9 Using Agent-Based Modelling and Social Network Analysis to Gain Further Insights into the People of Medieval Scotland (by Cornell Jackson)

In order to get some more possible insight into the process of selecting charter witnesses in medieval Scotland, it was decided to build a model to seek to replicate the social networks based on charter witnessing during the 11th through 13th centuries in Scotland. In general, the plan was to create rules for the model to generate social networks that would be compared to an empirical network generated from the charter data in the database. The closer the match, the more probable that these rules were the ones actually used in medieval Scotland to select charter witnesses.

Agent-based modelling is a relatively new paradigm of system modelling (Monostori et al, 2006). A model is a representation of some real system (Starfield et al, 1990). According to Bonabeau (2002), an agent is a computational system that is situated in a dynamic environment and is capable of exhibiting autonomous and intelligent behaviour. Agents could interact, communicate and exchange information with each other. Sammarco et al (2014) describe the common properties of computational agents to include the following:

- Autonomy – Agents act based on both their internal state and the behaviour of others in the environment.
- Intelligence – Agents have some kind of intelligence from applying fixed rules.
- Interaction – Agents are able to interact with their environment and other agents.
- Adaptation – Agents adapt their behaviour to the changes of the environment based on their programmed intelligence.

Agents may represent people or technology, such as a workstation or machine, in the system being modelled. One key feature of agent based modelling is that in a multi-agent system, complex actions emerge from interactions among agents. So, a multi-agent system exhibits emergent behaviour that cannot be derived from individual knowledge but from the interaction and information exchange between many agents (Monostori et al, 2006).

Generally one starts simple when building an agent based model (Railsback and Grimm, 2012). It may be thought simple models may not provide much insight into real systems. However, the seminal studies by Thomas Schelling (1969, 1971), who won the Nobel Prize in Economics in 2005, was able to use agent based modelling to explain how racial segregation in the United States results from moderate preferences for same race neighbours even if there is no preference for totally segregated neighbourhoods.

Agent-Based Modelling and Social Network Analysis

In recent years, there has been more and more research combining social network analysis and agent based modelling. This is especially useful when the focus is on more fine-grained chains of events want to be modelled and macroscopic consequences of network dynamics are the focus of the investigation (Manzo and Tubaro, 2016).

Manzo and Tubaro (2016) mention several fields that are using both social network analysis and agent-based modelling. These include strategic networks (Buskins et al, 2014) and specifying network topologies (Axtell, 2001). Also, epidemiology has used both social network analysis and agent based modelling to understand the contagion effect and the roles of reciprocity and feedback loops in the spread of disease (El-Sayed et al, 2012).

Manzo and Tubaro (2016) note that there is tension between social network analysis and agent-based modelling on the emphasis placed on statistical estimation and causal inference citing Snijders and Steglich (2015). However, they feel there is much room for synergy between the two approaches that could significantly add to knowledge.

Charter Witness Selection Model Description

The purpose of this agent-based model is to simulate the process of selecting witnesses for medieval Scottish charters. The purpose of the witnesses was to testify if necessary in order to verify the charter.

In following the advice above to start simple when constructing a model, initially the building of the model focused on just one aspect. One key assumption is that the higher the status of the witness, the more effective the verification. Therefore, the key aspect that was concentrated on was status. The model assumes that the grantor of the charter would like to get the highest status witnesses that are available. The model steps through a series of witness types starting with the highest status ones. The model also assumes that the grantor would like to select the highest status person within a witness type. So, for example, the grantor would prefer the highest status bishop to be a witness if available.

Availability within the model is controlled by thresholds and a random number generator. Each witness type has a threshold of availability. The higher the status, the lower the threshold. The model generates a random number and if it is lower than the threshold this person is added to the witness list.

Below is a table that contains the witness types in status order along with the threshold value and the number of potential witnesses of each type. The potential number of witnesses are roughly based on a subset of the empirical co-witnessing network where all witnesses had at least 21 connections.

Table 9.1 Witness types and thresholds

Order#	Witness Type	Threshold%	#Potential Witnesses
1	King	5	1
2	Prince	5	1
3	Bishop	20	16
4	Chancellor	35	3
5	Archdeacon	40	16
6	Justiciar	40	6
7	Chamberlain	55	8
8	All others	70	100

Finally, the number of witnesses needed for each of the one thousand charters used was randomised.

Methodology

In general, the methodology used in this research generates networks from the model and compares these to an empirical network. A statistical technique is used to compare the networks and if the comparison is close enough to be considered statistically significant then there is a high degree of probability that the rules in the model are the same used by grantors in medieval Scotland.

The empirical network being used as a baseline is the co-witnessing network of all those witnesses that have at least 21 connections to other witnesses. It was felt that this network was easier for initial model testing rather than the full network of 9078 witnesses. Our subset of the full empirical network has 95 witnesses.

The statistical technique used to compare the two networks in social network analysis is the quadratic assignment procedure (QAP) correlation. We are using UCINET (Borgatti et al, 2002) to do this. This technique uses a traditional Pearson's correlation to see how the numbers in the two data matrices that represent the two networks move together or apart. There then is a test to see how much of the matching is due to randomisation. This technique requires that the two networks have the same number of witnesses. Therefore, only model generated networks containing 95 witnesses were compared to the empirical network.

Findings

The percentage of random correlations in the QAP correlation is called a p value. The smaller the p value, the better the match between the two networks. In statistics, traditionally only results that are considered statistically significant are deemed conclusive. The norm for statistical significance in the social sciences is a p value of 0.05 or lower. This is equivalent in this case of only 5% of the match between two networks is due to randomisation. However, other fields of research set the threshold for statistical significance higher with a p value of 0.1 or 10%. Based on advice from experts on statistical techniques, we set our threshold for statistical significance at 10%.

The model generated 23 networks that had 95 witnesses. These were compared to the empirical co-witnessing network of witnesses that had at least 21 connections with other witnesses. The p values ranged from 0.175 to 0.088. While the lower numbers meet the threshold for statistical significance, the average p value for all 23 networks was 0.12.

Conclusion and Next Steps

While this result is not statistically significant, it was surprising to see how close to statistical significance the model got by using only rules on status. This may not be a big surprise that status plays an important role in charter witness selection but it does show the potential for agent based modelling in understanding the past.

The next refinement to the model was to consider time. The charters were produced over a two hundred year period and witnesses lived and died within that time frame. The model will now give each charter an issue date and only witnesses alive at the time would be considered. All the previous rules on status still applied.

Unfortunately, the average p value increased to 0.33. This indicates the first draft of the new model needed more work but the project ended before this could be tackled. The hope is to be able to do this in the future.

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