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A Review of Network Approaches in Music Studies

This article provides a short introduction to the interdisciplinary field of social network analysis (SNA) and its applications in the humanities, including music. Network approaches can be useful in any discipline, but they are most commonly associated with applied mathematics, computer science, and sociological fields like economics and information studies. Networks are becoming more prevalent as a theoretical and methodological framework for addressing humanistic research questions. For subject librarians interested in digital humanities, an awareness and basic understanding of networks may prove helpful when advising students and faculty wishing to apply interdisciplinary techniques in their own research. An annotated bibliography of suggested resources, including guides on formatting network data, using software, and readings on the theory and practice of networks, follows this article.

Why should a librarian, and more specifically a music librarian, study networks? Anyone with a curiosity about how small and large systems interconnect, and how events occurring in one part of the system can cascade and spread to distant parts of the system will find networks to be fascinating objects of study. If you've thought about aggregate human behaviors that manifest as social media phenomena (think Internet memes and "viral" YouTube videos) or economic bubbles (for example, the recent U.S. housing bubble and resulting subprime mortgage crisis), then you might be motivated to study networks. If a random chain of events contributing to the spread of disease and epidemics interests you, then you might make an excellent student of networks. If you've ever thought abstractly about the ways in which particular ideas, practices or innovations travel through time and jump across cultures, then you might be a budding network amateur. If trying to find the shortest path from any given movie actor to Kevin Bacon amuses you, then… I needn't convince you further.

Musical and other humanities networks in practice

In recent years, humanists, in collaboration with technologists and designers, have begun to adopt network analysis as a means to explore the relationships between groups of people, things, places and events. One of the most significant of the digital projects to emerge from this kind of collaboration is Kindred Britain (http://kindred.stanford.edu). Kindred Britain is a network of 30,000 people, "mainly British, mainly dead," connected through ties of kinship. The site's navigational menu allows users to explore its people, connections and stories. One such story, about Mary Shelley's *Frankenstein*, connects the 1815 eruption of Mount Tambora on the Indonesian island of Sumbava all the way to a starry gathering at the Villa Diodati in Coligny, Switzerland, a year later when Lord Byron challenged his guests to a ghost story writing competition. From a network's perspective, one of the unique and distinctly *humanistic* aspects of this project has to do with the careful attention accorded to the metrics that were created or adapted specifically for its underlying data. For example, a tragedy index, developed as a measure of the premature and violent deaths experienced within a family, reveals that the women of Kindred Britain consistently show a higher tragedy score.[1] A depth function, used to count the number of an individual's ancestors present in Kindred Britain, makes the argument that Britons are profoundly and unusually interconnected. These metrics are included in the network panel alongside more commonly encountered measures of

centrality and attributes such as gender and birth date.[2] Other major digital humanities applications of networks include Mapping the Republic of Letters (http://republicofletters.stanford.edu/), and Viral Texts (http://viraltexts.org/).

Closer to the more familiar terrain of music history and musicology, network approaches have already begun to make an appearance. Linked Jazz (https://linkedjazz.org/) uses a combination of automation and crowdsourcing to extract relationship information from oral history transcripts. These relationships are captured in the form of RDF triples and visualized as a network. The stated aim of the project is "to build applications and services that facilitate the discovery and analysis of digital resources in the field of cultural heritage."[3] On the website, the reader may choose from several views of the Linked Jazz network. For instance, the "dynamic" view allows users essentially to play a game of six degrees by chaining together musicians and visualizing the paths that connect them to each other. Other views function more or less as personal, or ego networks; they allow the user to click on a particular artist and see the web of documented relationships she or he shares with other artists in the dataset. The Linked Jazz researchers are currently working on data enrichment to include attributes for gender and instruments played. They are also exploring ways of assigning greater meaning to the ties between artists, e.g., "mentor of" and "influenced by", so that questions requiring greater contextual information can be profitably explored. This will be an interesting project to follow to see the eventual solutions devised for visualizing these different types of relationship.[4]

Contributing to research on Renaissance polyphonic music, the Lost Voices Project (http://digitalduchemin.org/) takes on the problem of reconstructing the missing vocal parts of the final volumes of the four-voice *Chansons nouvelles*, a sixteen-volume work published by Nicolas Du Chemin between 1549 and 1568. The researchers modeled the stylistic profile of the whole corpus as a relational database containing thousands of analytic observations about the complete pieces. A primary goal in constructing this database was the ability to make good inferences about the missing note values in the cadences of the incomplete songs. A parallel effort was made to explore the Lost Voices dataset as a network problem. On the website, users can explore two networks; the first exploring the similarity of cadences in 200 songs, and the second on the similarity of the songs based in their succession of cadences. The cadence network explores the melodic context of the cadence, not its type (e.g., authentic, phrygian, plagal), in order to be able to say something about common and uncommon contexts and constructions. In this way, it was possible to see that the construction of the phrygian cadences was more diverse than expected. The researchers had supposed that most phrygian cadences would end on E to avoid accidentals, but a great many were identified that required a leading B-flat or E-flat.[5] Both networks implement a customized PageRank algorithm that calculates similarity on pair to pair basis within the dataset. For the network of songs, the researchers describe this model as follows:

