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Enhancing Visualization with Expressive Motion

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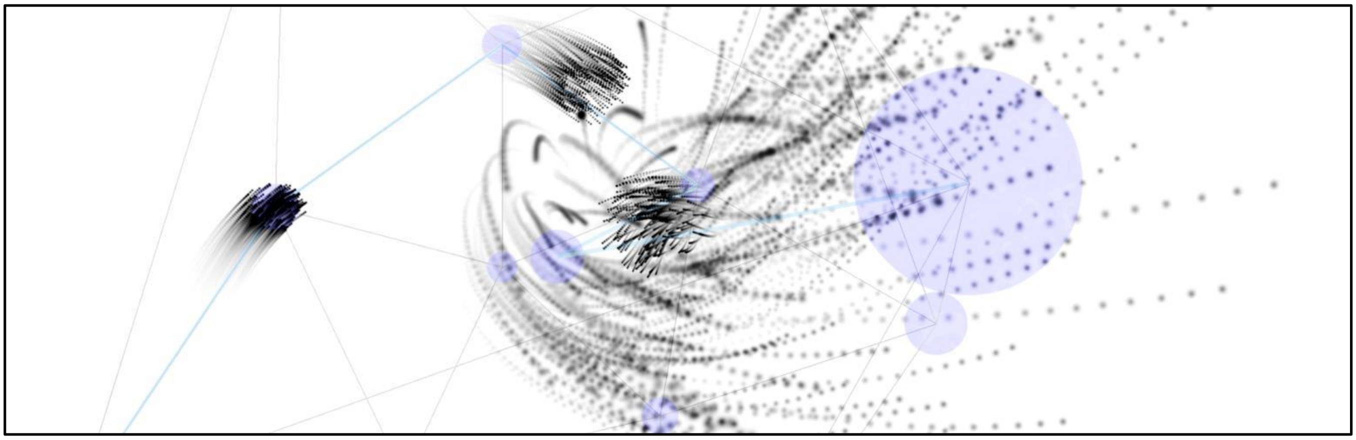

Figure 1. What is expressive motion?

Abstract

Motion is a fundamental perceptual channel, and we derive substantial information about the world around us from how things move in that environment, informing both cognitive and affective interpretation. While previous information visualization research has explored how motion can represent data, support pattern-matching and ease transitions [2, 13, 15], how to represent the rich expressive and affective capacity of animation remains a challenge. A history of expressive movement in the performative and visual arts offers insight into how movement patterns may carry meaning, yet current research provides only a limited understanding of affective motion features and the potential for expressive movements to be abstracted and applied in other contexts. Descriptive frameworks of human movement such as Laban Movement Analysis (LMA) provide rich analytical tools and principles that model the expressive capacity of movement but these remain descriptive rather than computationally tractable. In this paper we present an enhanced computational model for expressive motion that we developed with movement experts. We briefly describe the results of an ongoing study with choreographers and performers in using these features to express movement qualities and discuss potential applications for information visualization.

Introduction

Imagine two paintings of the exact same landscape by two different artists, where one artist uses smooth, flowing, gentle, positive strokes, and the other artist uses sharp, jerky, aggressive, negative strokes. The fundamental elements are the same: location, perspective, trees, mountains, ocean, but the experience of each painting is dramatically different. The interpretation of this visual experience involves both cognitive and affective processes. Our cognitive system is responsible for recognizing what elements are present and making sense of the environment, while our affective system interprets the environment from an experiential perspective [29, 32]. Affect is not limited to basic emotions, influencing more complex states such as: boredom, frustration and engagement [39], and has also been linked to cognitive performance in neuroscience research [12, 16]. Until recently, the design of affect in data visualizations has been accidental or a secondary consideration, discussed only in terms of aesthetic design [20, 28]. The importance of aesthetics and good design are acknowledged as fundamental to user engagement and pleasure [7, 22, 29], yet the discourse is sparse with respect to exploring affective dimensions of design. Our initial research shows that even simple geometric motions can elicit different affective responses [4, 24].

Motion has been of interest in information visualization research since the early 90s when animated user interfaces began to appear in personal computing applications [Lethbridge and Ware]. While motion has been determined useful for representing data values [15], filtering [2], spatial relationships [3], and transitions [13], the communicative potential of motion affect has not been deeply explored, although aesthetic effects of animation are acknowledged [11]. The ability of simple motions to communicate complex or nuanced behaviors has been shown in early perceptual research using simple shapes and short animated films [14, 37]. While some basic features of motion contributing to affect have been discovered using simple algorithmic motions, these techniques are limited in their expressive capacity, unable to represent complex behaviors and qualities [10, 24, 25]. When might data be perceived as floating vs flicking? What is the difference between data punching vs gliding onto a display, and how might this alter the perception of affect? We look at the rich history of movement theory in the performative arts to determine expressive qualities of human movement that might be abstracted and applied in information visualization contexts, enhancing affect and overall user experience.

