

EMVIZ: The Poetics of Movement Quality Visualization

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Abstract

This paper describes the design of an interactive visualization prototype, called EMVIZ, that generates abstract expressive visual representations of human movement quality. The system produces dynamic visual representations of Laban Basic-Efforts which are derived from the rigorous framework of Laban Movement Analysis. Movement data is obtained from a real-time machine-learning system that applies Laban Movement Analysis to extract movement qualities from a moving body. EMVIZ maps the Laban Basic-Efforts to design rules, drawing parameters, and color palettes for creating visual representations that amplify audience ability to appreciate and differentiate between movement qualities. EMVIZ was demonstrated in a gallery context. The audience reported that the system produces evocative and meaningful visual representations of Laban Basic-Efforts. This paper describes the metaphoric mapping process used to design and implement the visualization system and discusses the aesthetics of the resulting visual style.

Categories and Subject Descriptors (according to ACM CCS): I.5.5 [Pattern Recognition]: Implementation—Interactive systems; J.5 [Computer Applications]: Arts and Humanities—Arts, fine and performing

1. Introduction

A significant tool for creativity in artistic and design practice is the use and application of metaphor. From a linguistic perspective, metaphor involves the use of language to refer to something other than what was originally signified in order to make a meaningful connection between two domains of information [KM06]. One way of understanding the application of metaphor in art and design is as a mapping from one conceptual system onto another. This involves a cognitive process both in design and in audience reception where one domain of information is understood in terms of another [Cox06].

Creating artistic visualization combines interpretive metaphoric mappings with aesthetic approaches in representing data from one domain to another, primarily visual, domain. By designing mappings in conceptual space and operationalizing the mappings through computational parameters, new media artists can generate novel and aesthetically articulated visual representations.

Through the EMVIZ visualization system, we explore these metaphoric processes by mapping movement quality to parameterized abstract visualizations. The motivation for this project comes from our interest and expertise in both human movement—especially in the field of contemporary dance performance—and artistic visualization. The design

of our visualization system places attention on aesthetics, provides real-time response, and develops computational models from expertise-based knowledge on properties of movement.

We use metaphoric mappings that rely on artistic interpretation of human movement quality to generate data-driven visual forms, and illustrate a creative design process for communicating—in a novel and aesthetic way—expert knowledge around an important area of human activity. In doing so, we aim to open areas of exploration in the fields of human movement analysis, artistic visualization, and interactive dance performance.

2. Background

In this section, we review key concepts in artistic visualization, metaphoric mappings, human movement analysis, and our contribution to the literature which combines these concepts: mappings that use human movement as the source domain for artistic visualization.

2.1 Artistic Visualization

Artists have applied information visualization techniques by experimenting with various computer algorithms and principles of creative design to map data into visual domains. These art and design practices bridge ideas sourced across disciplines to provide solutions for the

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visualization community [Jud04]. These types of works are what we refer to when we talk of artistic visualization or visualization art. Inspired by interactive art, new media, graphic design, and social sciences, principles of artistic visualization have been widely discussed in the literature [VW07, VM07, LM07, Kos07, RG08]. Artistic visualization is based on expressing existing data in aesthetic forms that may not be immediately perceivable by the viewer in a literal or linguistic sense. Artistic visualization does not intend to resolve human-computer interaction problems such as literality or usability; rather, it constructs artistic forms by presenting data in an aesthetically compelling way that communicates through abstractions. Artistic visualization data mappings are interpretive, subjective, and follow a different set of conventions than those governing information visualization or scientific visualization. Their tendency to focus on experience over data, and communication over information identifies some of the key features of artistic visualization, particularly those that include interactivity. While artistic visualization frequently makes use of design principles and computational techniques to increase aesthetic perception through visual representation, it also puts the responsibility of imaginative interpretation on the viewer through their phenomenal observation of the visualization artifact. These principles reinforced our artistic process of meaning making and audience experience in the development of the EMVIZ visualization engine.

2.2 Metaphoric Mapping

Cox adapted concepts from linguistic and visual metaphor to arrive at a framework for understanding visual metaphors, or *visaphors* [Cox06]. In the visaphor framework, the mapping process is characterized by twelve properties or events (Table 1). For instance, mappings rely on a target domain and a source domain, and the properties from the source domain are mapped onto the target domain. In this project, we adopted Cox's visaphor framework to explore the creative use and the poetics of metaphoric mappings in the domain of human movement analysis.

