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Visually Mapping Cross-Referential Relationships Within Non-Linear Data Sets: Looking at Le Antichità Romane

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URL *http://www.bradtober.com/work/skydive/*

ABSTRACT This paper presents an information visualization titled *Mapping the Colosseo and the Panteon through Le Antichità Romane*. The base data set for this visualization, *Le Antichità Romane*, is a collection of etchings of ancient Rome by printmaker Giovanni Battista Piranesi. As a reference work the nature of this data is very much non-linear, although it features a significant hierarchical categorization. The concept for this visualization initially arose out of a colleague's desire to track each textual/image reference from both the *Colosseo* (Colosseum) and the *Panteon* (Pantheon) throughout the data set. These references cross the hierarchical structure of the data set. The final visualization uses an approach that leverages formal qualities such as value, pattern, directional arrows, and text labels to identify the relationships between the pages of the collection. In addition to an overview of the final visualization, this contribution details the design process that produced it, describing Skydive, a custom prototype/interface proof-of-concept data visualization tool for mapping cross-references within data sets. This process and the final visualization are further contextualized by describing their relationships to set/graph theory concepts as found in Euler, spider, and constraint diagrams.

INTRODUCTION

Mapping the Colosseo and the Panteon through Le Antichità Romane (*Mapping* henceforth; FIGURE 1) is a custom-designed, purpose-specific information visualization of Le Antichità Romane, a collection of etchings of ancient Rome by printmaker Giovanni Battista Piranesi. *Mapping* visualizes the overall non-linear framework of *Le Antichità Romane* and then focuses on tracing cross-hierarchical references of two well-known structures, the *Colosseo* (Colosseum) and the Panteon (Pantheon), within and across that framework. This article discusses *Mapping* by describing *Le Antichità Romane* (the base data set for the visualization), referencing fundamental concepts from set and graph theory (Euler, Venn, spider, and constraint diagrams), introducing Skydive (a custom prototype/interface proof-of-concept data visualization tool), and formally analyzing the design of the visualization.

CONTEXT

DATA SET

Giovanni Battista Piranesi, born outside of Venice in 1720, was as much an architect as he was a printmaker, and thus it should come as no surprise that one of his most significant works—*Le Antichità Romane*—focuses on the urban environment of ancient Rome and its constituent structures.[1] *Le Antichità Romane*, first published in 1756, reflects Piranesi's archaeological methodology in its compilation of engraved maps, building plans, illustrations, and explanatory indices/annotations.[2] *Mapping* references Brown University's first edition digitization of *Le Antichità Romane*, which consists of 130 high-quality images of the pages of the original work.[3] The following outline provides an overview of the structure of *Le Antichità Romane*, as is specific to this particular digitization:

1. Non-content (17 images: 1–6, 8, 10, 104, 110, 122, and 125–130)
   A. Includes covers, endpapers, and other blank / interstitial pages
2. Content
   A. Portrait of Piranesi by Polanzani (image 7)
   B. Title page (image 9)
   C. Frontispiece (image 11)
   D. Preface (2 images: 12 and 13)
   E. Imprimatur (image 14)
   F. Other publications (image 15)
   G. Plan of Rome
      1. Plates of the fragments of ancient Rome (4 images: 16–19)
         a) Roma map (image 16)
      2. Index of the fragments of ancient Rome (2 images: 20 and 21)
      3. Index of the remains of ancient Rome (40 images: 22–61)
      4. Plates of the remains of ancient Rome