Descriptive analytical frameworks from the performative arts, notably Laban Movement Analysis [21], provide a framework to analyze expressive qualities and behaviors of human movement. But this knowledge is typically a tacit, expert only space, and the development of algorithmic principles is largely unexplored. The case for incorporating LMA principles to enhance the believability of traditional animation has been made [5] and several attempts to computationally recognize low level motion features contributing to specific LMA qualities have been implemented in both animation [40] and choreography [33]. We explore how qualities and behaviors drawn from human movement can reliably be represented algorithmically, developing a model of abstract motion features that contribute to perceptions of expressivity, and propose that these features strongly contribute to affect. A principled understanding of these expressive features can be applied in information visualization contexts, expanding on the existing aesthetic applications of motion, enhancing affect and supporting cognition of data.

Recent qualitative studies have shown that the mapping of LMA concepts to abstract motion features is possible within a tractable design space [26], and ongoing research examining what motion features movement experts manipulate to create various Laban movement qualities will determine how these qualities contribute to perceived affect. This requires a computational model of how low-level motion features map to LMA concepts. In this paper we introduce such a model, developed in collaboration with Certified Movement Analysts (CMAs) from the performative and expressive arts. We describe the elements of the model and discuss how this work can contribute to applying motions that may enrich the affective and expressive capacity of information visualization.

Background

Information Visualization

The role of motion in information visualization contexts was initially explored with blinking text and visual objects [6, 34], and following the adoption of graphical user interfaces and computer animation, early applied research explored how moving icons might interrupt the user in application contexts [38]. The research has linked response times with motion speed but found no other significant effects, with further research examining the efficacy of motion to show spatial relationships and grouping, compared to established qualities such as color or shape [Ware and Limoges, 1994]. Working with several groups of data objects, questions regarding the determinants of motion similarity led to results that demonstrated the use of motion for filtering and grouping data, notifications and showing spatial relationships and dependencies [2]. Research has also investigated the effects of flicker, direction, velocity, phase, frequency and amplitude with phase found to be the most sensitive quality overall [15, 38]. Motion is both spatially and temporally minimal, making it an ideal candidate for encoding data in small screens, but there are affective externalities to consider when using motion. With few principles to inform the design of motion affect, we seek to develop these principles and inform best practices for using motion in information visualization contexts.

Psychological and Perceptual

Early psychological researchers used simple objects and motions in short films to create apparent behaviors [14]. These motions were perceived as actions or behaviors by study participants, who saw objects fighting, protecting, defending, hiding, kissing, among several other actions. A similar study was done using a single dot with frozen (traced) and animated paths of motion [37]. Participants were informed stimuli was of a walking path and responded with descriptions such as: determined, cautious, drunk and disorderly and fearless. In both research experiments, simple motions were perceived and described by participants in terms of human behaviors, however there is little known about the affective potential and lowlevel features that govern perception.

Abstract representations of human movement evoked perceptions of different qualities: tired, old, animate, mechanical, biological are examples [17, 18] . Later work that further abstracted limb movements saw successful recognition of emotions [9], and affective representations of arm movements in articulated and abstracted experiments a high degree of recognition for the affective dimension of arousal [31]. Research has explored capturing and generalizing expressive movements and gestures to be applied as emotional transforms [Kenji et al. 1996]. The detection of emotion and expression from has been further explored with automated detection techniques [8].

Recently, interdisciplinary research combining computer animation, psychology, cinematography and motion capture technologies with a central goal of understanding the affective properties of motion suggests that speed, shape and changes in trajectory, play a significant role in both single point and textures of motion, multiple points with a shared motion shape [4, 24]. Recently these findings were substantiated by related work in motion volumes: 3 dimensional motion textures or motionscapes [10].

