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Using Social Network Analysis to Reveal Unseen Relationships in Medieval Scotland

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Abstract

This article will describe social networks and the concepts of social network analysis. It will then move on to describe some of the uses social network analysis has been put to in historical research. This will be followed by a description of the People of Medieval Scotland database, which provides the data for this research. Finally, the social network analysis techniques used in this research will be described and the preliminary results that reveal findings that traditional historical methods had not will be discussed, including identifying an additional role played by Duncan II Earl of Fife, and using network density model for the diffusion of innovations to identify opinion leaders in medieval Scotland.

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1. Introduction

This short article will describe the ongoing research being conducted jointly by Kings College London and the University of Glasgow to understand the social networks of the medieval Scottish elites from the years 1093–286. This article will start with a description of social networks and the concepts of social network analysis (SNA). It will then move on to describe some of the uses SNA has been put to in historical research. This will be followed by a description of the 'People of Medieval Scotland (PoMS) database', which provides the data for this research. Finally, the SNA techniques used in this research will be described and the preliminary results that reveal findings that traditional historical methods had not will be discussed. This is another example of how digital technology can assist the humanities.

2. SNA

Social networks are defined and measured as connections among people, organizations, political entities (states and nations), and/or other units. SNA is a theoretical perspective and a set of techniques used to understand these relationships (Valente, 2010, p. 3). Christakis and Fowler (2010, p. 32) say that the science of social networks provides distinct ways of seeing the world because it is about individuals and groups and how the former becomes latter.

Valente (2010, pp. 3–7) says that relationships matter because relationships influence a person's behaviour above and beyond the influence of his or her attributes. A person's attributes do influence who people know and spend time with: their social network. Valente quotes Borgatti *et al.* (2009), 'one of the most potent ideas in the social sciences is the notion that individuals are embedded in thick webs of social relations and interactions'. The reason that social networks are so important is because human beings are ultra-social animals that create social networks (Haidt, 2006). Christakis and Fowler (2010, p. 214) add that human beings just do not live in groups, they live in networks. Valente argues the traditional social science approach that using random sampling is not adequate for measuring

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network concepts because random sampling removes individuals from the social context that may influence their behaviour. Valente explains that one primary reason social network research has grown in recent decades is that scholars have become dissatisfied with attribute theories of behaviour. Many attribute theories have not explained why some people do things (e.g. quit smoking) while others do not. Social network explanations have provided good explanations in these cases.

3. Use of SNA in History

So, how can SNA be used in history? There has been a growing use of SNA in history recently. Wellman and Wetherell (1996) suggest to the historians the usefulness of using a social network analytic approach to studying communities and community-like social structures, such as kinship groups and work groups. The seminal work in using SNA in historical research is Padgett and Ansell's (1993) research on the rise of the Medici in renaissance Florence. Their work showed that the rise of the Medicis came from their ability, especially the ability of Cosimo de Medici, to take advantage of the gaps in connections in the social network which the Medicis were able to bridge to take political control of Florence. Since then, the use of SNA in historical research has been steadily increasing.

Such studies encouraged increasing use of SNA in history. However, Wetherell (1998) has identified three reasons why historians have been slow to adopt SNA. First, the conceptual orientation of historical SNA remains unfamiliar to historians. Secondly, quantitatively oriented historians are few in number. Thirdly, SNA data requirements are formidable. These include the need for evidence of social interaction among all members of a social system for a variety of behaviours and the need for a broad range of high-quality records for the place, time, and activities being studied. Finally, SNA is problematic for historians because they are plagued by an incomplete historical record and imperfect understandings of past social relations.

More recent use of SNA in history can be found in Gramsch (2013), Habermann (2011), Lemercier (2012), Lemercier and Zalc (2011), McLean (2007), Mitsiou (2012), Rose (2011), and Ruffini (2008).

4. Using SNA with the PoMS Database

The PoMS database holds data on all known people, who are highly interconnected, between 1093 and 1314 mentioned in over 8,600 contemporary documents (Bradley and Pasin, 2013; Beam *et al.*, 2012). This was funded by the Arts and Humanities Research Council in the UK. The current research is part of the Transformation of Gaelic Scotland project funded by the Leverhulme Trust. This exploratory research has the goal of understanding the role of social networks among the elite of medieval Scotland. It also has the goal of exploring the appropriateness of SNA techniques for this data set, and perhaps for other similar collections.

