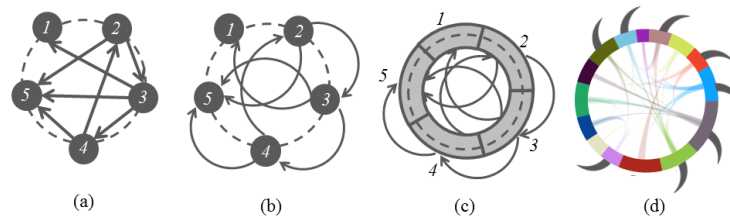# Artistic Inspired Data Visualization Design Process

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Figure 1: *Making a Spirograph: (a) five nodes are placed on the boundary circle, (b) some edges are moved outside of the boundary circle, and (d) Spirograph inspired graph visualization [ECS14].*

Abstract
In this paper we describe our design process for creating artistically inspired data visualizations. We consider graphs as an example of interest for data visualization, and present several novel graph layouts developed using this design process. Through our exploration, we have become increasingly convinced that any intriguing pattern, mesmerizing ornament or exciting art piece may be a source of inspiration for new graph layouts. However creating a mapping between a graph and the selected pattern is hard and challenging, and can be helped by using a methodical and iterative design process.

Categories and Subject Descriptors (according to ACM CCS): Graph Visualization, Aesthetic.

1. Introduction

In recent years, the importance of InfoVis as a discipline has increased rapidly due to the spread of computer systems and the information explosion. One challenging InfoVis task is to present large or complex data-sets in the often limited screen, often leading to overcrowding and general congestion. Extremely dense layouts of complicated data sets can be tedious to explore [Zha07]. However, it has been shown that attractive and engaging visualizations can help analysts in their exploration tasks [CM07]. Also, in more casual environments, aesthetically pleasing information visualizations may invoke curiosity, and excitement [PSM07]. Nowadays, aesthetic appeal is a major concern in visualizations integrated in the larger environment [SLH03, CM07]. We describe a methodical design process for creating data visualization based on an aesthetic inspiration. We discuss graphs as they are an active area of information visualization,and explore the use of a variety of aesthetic patterns as sources of inspiration. There are a plethora of possibilities of interesting patterns in art and design. Therefore, one question is which patterns should be considered? Given such a huge choice, are all productive? Also, how can the selected patterns be mapped to new layouts for visualization? Creating a mapping between data and a selected pattern can be hard and can be aided by a well-thought design process for addressing several objectives which are sometimes in conflict with each other:

- The layout should clearly and accurately represent the data.
- The layout should adhere to the selected aesthetics (i.e. there should be a fair similarity between the layout and the selected pattern; and use of factors like arrangements, color palettes, etc. in a manner that to some extent matches with the chosen aesthetic).
- The new layout should be applicable in practical scenarios.

We describe our methodical and iterative design process for creating artistically inspired graph visualizations according to these objectives. The scope and variety of alternate aesthetics is enormous. We illustrate our process with four diverse example patterns.

2. Related Work

There are several data visualizations which consider aesthetics. Cawthon and Vande Moere report on two different interpretations of aesthetic in data visualizations [CM07]. One, aesthetic refers to

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the measurable factors used for improving the efficiency and effectiveness of tasks such as minimizing edge crossing or edge bending. Two, aesthetic can refer to the beauty of the visualization and reflect personal judgement. Interestingly, their study shows that even application of the second interpretation of aesthetics reduces task abandonment and erroneous response. Thus, attractive visualizations may help people more readily perceive the information contained in the visualizations and may engage analysts more deeply in their tasks [Zha07, CM07].

Recently, visualization attractiveness has been receiving more attention such as Informative Art [HS03] and InfoCanvas [MS03] (for review see Pousman et al. [PSM07]) Viégas and Wattenberg present a survey of projects in artistic information visualization [VW07]. They explore how an approach that focuses on being aesthetically pleasing improves scientific analytical reasoning in information visualization. Lin and Vuillemot [LV13] use Spirograph patterns for visualizing tweets collected during CHI 2013. Heinrich and Weiskopf [HW12] use parallel coordinates to create artistic images, based on footprints. Etemad and Carpendale introduced ShamsehTree [EC09] as a visualization for large trees that leveraged Persian floral patterns, to design a tree visualization that can present a large tree (around 75000 nodes). PaisleyTree [EBB*14] introduces a hybrid visualization for trees with arbitrary depth and breadth. In this size-invariant tree visualization, combines node-link, adjacency and nested layouts to represent large trees.

