Network Analysis

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Abstract Over the last few decades, network analysis has grown in popularity in the humanities and presents extensive opportunities for studies in theology, offering a way to examine relational objects or entities, considering not only the importance or value of the things that are connected to one another, but the relationships themselves, and the structures they create. This chapter examines the adoption and uses of network analysis methodologies, introducing some basic terms and concepts, more broadly considering how they might be approached. It considers the appropriate questions to ask not only of the methods, but also of the data and research questions themselves before network analysis is used. In doing so, it acknowledges the criticisms and realistic precarities of the supposed concrete concepts in computational methodologies. While highlighting the complexities of network analysis, it also points to some best practice examples of different types of network analysis in theology and the wider humanities and how they might be emulated, demonstrating how network analysis may contribute fresh insights into traditional scholarly narratives.

Keywords Visualisation, Abstraction, Heuristics, Quantitative and Qualitative Methods, Historical Network Analysis

In his canonical 2002 book, *Linked,* Albert-László Barabási explored the history and prevalence of networks in the world, and how studying them opens new avenues of understanding, predicting that "network thinking is poised to invade all domains of human activity and most fields of human inquiry" (Barabási 2002, 222). His extensive work moved beyond hypothetical or random networks to develop theories and methodologies based on and suitable for real-world scenarios (ibid., 23; id. & Albert 1999). In doing so, Barabási built on work by Duncan J. Watts and Steven Strogatz, who sought to demonstrate that networks were not merely a means to explore and analyse social interactions, but all manner of connections including neural networks, power-grids, and transport systems (Watts & Strogatz 1998). Together, these publications were on the mathematical forefront of what Ruth Ahnert, Sebastian E. Ahnert, Catherine Nicole Coleman, and Scott B. Weingart term the "network turn" for humanities, a new focus and emphasis on the possibilities and value of network analysis in examining the human experience across disciplines (Ahnert et al. 2020, 3). In its simplest terms, network analysis offers a means of examining relational objects or entities, considering not only the importance or value of the entities that are connected to one another, but the relationships themselves, and the structures they create. Given the number of possibilities that this mode of analysis offers, it is unsurprising that network analysis has witnessed a surge in use not only in the natural and so-

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cial sciences, but in the arts and humanities too, offering a new framework through which to explore traditionally humanist topics. The term *network* is not unfamiliar to scholars in the humanities and has long been used to metaphorise systems of communications and relationships; computational network analysis, then, can be used to quantify and formalise qualitative concepts that have been regularly theorised and discussed (Ahnert et al. 2020, 7; 13–24[1]).

Computational network analysis shares a variety of benefits with wider quantitative methodologies, enabling a type of *macroanalysis* or *distant reading* to view a great number of sources on a much larger scale, in ways that have not heretofore been possible (or practical) with manual or analogue means. For network analysis, this bird's eye view approach to the sources allows researchers not only to reconceptualise individual people or concepts, but entire structures of interactions, systems of relation, and societal roles. At its most fundamental, computational network analysis "makes it possible, with relative ease and speed, to measure the relationships between many entities in multiple ways, allowing a rich, multidimensional reading of complex systems never possible before" (Ahnert et al. 2020, 7).

This chapter examines the adoption and uses of network analysis methodologies, introducing some basic terms and concepts and broadly considering how they might be approached. It considers the appropriate questions to ask not only of the methods, but also of the data and research questions themselves before network analysis is used. In doing so, it acknowledges the criticisms and realistic precarities of the supposed concrete concepts in computational methodologies. While highlighting the complexities of network analysis, it also points to some best practice examples of different types of network analysis in theology and the wider humanities and how they might be emulated, demonstrating how network analysis may contribute fresh insights into traditional scholarly narratives.