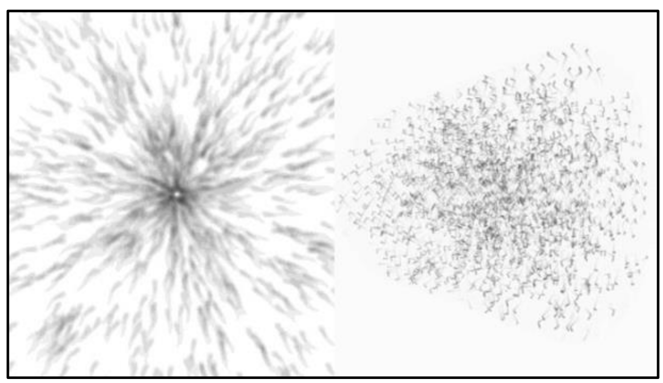

Figure 2. Affective Motion Textures

Performative Arts

Laban Movement Analysis (LMA) provides low level descriptive concepts that define expressive movement qualities and actions in terms of body, space, shape and effort. A key component in this framework is space, defining positions, transitions and limitations with geometric polyhedral, forming movement scales that define common trajectories for spoke and arc like movements through a space. Reach space defines the extent of movements in

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relation to the body core and may be defined as near, middle or far. The Effort Factors: flow, weight, space and time, each have an indulging (free, light, indirect, sustained) and condensing (bound, strong, direct and quick) component that defines qualities of movement, but are severely nuanced and not orthogonal dimensions. Combinations of 3 effort factors create drives such as action, passion, spell and vision, and 2 effort factors combine to create states such as awake, dream, mobile, remote, rhythm and stable. The basic effort actions found in action drive are combinations of the indulging and condensing components of time, weight and space and have accessible definitions such as punch, flick, float, glide, dab, wring, slash and press.

Phrasing has several applications that may define the building up or ramping down of a movement quality, speed for example; at the body level it defines the sequencing of movements: simultaneous, sequential and successive. We explain in section 4.2 and 4.3 how we developed a model, through qualitative design studies informed by CMAs, that can reliably represent these core movement qualities. Our model forms a tractable design space of low-level abstract motion features that can reliably communicate expressive qualities.

Motivation

Expressive movement qualities from the performative arts have yet to be modelled algorithmically and abstracted such that their affective properties may be applied in non-embodied visualization contexts. We conducted 2 studies, one with videogame designers and videographers and another with CMAs, both using abstract motion tools to create motions that elicit affect. This revealed the expressive shortcomings of existing tools and the need to embed domain specific concepts (LMA) into a computational model, such that reliably recreation of qualities and behaviors is possible.

Our Model

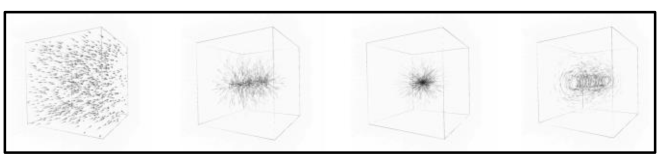

Figure 3. Motion Shapes (left to right): linear, radial, spherical and circular [Feng et al. 2014]

Figure 4. Path Deformations (left to right): straight, angular, wavy

Examined Features of Affective Motions

Previous research in affective motion was expanded using artists and designers in a qualitative study tasked with motion creation, given a limited parameter set of motion features, to determine the capabilities and limitations of features that communicate affect. Designers created motions from a small set of low-level, algorithmic features to control the appearance of textures and volumes, 2d and 3d motionscapes respectively that looped continuously [Figure 2]. Motion shape was linear, radial or spiral, cylindrical or spherical and determined the main trajectory of several objects in a 2d or 3d area or volume [Figure 3]. Motion objects were amorphous soft black points, with parameters to control their amount, density and individual size. Speed and direction were simple parameters in the model, and path deformations, straight, angular and wavy, altered the movement of a motion orthogonal to the main trajectory [Figure 4]. Using these low-level abstract motion features our designers were surprised with the ability to create motions such as organic and mechanistic motions [25].

Properties	Examined Features	Movement Factors
Shape	linear, radial, spiral, cylindrical, spherical	spokes and arcs, polyhedra, spherical
Space	plane, cube	axis, plane, cube, polyhedra; reach space (near, middle, far)
Quality	speed, direction path deformations (smooth, angular, wavy)	speed, twist, path sharpness; rhythms (smooth, angular, boxy, flip flop)
Appearance	density, spread, object size	density, spread, object size
Change	user controlled parameters	interpolated qualities, phrasing, sequencing

Table 1. Development of Computational Model

CMAs Working with Affective Motions

We used existing models of affective motion textures and with CMAs in a qualitative study examining the potential to represent LMA concepts and determine what motion parameters are most important [26]. Insights through motion creation and interviews revealed that existing algorithmic models did not afford the ability to quickly change a motion parameter, cue changes in parameters or sequence several motions to form a composite expressive motion. While a dense, twisting motion represented a heavy weight, and sustained time, and path deformations represented rhythms with even phrasing, these continuously looping ambient motion textures were limited in their ability to communicate several key LMA concepts such as Space, Shape, Effort and Phrasing. Existing motion parameters may have afforded the communication of a single quality or affect, but were not expressive, lacking many of the key features that govern complex gestures and embodied movements. Table 1 summarizes these and other insights and illustrates the transition from previously examined features of affective

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motion textures to a new model incorporating movement factors from LMA theory and practice. [Table 1].