> Our calculations are based on the cadential organization of each piece according to a "successive pair" model:
>
> The Final Tone of the Last Cadence in the piece (something like its modal final)
> The Final Tones of Successive Pairs of Cadences (for instance D + G)
> The Types of Successive Pairs of Cadences (for instance Plagal + Authentic)
> A weighting factor for the total number of Cadences in Each Piece (which might be less than the number of poetic phrases, on account of musical repetitions).

The greater number of such "pairs" shared by any two pieces (regardless of where the pairs appear in the works), the more similar we judge them.[6]

An interesting potential direction for this work might include integrating the texts of the songs to see if the neighborhoods or families detected can be matched with specific thematic or expressive content, or rhetorical devices. For example, a given theme could be courtly love, a pervasive emotion could be despair or hopelessness, and a rhetorical device could include the proposition or confirmation.[7] Then, perhaps something like a large-scale expressive analysis of Renaissance song might become feasible.

Other network approaches in music studies tend to shade into sociology; they include research on music scenes and the international music trade.[8,9]

Network concepts

On a very basic level, network visualizations represent "stuff and relationships."[10] The "stuff" appears in circles, which are called nodes, while the relationships that connect the stuff are called edges. Arguably, the most widely known kind of network is the family tree. In thinking about the relationships between two family members (nodes), one could define them as being either symmetric or asymmetric. For the purposes of illustration, let's take the Mendelssohn family. Abraham Mendelssohn was the spouse of Lea Salomon, but it is equally true that Lea Salomon was the spouse of Abraham Mendelssohn. Therefore the relationship between the two is symmetric, or, in network parlance, *undirected*. The relationship between Abraham and Fanny is however different. Abraham was Fanny's father, but the reverse is not also true. Their relationship is asymmetrical. This is an example of a *directed* edge, which is to say an edge that connects one node to another where the direction matters.

If I were to format the Mendelssohn family as data for use in a network visualization tool, the following would be a simple way to do it. Table 1 is a combined node and edge list, with a header row indicating the source node, the target node, and the type of edge that connects the two. As mentioned above, the directionality doesn't matter between spouses (Abraham and Lea could be reversed), but it does matter for parent-child relationships. Normally, directed edges have arrows that indicate their flow, as seen in Figure 1. I'll note in passing that for more complex datasets, it may be desirable to store node and edge lists as separate tables, with a unique identifier for each node acting as the shared value between the two lists. Keeping separate node and edge lists is advantageous for recording data attributes like gender, dates of birth and death, or any other assertions that a researcher may want to capture about the nodes.

A network with one type of node is called a single mode, or unipartite graph. This is true of the Mendelssohn family tree, since all of the nodes represent family members. It

Table 1. A simple way of formatting data to record two generations of the Mendelssohn family.

Source	Target	Type
Abraham	Lea Salomon	Undirected
Abraham	Fanny	Directed
Lea Salomon	Fanny	Directed
Abraham	Felix	Directed
Lea Salomon	Felix	Directed
Abraham	Rebecka	Directed
Lea Salomon	Rebecka	Directed
Abraham	Paul	Directed
Lea Salomon	Paul	Directed

Data from Wikipedia.

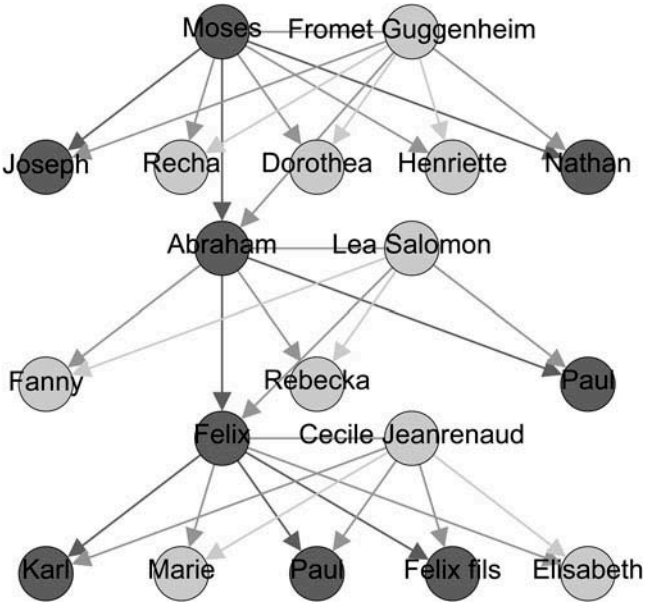

Figure 1. An example of a directed graph showing three generations of the Mendelssohn family, coded for gender. Visualization created in Gephi.