3. Design Process Overview

We describe the process by which we have drawn upon various art and design aesthetics to create new graph layouts. These new layouts borrow to at least some of the unique factors from the chosen aesthetic. Any intriguing pattern, mesmerizing ornament or exciting art piece can be used as a source of inspiration for a new layout. The steps are:

Step 1 Immerse oneself in different types of aesthetic patterns to establish a personal context. Explore widely, and look for patterns (e.g. traditional artworks, math, and nature), and including variations from art and design (our examples: Persian floral patterns, star patterns, Celtic knots, Escher and Voronoi diagrams).

Step 2 Make a selection from the above patterns.

Step 3 De-construct the selected pattern by looking for structural repetitions and motives. Build an understanding of what makes the selected pattern work.

Step 4 Consider possible mappings to a graph. Working with concrete data is helpful. Data characteristics can sometimes show the way to proceed in developing a mapping.

Step 5 Conduct an iterative process between, sketching, modifying, extracting the layout, aligning with math/algorithm, aligning with data, aligning with selected pattern, and getting feedback from data experts. Figure 2 shows there is no *Start* and *End* to this iteration step. Each action can be connected to any other action depending on the design process. For example after sketching a mapping, we may start with getting feedback from expert and then move to aligning with data, and aligning with math, or we can first align with selected patterns and then move to aligning with math and get expert feedback.
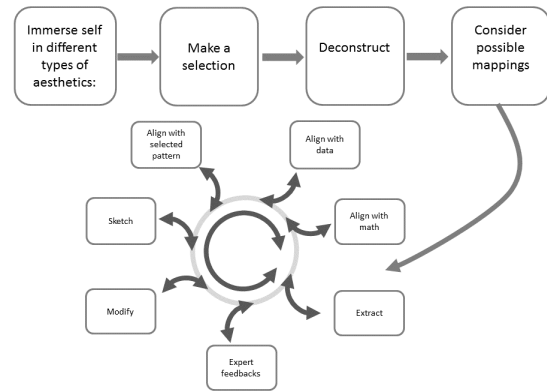

Figure 2: *Schematically representing the design process.*

After selecting the desired pattern, chosen pattern aspects need to be mapped to a graph layout. However, this is a hard task and sometime may seem impossible. During this hard task we need to remember to respect these two objectives that are commonly in conflict: the layout should clearly and accurately represent the data; and should be pleasing, adhering to the principles of the chosen aesthetic, through use of similar layout patterns, arrangements, and color palettes, etc. As illustrated in the Figure 2, we use an iterative approach. We start by searching for patterns which have specific features in their structure, which may map to the elements of the data (e.g. graph). For instance, patterns with repetitive elements or symmetrical structure are good candidates for this purpose. More specifically, in order for a designer to be able to show a given feature of data, she or he needs to find an aspect of the pattern to which that feature can be mapped.

Since the role of edges in graph applications is also fundamentally essential, we can consider the above strategy for edges. Equivalently, nodes of the dual graph [BM76], can be mapped to the repetitive elements similar to the strategy for mapping edges. In another words, for given graph G, we first build $D(G)$, the dual(line) graph whose nodes are edges of G and two nodes of $D(G)$ are adjacent if their corresponding edge in G has a common vertex [BM76]. Then our process can be used for $D(G)$ by mapping nodes of $D(G)$ (or edges of G) to the similar elements of the pattern.

Figure 3: *Inspirations: Left: "Columbus Landed in India" by Hundertwasser 1969 [HW1] (Creative Commons license [CCl]). Right: Example of ornamental floral patterns [vb].*

Since, often one starts by finding one appropriate aspect of the pattern to map to one aspect of the data, the goal of the iterative step (step 5) is to increase the degree to which the new layout adheres to the selected aesthetic principles of the chosen pattern. In this step, we may try to include more details and features of the graph with more intricate parts of patterns. We also, may tweak the design by rearranging the nodes' representatives, by reducing clutter, by changing the color palette, and by enhancing the symmetry of design. Even after these refinements, we might come to the point that we need to change the pattern and the mapping (see Figure 2). In the following sections, we illustrate this design process by describing layout development.