Visaphor Characteristics
• Visaphor is defined by having two parts: target domain and source domain.
• Visaphor provides understanding of the target domain in terms of the source domain.
• The target and source domains each represent an implication or conceptual system, also called a concept network.
• A concept network includes collections of beliefs, concepts, symbols, technologies, cultural biases, assumptions, other metaphors, personal impressions, other property systems, and other worlds.
• Properties or characteristics from the source domain are mapped onto the target domain.
• This is not a one-to-one mapping; some characteristics get mapped, others do not.
• This is not an arbitrary mapping; it has to make sense.
• In this mapping, new meaning arises through novel association and contributes to target domain concept network.
• Some visaphors have become embedded in culture so that we no longer recognize their metaphorical nature; they are interpreted as literal or conventional.
• The metaphoric-content continuum ranges from conventional everyday visaphors to the novel, figurative visaphors.
• Aesthetics and creativity influence the position of visaphors on the metaphoric content continuum.
• The audience interpretation depends on the context and the communication setting.

Table 1: Cox's visaphor framework [Cox06].

2.3 Human Movement Analysis

Our human relationship with movement is fundamentally significant because we constantly move through space, interacting with the world in a ceaseless flow of understanding —the world through— movement. Movement is an outer manifestation of an inner state (or intention) and the part of ourselves that extends to and interacts with the physical world [LB80, MY88]. We are familiar with many activities related to movement, such as walking up a hill or running across a football field. We can also sense movement from a still scene or a photograph of humans in motion. However, dancers have a particularly deep relationship with movement in that they rely heavily on movement to communicate choreographic concepts. Often, dancers do so without the aid of additional elements of staging, such as props or narrative text, relying only on their trained physicality to express choreographic intent. A dancer's ability to embody a wide variety of qualities of movement is central to this task. However, while variations in movement quality can be perceived as aesthetically pleasing by lay audiences, the ability to critically discern, describe, and differentiate between movement qualities tends to be limited to experts who have experience or training in movement practices. From our prior experience in interviewing lay audience members on their experience of a dance performance, questions such as, "What did I just see?" or, "What was the movement telling me?" frequently arise. To allow audiences to perceive and explore movement qualities, we examine strategies in representing the aesthetic and communicative properties of human movement quality through metaphoric mapping, computation, and artistic visualization.

Laban Movement Analysis (LMA) is an analytical and embodied system for understanding human movement that is based on the work of Laban and subsequently expanded by Bartenieff [BL80]. LMA looks at movement through four different components: Body, Space, Effort, and Shape. Taken together, all four components comprise a rigorous framework for movement analysis [LL74, Sch08, BB07], and have been applied to different computational research areas [CCZB00, LLR05, RD07, Sch09]. Since we are interested in the expressive aspects of movement, we focus our research on LMA Effort, the aspect of LMA that defines *qualities* of movement. In the LMA system movement quality is defined through its Effort.

Effort analysis categorizes human movement quality using four parameters: *Space*, *Time*, *Weight*, and *Flow*. Each of these LMA Effort parameters is a continuum bounded by two extreme values. One value is the result of "indulging" through the LMA Effort, while the other is the result of "fighting" through the LMA Effort [LL74]. Space is related to the subject's attention to the surrounding environment and the directedness of their interaction with it. A multi-focused or meandering intent results in an *Indirect* movement while purposeful intent results in *Direct* movement. Time is related to the mover's sense of urgency. A sense of leisure is connected to *Sustained* Time while a sense of urgency is connected to *Sudden* Time. Weight is related to the mover's sense of presence in the

world and the impact they make upon it. A buoyant attitude creates *Light Weight* while a vigorous presence creates *Strong Weight*. Flow is the feeling of “aliveness” and is marked by the ability to move between mental states with fluency. A sense of abandon marks *Free Flow* while a feeling of restraint marks *Bound Flow*.

In everyday movement, some parameters are emphasized while others are minimized [LL74]. For instance, when a mover is in what Laban calls the *Action Drive*, their attention to Flow is minimized. In the Action Drive, the extreme values of Space, Time, and Weight combine to create eight qualities, outlined in Table 2. These movement qualities are so prevalent in daily activity that Laban calls them the *Basic-Efforts* [LL74]. We describe in section 3 a prototype system, called EffortDetect, that applies expert knowledge to building a system that recognizes Basic-Efforts as performed by a dancer. We use this as a starting point to apply a visaphor-oriented approach to movement quality visualization.

