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Nodes, Edges, and Artistic Wedges: A Survey on Network Visualization in Art History
Supplementary Material

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1. Introduction

In this supplementary material the 28 online resources (9 online approaches without publications and 19 blog posts) are discussed.

2. Online Approaches

Apart from the papers with online approaches discussed in Section **??**, we also found nine online AH network visualizations without a proper publication and 19 blog posts.

2.1. Interactive Websites

The interactive websites presented network visualizations from all the different categories we discussed in Section **??** (i.e., influences [Eph], similarities [Eph, KD18], travels of artists and artworks [RKD, Tra, Bes], co-exhibitions [Art], and social relationships [Lin, Kin, Iti]).

Visualization Approaches Since the approaches analyzed a wide range of different topics, various visualization methods were used.

Ephemera [Eph] is an online 3D exhibition space where project results of the Digital Art History Summer School (DAHSS) 2021 [Dig] are exhibited. The following includes some examples of the works of some of the participants. One of the exhibited works is part of a **node-link** diagram about Dürer and his various relationships (e.g., influences, in which museums which of Dürer's paintings were exhibited or family relationships) by Klinke. Various further node-link diagrams visualize similarities or commonalities between artists. One by Santos shows the common causes of death of more than a hundred painters, where diseases are the graph's nodes. Cao visualized Chinese artists from the Song Dynasty and their painting sizes in node-link diagrams for different time periods. Baroncini displayed in a directed **ego-network** which artworks contain an eagle. A node-link diagram by Novelli Duro shows artists and their connections to,e.g., catalog or jury, at the reception of the exhibition "Brazilian Salon" in 1884. Further, Bellan shows painters from Lebanon and their places of education in another node-link diagram.

ArtVis [Art] visualizes co-exhibitions of modern artists between 1905 and 1915 in an interactive combination of **radial ego network and donut chart** with the selected artist in the middle. and their co-exhibitors aligned around a circle with rays going outwards from the middle. Nodes at the intersections of the rays with concentric circles denoting the years show the years and amounts of co-exhibitions between artists. The nodes are colored according to different properties (nationality, gender, age group, if the artist was alive or dead at the time of the exhibition). The donut chart denotes how many artists fall into which categories of the selected properties (e.g., percentages of male/female co-exhibitors). It is also possible to select a co-exhibitor or search for an artist to highlight all the artists who exhibited with both of them. A line chart and bar chart combination and a (stacked) area chart show more information about the number of exhibitions and exhibited artworks over time.

RKD Research [RKD] is a research website of the RKD - Netherlands Institute for Art History. It contains information about many artists from different countries and time periods as well as their artworks including images of them. The artist page displays an interactive **map** visualization of an artist's travels. Birth and death places are shown as well as places of work. Edges show an artist's routes.

Interactivity All approaches presented in this subsection were interactive, showing that interaction assists in further exploring various relationships. One of them is X Degrees of Separation [KD18], which is a website that has an underlying network of artworks connected by similarities. The user can choose two artworks and will be shown images of all artworks on the path between the two selected ones.

Linked Visions - Whistler and Roussel [Lin] visualizes various social relationships, among them student-teacher, colleagues, friends, or family relationships, of one or both artists in an interactive online node-link diagram that can also be seen as two ego networks of both artists. Selecting a person displays additional information together with a node-link diagram of all of their connections. The relationship types to be visualized can be filtered.

Itinera [Iti] is an interactive online tool that visualizes social networks of intellectuals and artists from the 18th and 19th centuries in radial ego-networks with the painter in the middle and other people aligned in a circle. By clicking on them, their networks are shown. A different view shows the stops of one or multiple painters' travels as dots on a timeline without links. The more dots per year, the more different locations a painter visited. There is also a map view with an attached timeline, where the year can be selected and, again, multiple artists' locations can be compared. The locations are visible, but the background map seems to be currently broken.

Temporal and Spatial Contexts Many approaches used temporal and spatial aspects to add more context (e.g., to travels of artists or artworks, social relationships, or co-exhibitions).