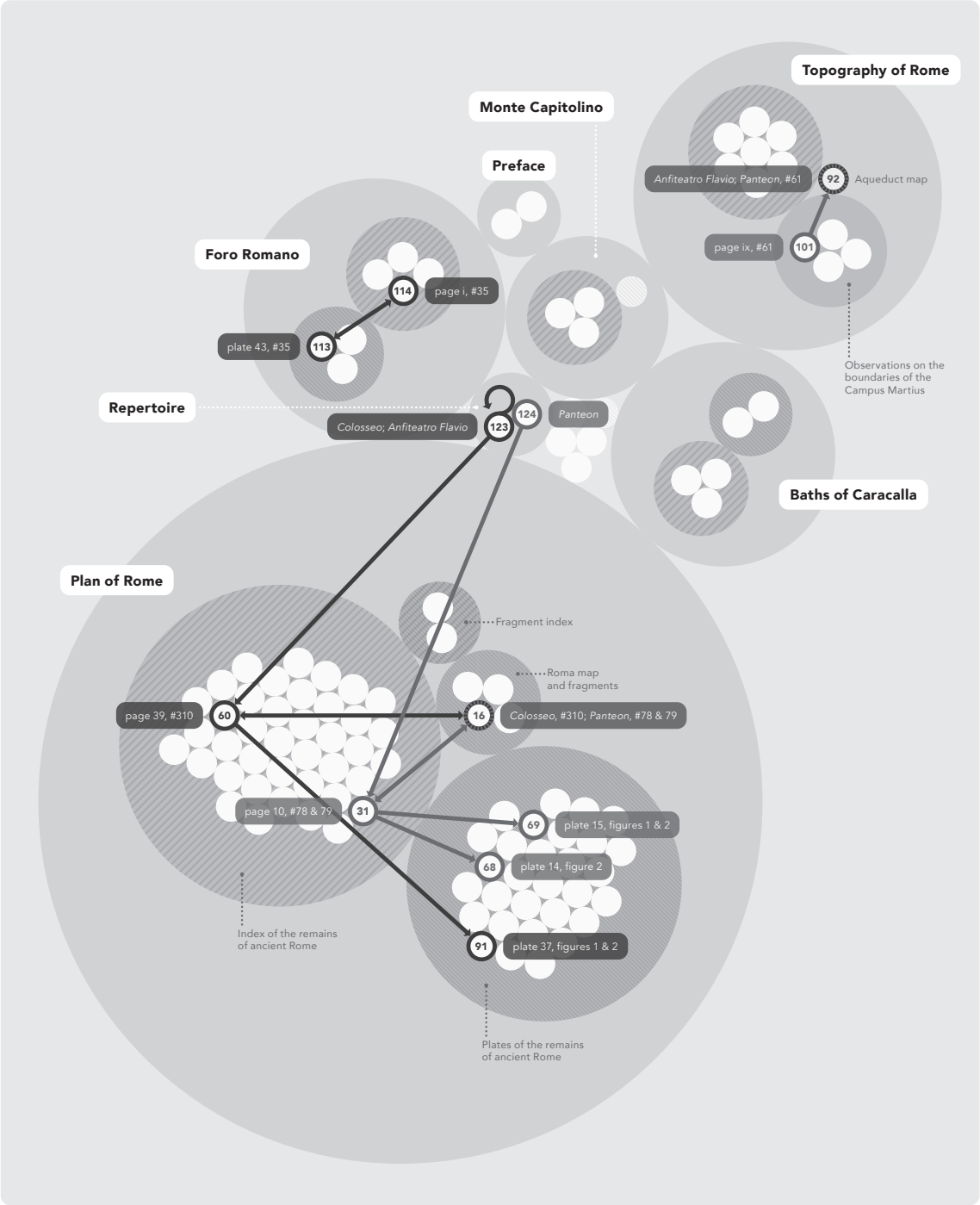

FIGURE 1: *The full Mapping visualization*

(30 images: 62–91)
H. Topography of Rome
1. Aqueduct map (image 92)
2. Explanation of the Aqueducts (7 images: 93–99)
3. Observations on the boundaries of the Campus Martius (4 images: 100–103)
I. Baths of Caracalla
1. Plates (2 images: 105 and 106)
2. Index (3 images: 107–109)
J. Foro Romano
1. Plates (3 images: 111–113)
2. Index (4 images: 114–117)
K. Monte Capitolino
1. Plate (image 118)
2. Index (3 images: 119–121)
L. Repertoire of the remains of ancient buildings in volume 1 (2 images: 123 and 124)

This outline clearly points to the presence of a hierarchical structure in *Le Antichità Romane*; however, any sort of linear narrative that might be present—beyond the overarching topic/theme itself—is deemphasized in a number of ways, including by the lack of a consistent system of page numbers to facilitate navigation. Instead, the various sections of the content (such as "Plan of Rome" and "Repertoire…") are connected via an elaborate system of cross-references that increase the complexity of the hierarchical organization of the work. The nature of this complexity is especially evident when following the cross-referential relationships of individual structures/buildings throughout *Le Antichità Romane*, and thus necessitating a visualization like *Mapping*. In particular, *Mapping* visualizes the cross-references of two well-known structures, the *Colosseo* (Colosseum) and the *Panteon* (Pantheon).[4] For example, one such sequence of cross-references for the *Colosseo* begins on the page represented by image 123, located in the "Repertoire…" section. Here, one *Colosseo*-related remark references another on the same page, but also references image 60 in the "Index of the remains…" section of the "Plan of Rome." Image 60 then references image 91 in the "Plates of the remains…" and image 16 (the "Roma map") in the "Plates of the fragments…" section.