Weight	Space	Time	Basic-Effort
Strong	Direct	Sustained	<i>Press</i>
Light	Direct	Sustained	<i>Glide</i>
Strong	Direct	Sudden	<i>Punch</i>
Light	Direct	Sudden	<i>Dab</i>
Strong	Indirect	Sustained	<i>Wring</i>
Light	Indirect	Sustained	<i>Float</i>
Strong	Indirect	Sudden	<i>Slash</i>
Light	Indirect	Sudden	<i>Flick</i>

Table 2: Effort parameter values for each of the eight Basic-Efforts.

2.4 Human Movement as Source Domain in Metaphoric Mapping

Visaphoric mappings of human movement have been reported in the literature, but few have used an artistic approach that relies jointly, as we do, on design-based thinking, attention to aesthetics, real-time system response, and a source domain of expertise-based knowledge on universal properties of movement. Bartram and Nakatani mapped low-level features of movement (such as amplitude, speed, direction, fluidity, and contour) generated by a single gesturing hand to three types of affective impressions: positive valence, negative valence, and calm [BN10]. The mapping was derived through statistical analysis of qualitative feedback from users. While the work has substantial explanatory power in its production of the perception of visual motion, it is not concerned with our own focus of interactive artistic visualization.

Glow [OWS*08] is an interactive dance performance that uses interactive video technology to generate real-time responsive abstract graphics with sensual and grotesque qualities. While *Glow*'s visualization engine produces highly compelling, aesthetic results, it does not seem to use visaphoric principles, such as that of explaining one

domain in terms of another. A more deliberate use of visaphoric mappings is made in some tools from Synchronous Objects [PS09], an interactive visualization toolkit that uses choreographic data to determine drawing parameters such as direction, number of brushes, brush shape, brush size, and hue. The data visualized are choreographic information such as the pattern of exchanges of choreographic cues, the number of dancers, and the distance between dancers. The closest example of what we aim to achieve is provided by Gutknecht *et al.*, who created an interactive visual response of a Butoh dance performance [GKLS08]. Motion attributes such as intensity, direction, and flow were mapped to a circumplex space of affect, consisting of “pleasantness” and “activation”. These were then mapped to visualization parameters such as size, color, direction, and speed of the visual elements. However, the mappings were designed to support the specific narrative of the performance and were not intended to reveal features that are independent of narrative and inherent in all movement, as LMA features are.

3. EffortDetect and EMVIZ

In order to generate movement quality data, EMVIZ used a real-time machine-learning prototype system called EffortDetect that applies LMA to extract movement qualities from a moving body in the form of Laban Basic-Efforts. EffortDetect was originally developed by the Institute for Advanced Computing Applications and Technologies at the University of Illinois and the University of Illinois Dance Department in collaboration with Dr. Thecla Schiphorst, at the School of Interactive Arts and Technology at Simon Fraser University [PMGT10]. We have adapted and iterated this initial research. Figure 1 illustrates how EffortDetect integrates into EMVIZ. While a limited number of experimental systems recognize LMA Effort based on position and velocity of body parts [SPD09, ZB05], we chose EffortDetect because its wearable hardware system is portable and ideally suited for performance and installation in gallery spaces.

EffortDetect is composed of two main system components: a wearable hardware accelerometer based system (Figure 1a) and a software interface (Figure 1c). This hardware system is worn on the wrist of a dancer (Figure 1b). The hardware system consists of an accelerometer, a microcontroller, and a radio transmitter that transmits a stream of acceleration data generated by the accelerometer. The software takes that stream of Basic-Efforts, translates it into a stream of higher-level motion features, and then feeds the motion features into a trained machine-learning system that recognizes patterns in the motion feature stream. The final output of the system is a stream of Basic-Effort vectors (Figure 1d). Each Basic-Effort vector consists of eight real-number values between 0 and 1, representing the system's confidence in a Basic-Effort's presence in the movement (e.g., Dab=0.035, Flick = 0.442, Float =0.025, Glide=0.0, Press=0.0, Wring=0.006, Slash=0.0, Punch=0.0451). We map values

