Embodying Diagramming through Pen + Touch Gestures

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ABSTRACT

Ideation, the process of generating new ideas, is central to design tasks in which the goal is to find novel solutions around a set of requirements. Designers create diagrams as external representations of ideas. Ideas and the design process from which they emerge are embodied by both the gestures used to create diagrams and the diagrams themselves. Interaction design needs to leverage embodiment to support creative cognitive processes. We hypothesize that expressive embodied gestures for transforming diagrams will stimulate design ideation. We introduce new bimanual gestures for creating diagrams. We posit implications for the design of gestural interaction to support design ideation.

INTRODUCTION

Ideation, the font of innovation, means the process of generating new ideas. Ideation is central to design. *Design* is a purposeful and creative process in which means to an end is laid down. Design processes are supported by embodied representations, including gestures, tangibles, and diagrams, which have been found to help people think [13, 11, 21, 14]. Embodied representations externalize ideas to supplement cognition. The proliferation of sensory interaction modalities, such as multi-touch surface, pen, and computer vision, enables cost-effective development of new forms of embodied interaction. Leveraging embodiment in interaction design is key to mitigating the cognitive and neuromuscular load inherent in design environments with large visual spaces and complex command sets.

A *diagram* is a design thinking tool that enables and stimulates imagination, facilitating conceptualization. Diagrams mediate exploration of relationships between concepts, using ambiguous visual representations to foster varied, flexible interpretations. Architects see a diagram as an "engine of novelty" [15], documenting aspects of integral design thinking processes [18]. The philosopher and cultural theorist, Deleuze, identifies the diagram as an abstract machine, "defined by its informal functions and matter and in terms of form makes no distinction between content and expression, a discursive formation and a non-discursive formation" [4].

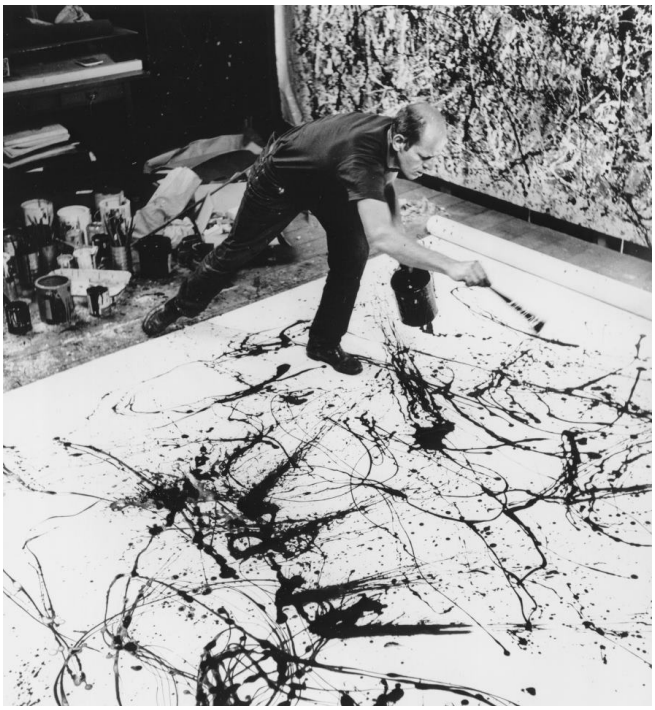

Figure 1: Photograph by Hans Namuth of Jackson Pollock engaging in gestural painting [20].

We hypothesize that expressive embodied gestures for creating diagrams will stimulate design ideation. Gestural interaction (e.g. Figure 1) supports exploratory ideation processes, such as sketching ideas and using one's hands (sometimes with tools) to transform representations in different ways. We are developing a new embodied diagramming environment to investigate impact on creative cognitive processes. We derive new bimanual pen + touch gestures (combining pen and multi-touch input) for diagramming. We are evaluating our new environment and gestures in architecture education.

This paper begins with a discussion of related work. Next, we introduce a new diagramming medium and propose novel pen + touch gestures stimulating design ideation. We describe a context for evaluation. We conclude with this research's potential implications for designing gestural interaction.

RELATED WORK

We ground design of our new medium and pen + touch gestures in embodied cognition. We build upon prior sketch design environments and bimanual interaction techniques.