4. Node-Ring Layout

Here, as one of the supporting examples, we show the derivation of Node-Ring layout [ECS]. Since graphs nodes can be represented by circles, we searched for patterns with many circles or dots, selecting Hundertwasser's paintings (Figure 3 Left) and Australian aboriginal dot paintings (Step 1 and 2).
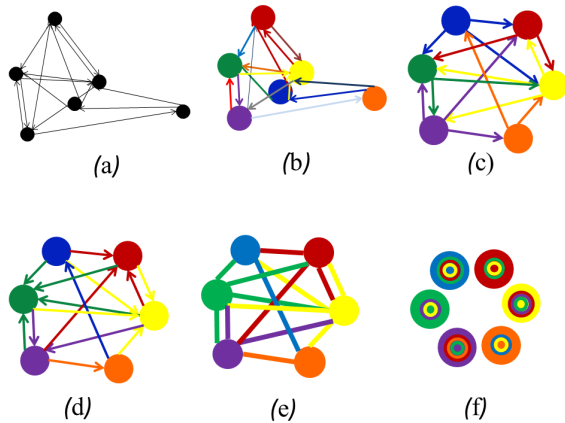

(a) *(b)* *(c)*

(d) *(e)* *(f)*

Figure 4: *Diagrams of the design process of Node-Ring layout.*

Figure 4, shows the mapping steps for Node-Ring layout. Each node is represented with a colored circle, and initially, each edge with colored line. The arrangement of nodes (Figure 4, (a)) and the selection of colors were initially random (Figure 4, (b)). Next, in an align with pattern step, we explored arrangements of nodes such as circular, spiral and symmetrical (Figure 4, (c)). Then we tried coloring edges based on either the color of their node of origin or their destination node (Figure 4, (c) and (d)). To reduce edge clutter, we colored the edges according to their destination node and dropped the arrowheads since directions of edges can be seen by their colors (Figure 4, (e)). For example a red edge between the blue and the red node implies that the edge direction is from blue to red. Next, inspired by Hundertwasser's paintings, we took the color coding idea further and mapped the entire edge to a colored ring inside of the source node (Figure 4, (f)). This is also an align with pattern step. Now, all adjacent edges of each node are nested within the source node. A red ring inside the blue node represents the directed edge from blue node to the red node.

5. Daisy Layout

This example was inspired by ornamental patterns of daisy flowers (See Figure 3 Right). As in Node-Ring, nodes are represented by circles but the edges are represented by a linear element attached to the source node, pointing to the destination node. These linear elements, could be simple lines (Figure 5 (b) and (c)), or more decorative elements such as daisy petals shown in the Figure 5(d) (aligning with the pattern step). We first colored all daisy nodes with one color and all edges (daisy petals) with another. However, as seen in the Figures 5 (d) the overall representation is still different from daisy ornamental patterns. The arrangements of daisy petals around the core is usually symmetric. This symmetry can be satisfied if all edges (petals) are distributed symmetrically around a node (see Figure 6 (b)). However, edges in our design point to their destination node (see Figure 6 (a)). To enable symmetric petal placement we use color to show edge connections. The position of the petal shows the source node and the color of the petal shows the destination node (Figure 6 (b)).
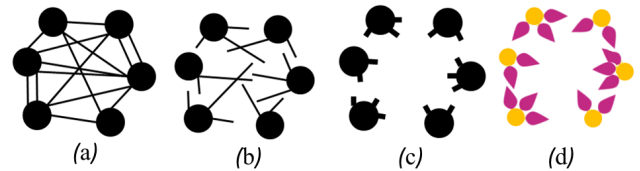

(a) *(b)* *(c)* *(d)*

Figure 5: *Showing the steps from left to right illustrating the replacement of edge lines by daisy petals.*
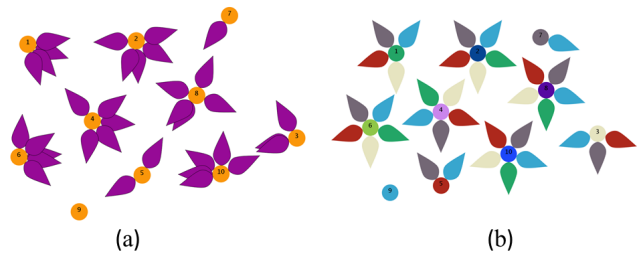