is possible to have a bimodal, or bipartite graph with two types of nodes, e.g., authors and journals, as is occasionally found in co-citation network analyses. Bipartite graphs are often used to study patterns of participation. One could imagine, for example, a bipartite graph of librarians and their conference attendance, or friends and their affiliations with social groups.

In my own work, I've been interested in the problem of visualizing the process of adaptation across two texts. Throughout much of the history of opera, it was common practice for librettists to select popular stage plays to adapt into the book of an opera. Librettos are considered functional texts; the words are intended as a support for the composer's musical thought. Hence the work of adaptation often involves modifications in order to ensure that the needs and conventions of the musical form are met, i.e., short, singable phrases, an aria for each major vocal part, etc. Stage plays did not have the same set of conventions, so this process usually involved significant cuts and reappropriation of dialogue.

My work to date has focused on the text of a libretto written by Felice Romani (1788–1865), and its source play by a French actor, Honoré-Antoine Richaud Martelly (1751–1817).[11] Romani wrote *I due Figaro* in 1820 for a new production with composer Michele Carafa at La Scala of Milan. For this assignment, he chose to adapt what at the time was an immensely popular play, Martelly's *Les deux Figaro*, which first appeared on the Parisian stage in 1794 during the French Revolution, and achieved a long-lived success throughout the European continent for the next 50 years. Martelly himself had wished to capitalize on the fame of Beaumarchais's protagonist with this spurious third installment in which the wily servant Figaro gets his just deserts at the hands of his noble masters.

In my experiments, I modeled both texts as character co-appearance networks. During this process, I came across an interpretation of my findings that relates to the

concept of weak ties. In graph theory, it is a general principle that strong ties (or edges) between nodes represent close relationships; they appear as dense clusters in network visualizations. Weak ties conversely represent more casual relationships, and they can, on occasion, connect distant parts of a network. Researchers of networks take a particular interest in weak ties because they are capable of performing an important role in diffusion processes.[12] Essentially, a weak tie can act as a bridge between distant parts of a network. In this way, weak ties have the potential to influence behavior, spread ideas, spur a chain reaction, or otherwise introduce significant change with great efficiency.

Although my networks are small in scale, I found a plausible weak tie in both texts, and interestingly it was not the same person. The French source play centers on a battle of wits between Figaro and Chérubin, who disguises himself as a servant (the second eponymous Figaro). Chérubin acts as an important bridge between the play's two groups of schemers: Figaro and Don Alvar on the one side, and the Countess, Inez and Suzanne on the other. In my model of the Italian libretto, however, Susanna appeared to take over this role from Cherubino. This is an interesting observation for a few reasons. First, it was advantageous for Cherubino to get closer to Inez, his love interest, since without this step there could be no love duet. In the French source play, the love plot is so marginal that Chérubin and Inez never have a scene together. Second, it is interesting from a feminist perspective that a female character (Susanna) takes over this role of influence in the Italian libretto.

Of course, feminism was the furthest thing from Romani's mind; he was more likely making decisions based on his sense of vocal *tessitura* and balance.[13] And whereas a twenty-first century reader might welcome Susanna's greater agency in the plot of the Italian libretto, a period audience might have construed her role more pejoratively. Susanna gets recast as a *Commedia*-style Colombina, or tricky slave. She thinks nothing of deceiving her noble master, the Count, and she encourages Inez to disobey the wishes of her father. With this said, despite the differences in both texts, the outcome is largely the same: Cherubino and Inez are united, and Figaro and Don Alvaro are banished from Almaviva castle.

Could I have reached the same conclusions through close reading? Probably. Indeed it is likely that I had some sense of the structural differences, because I began my explorative data analyses by attempting to model the gender balance of both texts. However it was through the iterative process of gathering data, finding ways to represent it graphically, and reading about networks that my ideas about the texts began to take more solid form. Though time consuming, the process of reading and rereading to gather data for a visualization tool brought me into close and repeated contact with my source texts, such that my knowledge of them was greater than it otherwise might have been. And technical hiccups aside, it was actually fun to think about the problem of adaptation from the standpoint of social network analysis. Will networks be an appropriate framework for most questions in music studies? Surely not. But for any questions having to do with systems or structures, the patterns that characterize them, and the dynamics that animate them, then network analysis might be an approach well worth exploring.