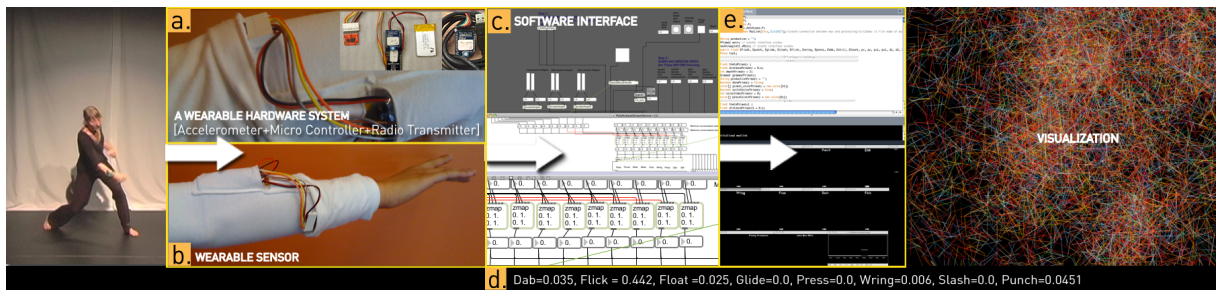


Figure 1: A system diagram of EffortDetect and EMVIZ system. (a) Components of the wearable hardware system. (b) The wearable sensor worn on the wrist of a dancer. (c) Software interface. (d) A stream of Basic-Effort vectors. (e) EMVIZ Software interface.

of each Basic-Effort vector to our source visual metaphor algorithms using design rules, drawing parameters, and color palettes to create a meaningful visual representation of movement quality. Figure 1e presents EMVIZ software interface.

4. The Poetics of Metaphoric Mapping

In this section, we detail our mapping strategy between movement quality and generative visual elements. In applying Cox’s Visaphor framework, we define movement quality as the source domain and elements of visual design as the target domain. Figure 2a summarizes the interpretative technique we employed in mapping characteristics of movement quality onto equivalent elements of visual design.

4.1. Effort Parameters and Generative 'L-System' Line Qualities

The parameters for each Basic-Effort were mapped onto characteristics of lines in a way that is consistent with principles of *two-dimensional design* [Won72]. Though simple, a line can convey meaning or emotion through characteristics of its visual form [LGB06]. A horizontal line can represent a sense of peacefulness or calm, while a vertical line can communicate a feeling of strength. A diagonal line can represent a feeling of motion and action. Round or curved lines can represent restfulness, while a short line can communicate a feeling of hurry or nervousness. Thus, line characteristics can be metaphorically mapped onto the domain of the human body in motion. For instance, the forceful or vigorous quality of Strong Weight can be represented by a vertical line, while a diagonal line can convey Sudden Time. We detail our interpretive choices in Figure 2a.

Our line qualities are used to determine generative drawing rules for an L-system engine that is at the heart of EMVIZ. First described by Lindenmayer in 1968, an L-system interprets a string of characters as a linear sequence of instructions, generating graphics with an organic aesthetic [PLH*96]. For instance, *F* can be defined as the symbol for the command, “Draw forward a step length of 10 pixels”. Plus (+) instructs the drawing

procedure to turn right by 90 degrees. Thus, the command *F+F+F+F* would be interpreted as a command to draw a 10x10 square. L-systems have been used by numerous artists, designers, and researchers as a generative process to create complexity with a series of simple yet cumulative rules. For instance, McCormack explores the use of L-system techniques in various ways to generate natural patterns or 3D plants animation such as in *Turbulence* (1995), *Morphogenesis* (2001-2004), or *Bloom* (2006) [Whi04, MBDJ04]. Hemburg explores the uses of L-system algorithms to generate a surface and form for architectural design [OH07]. Similarly, we use an L-system algorithm in EMVIZ to generate complex, abstract visual elements using sparse data. Figure 2b and 2c presents the six drawing rules for each Effort parameter. In this implementation, the L-system has four main visual parameters: line length, line stroke, line rotation, and color palette. The length, rotation, and stroke of line visual elements were mapped onto values taken from the stream of Basic-Effort vectors.