Submitted for review.

Embodied Interaction to Promote Cognition

Cognitive models, including those associated with creativity, are embodied [5]. Embodied interactions promote cognition through physical movement. For example, when readers manipulate objects that correspond to characters and actions in a text, it greatly enhances comprehension and memory, as measured by both recall and inference tests [6]. Tversky et al. demonstrate that gestures help people not just to communicate meaning, but further, to remember and to understand complex ideas [24]. Of particular value are iconic gestures, whose shape maps directly to what they mean, metaphoric gestures, that use spatial representation to convey relationships (such as distance), and embodied gestures, which encode knowledge motorically, as images and diagrams encode pictorially. These gestures augment memory, and the representation of meaning. Together, these species of gestures provide us with cognitive guidance for how to develop gestural interfaces that will help designers manipulate diagrams and create ideas as they interact.

Sketch Design Environments

Sketches act as interactive imagery [7] in which strokes are drawn, re-drawn, drawn over, and erased, transforming ideas. Ideas are externalized, manipulated, reflected upon, and reinterpreted [22]. Designers quickly sketch out ideas while simultaneously manipulating diagrams in various ways, supporting creative discovery as externalized ideas are combined and restructured [25]. Sketches can be rigorous in visually describing details, but also ambiguous using abstract forms and implicit visual features.

SILK is a user interface (UI) design tool that enables rapid prototyping interface designs through sketching [16]. The primary goal of SILK is not to promote creative UI design, but to facilitate quickly designing UIs and testing basic interactions. The explicit shapes and symbols needed to form recognizable sketches of UI components oppose our goal to facilitate ambiguity to promote design ideation. Electronic Cocktail Napkin is a pen-based collaborative design environment that supports abstraction, ambiguity, and imprecision in sketching [8]. Instead of focusing on sketch recognition, the present research addresses how gestural interaction can support creative processes.

Bimanual Interaction

We seek to embody diagram interactions through bimanual pen + touch gestures. Guiard developed one of the first models of bimanual interaction, the *kinematic chain* [9]. In a kinematic chain, the non-dominant hand (NDH) acts to define a reference frame for the actions of the dominant hand (DH). When drawing on paper, this is equivalent to the NDH positioning and rotating the paper in conjunction with the DH making marks with a pencil. We will design bimanual interaction techniques using the kinematic chain model.

The benefits of bimanual interaction are well documented. Toolglass widgets are translucent interface tools that are positioned with the NDH, and interacted with using the DH [2]. A kinematic chain is formed, where the NDH hand defines which elements are affected by the widget through positioning, and the DH selects which operations to perform and provides fine grain control over how operation parameters are manipulated. Hinckley et al. recommend that the pen by itself always makes marks, but when combined with touches creates new forms of interaction [10]. Brandl et al. investigated benefits of bimanual interactions across different input modalities [3]. They compared time and errors to complete path following tasks using touch with both hands, pen with both hands, and pen with DH and touch with NDH. Findings indicated that pen and touch was quicker, more accurate, and more preferred.

EMBODIED DIAGRAMMING ENVIRONMENT

We are developing a new diagramming environment to investigate impact of embodied gestures on creative design processes. We introduce a new diagramming medium and propose pen + touch gestures for transforming diagrams. We are deploying our environment in architecture education to investigate impact on design ideation. We are engaging in iterative design using formative evaluations in architecture education to improve our diagramming environment and gestures.

Information Composition + Sketching

We introduce a new diagramming medium that integrates information composition with sketching in an infinite zoomable space. *Information composition*, a diagramming medium for representing a personal information collection as a connected whole, supports reflection when performing information-based ideation tasks [26]. Designers engage in *information-based ideation* tasks, using information as support for generating new ideas [12], such as investigating how properties of different materials will impact a design. Composition authoring is a process of gathering clippings from information resources. These clippings function indexically, enabling access back to the information resources. As a diagram, an information composition expresses relationships between gathered ideas through implicit visual features, such as spatial positioning, size, color, and translucence. As holistic sensory media, compositions are designed to engage thinking about, authoring, annotating, and reflecting on collections as records, sources, and media of ideation.