1. Network Analysis – Tools, Terms, and Traps

The "ease and speed" of network analysis often relies on the relative simplicity of certain elements that are consistent across use-cases. While networks themselves can be constructed from any conceivable selection of relational entities, there are common elements of networks that can allow for comparisons across individual studies and broader fields of interests. Networks are made up of actors, objects, or concepts – known as *nodes* – and the relations between them – referred to as *edges.* While simple networks may only contain one type of node and edge, networks can be made more complex with the addition of more connection types, and one network may easily contain many different relationships at once, as we will see below. These

1 For more on networks as *thought experiments,* see ibid., 43; O'Neill 2015

types of relations may vary in their type in other ways as well, leading to *directed* and *undirected,* or *weighted* and *unweighted* networks. In an undirected network, an edge only represents whether two entities are connected, rather than accounting for characteristics such as reciprocity, order, or hierarchy; in contrast, a directed network considers the direction of a relationship. In a weighted network, values or weights are assigned to edges, e.g., strength, time, or distance. In unweighted networks, all edges are considered equal. For example, in an epistolary network of letter correspondents, each node would represent a letter writer or receiver, and the edges between them represent a set of correspondence. The network could be directed and weighted, where the *to* and *from* categories inherent in letter-writing practice are used to infer a direction in the relationship, though reciprocal correspondence would create a directed edge going in both directions. In turn, each letter contributes to the weight of an edge.

Visualisations are often the most utilised feature of network analysis. While they offer a quick overview of the dataset and relations, they can sometimes obscure as much as they reveal (cf. the chapter from J. Peters in this volume, p. 317). Katherine Bode in fact argues that graphics can hinder analysis, and "a focus on visualization impedes scholars' understanding of the evidence available to construct and interpret network models and creates perhaps insurmountable barriers to recognizing and accommodating the evidence that is absent" (Bode 2018, 125). This "hinderance" often stems from viewing these visualised networks as facts, wherein network graphs are studied as exact replicas of the source material instead of malleable representations of interactions. The arrangement of nodes and edges in a visualised network graph are an explicit design choice that more often revolves around aesthetics than any significant computational meaning; and even when they are quantitatively arranged, these often use algorithms that are not rigorously inspected or studied. In many cases, network graphs are more decorative than definitive: just as a metaphor *represents* rather than *replicates* that which it describes, so too is there an ontological gap between the visual representation of a historical period in a network and history itself (O'Neill 2015, 4–6; Ciula et al. (2018), 48; Lattmann 2018, 128f.; 139f.; Brughmans et al. 2016, 8). As Ahnert et al. (2020, 70) have argued, visualisation is instead "an additional means of producing, exploring, and analysing information that has proven value in both the liberal arts and the sciences." Visuals can be conducive, but we must consistently acknowledge what they can and cannot convey, using the graphs not as evidence, but as one of a number of means to explore and explain phenomena in networks.

Visualising networks offers a general overview of a network and a means to draw quick conclusions, but as Moretti (2011, 12) has argued, to gain more fruitful insight researchers should "turn away from images for a while, and let intuition give way to concepts […] and to statistical analysis." Using quantitative network measurements allows for a more in-depth understanding of networks as whole structures, as well as detailed observations about interactions and individual elements, necessitat-

ing a shift to the numerical and the greater use of measurable and quantifiable modes of analysis. Many of these modes, collectively termed *centrality measurements,* act as proxies for influence or importance, considering as the name suggests how central a node may be to the functioning of the network, and returning a number scoring their structural role based on different algorithms. *Degree* measures the number of connections (weighted or unweighted) for each node; *betweenness* establishes the likelihood that a node may act as a broker or intermediary; *eigenvector* measures the extent to which a node may influence others who are themselves highly influential; and *closeness,* quite simply, measures how close a node is to every other entity in the network. Each measurement offers a unique insight in the network and its components, and when built together can create fresh perspectives on structures of communication and connection that are more detailed than visualisations alone.