PROCESS

The process of developing the design of *Mapping* was informed by a number of fundamental approaches to information visualization and diagramming. One such approach involved the use of nested circles to represent a hierarchical structure. Using this technique, data

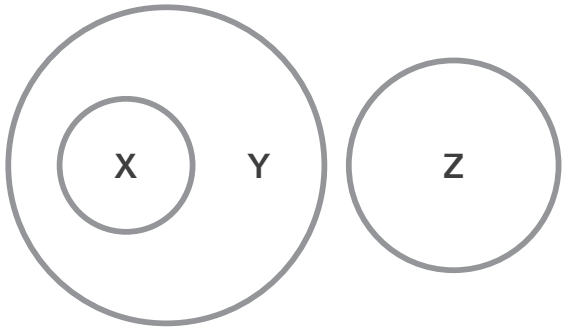

FIGURE 2: *Sample Euler diagram*

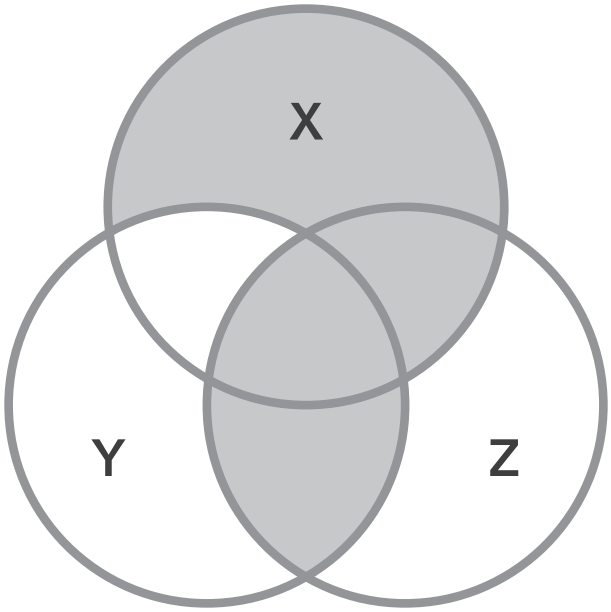

FIGURE 3: *Sample Venn diagram representation of the same scenario in figure 2*

elements (represented by circles) at the same level of hierarchy are encompassed by a larger circle, which is then laid out alongside other groupings of the same level of hierarchy, and so on. Often, achieving this type of layout efficiently relies on circle-packing algorithms, an example of which can be seen in a bubble chart example generated using the D3/Data-Driven Documents JavaScript library.[5] The bubble chart lacks a nested hierarchy, instead using scale to communicate relative importance. Perhaps most valuable for Mapping, the nested circle technique, in contrast to more conventional node-link diagrams or rectangular space-filling treemaps, "makes it easier to see groupings and [the] structural relationships" of data.[6]

Euler diagrams (FIGURE 2), of which familiar Venn diagrams (FIGURE 3) are a special case, also visualize

