A Design Space for Heterodox Methods in Information Visualization

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Abstract— Recent research has looked into the application of: artistic rendering, distortion methods and various other unique i.e. heterodox rendering methods to information visualization. What is the design space of such methods for non-spatial visualization? In this work, we propose a three part design space formed around the types of visual elements each of these various methods manipulate. Then we explore the proposed framework's applicability to information visualization via a survey of existing heterodox visualization methods currently in use, and discuss potential untapped areas to explore.

Index Terms— Information visualization, illustrative rendering, non photorealistic rendering, theory of visualization.

1 Introduction

Information visualization's foray into the use of Heterodox Visualization (HV) methods is quite recent at the time of this writing, but a look into scientific visualization will show a long history of artistically-inspired and other heterodox visualization methods. These methods have been applied to various domains, e.g. volume rendering [1], multivariate geographic information systems [2], and flow visualization [3] name a few. These methods have helped simplify and improve scientific visualizations by either by eluding unimportant features, highlighting details of interest, or otherwise disambiguating the depiction of their target visualizations. It must be said that this is not a comprehensive listing of artistically inspired methods being applied to scientific visualization, but it does show that HV methods have been successfully applied to a visualization domain. Our proposed design space seeks to provide classification of extant HV methods when applied to information visualization, as these methods are likely to benefit information visualization. The sectors of our design space are defined mainly by how the subsequent studied HV methods modify their target visualization(s).

In addition to the positive effects of the previously stated applications of HV methods, other studies have quantified the benefits of HV methods. For example, given an object representation, recognition is significantly faster when objects are rendered with simpler line-based methods over complex more realistic methods. [4]; this also extends to caricature depictions of human faces, the caricature being a simplification of an actual face. When HV methods based in abstraction are used to depict regions of low interest, these regions have been shown to be visually optimal (reduced eye movement and number of regions viewed) [5]. Other HV methods like sketchiness and blur have been shown to be useful for qualitative visual segmentation [6].

While there is not yet sufficient research to provide concrete placement for the application of every HV method to information visualization (an important limitation) our proposed design space does provide structure for a systematic investigation. Additionally, other related research and expert opinions both suggest that such a design space is of benefit to the visualization community. To the best of our knowledge, a systematic approach to the study of HV methods has yet to be performed. It is also important to note that several years of applying illustrative techniques to scientific visualization has benefited that community; and we hope our design space can produce a similar paradigm for information visualization. Towards this end goal, we contribute both an initial decomposition of both the HV and information visualization design spaces, a review of how extant methods fit within this spaces, and examples of their effectiveness.

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2 Background

When exploring HV methods for application to the existing information visualization design space, we of course first reviewed current HV techniques. These methods exist for a variety of applications, and this diversity will likely lead to a somewhat faceted domain. Given that a full survey is beyond the scope of this work, it is extremely important that it be understood that a summarization of the most representative HV methods approaches will be applied to the most significant facets of our proposed design space. This is necessary as almost any method which does not present a direct mapping from data to visualization primitives, could (by definition) be classified as an HV method. We deem it necessary to present a broad roadmap of the design space first, and then extend the major roads to other related areas. If an overly specific classification of the numerous HV techniques which already exist is attempted, it may lead to a design space so faceted that its usefulness becomes hindered. Next we will move on to the major ways HV methods alter images.

3 Media Simulation / Emulation

Broadly, HV methods that model natural media can be divided into those methods that attempt to simulate and those that emulate techniques used by human artists e.g. Painting on canvas [7], woodcut printing, or pen and ink on paper. We typically classify simulation techniques as those which reproduce a particular technique by way of any means needed to produce the intended effect. Emulated techniques try (typically as closely as possible) to replicate or model the physical properties of a given technique and/or media. For example a simulation of a pen and ink technique might use some sort of random distribution function to produce textured lines that appear "inked". Emulation on the other hand, would likely have models the ink (viscosity, transparency, gravity, etc.) and/or paper (fibre orientation, absorption, etc.). While there may be a technical difference, we will use simulation to mean both simulation and emulation. We will use emulation specifically if the technical means of producing the intended technique is especially distinctive when applied to visualizations.

4 STYLIZATION

HV methods need not only simulate techniques inspired by natural media. Some may be artistically inspired, but not tied to a specific technique. We will categorize these techniques that do not easily fit into the natural media simulation category as "stylized". We have separated these stylized techniques into two main categories. 1. image/region-based: includes techniques that apply stylization to whole images or large image regions, and 2. primitive-based: techniques that apply stylization to a rendered image's primitives. Examples include, image warping effects, some pixelization effects, photographic filters, The Kypriandis et al. taxonomy [8] classifies stylized methods into four categories: stroke-based (images are built from various strokes of color, texture, and size), region-based (images are segmented into regions that are processed), example-based (images are used as a reference to render another image in the referenced style), and image processing/filtering methods (sampling methods are re-purposed to produce stylized images). But the four Kypriandis categories can be thought of as special cases or extensions of our two categories.

