Measuring Creativity: Multi-Scale Visual and Conceptual Design Analysis

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Abstract
Multi-scale creative web designs organize content across zoom levels, presenting new challenges for web page segmentation, content identification, and creativity evaluation. We propose building a novel computational model, combining visual and conceptual features, to quantitatively represent and analyze multi-scale designs. Using the model, we will compute metrics—emergence and visual presentation of ideas—that required expert feedback.

Research Situation
I am a 3rd year PhD student working with Dr. Andruid Kerne. My research investigates analysis methods for multi-scale creative web designs. I defended my dissertation proposal in Spring 2017. I plan to graduate in Fall 2018. This graduate student symposium is ideal for presenting my ideas as valuable feedback from mentors and peers—in fields such as HCI, art, design, psychology, and computer science—could significantly support the proposed research.

Context and Motivation
New assessment techniques are required to support creative design learning and teaching [9]. Creative learning and innovation are essential to personal well-being and economic growth [4, 15]. The World Wide Web provides a context for creative innovation that addresses challenges posed by the new global economy [17]. The web is charac-

terized by heterogeneous information sources, media types, and representation formats [2]. Human understanding of web content is driven by visual perception, in which human beings have highly evolved [18]. Perceptual grouping in vision enables us to form meaningful spatial, temporal, and causal relationships [19]. The problem is that computational methods have not yet achieved these abilities.

Computational means for giving people feedback in their creative design processes is the research challenge my dissertation will address. In today's web pages, visual layout does not align with its DOM structure, making it difficult to identify the content and its relationships [6]. Web page segmentation algorithms based on visual perception help overcome this problem [6, 12]. However, these algorithms operate on a single zoom level. They were not developed for analysis of multi-scale designs, which organize content at multiple zoom levels, e.g., infographics created using Photoshop or Illustrator, presentations created with Prezi, and exhibits created with IdeaMâché [13].

Prior work employs visual features for building a computational model in order to predict users' first impressions of web page aesthetics [20]. Creative cognition research employs conceptual features for computing metrics, such as emergence of ideas [23, 11], with the help of human raters. Combination of visual and conceptual features has been shown useful toward mining designs from the web [12]. However, such a combination has not been employed to build a computational model for measuring dimensions of creativity. We will develop novel methods, using such combination, for evaluation of multi-scale creative web designs, through these specific aims:

- Identify clusters in multi-scale designs using visual and conceptual features
- Measure creativity in multi-scale designs by building a computational model and automate calculation of metrics, such as emergence and visual presentation of ideas
- Develop guidelines for crowdsourcing content identification to deal with limitations of machine analysis
- Develop a design learning dashboard for supporting expert monitoring and feedback on multi-scale designs

Background and Preliminary Work

Visual perception plays a dominant role in human cognition, as it allows us to accurately decipher distant spatial information [18]. Grouping, a prominent phenomenon in visual perception, follows principles of proximity, color, size, orientation, symmetry, and continuity [19]. Bertin, in Semiology of Graphics [3], organizes visual variables—size, color, value, shape, texture, orientation—based on their associative, selective, ordered, and quantitative perception. Tufte's information design principles, such as consistency, foreground/background relationships, stratification, limited use of saturated color and heavy weight, and other particulars of layering and separation, exploit visual perception [24].

The 2005 NSF workshop report discusses multiple dimensions of creativity and the need to employ mixed-methods for assessment [21]. Dow et al. measure quantity and quality of ideas in tasks such as web advertisement design and product design. They use click-through data and expert ratings [8]. Siangliulue et al. build a computational semantic model of solution space, combining implicit human actions and machine learning, which enable interventions that improve number, diversity, and quality of ideas [22].

Curation, an art practice, is the creative conceptualization and organization of a spatial context for works—which are collected, interpreted, and visually arranged to produce a culturally meaningful exhibition [16]. *Free-form web curation* is a form of new media [14]—designed to enable

users to conceptualize and create new spatial contexts—in which they discover, interpret, and represent relationships, by composing found content elements and their own expressions, on the web and in the cloud. Our current paper presents free-form web curation strategies—Collect, Assemble, Shift Perspective, Sketch, Write, and Exhibit—that support creative design processes [10].