Tracing Picasso [Tra] is an interactive online demo that shows the travels of Picasso's paintings on a map with an animated timeline. Circle sizes show the number of artworks per city at a certain time. Clicking on an edge shows the artwork's title, source and destination city, and the transaction type (e.g., purchase, gift).

Figure 1: Travels of a painting. The horizontal lines correspond to different cities clustered by countries and continents. The length of the bars corresponds to the time an artwork stayed at the same place, and circles denote exhibitions that featured the painting. Edges between bars show ownership changes. Best [Bes]. Permission to use pending.

Best [Bes] shows an interactive timeline with links on his website that displays the travels and ownership changes over time of 18 paintings by van Gogh (see Figure 1). The period can be selected on the interactive timeline. Cities are shown as horizontal lines, vertically grouped by country and continent. The location of an artwork is visualized as a bar on the lines displaying the timespan it stayed there. Edges between the bars show the ownership changes of an artwork. Circles on a bar denote exhibitions the artwork was featured in. Hovering over the bars or circles displays additional information (e.g., the name of the city, owner, exhibition title, or venue). Another view shows the travels of an artwork on a map with an interactive animated timeline.

Kindred Britain [Kin] is a website visualizing relationships (i.e., marriage, lineage, and siblings) of famous British people, where it is possible to filter for painters. In the node-link diagram, the edge color denotes the relationship type. Nodes can be colored, for example, by gender, centrality, birth date, or number of tragedies of the persons. The node-link diagram is shown in a multiple-linked view display containing a linked timeline and a map view. The timeline shows the life spans of the artists as horizontal bars linked

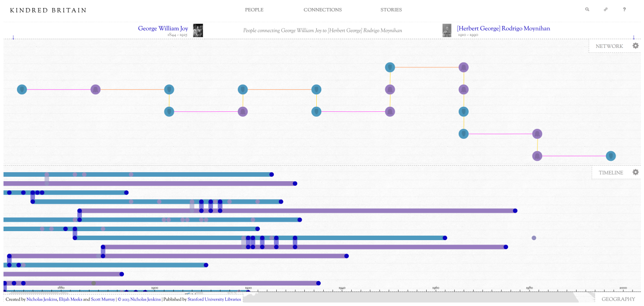

Figure 2: Kindred Britain [Kin] showing how two artists are connected in a node-link diagram (top) and the people's common events linked on a timeline (bottom). Permission to use pending.

by common events (see Figure 2 bottom). It is also possible to visualize the connections between two painters (see Figure 2 top). The map view shows a choropleth map where the countries are colored according to the criteria selected for the node colors. Further statistical visualizations about the contents of the whole database and selected cases can be seen in the statistics section of the webpage.

2.2. Blog Posts

The 19 blog posts also spanned a wide range of different relationships, including all of the ones from our main categorization, except travels. The blog posts analyzed influences [Ben15a, Ben15b, Ben15c, Ben16], similarities [Ben15a, Ben15b, Ben15c, Ben16, Cho19, Lin13d, KCM*, Smi21a, Smi21b], co-exhibitions and art market [RT21, Dav22, Mil18, Rei], and social relationships [Oh17, kar22, Fox13, Lin13a, Lin13b, Lin13c].

Visualization Approaches Different approaches were used to visualize the various relationships.

Kumar et al. [KCM*] analyzed images on the Wikipedia pages of "art" for different languages as well as pages linked to it (concepts). A **node-link** diagram shows the different Wikipedia languages and images that were used on the "art" page as nodes. Node sizes of the images correspond to the number of times it was used. Another node-link diagram displays Wikipedia language versions as nodes and shared concepts between them as edges.

Renz and Tissen [RT21] used the data of MoMa exhibitions between 1929 and 1989 to analyze co-exhibitions between artists with node-link diagrams. Artists are the nodes and their colors correspond to the nationalities.

