

# Visual Analytics of an Eighteenth-Century Business Network

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## Abstract

This paper presents the results of an interdisciplinary experiment. We apply visual analytics to study the business networks of a merchant based in Jamaica with extensive commercial links with Liverpool in the late eighteenth century. Social network analysis techniques, and in particular graph theory, have been applied to the quantitative data to understand the dynamics of the networks identified by the merchant's accounts ledger. The network, once constructed and visualised, provides tangible evidence of our case study's level of involvement in the slave trade and slave trade networks between 1779 and 1793. However, social network analysis using graph theory allows us to model the intangible evidence; that is, an examination of the relationships, and therefore dynamics, of this business network. Importantly, this paper identifies the predictive qualities of this research methodology when analysing an historical case study.

## Introduction<sup>1</sup>

*A social network consists of a finite set or sets of actors and the relation or relations defined upon them. The presence of relational information is a critical and defining feature of a social network.*<sup>2</sup>

The social sciences have long been interested in the interaction and dynamics of social networks, of which business networks are a subset. Interdisciplinary studies use visual analytics and graph theory in order to model and analyse relationships between network entities (actors). For example, an analysis of centrality within social networks provides researchers with an understanding of the dynamics of those groups under investigation. An analysis of such group dynamics is of interest to the historian by providing a greater understanding of how business networks within the eighteenth century operated.

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<sup>1</sup> The authors would like to thank Mark Casson, Graeme Milne and Nick White for their comments on drafts of this paper. All errors are of course, ours alone.

<sup>2</sup> S. Wasserman & K. Faust, *Social Network Analysis: Methods and Applications*, Cambridge University Press, 1994, p. 20. The authors provide a detailed and comprehensive overview of social network analysis.

As noted in the quote above, social networks comprise a set of actors that are in some way connected. These connections could come in many forms; from familial ties to co-investors to membership of the same cultural or social institution. However, whilst actors may be in some way connected, it does not mean that their relationships through this commonality are in any way equal. In addition, these relationships may be quite complex. Therefore, in social network analysis it is the interplay of relationships that define the social network rather than just their membership of an abstract dataset or institution.

The purpose of this paper is to disseminate the results of an interdisciplinary experiment in the application of social network analysis methodologies to an historical case study. The experiment aims to test the hypothesis that historians could better understand the dynamics within social networks identified by primary sources by applying techniques used in the analysis of contemporary networks. It aims to utilise visual analytic tools to demonstrate their viability in the analysis of historical data. Once the network is visualised, graph theory analysis has been applied to the networks to determine the dynamics of the individual actors identified.

This paper uses the case study of an eighteenth-century slave trade network. The slave trade was a very important part of Britain's first empire and Liverpool's trade in the late eighteenth century and facilitates the analysis of a network which is both local to Liverpool and trans-national between Britain and its most important slave entrepôt, Kingston, Jamaica.<sup>3</sup> The network itself, once constructed, provides tangible evidence of our case study's level of involvement in the slave trade and slave trade networks between 1779 and 1793. However, social network analysis using graph theory allows us to model the intangible evidence; that is, an examination of the relationships, and therefore dynamics, of this slave trade network. This provides a greater depth of analysis and understanding of the organisation of merchants involved in the slave trade at this time. As this case study only spans a period of fifteen years, we have not analysed change over time.<sup>4</sup>

This paper demonstrates that the approach used is of benefit to the historian in understanding the dynamics of networks identified by their datasets in three ways. First, the tools used in this analysis provide the means by which large historical networks may be visualised. Second, it demonstrates that measuring intangible evidence, such as centrality relationships amongst business networks,

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<sup>3</sup> For a recent update on Liverpool's involvement in the slave trade see David Richardson, Suzanne Schwarz and Anthony Tibbles (eds), *Liverpool and Transatlantic Slavery* (Liverpool: Liverpool University Press, 2007).

<sup>4</sup> This is something we will be dealing with in future work however.

provides us with an understanding of their dynamics. These quantitative results are supported by the literature surrounding the case study. Third, this approach demonstrates that this methodology can be predictive; it highlights key actors within a network that would not be identified using traditional historical analysis.

This paper is organised as follows. First, we describe some of the terms and methodology in network analysis used within this study. Second, we introduce the background to the case study. In section three, we examine the case study through quantitative analysis of the slave trade network. In section four, we highlight the issues with using this methodology identified by this study. Finally, we make our conclusions.