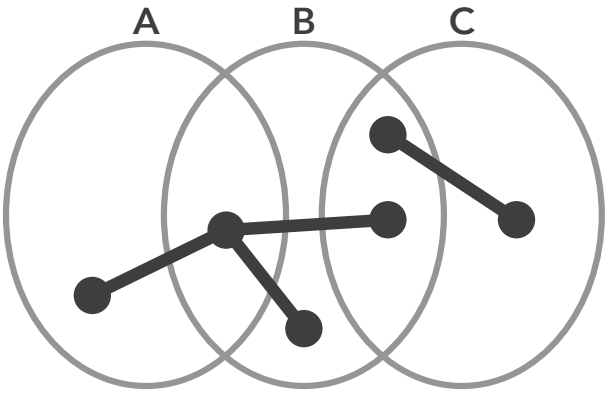

FIGURE 4: *Sample spider diagram*

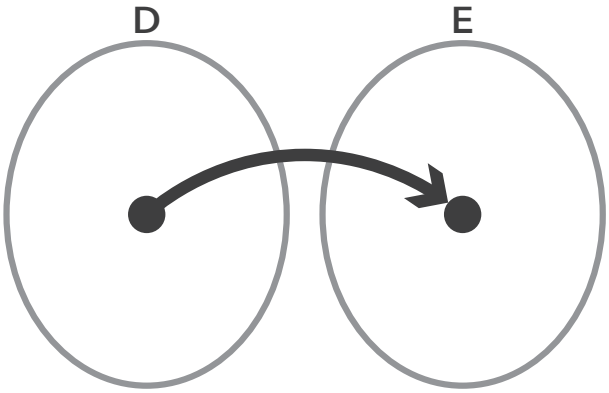

FIGURE 5: *Sample constraint diagram*

FIGURE 6: *Items II.A (portrait), II.B (title page), II.C (frontispiece), II.E (imprimatur), and II.F (other publications) are represented by a set of five white circles*

structural relationships. They are often used to visually demonstrate logical concepts of mathematical set theory and identify the relationships between various sets. This approach uses closed contours to split the plane into zones. These contours can be nested inside of and/or intersect other contours (Venn diagrams must visualize all possible intersections of contours, while Euler diagrams may display only a particular subset as is necessary).[7] This means that Euler diagrams can visualize extremely complex hierarchies. However, as more contours become part of the diagram, it quickly becomes visually overwhelming and its information can prove challenging to comprehend.

It is possible that *Mapping* could have visualized the *Colosseo* and *Panteon* cross-references using an approach that closely resembled an Euler diagram alone; it would be likely, however, that the cross-references would be indicated using awkwardly shaped and placed contours. Instead, *Mapping* also incorporates aspects that resemble characteristics of spider (FIGURE 4) and constraint (FIGURE 5) diagrams. Spider diagrams impose a spider (tree) diagram on top of the contours of an Euler diagram, with nodes placed in different zones.[8] Constraint diagrams extendspider diagrams further by adding directional arrows to indicate binary relationships between specific parts of the diagram.[9] While *Mapping* is not intended to be a strict representation of either a spider or constraint diagram, it appropriates key elements of both in order to impose an additional system of organization on top of the hierarchical structure of *Le Antichità Romane*.

The final design of *Mapping* was developed, in part, through the use of *Skydive*, a custom prototype/interface proof-of-concept data visualization tool designed and developed using Processing, a programming language and development environment, based on Java, that promotes software literacy within visual art and design. *Skydive*, while initially developed for another purpose, was useful in automating certain steps of the design process—particularly, the generation of a rough layout from data stored in an XML file. Please refer to the technical brief that accompanies this article for more information on *Skydive*.

VISUALIZATION ANALYSIS

As alluded to in the previous section, *Mapping* consists of two integrated systems of visual organization. The first visualizes the structural hierarchy of *Le Antichità Romane* using nested circles. At the highest level of visual hierarchy, twelve circles represent items II.A through II.L from the outline introduced earlier in this article (*Mapping* does not

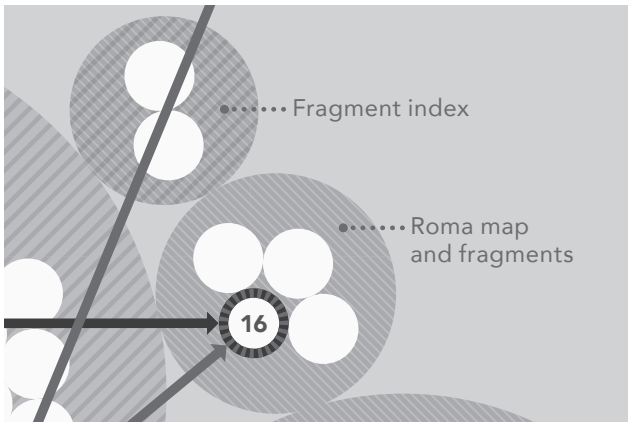

FIGURE 7: *Item II.G.2 (index of the fragments of ancient Rome) functions as an index, even though it is actually presented as a sequence of plates*