The first technique used drew on one of the two-mode networks that the PoMS data made available. In two-mode networks, two kinds of entities, say witnesses and charters, are dealt with. The two-mode network method comes from the pioneering work of Davis *et al.* (1941), where he was able to determine the cliques among a group of women from a network of women and the social events they attended. In this research, the two sets of actors are legal documents called charters and the people who witness them. As a result, you will see links between witnesses and charters but not among the witnesses and charters. A two-mode network becomes even more useful by the affiliation technique. Here, a one-mode network was created, say only persons, or a network that connects witnesses who have witnessed the same charter together. The resulting affiliation network shows when people were present together to witness a charter.

However, it should be noted that historians have established that administrative documents such as charters were intended to represent actual social events (Hammond, 2013, pp. 8–13). Recent research across the medieval era has shown that many charters were produced at formal political assemblies (Reuter, 2006, pp. 193–216). The analysis of social

networks has focused on charters strictly defined as this is the document type which is most likely to represent a social moment when significant numbers of people came together in one location and interacted in a socially prescribed and structured way. Charters strictly defined make up about 66% of the documents in the pre-1286 PoMS database. Furthermore, Dauvit Broun has determined that individuals named in charter witness lists were almost always physically present at the 'ceremony', whether a large political or ecclesiastical assembly or smaller event (Broun, 2011). The act of witnessing a charter carried with it legal responsibilities in terms of the possibility of being called on later to testify to the veracity of the transaction of property that was the subject of the charter. Transfers of property in the medieval period were often challenged. Thus, the witnesses bore an implicit social relationship to the grantor, beneficiary, or the property being transacted, and were often friends, family, or neighbours of either the grantor or beneficiary. Thus, the role of being a charter witness is pregnant with social connections. However, it should be noted that two people witnessing a charter does not by itself provide evidence of a social relationship. The evidence of a social relationship will come from the things mentioned above.

An affiliation network can also keep track of how many times a particular witness has witnessed a charter with every other witness. The theory is that the more often two witnesses witness charters together, the more probable there is an actual social relationship between the two people. Therefore, as the number of charters witnessed together rises, the more probable the resulting network is an actual map of the social relationships. Of the 9,078 people in the PoMS database who had witnessed charters, over 90 of them had witnessed more than 20 charters together with at least one other person. This is an indication that the network mapped a number of actual social relationships.

Another technique used was creating ego networks. Ego networks are networks where the focus is on all the people connected to a selected person and the interconnections among these people.

The final technique used involved using network models of diffusion of innovations to track how charter innovations spread. The theory of the diffusion of innovations proposes an understanding of how new ideas are adopted. The charter innovation that was followed was the Scottish 'regnal sicut' clause. This clause introduced the then new idea of the kingdom of Scotland. The charters spreading this idea used either the phrase 'Kingdom of Scotland' or the phrase 'Kingdom of the Scots'. Since the goal of this research project was to understand how Scotland transformed into a nation, discovering how the spread of this innovation in charters helped propagate the idea of Scotland as a nation. All the 12th-century grantors of charters were identified and data used in the database to indicate who used the clause. Then, SNA was used to see how this innovation diffused among the Scottish elite.

The theory of the diffusion of innovations was created by Rogers (2003) and explains how change spreads through a population. Traditionally, diffusion research would trace the innovation through time through the network. However, because of the uncertainty surrounding the dating of charters, this is not possible. Instead, two network theories on how opinion leaders drove innovations would be used to see if these correlate with opinion leaders identified by traditional historical methods.

Using Roger's work, Valente (1995) proposed two models of how to do this. First, in the opinion leadership model, Valente proposes that opinion leaders in the network would tend to be early adopters of innovations. Secondly, the network density model said that those with lower ego network density would also tend to be early adopters of innovations. Network density is the ratio of the actual connections in the network over the total potential connections in the network. Based on the work of Granovetter (1973), Valente argues that weak bridging ties bring new information into the network, and those with lower network densities tend to have weaker bridging ties. Granovetter (1973) defines weak bridging ties as connections between different groups that allow information and behaviours to spread throughout a population. This also explains why opinion leaders are early adopters because they tend to have lower network densities.

Another way to look for those who could possibly be a conduit for new ideas is to see who has what is called in SNA the highest betweeness centrality. This measures how often a person serves as a bridge from one part of the network to another. One can see how this would be important in diffusing innovations. However, there is a major caveat to this. The way that betweeness centrality is calculated means that missing data can have a significant impact. The more missing data there are, the more the betweeness scores of the remaining nodes are artificially increased. Unfortunately, there is a lot of missing data in the PoMS database from northern and western Scotland.