Just like network visualisations, the most effective employment of and analysis using these measures requires some understanding of the algorithms and parameters used in the calculations, which may not always be obvious in off-the-shelf software. Many available tools for network analysis cater to a range of skills, from user-interface based software or sites, such as *Gephi*[2] or *Palladio*[3], to coding packages, such as *NetworkX*[4] in *Python.* In deciding the most suitable option for a researcher or study, there is a trade-off between ease of use and computational control, and a combination of these tools may offer the best arrangement. One must bear in mind that each tool may have different defaults or limitations in their parameters, meaning that results for the same measure may differ between software, complicating analysis and replicability. When utilising these computational measures in humanistic study it is equally important to establish how they align with more traditional concepts and ideas; that is to say, how can quantitative and computational terms be translated into something more appropriate for specific humanistic research projects? In examining the potential of network analysis, the goal should not merely be to apply methodologies and theories from the social sciences to humanistic inquiries wholesale, but to create new modes of analysis that can transcend one specific topic and reconcile the two disciplines: not just adopting but *adapting* quantitative methods to suit humanistic investigations.

Though these computational measures are – tentatively – more informative than visuals alone, they still do not represent fact and are as equally open to interpretation and manipulation: quantitative results from these measures can and *should* be interrogated, challenged, and unpacked with the same scrutiny with which scholars have approached traditional humanistic sources for hundreds of years. In doing so, it is important to recognise that these measures are not only reliant on computational black-box algorithms, but the researcher's own active decision-making process

2 See https://gephi.org (Accessed: 23 June 2024).
3 See https://hdlab.stanford.edu/palladio (Accessed: 23 June 2024).
4 See https://networkx.org (Accessed: 23 June 2024).

as well. Like other forms of computational and quantitative methodology, much of network analysis is defined by sources or data collection, and how they prompt questions about core network elements. How has the network been defined and what are its boundaries? What/who is or is not included? What is considered a relationship? How have all these elements been transformed from historical or theoretical constructs into data or metadata for computational analysis? The answers to these questions, and the mode of data collection itself, may be led by the research question or the nature of the sources themselves. But some of these decisions may already be made ahead of time by how these factors – amongst others – create natural limitations; i.e., if a research project focuses on one archive, the collection itself will limit the reach of the network. For the most part, however, these are decisions that the researcher themselves must make in the process of collecting information for the network before it is even created.

By considering these questions and their impact on network analysis, Ahnert et al. (2020, 13; 75) argue that the *process* of network analysis does not begin with the network itself but rather the method of abstraction by which sources are transformed into quantitative networks. This process, whereby researchers unpack the different layers of information in qualitative sources, "requires a prior *mental* manoeuvre of translating cultural artefacts into an abstracted form to see whether they are compatible with the input requirements of the available tools" (ibid., 75). By actively acknowledging and engaging with this process of abstraction, we can more critically consider how sources are adapted for network analysis and how network analysis fits a particular set of sources, considering what is and what is not included. Importantly, this must be understood as a continuum: even at the strictest level of abstraction, the dropped information is not ignored indefinitely, but is merely not in use right now, much like qualitative selection and analysis of sources (ibid., 51).

This process is not just a question of what is abstracted, but *how* the sources are transformed. Criticism has focused on this supposed inability in network analysis to grasp the more complex ideas of humanities disciplines; as Elwert (2020, 182) critiqued in his survey of network analysis in religious studies, this approach "tends to reduce religious phenomena to social processes but neglects the content of religious exchange… [which] might in part explain why network analysis has been adopted rather reluctantly in main-stream religious studies." This assessment is problematic, however, placing responsibility for these *failures* on the methodology itself, rather than how it has been applied. To use computational network analysis to its full advantage, greater effort and active participation in the abstraction process is required, reflecting on how the transformation from concepts and constructs to quantifiable connections is, ultimately, defined by the researcher. This abstraction offers an important and iterative means to more concretely examine and conceptualise sources and data and their meaning or value in scholarly narratives. Paying more critical attention to this process and what it means for networks counters any blanket rejections of network analysis and suggestions that it does not suit theology and religious studies.