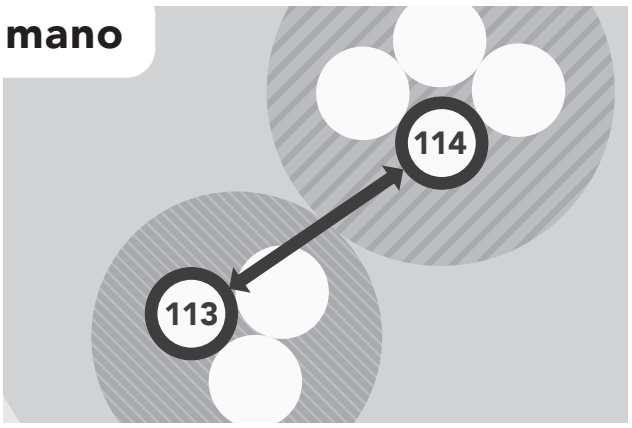

FIGURE 8: *Some cross-references are bi-directional*

visualize the non-content images of *Le Antichità Romane*). Items II.A (portrait), II.B (title page), II.C (frontispiece), II.E (imprimatur), and II.F (other publications) are represented by a set of five white circles located just above the center of the visualization (FIGURE 6). Of these circles, one (representing item II.C) features a light top-left to bottom-right diagonal background pattern, indicating its status as a standalone plate—arguably, item II.A is a "plate" as well, but it is not numbered as part of the plate sequence of *Le Antichità Romane*. In general, identifying numbers are not provided for all images; they only appear for those relevant to the *Colosseo* and the *Panteon*.

The seven other items (II.D and II.G through II.L) are presented as larger gray circles that contain deeper levels of hierarchy within them. These circles feature descriptive text labels set on a white background. The entire visualization was designed in grayscale to accommodate potential publication/printing limitations. The largest gray circle represents item II.G, the Plan of Rome, and encapsulates four other circles for items II.G.1 through II.G.4. The circles for items II.G.1 (plates of the fragments of ancient Rome, including the Roma map) and II.G.4 (plates of the remains of ancient Rome) feature a top-left to bottom-right diagonal background pattern, indicating that they contain plates. The circle for item II.G.3 (index of the remains of ancient Rome) is characterized by a bottom-left to top-right diagonal background pattern, which identifies its content as a set of indices and/or explanations. Item II.G.2 (index of the fragments of ancient Rome) is represented by a circle with a cross-hatched pattern (a combination of the "indices/explanations" and "plates" patterns) due to the fact that the item functions as an index, even though it is actually presented as a sequence of plates (figure 7). Within each of the circles for items II.G.1 through II.G.4, individual images are shown as small white circles. The remaining hierarchical elements of *Mapping* are visualized using the same formal techniques.

The second system of visual organization present in *Mapping* traces the cross-references of the *Colosseo* and the *Panteon* through *Le Antichità Romane*, and consists of a series of text labels and directional arrows. Individual images in which there are specific references to either building are identified with a gray outline; *Colosseo* references are identified with a darker gray than that used for *Panteon* references. Images with references to both buildings (images 16 and 92) are characterized by a dashed outline (visible in FIGURE 7). Next to each identified image, a textual label provides further details about the nature and/or location of the reference within that particular image. If a reference within one image relates to a reference within another, an arrow links the circles representing those two images together, with the direction of the arrow indicating the direction of the cross-reference. As is sometimes the case—with images 113 and 114, for example—these cross-references may be bi-directional (FIGURE 8). The following two subsections describe both the *Colosseo* and the *Panteon* (cross-)references visualized by *Mapping*.

COLOSSEO

- In image 16, the *Colosseo* is labeled with the number 310, which references the index listing in image 60.

- In image 60, index listing 310, for the *Colosseo*, refers to the location of the building in image 16,

as well as to figures 1 and 2 in image 91.