5. Findings so far

This work is still very preliminary, but some interesting findings have appeared from the use of SNA. These come in two categories. First, is the large amount of co-witnessing of significant number of charters as described above. More specifically, is finding out that Duncan II, Earl of Fife, who historians knew was a very prominent noble in Scotland, possibly played an additional further role in Scotland as revealed by SNA. Secondly, the investigation of the diffusion of the Scottish 'regnal sicut' clause was able to confirm the importance of the royal courts in the adoption of that innovation. Additionally, the network densities matched those who the historians identified as opinion leaders. Finally, the network density model identified an opinion leader who was not recognized through traditional historical methods.

Duncan has witnessed more than 20 charters with 27 people, while William del Bois, the chancellor whose role is to manage charters, has only done that with 15 other witnesses. Also, Duncan has witnessed more than 40 charters with seven people, while William has done the same with only two other witnesses. However, Duncan has witnessed charters with 630 other witnesses, while William, the chancellor, has witnessed charters with 479 other witnesses. Overall, William has witnessed 213 charters, while Duncan has witnessed 210 charters. So the question is why does Duncan, Earl of Fife, have so many more connections than anyone else? There is no definitive answer to this question yet, but the leading hypotheses centre on Duncan's possible role of running Scotland north of the Firth of Forth for King William I, taking advantage of his brokerage opportunities and enhancing social skills.

In order to investigate the diffusion of the Scottish 'regnal sicut' clause charter innovation, two networks were used. First, a network of the relationships between the adopters of the innovation was created to see if this was diffused through the relationship network. In Fig. 1, there is a visualization of the relationship network where the adopters are in white. The software used to do the network calculations was UCINET (Borgatti *et al.*, 2002) and NetDraw (Borgatti, 2002) was used to visualize the network.

When an ego network of King William I was created, there was an interesting result. As seen in Fig. 2, all of the king's connections are adopters of the innovation. The same result was found in the ego networks of Alexander II, David I, Malcolm IV, and David, Earl of Huntingdon, the brother of William I, and Malcolm IV. This confirms the importance of the royal courts, not surprisingly, in the spread of this innovation.

However, there is a serious limitation with using this relationship network. This network was based solely on the relationships of the adopters of this innovation. It is sparse and when testing the opinion leadership and network density models on ego networks, no correlation was found between these two as can be seen in Table 1. Density is the percentage of the potential connection being used in the network.

A network was built using the charter co-witnessing of all 9,078 witnesses in the database. This time a strong correlation using these two network models as can be seen in Table 2.

In addition, there was a strong correlation between those identified as opinion leaders by historians, highlighted in black, and those with relatively low ego network densities. This model was also able to identify Malcolm, Earl of Atholl (bold and underlined), as a potential opinion leader, highlighted in