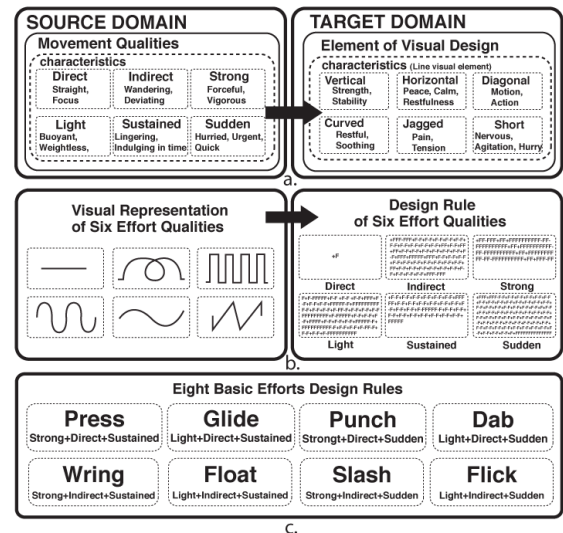


Figure 2: (a) The conceptual mapping from movement qualities (Source Domain) to element of visual design (Target Domain). (b) An example of visual representation for each Effort Quality. (c) Eight Basic-Efforts Design Rules.

MOTION FACTORS	SPACE		WEIGHT		TIME		
EFFORT QUALITY	Direct	Indirect	Strong	Light	Sustained	Sudden	
EFFORT CHARACTERISTICS	Straight, Single, Focus, Undeviating	Flexible, Wandering, Deviating, Spiraling	Forceful, Vigorous	Buoyant, Weightless, Easily overcoming gravity	Leisurely, Lingered, Indulging in time	Hurried, Urgent, Quick	
KANDINSKY COLOR CHARACTERISTICS	Silence of Death Peaceful, Light Blue, Heavenly Color	Excentric Green, Peace, Stillness, Quiet	Powers Motion Green, Red, Yellow, Orange, Strength, Energy	Motionless White, Harmony of Silence, Not a dead silence	Concentric White, Harmony of Silence, nothingness	Sad & Ailing Silence Red, Yellow, Orange, Loud, Sharp, Hash, Radiant	
EFFORT ELEMENTS COLOR PARLETTES							
EIGHT BASIC EFFORT COLOR PARLETTES							
<i>Press</i>	<i>Glide</i>	<i>Punch</i>	<i>Dab</i>	<i>Wring</i>	<i>Float</i>	<i>Slash</i>	<i>Flick</i>

Figure 3: A poetic mapping between Kandinsky color model and Laban Basic-Effort characteristics. Effort quality characteristic was mapped onto Kandinsky color characteristics. The combination of three Efforts quality create a color palette for each Basic Effort such as *Punch* is composed of *Direct*, *Strong*, and *Sudden* Effort quality.

4.2. Effort Parameters and Color

The line elements were rendered in color by applying a model inspired by Kandinsky's theory of color [KS77]. Kandinsky, a Russian painter and theorist, is known for his introduction of the concept of abstraction to the field of painting through his use of color 'mapping' techniques. Kandinsky explored the harmonious relationship between sound and color and used musical terms to describe his painting process [KS77]. Kandinsky proposed that color communicates an inner expression, emotion or idea to the spectator much as Laban proposes that movement quality is an indicator of inner physical attitude. We adapted Kandinsky's color model to our system's drawing parameters, resulting in a subjective and expressive use of color in our mappings (Figure 3).

4.3. System Implementation

The EMVIZ prototype was developed using the Processing Development Environment. In order to create a visualization system that responds in real-time to movement, EffortDetect system was used as mentioned in section 3. Figure 4 shows sample output from EMVIZ for each of the eight Basic-Efforts as they were performed by a dancer.

5. Audience Response

In this section, we summarize a pilot feedback session conducted at an art gallery where we exhibited a prototype of EMVIZ. The pilot feedback session involved an audience composed of a mix of various experts from the fields of computer science, dance, visual arts, and scientific visualization. In this pilot session, a dancer with university-level LMA training repeatedly and in random sequence performed movements that embodied each of the

Basic-Efforts. Generative visualizations that responded in real time to the sensed movement of the dancer were simultaneously generated, displayed and projected by EMVIZ. This prototype of the EMVIZ system was installed as an interactive installation at the Surrey Art Gallery in British Columbia, Canada. Figure 5 shows sample image from the exhibition (More images can be found at <http://www.patsubyen.info/emvizPaper/gallery/gallery.html>). In order to create an interactive experience, we invited attendees of the event to use a glove equipped with the EffortDetect wearable hardware system to interact with the visualization system and to move with various qualities while guided by a video demonstration illustrating the concept of motion qualities and LMA Effort.