(a) *(b)*

Figure 6: *Daisy layout: directed graph with 10 nodes and 35 edges. Left: non-symmetric arrangement, petals are oriented toward their destination nodes (directional constraint). Right: symmetric arrangement, petals are uniformly distributed around the node.*

In the symmetric arrangement, colors represent the direction of edges. In the non-symmetric arrangement, each petal represents an edge directed towards the destination node, which can lead to adjacent petals overlapping (Figure 6). Thus there is a design choice to be made between symmetric and non-symmetric arrangements.

6. From Celtic Knot to Spirograph

This example for visualizing graphs (particularly, weighted graphs) was inspired by Celtic knot patterns (see Figure 7). Here, nodes are represented by circles and edges by interlacing curves. To have a symmetric structure and reduce cluttering, we position vertices uniformly on a circle, drawing interlacing curved edges outside of the circle (see Figure 7 (c)). The number of repeating knots (loops)
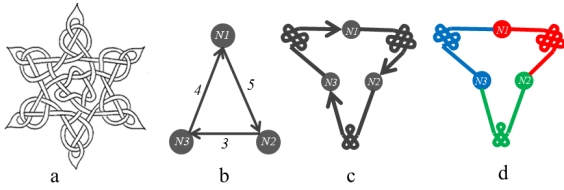
Figure 7: *a: Inspiration for Celtic Knot layout. b: A small graph with three nodes and three weighted and directed edges. c: The sketch of the same graph in the Celtic-Knot layout. d: Same graph, nodes are colored and the direction of edges is shown with colors.*
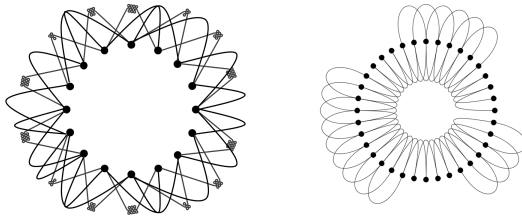
Figure 8: *Left: Celtic-Knot layout for a graph with sixteen nodes and thirty three edges. Right: Mapping edges to circular arcs.*

on each edge can be proportional to the weight of each edge as shown in Figure 7 (b , c). Directed edges can be shown with arrows, double lines, tapered, or color coded curves (Figure 7 (b, c, d).

For denser graphs the intersections of interlacing edges in addition to original edge crossings, makes the layout more cluttered and more complex (Figure 8 Left). Due to these drawbacks, we considered a Spirograph Layout. Rather than mapping edges to interlacing curves, in Spirograph Layout the edges cab be mapped to simpler curves (Figure 8, Right). Arcs can be internal or external to the boundary circle. The presence of many circular arcs in Figure 8 Right does look like Spirograph patterns.

Figure 1 shows how a simple graph in a node-link layout can be converted to Spirograph layout. First all nodes are arranged on the circle. Then the edges are divided into two sets: internal and external. In Figure 1 (b), external edges are drawn outside the circle and internal edges inside. Then, (Figure 1 (c)), all edges are drawn as circular arcs. To avoid miss-interpretation of the boundary circle as edge connectivity, we gave a thickness to the boundary circle (i.e. boundary ring) and replaced nodes by arcs on this ring (Figure 1 (d)). Spirograph provides a natural way to support external and internal edges (See Figure 1 d) and can include other features such as node and edge weights. Echo-Spiro visualization [ECS14] expands the idea of this layout and its application for visualization of ecological networks. The possibility of having internal and external edges is very useful for these types of graphs.

7. Conclusion

In this paper we described our design process and basic ideas behind one method for using of different types of aesthetics in generating new graph layouts. Node-Ring layout [ECS] minimizes edge crossing by representing edges inside the nodes. Daisy layout uses floral patterns to create a new layout. Sketching the idea of Celtic

Knot layout revealed potential challenges for this approach for creating new layouts. However, our efforts in designing Celtic Knot layout aided us in developing the Spirograph layout, which is introduced in Eco-Spiro visualization [ECS14]. These layouts were applied to ecosystem data, successfully showing weighted nodes, and weighted directional edges. Through these examples we have shown that our design process is general enough to be used for derivation of various data visualizations.

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