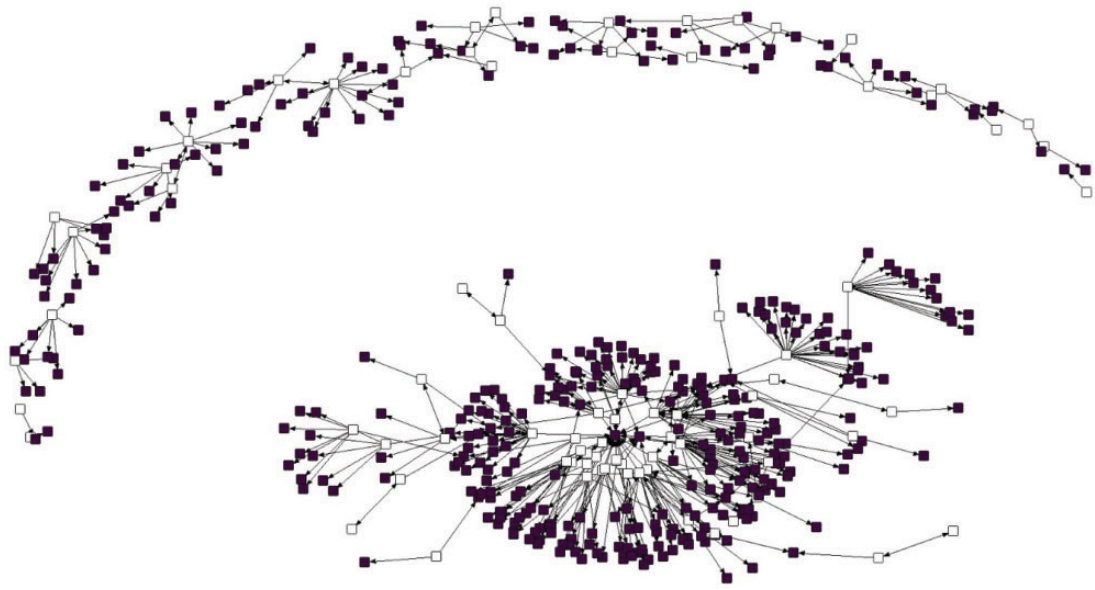

Fig. 1 Relationship network (innovation adopters in)

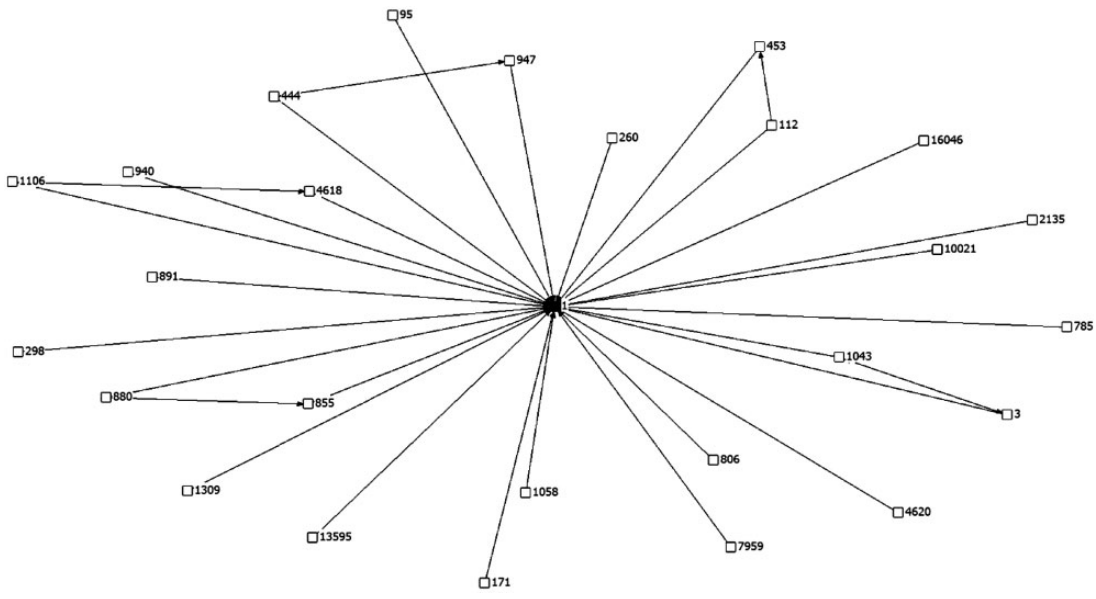

Fig. 2 Ego network of King William I (innovation adopters in white)

red, while eliminating Waltheof and Robert of London (in italics) as opinion leaders.

As can be seen in Table 3, there is little correlation between the opinion leaders identified using traditional historical methods and high betweeness centrality scores. The only person who has both low ego network density and high betweness centrality is Duncan, Earl of Fife. Countess Ada, who is the

Table 1 Network density test for relationship network

ID	Name	Density in Relationship Network	Opinion Leader?
13	Duncan earl of Fife	0	Y
134	Bishop Richard of St Andrews	0	Y
970	Walter of Lundin	0	M
95	Countess Ada	0	Y
966	Henry Revel	0	N
238	Malcolm Earl of Atholl	0	Y
575	William of Lamberton	0	N
6175	Richard Gordon	0	N
1335	Waltheof, son of Cospatric	0	M
13595	Robert of London	0	N
1399	Margaret, Henry Revel wife	0	N
3	Walter son of Alan (Steward)	0.48	Y
112	Richard de Moreville	1.75	Y
14	Robert de Quincy	8.33	Y
855	Bernard son of Brian	10	N
13892	Richard Lovell, Lord of Hawick		N

Y = Yes, N = No, and M = Maybe.