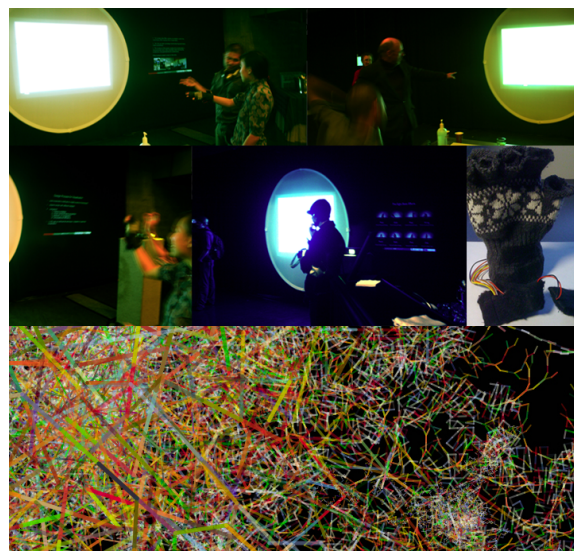


Figure 5: Interactive installation at the Surrey Art Gallery in British Columbia, Canada.

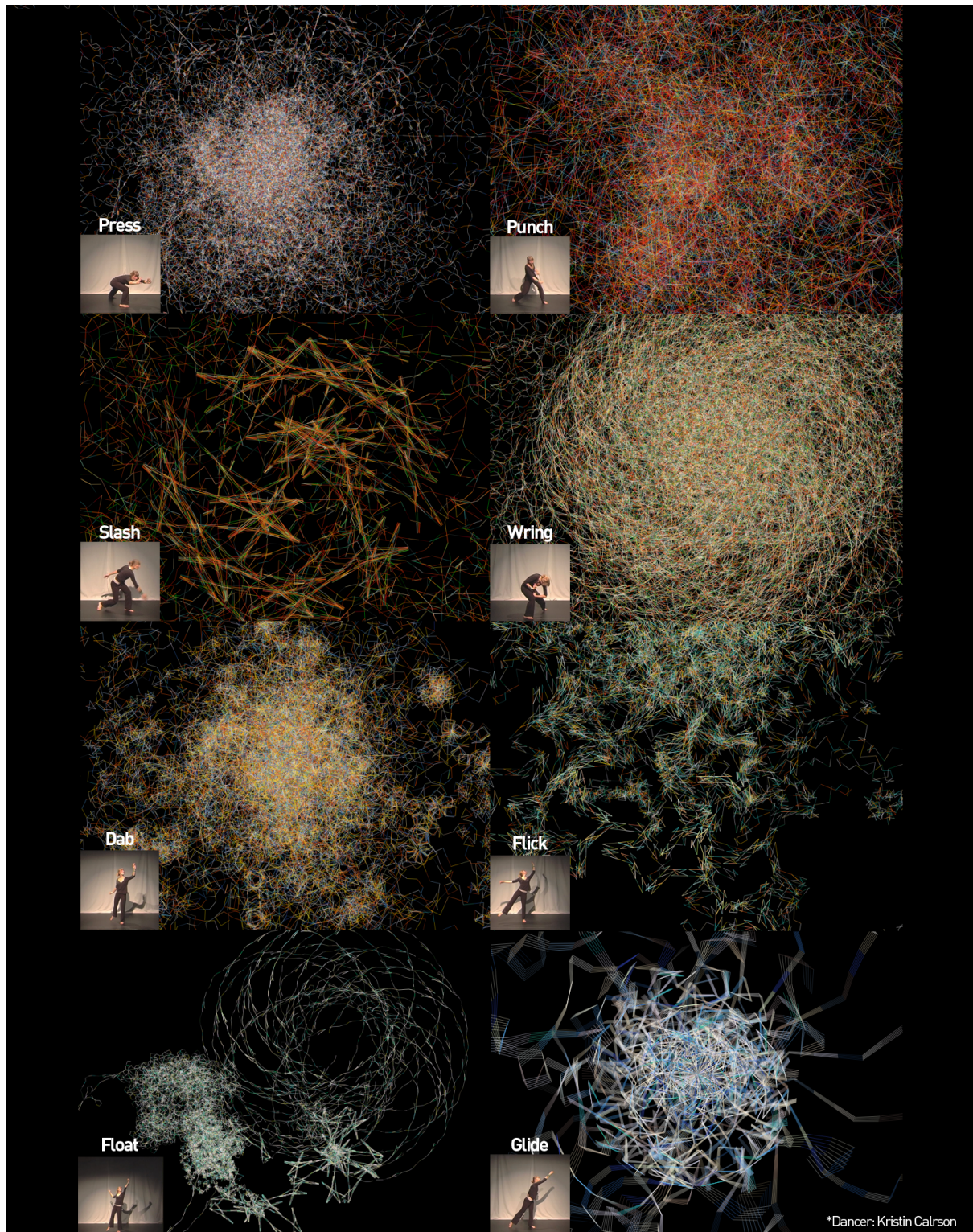


Figure 4: EMVIZ's visaphoric approach to visualizing movement quality: Laban's eight Basic-Efforts represented through a poetic and communicative mapping to color and visual forms.

The audience reported being able to see the correspondence between the visual representations of the movement with the movements themselves. They provided feedback on the aesthetic qualities of the visualizations and described them as “evocative”, citing aesthetic unity as a particularly strong feature of the visualization. They reported that the visualizations helped their ability to detect and interpret changes in the qualitative aspects of the dancer’s movement, as well as connect them with the dancer’s own experience of movement quality. Direct, Indirect, Sudden, Light, and Strong Effort parameter values were particularly legible in the visualization. However, not all effort qualities were equally legible to the audience. For example, the correlation between Sustained Time and its visual counterpart was not always recognizable. Also, the audience felt that the appearance of and transition between the visual elements may move too quickly to be fully appreciated. A transition between two different Basic-Efforts may be useful to address this problem. Finally, they reported that the complexity of the visualizations could be reduced somewhat and the graphics enlarged in order to highlight the individual differences between the visualizations.

Many of these issues can be quickly resolved by adjusting the drawing rules and parameters while preserving the conceptual framework of the mappings. For instance, the animation speed can be adjusted by changing the frame rate setting for the animation. The rules may be modified to reduce the visual complexity of line elements. Other issues, such as finding a way to transition between two Basic-Efforts, will require exploration into computational techniques for interpolating between visual representations of two different Basic-Efforts.

6. Conclusions and Future Work