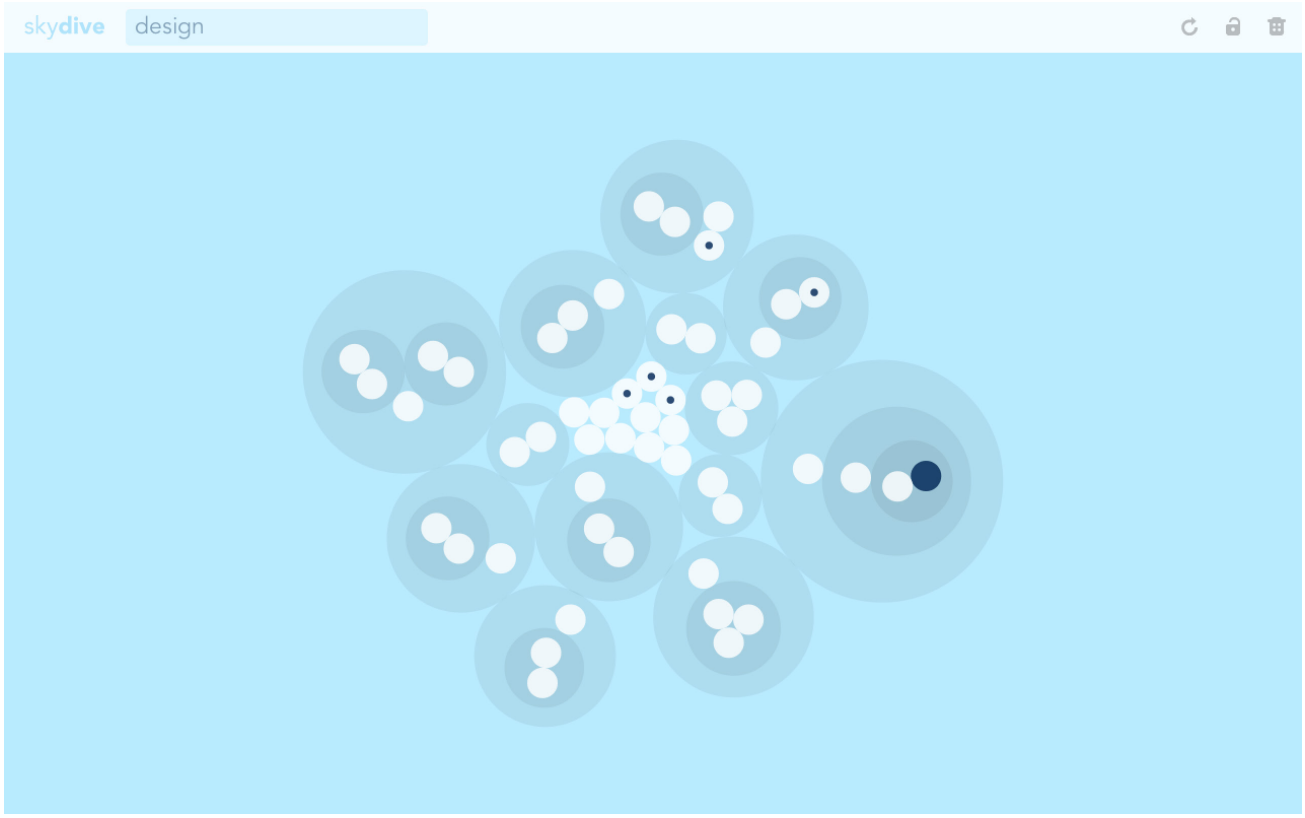

FIGURE 9: *Screenshot of Skydive*

- In image 91, figures 1 and 2 depict the *Colosseo*.
- In image 92, the *Colosseo* is indicated (as the *Anfiteatro Flavio*).
- In image 113, the *Colosseo* is labeled with the number 35, which references its index listing in image 114.
- In image 114, index listing 35 references the *Colosseo*, which references its location in image 113.
- In image 123, the listing for the *Colosseo* references the listing for the *Anfiteatro Flavio* in the same image, which then references index listing 310 in image 60.

PANTEON

- In image 16, the *Panteon* is labeled with the numbers 78 and 79, which reference the index listings in image 31.
- In image 31, index listings 78 and 79, for the *Panteon*, refer to the location of the building in image 16, as well as to figure 2 in image 68 and figures 1 and 2 in image 69.
- In image 68, figure 2 depicts the *Panteon*.
- In image 69, figures 1 and 2 depict the *Panteon*.
- In image 92, the *Panteon* is labeled with the number 61 (this does not cross-reference image 101 due to the fact that image 101 is not part of an index listing).
- In image 101, the *Panteon* is mentioned in the fifth paragraph, referring to number 61 in image 92.
- In image 124, the listing for the *Panteon* references index listings 78 and 79 in image 31.