The formation of networks and use of computational analysis therein relies not only on abstraction but, as with any other scholarly practice, the original selection of sources and data as well. Networks, then, are much like archives: they are not organic, naturally occurring entities but carefully curated collections subject to layers of selection, from the original writers or creators through a multitude of readers, archivists, and scholars up to today. Acknowledging these layers and influences not only improves understanding of the analysis and its results, but often the sources themselves too. While this type of critique and recognition in methodology applies across computational methods in the humanities, it is especially important when using network analysis to examine relational objects to acknowledge our own, somewhat hierarchical, relationship with the network as well.

2. Best Practice and Best Examples

The fact remains that, when used effectively, combining the qualitative and quantitative allows for a more nuanced and well-rounded understanding of topics, in which elements of both disciplines can be used simultaneously: close *and* distant reading, interpretative *and* descriptive work. As the remainder of this chapter turns to examples of different types of network analysis in the humanities, it is important to consider how this nuanced application forms ideas of best practice: contributing both to understandings of computational practice and traditional scholarly narratives, while reflecting critically on the process and discerning application of appropriate methodologies.

One of the most popular forms of network analysis in the humanities is *social network analysis* or SNA, examining networks primarily built on either pre-existing evidence of interactions or recorded from interviews and observation, and is the approach most commonly found under the umbrella term *historical network analysis.* In studying letter metadata – information *about* documents, rather than the contents of sources themselves – Ahnert & Ahnert (2015) utilise this approach to examine underground networks of Protestant communities in the reign of Catholic Mary I of England. Quantitative network analysis of epistolary networks in this period unsurprisingly confirmed some expected actors of importance, in particular prolific martyrs. But having identified these actors, the measures were also used to construct network fingerprints to find potentially unknown or unexpected actors in similar roles, creating replicable experiments not only for this singular dataset but beyond as well. In using computational measurements to identify different types of interaction profiles in the network, Ahnert and Ahnert demonstrate how quantitative network analysis employed in tandem with extensive traditional historical knowledge to understand how these network roles translate into early modern realities can offer nuanced insight into relational structures.

While similarly investigating historical networks, Düring's (2016) exploration of Jewish support networks during the Second World War uses a variety of relationship categories, including "form of help, intensity of relationships, motives for action, date of help and date of first meeting" based on primary first-hand accounts. In doing so, Düring examines not only the *existence* of edges but their explicit role in the societal structure and how this may indicate certain nodes or relationships of importance. By investigating the history of the Segal family as a case study, network analysis is used to examine brokerage relations providing aid. As such, Düring applies computational methodologies as a formal mode to both qualify and quantify hypothesised roles in historical interactions.

While Ahnert and Ahnert utilise metadata to build social networks, Düring extracts the interactions from the available texts themselves, an approach Bourke (2024) similarly adopts in his examination of women writers in John Locke's correspondence. Acknowledging that the correspondence of John Locke fails to offer metadata "comprised of diverse senders and recipients," Bourke instead makes use of the contents of the letters as well, including instances of citation – where a writer mentions another person – and co-citation – where two people who are not the writer are referenced alongside one another – to build additional networks of social interaction. This is to say, where Düring extracts network edges out of text that explicitly *describes* social interactions, Bourke's citation and co-citation networks replicate *inferred* connections, layering metadata and network constructs with careful close reading. In doing so, Bourke (2024) "map[s] the intellectual and social structure of the conversations Locke was having within his correspondence," critically offering space to (namely female) actors that otherwise hold little sway in a metadata-only network, and examining how this may indicate other actors of influence.

One of the more popular uses of these co-citation networks in religious studies is examining relational structures surrounding Jesus in the Bible, again extracting data for network edges from relationships both described and inferred in the text. McClure's (2020) paper goes beyond utilising these structures as a means to explore Jesus' social network as one singular entity, instead constructing different networks from the four Gospels of the New Testament and comparing results to consider how network analysis may contribute to more traditional examinations of literary and textual overlaps and differences between the Gospels. This study both confirms already identified points of overlap or differentiation, but also identifies new points of interest – in particular around the inclusion of women and stigmatized people – that may have been acknowledged in a textual context, but not a relational structure one. McClure's investigation is primarily based on pre-existing narratives, and she acknowledges that the findings are likely unsurprising to biblical scholars, but argues that the study "supplements their textual, historical, and theological observations by exploring relational and structural patterns not previously examined" (ibid. 47), effectively demonstrating how network analysis can still offer interesting insights into scholarly debates with a long and rich history.