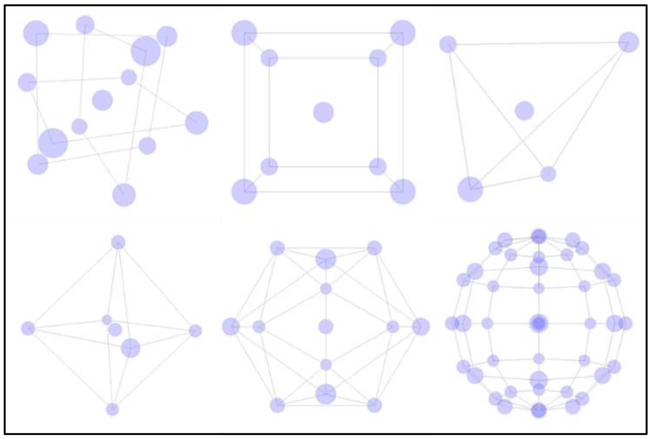

Figure 5. Space Shapes (left to right, top to bottom): plane, cube, tetrahedron, octahedron, icosahedron and sphere

Extending Properties of Affective Motions

Through qualitative studies with movement experts we identified how common LMA concepts can be expressed with low-level motion features and geometric primitives in a model that is accessible to movement scholars, represented using LMA terminology. Our current model defines a main motion trajectory by specifying vertices in LMA space shapes at varying levels of reach space: near, middle, far [Figure 5]. Motion quality is controlled by speed, twist, and path *sharpness* (how tightly a motion follows the trajectory specified by selected vertices [Figure 6; Figure 7]. Rhythms that are deformations to the main trajectory such as smooth (sinusoidal), angular, boxy and flip flop (alternating high / low) [Figure 8]. Object appearance such as the number and density of particles, volumetric size and individual object size, are included from previous texture parameters [4], as these have been noted by CMAs as contributing to perceptions of LMA Effort factors, light / heavy weight and direct / indirect use of space. The phrasing of a single motion can control qualities such as speed and appearance, using a crescendo (<), decrescendo (>) and both (< > [loaded in the middle]) that correspond to popular animation qualities of easing in, easing out and both, respectively [19]. Body level phrasing is achieved by sequencing 1 motion to trigger 1 or many other motions, and motions can also be blended into one another using soft or hard interpolated transitions.

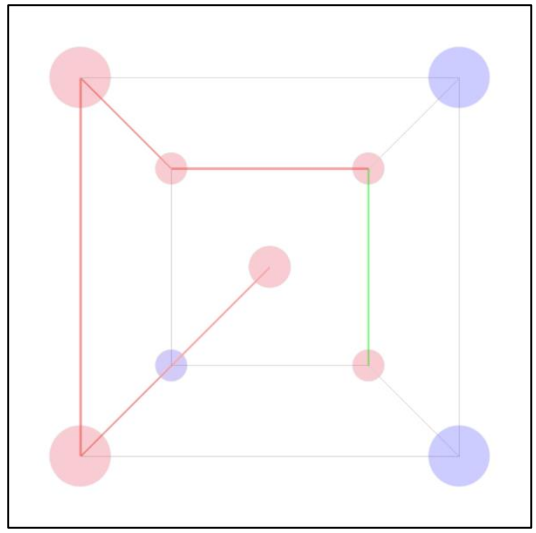

Figure 6. Selecting Vertices

CMA Reactions to LMA Representations

We held a recent research residency that included several visiting CMAs and movement scholars and conducted a design study where participants used our model to create expressive motions. Participants enjoyed the expressive capacity of being able to work with familiar concepts such as space shapes and reach space to represent scales of movement, but wanted finer controls for path sharpness, currently limited to bound, tight and loose. It was suggested that several appearance and quality parameters would benefit from start and end values that would be interpolated during a motions execution. Sequencing several motions was of interest, but needed finer control over delay and blending of motions.