Software

There are many excellent, free network analysis software tools that exist for both the Mac and PC platforms. Marten Düring makes an excellent case for why Palladio (http://palladio.designhumanities.org) should be the beginner's network visualization tool of choice. It is relatively easy to learn, and includes a sample dataset for experimenting. It runs in a browser, and therefore doesn't require a software installation. Palladio can be used to visualize single mode and bimodal networks, and to scale nodes by degree

centrality (in other words, by the sum of the nodes' edges). Palladio also has a great deal of other functionality that makes it an attractive choice.[14]

But for more complex network metrics, a different tool will be preferred. The one I've used with the greatest frequency is Gephi (https://gephi.org/), in part because it is widely used among digital humanists, and I didn't have far to look for guidance and inspiration. That said, it is a difficult tool to learn. Pressing its many and various buttons will usually produce a result, but whether or not that result is meaningful for your data will depend on your understanding of graph theory, measures of centrality, and so on. This kind of understanding takes time to build. Fortunately, a good deal of information on networks can be found online (see Suggested Resources for guidance on formatting network data, using Gephi, and reading about network analysis). In addition to Gephi, other network visualization tools include Cytoscape (http://www.cytoscape.org/), Nodegoat (http://nodegoat.net/), and NodeXL (http://nodexl.codeplex.com/).

Suggested resources

Data assembly

Marten Düring, "From Hermeneutics to Data to Networks: Data Extraction and Network Visualization of Historical Sources," Programming Historian, entry posted February 18, 2015, http://programminghistorian.org/lessons/creating-network-diagrams-from-historical-sources (accessed April 15, 2016).

Düring's tutorial introduces a "simplified version" of the coding scheme he developed as part of his doctoral research on Ralph Neuman's memoir, *Memories from My Early Life in German; 1926–1946*. Extracting networks from unstructured text, Düring explains, is often more difficult than reusing preexisting datasets (e.g., e-mail logs or questionnaires) because relationships have to be defined, and those definitions will be highly contingent upon the researcher's perspective and chosen object of study.

Amanda Visconti, "Get Your Data into Gephi: A Quick and Basic Tutorial," Literature Geek, entry posted September 9, 2013, http://literaturegeek.com/2013/09/09/datainto gephi (accessed April 15, 2016).

Visconti presents both a simple and more complex way of manually coding character interactions in James Joyce's *Ulysses*. Her coding scheme could productively be applied to any literary character co-appearance network.

Software Tutorials

A note: all of these tutorials are for Gephi version 0.8.2. In December 2015, the developers released Gephi 0.9.0, which addressed Java compatibility problems. I haven't yet seen any tutorials for this new release, and indeed it may take some time for the user community to catch up. Furthermore, according to the Gephi Marketplace blog (https://marketplace.gephi.org), most of the third party plugins, which extend the functionality of Gephi, have been developed to work with version 0.8.2.

Martin Grandjean, "GEPHI—Introduction to Network Analysis and Visualization," entry posted October 14, 2015, http://www.martingrandjean.ch/gephi-introduction/ (accessed April 15, 2016).

Grandjean is an expert in visualizing social media data. His descriptions of the

layout and statistics algorithms in Gephi are lucid and approachable. He includes excellent advice on enhancing the legibility of network graphs.

Clément Levallois, "Gephi Tutorials and Plugins," http://www.clementlevallois.net/gephi.html (accessed April 15, 2016).

Levallois has authored several Gephi plugins and has a background in economics and literature. He has created a series of tutorials on Gephi ranging from introductory to advanced. His graphical cheat sheets will be invaluable to beginners.

Hoyt Long, and Richard Jean So, "Literary Networks," Digital Humanities Initiative, entry posted January 19, 2014, http://dh.rutgers.edu/networks/ (accessed April 15, 2016).

Long and So use bibliographic data to study modernist literary networks. This tutorial includes some of the motivations for using the filters in Gephi to weed the edge cases, if, for example, one's interest lies primarily with the stronger connections of the horde. The steps in this tutorial describe one of the reasons to project a bipartite network, one with two types of nodes–poets and journals, to a unipartite graph; it improves the legibility of the ties between the poets whose work has appeared in the same journals.