These studies primarily adopt close-reading techniques to extract information for social network analysis, but networks can also be employed as means of text analysis in and of themselves. While social network analysis primarily focuses on social relations between objects or, as in these case studies, people, similar structures can be used to study singular or canons of text, producing similar insights to other forms of digital text analysis such as topic modeling (cf. the chapter from M. Althage in this volume). This may involve word association or semantic networks, which attempt to replicate mental representations and understandings of linguistic connections, but it may also resemble something similar to the co-citation networks, using co-occurrences of words in a sentence or paragraph to construct networks (Czachesz 2016, 43[5]). Like Jennifer M. McClure, István Czachesz also employs network analysis to examine differences and similarities between Gospel stories, but instead using these word co-occurrences to consider literary and linguistic differences, rather than social ones. In doing so, Czachesz critically examines how ideas or elements are emphasised differently across iterations of miracle stories. Though methodologies such as these offer simplistic findings when applied on a small scale, Czachesz's study acts as a model of the possibilities of these approaches when applied to a much larger textual corpus.

The use of network analysis to explore literary and linguistic connections is just one demonstration of how nodes may be made up of any relational entity. With this in mind, *Actor-Network Theory* (ANT) – proposed by Bruno Latour in the 1980s – suggests that everything in the world exists in one network together, including humans and non-humans, both animate and inanimate, extending as much to ideas as to physical objects and beings (Latour & Woolgar 1986; Latour 2005; Van Oyen 2016). This theory acknowledges that ideas and objects are not just connected to one another, but are able to influence and impact one another, as much as nodes in a social network might. Checketts (2017) utilises this theory as a new framework examine and unpack the relationship between Christianity and technology, and the evolving place of both in the modern world. While Checketts' argument remains qualitative rather than quantitative – choosing not to evoke the digital and technological mediums he discusses – he performs the important manoeuvres discussed above to translate theological debates into network theory, setting the stage for possible computational measures in a further study.

While best practice is still developing around these different types of networks and their varied applications in the humanities, we can posit how layering these approaches might provide the most fruitful insights. Take, for example, the development and spread of ideas across Europe during the Reformation. Several state papers contain evidence of interactions between important rulers, theologians, and religious leaders, and building networks out of these may allow us to consider structures of influence and power. These already offer an interesting framework to examine inter-

5 For further examples see Purschwitz 2018; Sangiacomo et al. 2022.

actions using social network analysis methodologies; but how could this be layered further with other modes of network analysis? What if these epistolary metadata networks were supplemented with citation or co-occurrence networks built with the *contents* of the letters? Or, to take it another step, moving closer to Latour's *Actor-Network Theory,* what if the nodes were made of both correspondents and the *ideas* in the letters or wider writings, as in semantic networks? Can we model connections between language choices in tracts or translations, the theologians who wrote them, and the evolution of religious change in the early modern world? While these remain only hypothetical questions, it prompts thinking as to the possibilities of multi-layered and multi-dimensional networked thinking in religious and theological studies.

Though network analysis may also only go as far to confirm actors and entities of importance or structures that are already confirmed in traditional scholarly literature, this holds value in validating supposedly new discoveries that may also appear. By employing these methods as new frameworks of understanding rather than new types of *evidence,* we can adjust expectations of what computational network analysis will achieve, and therefore how useful it is. In doing so, we can also prompt new means of approaching questions around importance or influence and redefine how we conceive of connected structures throughout theology and religious studies. The interaction between quantitative and qualitative mentalities is therefore an iterative, heuristic one. Though some elements of traditional qualitative research may resist the idea that aspects of the humanities can be quantified, it is undeniable that these methods offer modes of measurement and, more importantly, *comparison,* that have not so easily been achieved before. While it is important to recognise the malleability and even *fallibility* of data and the structures they create, by acknowledging and *incorporating* this awareness into our approach, computational network analysis can offer exciting and thought-provoking outcomes, and when used together with traditional approaches, can create more developed research processes and enriched narratives in theology, religious studies, and beyond.