Kerne et al. formulated an information-based ideation methodology for evaluating curations that users develop through engagement in open-ended tasks and activities [11]. Their *elemental* ideation metrics—Fluency (number of ideas), Flexibility (number of categories of ideas), Novelty (rareness of an idea)—apply to the individual elements. Their *holistic* ideation metrics—Emergence, Visual Presentation, Exposition, Relevance—apply to the assembled whole. Elemental metrics were computed algorithmically. Holistic metrics were assigned by human raters based on clear and explicit scoring guidelines. Emergence refers to development of new features not originally present in component concepts. Visual Presentation refers to spatial organization of ideas in a clear and coherent manner.

Research Objectives and Questions

My *long-term goal* is to transform learning, design, and creativity through novel approaches to engagement with interconnected information networks. The *objective of this proposal* is to develop methods for analyzing multi-scale visual and conceptual design. The *principle research question* is how to scale holistic evaluation of multi-scale creative web designs. The *central hypothesis* is that the novel methods will reduce the effort required for evaluation and feedback. We plan to develop a multi-scale design model to quantitatively represent the creative design in web pages. This model will be the foundation for automating evaluation, such as emergence and visual presentation of ideas.

Figure 1: Jordan Jump's multi-scale curation, *Laundry Notifier* [https://ideamache.ecologylab.net/v/teGYF8lbi5/], visually and conceptually organizes clusters of ideas at multiple zoom levels. We see clusters of needs, design, prior work, and technologies.

Methodology

The present research addresses web-based, free-form multi-scale curations (Figure 1). The approaches we develop can be extended to other forms of visual content.

We will analyze semantic representations of free-form web curations, as a form of visual and conceptual design. The semantic representation of a curation includes visual features, such as position, scale, and layer of each element. Elements gathered from the web include semantics for source and link URLs. Created elements will also include type specific semantics. Sketches will contain stroke data. Writings will contain character and formatting data. We will use interaction logs, such as actions of changing the viewport in the zoomable space, gathering elements, sketching, writing, grouping, and transforming elements and groups.

Identify clusters using visual and conceptual features
We will develop a multi-scale design model to quantitatively represent creative expression. The goal is to represent how elements and their concepts are organized and mutually related. A standard vision-based algorithm would fail to recognize nested relationships in an infinitely zoomable canvas. In conjunction with semantic representation, we will use interaction logs to accurately determine users' model of organization. Using this model, we will compute metrics that previously required human evaluation [11].

We will extract descriptions from visual elements, such as images, using the state-of-the-art TensorFlow library [1], to automatically label content. We will extract descriptions from writing elements, such as labels that users annotate on groups. We will use different clustering algorithms and several distance functions to identify scopes and boundaries among element descriptions, which are presented in a curation. In other words, we aim to separate and group individual elements in a curation to clusters.

Measure creativity in multi-scale designs
We will use the multi-scale design model to compute holistic metrics. We will extract keywords from the element descriptions to represent a concept. Intuitively, words that appear frequently, with important syntactic function roles—e.g., a subject or the main predicate in a sentence—and specific characteristics—e.g., all characters capitalized—are likely to be important words. We will consider using these properties in selecting keywords from potentially multiple textual descriptions for an element. We will compute Emergence metric by comparing co-occurrences of the extracted concepts to that within the Google Ngram dataset [5].

We will compute Visual Presentation metric by taking into account extracted features, such as use of multiple scales, whitespace and sketching among clusters, position, alignment, size, color, and font styling, for effective layering of information and conveying of relationships.

Develop guidelines for crowdsourcing
With advances in computer vision and machine learning, automated identification of content has become highly robust and accurate. However, the accuracy largely depends on the machine learning model used and training dataset. As we discussed, machines are yet to come close, in terms of advanced human visual perception mechanisms [18, 19]. Moreover, machines have limitations of identifying contextual and nuanced meanings.

We will make use of human-in-the-loop computation for obtaining rich descriptions of visual elements, when the confidence scores for labels returned from the TensorFlow library are below a certain threshold value. We will formulate detailed guidelines based on qualitative methods, such as visual discourse analysis [7], for engaging microtask workers on crowdsourcing platforms. This will provide us with memos—Locating, Big Picture, and Specification—that uncover visual, relational, contextual, and cultural details.

Develop a design learning dashboard
We will develop a design learning dashboard to enable collaborating instructors view and filter students curations and the computed metrics. We will develop various views, visualizations, and configurations of metrics to support them in teaching and evaluation.

We will engage in dialog with instructors about what metrics mean, how they relate to learning objectives, and how to improve them. Our plan includes annual workshops with collaborating instructors. We will study how they use the current metrics, and also develop new ways to analyze and visualize students' creative processes and design products.

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