## Network Analysis

A network may be defined as an interconnected group or system. Therefore, we may talk in terms of a computer network, a credit network or a social network. There is a tendency to assume that just because entities are linked that they must form a cohesive social network. However, this is not necessarily the case and the relationships between network members must be explored to fully understand their cohesiveness. Relationships such as power and centrality are of interest when analysing social networks as these identify the dynamics that enable (or disable) the network. This can be achieved through the application of mathematical models such as graph theory.

In order to explain the social network visualisations presented in the next section, it is worthwhile providing a brief overview of graph theory terminology relevant to the analysis.<sup>5</sup> A graph comprises a set of *points* (or *vertices*) which are connected to other points through *edges* or *arcs*. Two points that are directly connected by an edge are said to be *adjacent*. The number of other points to which any given point is adjacent is called the *degree* of that point. Given two points in a given graph,  $p_i$  and  $p_j$ , a *path* is a sequence of one or more edges beginning at  $p_i$  and passing through intermediate points to end at  $p_j$ . The *distance* between points is calculated by the number of edges in a path. The shortest paths linking pairs of points are called *geodesics*. Points falling on the geodesics between a given pair of points stand *between* these end points. Figure 1 provides an example of a small graph.

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<sup>5</sup> It is not the intention of this paper to present a detailed overview to the field of graph theory. However, it is necessary to explain some of the terminology used. For detailed explanations, see Wasserman & Faust (1994) who provide an extensive study of various measures available. See also Linton C. Freeman, “Centrality in Social Networks Conceptual Clarification”, *Social Networks*, 1: (1978/79) 215-239.

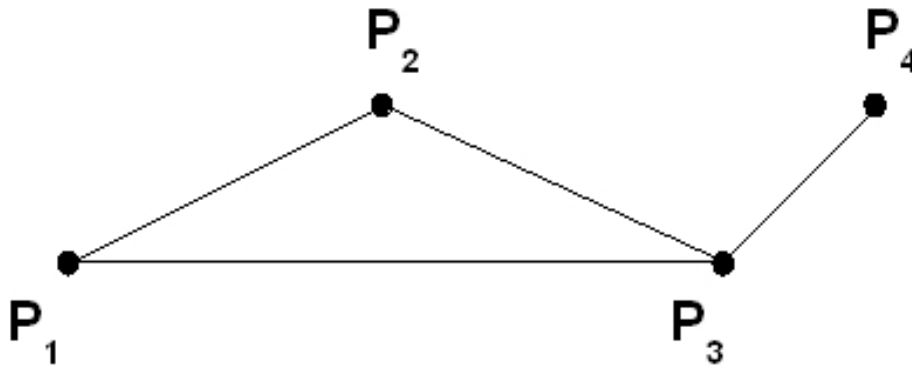


Figure 1. A graph with four points and four edges.

In the illustration above, points in the graph above are numbered P1 to P4. P1 is adjacent to P2 and P3, but is not adjacent to P4. Points P1 and P2 have degrees of two and P3 has a degree of three. However, due to P4's position on the periphery of the graph, it has a degree of one. There are two paths from P1 to P4; the first through two other points, P2 and P3, the second directly via P3. The distance is equal to the number of edges in a path. Thus, using the first path P1 has a distance of three to P4 and via the second path, a distance of two. As the second path is shorter than the first, this is the geodesic. P3 is between P1 and P4.

Four measures of centrality are identified as useful in providing an analysis of the network dynamics within our case study. It is not the focus of this analysis to suggest which is the most “correct” measure of a graph. However, a combination of various measures provides an overview of the dynamics of the network from different viewpoints and an appreciation of the actors’ roles therein. The measures of the network are:

*Out-degree centrality.*<sup>6</sup> This measure analyses the expansiveness, or number of actors that a particular actor possesses or accesses. Out-degree centrality in this study uses the Actor Out-Degree Centralization (AODC) measure. An AODC value of zero indicates that all actors within the group are equal, as would occur in a regular lattice. An AODC value of one indicates that a single actor dominates all other actors within the network.

*In-degree centrality.* This network measure is used in social network analysis to identify the receptivity or ‘popularity’ of a given actor. That is, how many people want to access him or her as a

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<sup>6</sup> All measures used in this section are those detailed by Wasserman & Faust, 1994. These measures are built into the application, *SocNetV*, available from D.B. Kalamaras (2009), <http://socnetv.sourceforge.net>, accessed February 2009, which has been used to provide the results and visualisations in this paper.

network entity. This measure identifies those actors that are seen as key facilitators for other actors within the network. An Actor In-Degree Centralisation (AIDC) value of zero again indicates that all actors within the group are equal, as would occur in a regular lattice. An AIDC value of one indicates that all actors are linked to a single actor.