Readings

Franco Moretti, "'Operationalizing'; Or, the Function of Measurement in Literary Theory," *New Left Review* 84 (Nov-Dec 2013): 103–119, http://newleftreview.org/II/84/franco-moretti-operationalizing (accessed April 15, 2016).

For a theoretical grounding in humanities networks, or in distant reading approaches more generally, Moretti will be an indispensable source.

Tore Opsahl, https://toreopsahl.com/ (accessed April 15, 2016).

When a slightly more technical resource is desired, many consult Opsahl's blog for his explanations of the terminology of networks and their study and manipulation in the R programming environment. If you're as math challenged as I, just skip over the mathematical expressions and focus on the text.

Scott Weingart, "Networks Demystified," the scottbot irregular, entries posted 2011–2015, http://scottbot.net/tag/networks-demystified/ (accessed April 15, 2016).

For beginning and intermediate students of networks, I recommend wholeheartedly Weingart's series of blog posts titled "Networks Demystified" (he's currently up to eight). His writing on network theory is precise, accessible and entertaining.

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Notes

1. Elijah Meeks, "Statistics," Kindred Britain, http://kindred.stanford.edu/notes.html?section=statistics (accessed April 15, 2016). Meeks's essay on the statistical analyses performed on the Kindred Britain dataset includes many wonderful insights and visualizations.
2. Elijah Meeks, "Centrality and Notability," Kindred Britain, http://kindred.stanford.edu/#/story/full/third/third///centrality (accessed April 15, 2016). The centrality score in Kindred Britain is actually an aggregate of four measures of centrality: closeness, Eigenvector, betweenness, and PageRank.

3. M. Cristina Pattuelli, and Matthew Miller, "Semantic Network Edges: A Human-Machine Approach to Represent Typed Relations in Social Networks," *Journal of Knowledge Management* 19, no. 1 (2015): 73.
4. In graph theory, a case in which two nodes are connected by two or more edges is described as multiple, or parallel edges. Legibility often becomes a challenge in network visualizations with parallel edges.
5. Richard Freedman, "Close and Distant Reading: Data Analysis meets the Renaissance Chanson" (paper presented at the International Musicological Society Congress, New York, NY, June, 23, 2015).
6. Ibid.
7. Although the historical period is later, I am borrowing ideas from Catherine Gordon-Seifert, *Music and the Language of Love; Seventeenth-Century French Airs* (Bloomington, IN: Indiana University Press, 2011).
8. Nick Crossley, "The Man Whose Web Expanded: Network Dynamics in Manchester's Post/Punk Music Scene 1976–1980," *Poetics* 37, no. 1 (February, 2009): 24–49, doi:org/10.1016/j.poetic.2008.10.002.
9. Shin-Il Moon, George A. Barnett, and Yon Soo Lim, "The structure of international music flows using network analysis," *New Media & Society* 12, no. 3 (May 1, 2010): 379–399. doi:org/10.1177/1461444809346720.
10. Scott Weingart has a refreshingly informal way of introducing network terminology. See Readings under Suggested Resources.
11. This work was presented in Francesca Giannetti, and Anna Kijas, "Digital Madeleines and Breadcrumbs: Discovering the Musical Past Through Multimodal Analyses" (paper presented at the International Musicological Society Congress, New York, NY, June, 22, 2015).
12. Mark S. Granovetter, "The Strength of Weak Ties," *American Journal of Sociology* 78, no. 6 (May, 1973): 1360–1380.
13. Paolo Cascio and Victor Sànchez, preface to *I due Figaro o sia Il soggetto di una commedia*, by Saverio Mercadante and Felice Romani (Bologna: Ut Orpheus, 2011), ix–xiv. In Carafa's setting of the libretto, Cherubino was sung by a bass. Cherubino has a good deal of stage time with the Count (tenor) and Figaro (bass-baritone); therefore, it may have been for artistic motivations that Susanna (soprano) was entrusted with the bridge role, to introduce some vocal part diversity.
14. See Miriam Posner's tutorial at http://miriamposner.com/blog/getting-started-with-palladio/ for a look at Palladio's map, timeline, graph and gallery features.

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Institutional Subscriptions to Met Opera on Demand and the Berlin Philharmonic Digital Concert Hall, http://www.metopera.org/Season/On-Demand/, http://www.digitalconcerthall.com/

During the Fall 2015 semester, our library trialed two digital resources: Met Opera on Demand and the Berlin Philharmonic Digital Concert Hall. We examined their contents and usability, promoted them among faculty and students, and solicited feedback. Quality of content and positive user experiences persuaded us to eventually subscribe, but not without hesitations due to price, usability, and user agreements. Met Opera on Demand provides streaming video and audio access to 550 full-length performances of