Table 2 Network density test for witness network

ID	Name	Density in Witness Network	Opinion Leader?
13	**Duncan earl of Fife**	**8.47**	**Y**
3	**Walter son of Alan (Steward)**	**15.17**	**Y**
112	**Richard de Moreville**	**20.64**	**Y**
14	**Robert de Quincy**	**21.09**	**Y**
134	**Bishop Richard of St Andrews**	**22.94**	**Y**
970	Walter of Lundin	**31.97**	**M**
95	**Countess Ada**	**32.05**	**Y**
966	Henry Revel	**32.41**	**N**
238	**Malcolm Earl of Atholl**	**35.42**	**Y**
855	Bernard son of Brian	**41.41**	**N**
575	William of Lamberton	**61.54**	**N**
6175	Richard Gordon	**90**	**N**
1335	*Waltheof, son of Cospatric*	**100**	**M**
13595	*Robert of London*	**100**	**N**
1399	Margaret, Henry Revel wife		**N**
13892	Richard Lovell, Lord of Hawick		**N**

Y = Yes, N = No, and M = Maybe. Those in bold are opinion leaders identified using traditional historical methods. Malcolm Earl of Atholl was opinion leader identified using the network density method.

mother of two kings of Scotland and who historians believe is crucial to the diffusion of the regnal sicut clause, has only the 904th highest betweeness centrality score. Many of those who have the highest betweeness centrality scores serve as internal bridges to the network. Unless the innovation is coming from inside the network, internal bridges are not the key to accessing what Granovetter (1973) calls non-redundant information, which innovations often are. Opinion leaders tend to have access to non-redundant information because they have more links to outside the network, which is why they have lower ego network density. This is why Valente's (1995) network density model of diffusion of innovations is a better indicator of opinion leadership than betweeness centrality.

The research has been ongoing. We have expanded the sample beyond the original 15 people. We have found the correlation between low ego network density and those who are deemed opinion leaders by historians is still holding. This is a hopeful sign that what Valente has found can be applied to historical networks

Summary

In summary, while this research is still preliminary, it has shown the power of SNA to bring a new perspective to historical data:

- Using witness affiliation networks, we are able to show that Duncan Earl of Fife had an even more important role in Scotland than was previously believed.
- Using ego networks, we are able to show the key role that the royal court played in diffusing the Scottish Regnal Sicut clause.
- Using Valente's relational network models of diffusion of innovation, opinion leadership, and network density, we are able to match the historians identification of opinion leaders and identify a new leader.
- Betweeness centrality serves as a poor predictor of opinion leadership because a high score can indicate a person is an internal bridge with poor access to new ideas, which is key according to both Granovetter and Valente.
- The ongoing research has so far shown that correlation between low ego network density and those who are deemed opinion leaders by historians is still holding with an increased sample size.

Table 3 Opinion leaders betweeness centrality rankings

Rank	Betweeness	ID	Name	Density in Witness Network	Historical Opinion Leader?
2	0.029244	13	**Duncan Earl of Fife**	**8.47**	**Y**
14	0.015063	3	**Walter son of Alan (Steward)**	**15.17**	**Y**
96	0.005013	112	**Richard de Moreville**	**20.64**	**Y**
103	0.004844	134	**Bishop Richard of St Andrew**	**22.94**	**Y**
1717	0.000125	970	Walter of Lundin	**31.97**	**M**
904	0.000519	95	**Countess Ada**	**32.05**	**Y**
503	0.001249	966	Henry Revel	**32.41**	**N**
926	0.000491	238	**Malcolm Earl of Atholl**	**35.42**	**M**
1147	0.000334	855	Bernard son of Brian	**41.41**	**N**
2755	0.000013	575	William of Lamberton	**61.54**	**N**
1409	0.000212	6175	Richard Gordon	**90**	**N**
3408	0	1335	*Waltheof son of Cospatric*	**100**	**N**
7769	0	13595	*Robert of London*	**100**	**N**
		1399	Margaret, Henry Revel's wife		**N**
		13892	Richard Lovell, Lord of Hawick		**N**

Those in bold are opinion leaders identified using traditional historical methods. Malcolm Earl of Atholl was opinion leader identified using the network density method.

References

PoMS Beam, A., Bradley, J., Broun, D.,. Davies, J. R., Hammond, M., Pasin, M. (2012). *The People of Medieval Scotland, 1093–1314*. Glasgow and London. www.poms.ac.uk. (accessed 17 June 2012).

Borgatti, S. P. (2002). *Netdraw Network Visualization*. Harvard, MA: Analytic Technologies.

Borgatti, S. P., Everett, M. G., and Freeman, L. C. (2002). *UCINET for Windows: Software for Social Network Analysis*. Harvard, MA: Analytic Technologies.