5 COLOR MANIPULATION

Color is an important dimension in image communication; color can invoke activity or passivity, warmness, coolness, or playfulness. Color can also highlight or categorize. Despite its usefulness; however, color is an expensive dimension to manipulate in visualization. Poor, thoughtless, or a large number of choices can easily lead to data misinterpretation. Examples of HV, techniques include those that tone-map images with a given or limited pallet, introduce artistic effects via shading and lighting, and many others. HV colorization methods often modify the color of user defined image regions. This allows easy combination of HV color manipulation methods with other HV methods and somewhat weakens its status as its own area in our design space. Despite this, color will be considered separately as altering the color of images is a powerful effect, and it can be done independently of image primitives or spatial regions.

6 THE HETERODOX VISUALIZATION DESIGN SPACE

From our survey of many HV methods, three major trends emerge.

1. Many methods use image or object-space techniques (or hybrids where image-space operations dominate other operations).

2. There is a significant body of research dedicated to techniques which directly stylize primitives.

3. Manipulation of color (hue, saturation, depth, etc.) is an easy and effective method by which to alter primitives or whole images.

HV methods that fall under 1 and 2 are primary visual variables in visualization (primitives and image-space). Finally color 3, is given special treatment, as its modification can change the interpretation of the underlying data. Thus, we present a three part design space for Heterodox Visualization.

1. Spatial Sampling (Control of arrangement object or image spaces)

2. Primitive Mutation Fig.1 (Atomic control of image primitives shape, size, texture, etc.)

3. Color Mutation (Strong control of interpretive reasoning of 1 or 2 or used alone)

7 CONCLUSION

We know that illustrative rendering methods have been a benefit to scientific visualization; in this work, we have developed a three-part design space for applying heterodox techniques to information visualization. Spatial sampling approaches use illustrative techniques to aggregate and/or summarize; Primitive Mutation embellishes primitives themselves; and Colorspace Mutation transforms color to modify interpretation. The listed applications are suggestive and not in any way all-inclusive. As we mentioned earlier, this proposed design space does provide structure for subsequent systematic investigation which might yield additional and/or more complete categories. We must emphasize that this is an exploratory study; there is a significant amount of work to be done in this area. There are many HV rendering methods that have yet to be applied to the open field of information visualization

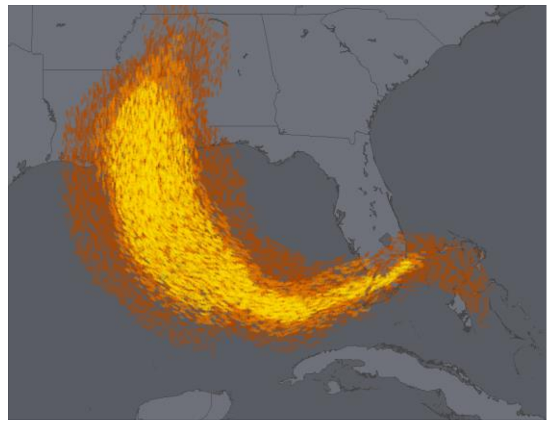

Fig 1. Short painterly strokes [9] at wind sample locations.

REFERENCES

[1] BRUCKNER S., GRÖLLER E.: Enhancing depthperception with flexible volumetric halos. IEEE Transactions on Visualization and Computer Graphics 13, 6 (2007), 1344–1351.

[2] HEALEY C. G., TATEOSIAN L., ENNS J. T., REMPLE M.: Perceptually based brush strokes for nonphotorealistic visualization. ACM Transactions on Graphics 23, 1 (2004), 64–96.

[3] INTERRANTE V., FUCHS H., PIZER S.: Enhancing transparent skin surfaces with ridge and valley lines. In VIS '95: Proceedings of the 6th conference on Visualization '95 (Washington,DC, USA, 1995), IEEE Computer Society, p. 52. 1

[4] WARE C.: Information Visualization: Perception for Design, second ed. Morgan Kaufmann Publishers, 2004. 1, 6

[5] SANTELLA A., DECARLO D.: Visual interest and NPR: an evaluation and manifesto. In NPAR '04: Proceedings of the 3rd international symposium on Non-photorealistic animation and rendering (2004), pp. 71–150.

[6] BOUKHELIFA N., BEZERIANOS A., ISENBERG T., FEKETE J.-D.: Evaluating sketchiness as a visual variable for the depiction of qualitative uncertainty. IEEE Transactions on Visualization and Computer Graphics 18, 12 (2012), 2769–2778.

[7] COCKSHOTT T., PATTERSON J., ENGLAND D.: Modelling the texture of paint. Computer Graphics Forum 11, 3 (Sept. 1992), 217–226.

[8] KYPRIANIDIS J. E., COLLOMOSSE J., WANG T., ISENBERG T.: State of the 'art': A taxonomy of artistic stylization techniques for images and video. IEEE Transactions on Visualization and Computer Graphics 19, 5 (2013), 866–885.

[9] STEED C. A., FITZPATRICK P. J., J. EDWARD SWAN II, JANKUN-KELLY T.: Tropical cyclone trend analysis using enhanced parallel coordinates and statistical analysis. Cartographic and Geographics Information Sciences Journal 36, 3 (2009), 251–265.