References

Ahnert, R., & Ahnert, S.E. (2019). Metadata, Surveillance and the Tudor State, *History Workshop Journal,* 87, 27–51. DOI: https://doi.org/10.1093/hwj/dby033 (Accessed: 23 June 2024).

Eid. (2015). Protestant Letter Networks in the Reign of Mary I. A Quantitative Approach, *ELH,* 82, 1–33. URL: https://www.jstor.org/stable/24477807 (Accessed: 23 June 2024).

Eid. (2023). *Tudor Networks of Power.* Oxford: Oxford University Press.

Eid., Coleman, C.N., & Weingart, S.B. (2020). *The Network Turn. Changing Perspectives in the Humanities.* Cambridge: Cambridge University Press. DOI: https://doi.org/10.1017/9781108866804 (Accessed: 23 June 2024).

Barabási, A.-L. (2002). *Linked. The New Science of Networks.* New York: Penguin Group.

Id., & Albert, R. (1999). Emergence of Scaling in Random Networks, *Science,* 286(5439), 509–512.

Bode, K. (2018). *A World of Fiction. Digital Collections and the Future of Literary History.* Ann Arbor: University of Michigan Press.

Bourke, E. (2024]). The Reception of Women Letter-writers in the Correspondence of John Locke (1632–1704), *Huntington Library Quarterly Special Issue. Network Analysis and the Early Modern Archive,* 86(2), 227–256.

Brughmans, T., Collar, A., & Coward, F. (2016). *The Connected Past. Challenges to Network Studies in Archaeology and History.* Oxford: Oxford University Press.

Ciula, A., Eide, Ø., Marras, C., & Sahle, P. (2018). Introduction to Historical Social Research, *HSR-Supplement,* 31, 7–29.

Checketts, L. (2017). The Cross and the Computer. Actor-Network Theory and Christianity, *Theology and Science,* 15(1), 116–127.

Czachesz, I. (2016). Network Analysis of Biblical Texts, *Journal of Cognitive Historiography,* 3, 43–67.

Drucker, J. (2011). Humanities Approaches to Graphical Display, *Digital Humanities Quarterly,* 5(1), 1–52. URL: http://www.digitalhumanities.org/dhq/vol/5/1/000091/000091.html (Accessed: 23 June 2024).

Düring, M. (2016). The dynamics of helping behaviour for Jewish fugitives during the Second World War. The importance of brokerage. The Segal Family's Case, *Mass Violence & Résistance.* Online. URL: https://www.sciencespo.fr/mass-violence-war-massacre-resistance/en/document/dynamics-helping-behaviour-jewish-fugitives-during-second-world-war-importance-brokerage-se.html (Accessed: 23 June 2024).

Elwert, F. (2020). Social and semantic network analysis in the study of religions. In F. Kerschbaumer, L. von Keyserlingk-Rehbein, M. Stark & M. Düring (Eds.), *The Power of Networks. Prospects of Historical Network Research* (pp. 172–186). London: Routledge.

Emirbayer, M., & Goodwin, J. (1994). Network Analysis, Culture and the Problem of Agency, *American Journal of Sociology,* 99, 1411–1454. DOI: https://doi.org/10.1086/230450 (Accessed: 23 June 2024).

Greteman, B. (2021). *Networking Print in Shakespeare's England. Influence, Agency, and Revolutionary Change.* Stanford: Stanford University Press.

Klein, L.F. (2013). The Image of Absence. Archival Silence, Data Visualization, and James Hemings, *American Literature,* 85(4), 661–688.