Borgatti, S. P., Mehra, A., Brass, D. J., and Labianca, G. (2009). Network analysis in the social sciences. *Science*, 323: 892–95.

Bradley, J. and Pasin, M. (2013). Structuring that Which Cannot be Structured: A Role of Formal Models in Representing Aspects of Medieval Scotland. In Hammond, M. (ed.), *New Perspectives on Medieval Scotland*, 1093–1286. Suffolk: Boydell and Brewer, Studies in Celtic History Series, pp. 203–14.

Broun, D. (2011). The Presence of Witnesses and the Writing of Charters. In Dauvit B. (ed.), *The Reality behind Charter Diplomatic in Anglo-Norman Britain*. Glasgow: Centre for Scottish and Celtic Studies, University of Glasgow, pp. 235–90.

Christakis, N. and Fowler, J. (2010). *Connected: The Amazing Power of Social Networks and How They Shape our Lives*. London: Harper Press.

Davis, A., Gardner, B. B., and Gardner, M. R. (1941). *Deep South: A Social Anthropological Study of Caste and Class*. Chicago, IL: University of Chicago Press.

Gramsch, R. (2013). Das Reich als Netzwerk der Fürsten. Politische Strukturen unter dem Doppelkönigtum Friedrichs II. und Heinrichs (VII.) 1225–1235. In *Mittelalter-Forschungen*, Vol. 40. Thorbecke: Ostfildern.

Granovetter, M. S. (1973). The strength of weak ties. *American Journal of Sociology*, 78, (6): 1360–80.

Habermann, J. (2011). *Verbündete Vasallen: Die Netzwerke von Grafen und Herren am Nordwestharz im Spannungsgefüge zwischen rivalisierenden Fürstgewalten (ca. 1250-1400)*. Norderstedt: Books on Demand GmbH.

Haidt, J. (2006). *The Happiness Hypothesis: Finding Modern Truth in Ancient Wisdom*. New York: Basic Books

Hammond, M. (2013). Introduction: The Paradox of Medieval Scotland, 1093–1286. In Matthew H. (ed.), *New Perspectives on Medieval Scotland, 1093-1286*. Woodbridge: The Boydell Press, pp. 1–52.

Lemercier, C. (2012). Formale Methoden der Netzwerkanalyse in den Geschichtswissenschaften: Warum und Wie?, *Historische Netzwerkanalysen (Österreichische Zeitschrift für Geschichtswissenschaften)*, 23, (1): 16–41.

Lemercier, C. and Zalc, C. (2008). *Méthodes quantitatives pour l'historien*. Paris: Découverte.

McLean, P. D. (2007). *The Art of the Network: Strategic Interaction and Patronage in Renaissance Florence*. Durham; London: Duke University Press.

Mitsiou, E. (2012). Networks of Nicaea: 13th Century Socio-Economic Ties, Structures and Prosopography. In Saint-Guillan G., Stathakopoulos(Hg.) D., *Liquid and Multiple: Individuals and Identities in the Thirteenth-Century Aegean*. London: ACHCByz, pp. 91–104.

Padgett, J. and Ansell, C. (1993). Robust Action and the Rise of the Medici, 1400 – 1434. *American Journal of Sociology*, 98(6): 1259–319.

Reuter, T. (2006). *Medieval Polities and Modern Mentalities*. In Nelson J. L. (ed.). Cambridge: Cambridge University Press.

Rogers, E. (2003). *Diffusions of Innovations,* 5th edn. London: Free Press.

Rose, I. (2011). Reconstitution, représentation graphique et analyse des réseaux de pouvoir au haut Moyen Âge: Approche des pratiques sociales de l'aristocratie à partir de l'exemple d'Odon de Cluny († 942). In *Redes. Revista hispana para el análisis de redes sociales*, Vol. 21, no. 1. Barcelona: Universitat Autònoma de Barcelona

Ruffini, G. R. (2008). *Social Networks in Byzantine Egypt*. Cambridge: Cambridge University Press.

Valente, T. W. (1995). *Network Models of the Diffusion of Innovations.* Cresskill, NJ: Hampton Press.

Valente, T. W. (2010). *Social Networks and Health: Models, Methods and Applications*. Oxford: Oxford University Press

Wellman, B. and Wetherell, C. (1996). Social network analysis of historical communities: Some questions from the present for the past. *The History of the Family*, 1(1): 97–121

Wetherell, C. (1998). Historical social network analysis. *International Review of Social History*, 43:125–44