Davis [Dav22] used the same dataset as Renz and Tissen [RT21] and also visualized co-exhibitions with node link-diagrams, but in this case, the nodes correspond to exhibitions, and there are edges between them if the same artist exhibited in both. Node size denotes the degree and their colors the communities. The diagrams were created for female and male artists separately.

Milliken [Mil18] also used the above dataset to analyze female artists who exhibited at MoMA. A node-link diagram shows artists and connections if they co-exhibited with each other. A second one shows exhibitions with at least 15 participating female artists as nodes linked by co-exhibitions of artists.

Oh [Oh17] made a video tutorial about creating a node-link diagram of important Renaissance figures, among them artists, where edges are links between peoples' Wikipedia pages. Node colors correspond to the profession (e.g., artist, philosopher, explorer).

Karora15 [kar22] used Oh's [Oh17] dataset and investigated different layouts for visualizing the relationships, among them a node-link diagram similar to Oh's [Oh17]. Further, two **radial** approaches were tested, either with all people aligned in a circle and edges in the middle or only high-degree nodes aligned in a circle and the rest in the middle. An additional **ego network** visualizes da Vinci and his connections. Influential people are represented as portraits (including da Vinci), the others only with colored nodes.

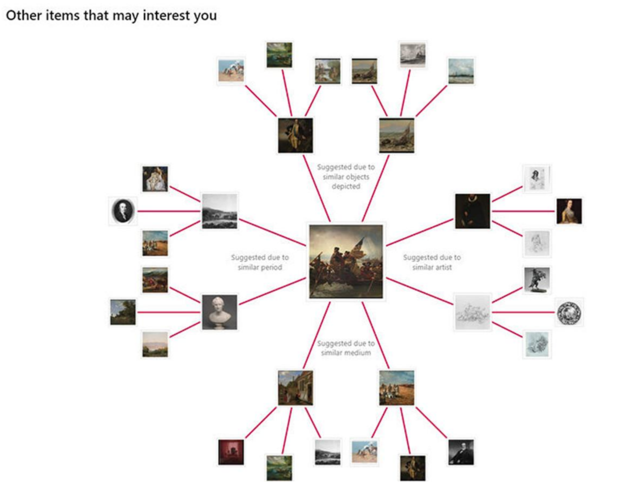

Figure 3: Ego network tree with similarities between an artwork (middle) and others. According to the similarity type, the similar artworks are arranged above, below, left, or right of the original painting. Choi [Cho19]. Permission to use pending.

Choi [Cho19] explored similarities between paintings from the collection of the Met Museum in an interactive ego network. Artworks are represented as nodes; edges denote their similarities in a **tree-like** structure. Four different similarity types are considered: similar objects, time periods, artists, or media. Depending on the similarity type, the similar artworks are structured in trees above, left, right, or below the original artwork as can be seen in Figure 3.

Reiche [Rei] used **treemaps** to visualize art market prices of the top 19 artworks from 2012 (see Figure 4). The artworks are categorized into three auction houses and visualized in rectangles labeled with the artists' names. The size of the rectangles denotes the price the artwork was sold for, and their color the price per square inch.

Interactivity Some of the blog posts also used interactivity to enable deeper exploration of the data. A blog post from Lincoln [Lin13d] visualizes the network of artworks of the Smithsonian American Art Museum created between 1900 and 1935. An interactive node-link diagram shows the artworks as nodes and an edge between them if they share at least five tags. The node colors

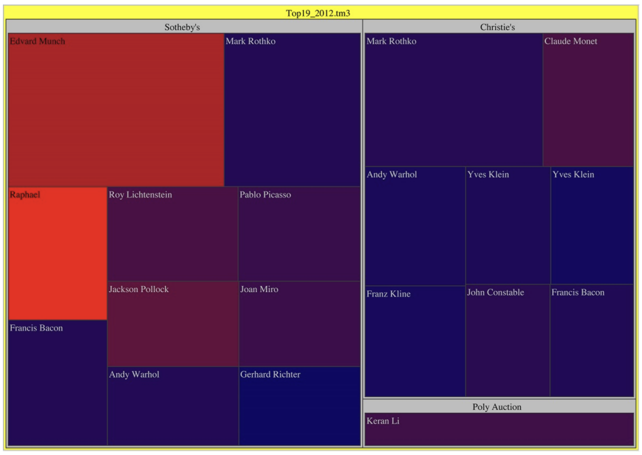

Figure 4: Artworks sold at different auction houses and their prices displayed in a treemap. Rectangle size displays the price, color price per square inch. Reiche [Rei]. Permission to use pending.