CONCLUSION

In discussing both the process behind designing and the final form of *Mapping*, this article has described an approach to information visualization that was developed with a very particular purpose (and data set) in mind. More generally, however, "the visualization of hierarchical information structures is an important topic in the visualization community," and it is becoming increasingly important to be able to easily identify connections within individual and across multiple data sets.[10] For these reasons, the author believes that, through its leveraging of aspects of several existing visualization techniques, the approach described in this article holds great potential for further investigation. Future work may include the development of a formal, more broadly applicable visualization model inspired by *Mapping*, as well as continued work on an associated software data visualization tool.

TECHNICAL BRIEF

Mapping the *Colosseo* and the *Panteon* through *Le Antichità Romane*, in part, builds upon the core concept of *Skydive* (FIGURE 9), a custom data visualization tool designed and developed using Processing (a programming language and development environment, based on Java, that promotes software literacy within visual art and design). As an early prototype/interface proof-of-concept, Skydive uses the Twitter Search API as a data set and visualizes cross-references within it (via hashtags) by using a hierarchical "droplet and cloud" metaphor. In the visualizations that Skydive produces, the smallest circles represent individual tweets, while a system of larger nested circles creates the hierarchy that relates individual tweets to each other. Once a Twitter search has been executed, a user can further manipulate the data returned by removing, adding, or changing the specific tweets that are returned. After committing to these manipulations, the visualization then updates accordingly.

Skydive itself did not produce *Mapping* in its entirety, but it was useful in automating certain steps of the *Mapping* design process—particularly, the generation of an initial rough layout. Accompanying this article is an XML file(see appendix) that represents the data visualized by *Mapping*. *Skydive* was used to generate a number of hierarchical visualization layouts from this data, which were then evaluated based on aesthetic characteristics. Once a suitable hierarchical layout was chosen, the system of cross-references of the *Colosseo* and the *Panteon* was added to the visualization manually (even though this data is present in the XML file). This was due, in part, to the fact that it was especially challenging to ensure that the individual elements of the visualization were positioned in a way they did not obscure other critical elements. Further work on *Skydive* may investigate how to effectively visualize all elements of a similar XML structure, resulting in a comprehensive tool for designing other visualizations like *Mapping*.

APPENDIX

DATA USED FOR MAPPING

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          </group>
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               <term id="92" name="Aqueduct Map" label="Anfiteatro Flavio; Panteon,
&#35;61" class="plate" />
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                    </term>
                    <term id="115" />
                    <term id="116" />
                    <term id="117" />
               </group>
          </group>
          <group name="Monte Capitolino">
               <term id="118" class="plate" />
               <group name="Monte Capitolino index" class="index">
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                    <term id="121" />
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          </group>
          <group name="Repertoire of the remains of ancient buildings in volume 1">
               <term id="123" label="Colosseo; Anfiteatro Flavio">
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               </term>
               <term id="124" label="Panteon">
                    <reference to="31" type="panteon" />
               </term>
          </group>
     </group>
</nodes>
```

BIOGRAPHY

Brad Tober investigates the potential of code-based and interactive visual communication technologies, aiming to contextualize their relationships to design practice and pedagogy. His practice-led research is often speculative, recognizing that forms of and methodologies for contemporary practice spanning design and technology are best developed through exploratory processes.

NOTES

1 Weiner, "Eighteenth-Century Italian Prints," 217.

2 Ibid., 221.

3 *Mapping* references Brown University's high-quality first edition digitization of *Le Antichità Romane*. More information is available at http://library.brown.edu/projects/rome/books/252240/.

4 Heather Hyde Minor, Associate Professor of Art History at the University of Notre Dame, has recently authored and published (through The Pennsylvania State University Press) a book on Piranesi and his work, Piranesi's Lost Words. *Mapping* was prompted and inspired by an engaging conversation with her as she was preparing her manuscript. More information is available at http://www.psupress.org/books/titles/978-0-271-06549-6.html.

5 Mike Bostock, "Bubble Chart" http://bl.ocks.org/mbostock/4063269.

6 Wang et al., "Visualization of large hierarchical data," 517.

7 Flower, Rodgers, and Mutton, "Layout metrics," 272.

8 Gil, Howse, and Kent, "Toward a formalization," 73.

9 Ibid., 74.

10 See note 6.

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