In our new diagramming medium, designers gather clippings while sketching out ideas and relationships amidst the collected information (see Figure 2). Complex interaction issues arise as designers intermix actions involving sketching, gathering clippings, and visual transformations.

Pen + Touch Gestures

We seek to reduce cognitive and neuromuscular load associated with tools supporting complex interaction by providing gestural interactions that are natural and intuitive and more directly connect designers to diagrams. The goal is not simply to make diagramming easier, but to aid designers in forming abstractions and investigating ambiguous representations through embodied experiences.

Figure 2: Early stage information composition + sketching diagram created by an architecture student in our field study after the first session. Students were asked to create a diagram on multiple scales investigating how contrast and juxtaposition of scales express relationships. Each visual clipping serves as an index for accessing information resources on the architect, Alberto Campo Baeza, and his work. The student has begun sketching over image clippings to emphasize important ideas and explore relationships in geometry.

While diagrams vividly convey spatial relationships and ideas, much of the thinking and mental models of the author are encoded in embodied creative processes of transformation. We define *diagram transformation* as any operation that changes a diagram to encode meaning, e.g.: adding and removing elements, affine transforms, color-space transforms, cropping, and distortion. Just as a designer uses her hands to transform physical diagrams (e.g. rotation, transparent overlays, folding or bending material), embodied gestures are needed for transforming our new diagramming medium.

The ability to quickly sketch an idea is important as suggested by others [1, 8, 23, 19]. As recommended by Hinckley et al [10], we propose that the pen, when used by itself, always makes marks. The exception is when pen input is combined with touches, that act as modifiers, invoking commands. This enables designers to fluidly switch between sketching ideas and manipulating or transforming diagram elements.

Designers form kinematic chains when interacting with physical media, such as orienting paper while sketching or rotating a model to find an advantageous angle for adding or removing parts. We propose using gestures with kinematic chains where the NDH gestures to select the transformation and element(s) affected and the DH (with a pen) precisely performs the transformation. Transforming a diagram may be exploratory and require reverting changes to investigate alternate ideas. In these kinematic chain transformation gestures, the NDH can also perform a gesture to undo or redo a series of transformations.

In an infinite, zoomable information space, designers will have difficulty keeping track of ideas and relationships between ideas due to limits of working memory [17]. We hypothesize that embodied gestures for manipulating scale, rotation, position, and zoom will support spatial cognition helping designers remember where ideas are located, as well as, think about relationships between ideas represented visually through spatial distance. A single touch gesture positions diagrammatic elements. A two point pinch gesture, involving either two fingers or a one finger and the pen, performs simultaneous scale, rotate, and translate.

Embodied gestures should not be limited to finger touches and pen points. Designers use their whole hands, arms, and body when creating diagrams. We propose whole hand gestures to transform multiple elements or regions of a diagram. Whole hand gestures are coarser than finger touches, allowing for broad transformations, such as aligning elements along a line represented by the side of one hand with fingers extended straight or sweeping elements into groups or piles.

Evaluation: Architecture Education

As a context for evaluating effects of embodied gestures on design ideation, we are engaging in an ethnographic investigation and field study in architecture education. Students in the graduate course, Visual Thinking: Theories and Methods of Diagramming, used a preliminary version of our dia-

gramming environment on a course assignment. We collected the diagrams they created, and video recorded their gestural interactions while working in the environment. We are in the process of analyzing this data. Additionally, we are recruiting architecture Ph.D. students to use the diagramming environment for a longer period as part of developing their dissertations. We seek to gain better understandings of architecture design processes and how embodied gestures can promote ideation in these processes. By the time of the workshop, we plan to have new findings.

CONCLUSION

HCI researchers have the opportunity to transform design processes with the development of new embodied pen + touch gestural interaction. Emerging sensing technologies make this transformative research possible. We need gestures that help offload cognitive processes to external forms addressing limits of human attention. Digital environments enable creation and exploration of large information spaces that can be dynamically transformed. Gestural interaction needs to be expressive to support diverse transformations. Developing gestural interaction techniques that use kinematic chains will help designers think about how elements are transformed and the relationships between elements and transformations.

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