EMVIZ is a visualization engine prototype that represents our exploration in design process and metaphoric mappings between movement qualities, in the form of Laban Basic-Efforts, and visual elements. The visual representations reflect aesthetic choices made in generative processes, design rules, and color styles. These choices were grounded in a theoretical framework for representing knowledge in a non-visual physical movement domain to a visual domain. We described a conceptual mapping and how we transformed it into a computational approach for generating visualizations using L-system drawing rules. EMVIZ was used in an interactive art installation during which the audience provided critical feedback regarding their response to the aesthetic and communicative properties of the visualizations. Audiences reported the system’s ability to support their ability to become aware of engage in, differentiate and furthermore, appreciate differing, various and changing movement qualities based on the changes in their own or alternatively in a dancer’s movement, with the aid of EMVIZ.

EMVIZ exemplifies an approach to artistic visualization that privileges embodied design processes and artistic

metaphoric mappings in generating sensory output from analytical movement frameworks developed from movement expertise in order to support a greater democratization of shared understanding of human movement. The EMVIZ framework represents a strategy for bridging expert knowledge with audience experience. We expect that artistic visualizations of movement quality can be useful in other areas, such as designing for attention and non-verbal communication in mobile devices, constructing meaningful interaction in public and urban spaces, and designing for virtual characters or virtual environments.

We are currently conducting more extensive research into the aesthetic and communicative properties of the existing version of EMVIZ. Our visaphoric approach could be applied to other kinds of L-system drawing rules and other visually generative techniques that can represent expressive movement, as described by LMA and other movement typologies. We aim to explore parameters for creating new drawing rules that generate new visual representations of movement qualities, using evolutionary algorithms for identifying these new parameters. Finally, we are currently developing an interface based on EMVIZ that can be used in live performance and in interactive installation.

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