Latour, B. (2005). *Reassembling the social. an introduction to actor-network-theory.* Oxford: Oxford University Press.

Id., & Woolgar, S. (1986). *Laboratory life. The construction of scientific facts.* Princeton: Princeton University Press.

Lattmann, C. (2018). Iconizing the Digital Humanities. Models and Modeling from a Semiotic Perspective, *Historical Social Research. Supplement,* 31, 124–146. DOI: https://doi.org/10.12759/hsr.suppl.31.2018.124-146 (Accessed: 23 June 2024).

McClure, J.M. (2020). Jesus's Social Network and the Four Gospels. Exploring the Relational Dynamics of the Gospels Using Social Network Analysis, *Biblical Theology Bulletin,* 50(1), 35–53. DOI: https://doi.org/10.1177/0146107919892841 (Accessed: 23 June 2024).

Moretti, F. (2011). Network Theory, Plot Analysis, *LiteraryLab,* 2, 1–12. URL: https://litlab.stanford.edu/assets/pdf/LiteraryLabPamphlet2.pdf (Accessed: 23 June 2024).

Nagel, A.-K. (2012). Measuring the Relational. How to collect data on religious networks. In L. Berzano & O. Riis (Eds.), *New Methods in the Sociology of Religion* (pp. 181–205). Leiden: Brill Academic Publishing [= *Annual Review of the Sociology of Religion,* 3].

Id. (2022). Network Analysis. In S. Engler & M. Stausberg (Eds.), *The Routledge Handbook of Research Methods in the Study of Religion* (pp. 375–386). London: Routledge.

O'Neill, L. (2015). *The Opened Letter. Networking in the Early Modern British World.* Philadelphia: University of Pennsylvania Press.

Perry, B.L., Pescosolido, B.A., & Borgatti, S.P. (2018). *Egocentric Network Analysis. Foundations, Methods, and Models.* Cambridge: Cambridge University Press.

Purschwitz, A. (2018). Netzwerke des Wissens. Thematische und personelle Relationen innerhalb der halleschen Zeitungen und Zeitschriften der Aufklärungsepoche (1688–1818), *Journal of Historical Network Research,* 2, 109–142. URL: http://jhnr.uni.lu/index.php/jhnr/article/view/47 (Accessed: 23 June 2024).

Rollinger, Ch., Düring, M., Gramsch-Stehfest, R., & Stark, M. (2017). Editors' Introduction, *Journal of Historical Network Research,* 1, i–vii. URL: http://jhnr.uni.lu/index.php/jhnr/article/view/19 (Accessed: 23 June 2024).

Sangiacomo, A., Tanasescu, R., Hogenbirk, H., & Donker, S. (2022). Recreating the Network of Early Modern Natural Philosophy. A Mono- and Multilingual Text Data Vectorization Method, *Journal of Historical Network Research,* 7, 33–85. DOI: https://doi.org/10.25517/jhnr.v7i1.129 (Accessed: 23 June 2024).

Van den Heuvel, Ch. (2015). Mapping Knowledge Exchange in Early Modern Europe Intellectual and Technological Geographies and Network Representations, *International Journal of Humanities and Arts Computing,* 9(1), 95–114.

Van Oyen, A. (2016). Networks or Work-Nets? Actor-Network Theory and Multiple Social Topologies in the Production of Roman Terra Sigillata. In T. Brughmans, A. Collar & F. Coward (Eds.), *The Connected Past. Challenges to Network Studies in Archaeology and History* (pp. 35–56). Oxford: Oxford University Press.

Watts, D.J. (2002). A simple model of global cascades on random networks, *Proceedings of the National Academy of Sciences of the United States of America,* 99, 5766–5771. DOI: https://doi.org/10.1073/pnas.082090499 (Accessed: 23 June 2024).

Id., & Strogatz, S.H. (1998). Collective dynamics of 'small-world' networks, *Nature,* 393(6684), 440–442.