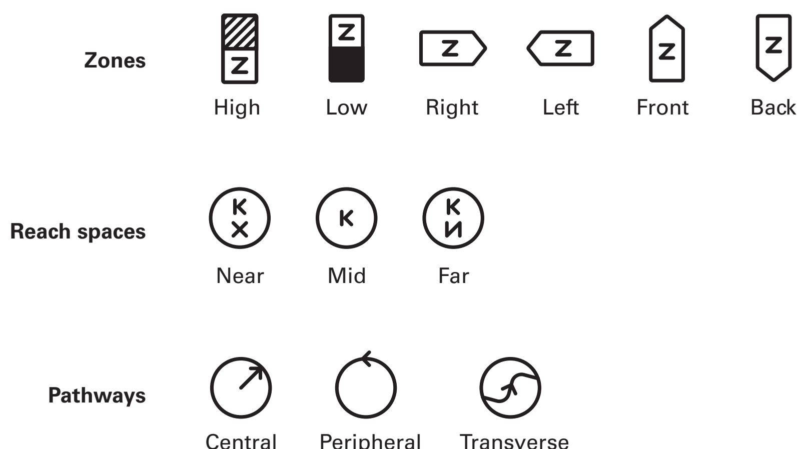

Figure 5.1
Symbols for kinesphere: zones, reach spaces, and pathways.

supports and/or delineates both its form and function. For example, a short person trying to get the attention of a friend in a crowd of people might use the high level of his kinesphere to wave his arms around so that the movement can be seen over the heads of the crowd. This action is needed to serve both functional (to avoid occlusion by the heads of other people) and expressive (to communicate with the friend) goals. A very tall person might only need to use the middle level to wave her arms around and attract a friend's attention because her height already allows arm gestures to be seen across a crowd, but this person still may use the high level and far-reach space of her kinesphere to serve the expressive goal of communicating urgency. The high level and far-reach space are still useful in this instance, even though they are not functionally necessary. Thus, the relationships between reach spaces and zones and levels are personal to each mover, and various tasks require different usages of them.

Pathways can be understood as the route that a movement takes through the kinesphere. As the body moves (both in terms of gestural and postural changes), choices about the trajectory may be apparent, distinct from locomotion, focus, or posture. The Latin word *trajectoria* means "throw across," so it is possible to imagine pathways as trajectories "thrown across" the mover's kinesphere in different ways. The process of that pathway unfolds

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over time and can be seen as relating to away, toward, or through the center; along the edge; or the space in between.

As an approach to the kinesphere, pathways serve as both expressive and functional choices. When giving someone directions (using hand and arm gestures to describe the route), the use of central and peripheral pathways might be better at describing getting from here to there (central) along a road (peripheral). Transverse pathways in this example might be confusing and unclear for delineating a route to follow. A basketball player (while handling the ball) might utilize central pathways to pass the ball to another player, while using transverse pathways to dodge, block, and feint (while holding the ball) in order not to lose the ball, and ultimately might engage a peripheral pathway to make that long, three-point shot.

Embodied Exercises

- **Initial exploration of the kinesphere:** In this exercise, you will explore the options of movement location around your body without changing your location in space.
    - Begin by standing in a neutral stance. Explore the space above your head. Do you automatically use your arms? Can you move your legs into this space? What associations does movement in this space engender? Try the same type of exploration for the middle and low levels. What feels familiar? What sort of actions do you think you do in these different spaces? Which level do you experience more fully with arms, legs, or core? How are they the same and different?
    - Do the same exploration for frontspace, backspace, and sidespace. What sort of tasks seem to be supported in these different zones? Do you experience a preference or familiarity with one zone over another?
    - Continue to explore the space around your body that defines your kinesphere. Make any notes about what you discover about both functionality and meaning. What space do you feel you have the greatest access to? Why do you think that is the case?
- **Using images to find meaning in space:** This exercise engages different attitudes toward space via distinct imagistic descriptions that invite exploration.

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  - Lie on the floor and feel everything drain out of you and into the earth. Grow roots down into the earth—how can you move and feel this connection? What if you were moving on the bottom of the ocean, in a muddy swamp, or on a rocky hillside?
  - Try moving toward your feet (down or forward), head (up or backward), and sides (right and left) on your belly and on your back. How does your experience change as you use the front zone of your body? The back zone? The sidespace? What changes occur in each of these iterations?
  - Gradually work your way to sitting, and then standing. What happens as you change your level in the space?
  - Notice how we manipulate the same ideas in Space through familiar images in the opening of this exercise versus more literal, explicit directions or tasks in the previous exercises.
- **Transforming body actions:** In this exercise, you will explore transforming the same basic body action through different concepts in Space.
  - Zones and levels:
    - Manipulate moving an object around on your desk in the front zone. Now try manipulating the same object in the right or left zone. How does your experience of the object change? What could this shift be useful for facilitating?
  - Reach spaces:
    - Enact back-and-forth lateral action of the open, outward-facing palm in three different reach spaces.
      - Wipe your nose (near); wave hello (mid); ward off unwanted attention (far).
  - Pathways:
    - Pick up a pencil using each kind of pathway.
      - Central (efficiency)
      - Peripheral (inefficiency or distraction)
      - Transverse (complexity, even emotional)

Notice which pathways seem to make sense to you for the task at hand, and how changing the pathway changes the meaning/experience of the movement.

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