denote clusters representing specific themes (e.g., city views, rural labor, self-portraits). Selecting a node highlights its connections.

Smid [Smi21a, Smi21b] interactively visualized a knowledge graph of artworks from the Metropolitan Museum of Art in a series of two blog posts. There are multiple different node types in the knowledge graph (e.g., painting, artist, owner, medium, tag) and edges with relationships between them. In multiple node-link diagrams, three paintings, their artists, nationalities, medium, and tags were shown. Selecting a painting node displays its image. Further, artist transitions between movements are investigated in a directed node-link diagram showing artists, their nationalities, and art movements they belonged to. Also, the contexts of tags are explored by showing tags, paintings they were assigned to, their mediums and donors, as well as time period of creation. In another node-link diagram, the focus is on artwork types and their mediums, as well as which artists cooperated in creating a painting. In a related diagram also the nationalities of the artists that cooperated for a painting are investigated. In another visualization, the top donors of artworks, the artworks they donated, and their time periods are analyzed. Another node-link diagram shows how to find similar paintings by looking at common tags, time periods, or mediums.

Temporal and Spatial Contexts Various posts incorporated spatial or temporal aspects into their network visualizations adding further context, for example, to analyze spatial and temporal aspects of artwork imitations or to temporally cluster student cohorts or analyze social relationships between artists from different cities. Bender created a dataset with artworks that show Venus and also published seven topical catalogs [Ben07, Ben] about it. The dataset is used for multiple network visualizations in Bender's blog. In entry number 53 [Ben15a] Titian's painting "Venus with the Musician" and its copies and variants are analyzed. The node shape and color denote if the artwork is a masterwork or a successor painting, drawing, or print. They are aligned along a timeline. Edges denote the relationships between the artworks (e.g., replica, copy, print). Posts 56 - 58 [Ben15b, Ben15c, Ben16] are also network analyses about creators and imitators of Venus artworks utilizing different tools for visualization. In one node-link diagram, creators' labels are written in uppercase, while imitators' labels are in lowercase. They are linked with edges denoting imitations. The nodes also state the year of creation/imitation and country, and some the number of imitators. Further node-link diagrams show the imitators per country, certain creators or ones with at least five imitators, or certain imitators, sometimes per country.

Fox [Fox13] created slides and accompanying text about West's workshop in London including an ego-network showing West in the middle and edges to his students. There are also some edges between students if a senior student taught a younger one. The clusters of students teaching each other, forming a big and a small node-link diagram, are further explored. Also, a hierarchy is shown that divides West's students into three different time periods spanning 20 years each.

Lincoln [Lin13a, Lin13b, Lin13c] investigated artist networks in a series of three blog posts. The post shows a comparison of node-link diagrams when multiple relationship types (student-teacher, family, etc.) are used compared to only artistic ones. Nodes are artists and edges are the relationships between them. The nodes are sized by degree and colored by eigenvector centrality. Another node-link diagram displays cities as nodes and edges between them if the data contains a relationship between artists inhabiting these cities.

Summary This section discussed various interactive websites and blog posts. Overall, both websites and blog posts employ various visualization methods to provide insight into the relationships between artists, artworks, and historical contexts.

- There was a heavy focus on node-link diagrams, but also interactive maps with edges, linked timelines, and other network visualizations were used.
- Interactivity was utilized to let users explore data, such as co-exhibitions, social networks, or travels, and provide additional details with visualizations.
- Temporal and spatial aspects provide deeper context.

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