A particularly interesting outcome was movement scholars discussing amongst themselves questions: what low level motion features create certain LMA qualities and what qualities are able to be reliably represented? There was a general consensus that while some basic effort actions, punch, float, etc…, could be reliably represented, the model affords greater ability to represent LMA states and drives, more nuanced but expressive qualities. Although it was entirely possible, the difficulty of representing movements as part of a non-embodied creative process was mentioned as a barrier. Potential applications of representing movements abstractly were discussed by movement scholars in the form of priming and teaching tools of LMA concepts.

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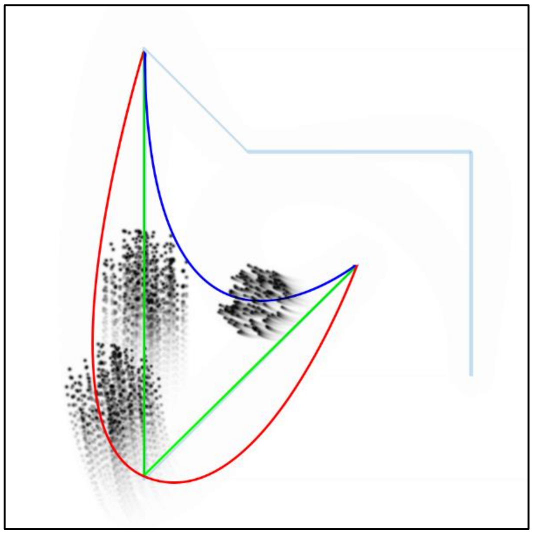

Figure 7. Path Sharpness (red, green, blue): tight, bound, loose

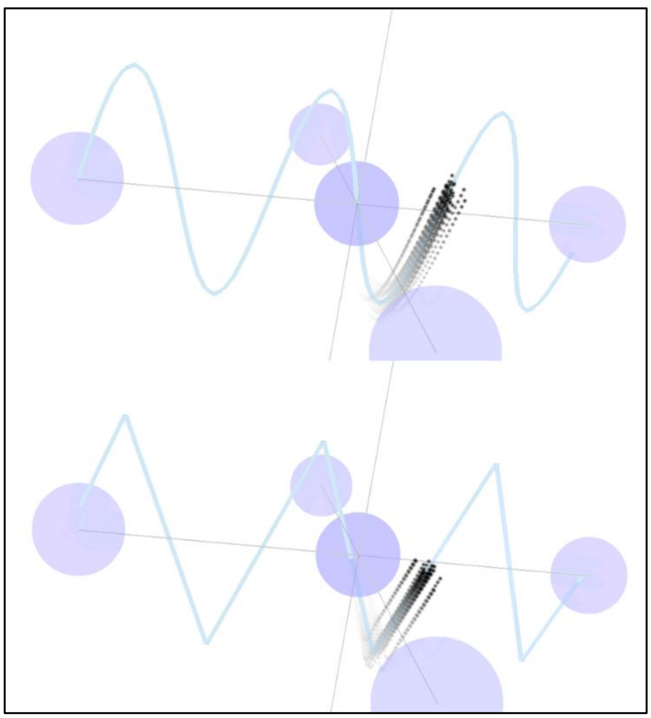

Figure 8. Smooth and Angular Rhythms

Discussion

Our ongoing research developing a computational model of LMA concepts capable of reliably representing expressive movement qualities manifested itself in a prototype motion editor demonstrated in a design study to numerous movement scholars. Initial reactions are promising, and confirms our previous qualitative studies that expressive movement qualities can be represented using abstract motion features, however it is crucial that the model accurately embed concepts from movement theory.

While we began examining the basic effort actions from LMA in an effort to represent what "punchy" or "floaty" data might look like, it quickly became clear that movement scholars wanted to represent more nuanced qualities in the form of LMA states and other drives besides action drive. This raises new questions of what passion, spell and vision drives might add to an information visualization, should it be possible to accurately represent them using abstract motions. What might spell bound, stable, or rhythmic data look like and when might it be necessary to increase passion in a data visualization? More generally, how do states and drives contribute to affect and can these perceptions be applied in information visualization contexts?

Future Work

We continue to develop our model with the help of movement experts in order to develop the capacity for representing movement qualities using abstract motion. We anticipate that our more tractable design space will allow us to correlate and study the low-level motion features CMAs manipulate to communicate specific expressive qualities. With a corpus of expressive motions developed by movement experts, we will also be conducting a quantitative study to determine how abstracted movement qualities contribute to affect. Our final study will apply expressive motions in information visualization contexts where possible and measure their ability to enhance user experience and cognition.

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