*Betweenness centrality.* This network measure identifies potential points of control within the trade network. Betweenness recognises that communication flow within a given network often does not rely on adjacent actors but along geodesics. Due to being focal points of communications within the group and subgroups, certain actors facilitate contact and communications within the network and can therefore be seen as major channels of influence. These actors form chokepoints for information sharing within the network. An Actor Betweenness Centralisation (ABC) value falls between zero, indicating that all actors have exactly the same betweenness within the network, and one, when a single actor falls on all geodesics between all the other (i.e.  $n-1$ ) actors (indicative of a star network). To calculate the Actor Betweenness Centralisation (ABC) value  $ABC(u)$  is calculated using the sum of  $\Delta(s, t, u)$  where the sum of  $(s, t, u)$  is the number of geodesics from  $s$  to  $t$  through  $u$ . Thus,  $\Delta(s, t, u)$  is the ratio of all geodesics between  $s$  and  $t$  which run through  $u$  and  $ABC(u)$  reflecting how often the actor  $u$  lies on the geodesics between the other actors of the network.

*Closeness centrality.* This measure analyses how close an actor is to other actors within the network. If an actor is close to other actors, it can quickly interact with all the other members of the network. In the communication of information, as these actors are close to all the other actors, they do not rely on others to convey information on their behalf. Therefore, this measure can be used to assess an actor's independence in the network as they are able to avoid the potential for control by other actors. The Actor Closeness Centrality (ACC) calculates the invert sum of the distances of an actor from all other actors within the network. An ACC value falls between zero, as would be indicated by a circular network visualisation, and one, where an actor has geodesics of length 1 to all other actors of the network and all the other actors have geodesics of length 2 to the other actors (i.e.  $n-2$ ) of the network, which would be indicated by a star network.

The network itself, once constructed, provides tangible evidence of our case study's level of involvement in his slave trade network between 1779 and 1793. However, social network analysis using these four measures allows us to model the intangible evidence; an examination of the relationships, and therefore dynamics, of this slave trade network. This provides a greater depth of analysis and understanding of slave trade networks at this time.

## Background to the Case Study

Samuel Rainford was a merchant based in Kingston Jamaica between 1774 and 1798. He emigrated from Liverpool and maintained business and personal contacts there throughout his time in Jamaica. He worked as an independent merchant, at his own risk and profit, and also as a factor, or agent, for merchants back in Liverpool. This meant that whilst he ran a business at his own risk, hopefully for higher profit, he also worked on commission for others.<sup>7</sup> This type of dual-role long-distance principal-agent relationship was normal during this period.<sup>8</sup> Sometimes family members were used to perform this agency function in the British West Indies and elsewhere, but often a suitably reliable person known to at least some of the principal actors in the network was used, as was the case here.<sup>9</sup> This was because family members were not always reliable.<sup>10</sup> Samuel Rainford had made a good choice in going to Jamaica. Whilst Liverpool was the leading British slave trade port at this time, Jamaica was the leading entrepôt for slaves in the West Indies. At the height of his business during this period, Rainford's merchant house dealt with a significant percentage of the slave sales in Kingston from Liverpool. Table 1 highlights his proportion of the trade in slaves to Jamaica from Liverpool. This demonstrates that he was a significant merchant in Kingston at this time.

Year	Liverpool to Jamaica Slave Trade	Liverpool to Rainford Slave Trade	% of Liverpool-Jamaica Slave Trade
1779	4,691	477	10.17
1782	6,584	936	14.22
1785	11,334	2735	24.13
1788	5,864	488	8.32
1791	15,375	1316	8.55

<sup>7</sup> Rainford Family Papers, Papers of Edward Chaffers, 920 CHA/1 (hereafter PEC), Liverpool Record Office.

<sup>8</sup> For good examples of these long-distance relationships to the West Indies see Douglas J. Hamilton, *Scotland, the Caribbean and the Atlantic World, 1750-1820* (Manchester: Manchester University Press, 2005) and S. D. Smith, *Slavery, Family and Gentry Capitalism in the British Atlantic: The World of the Lascelles, 1648-1834* (Cambridge: Cambridge University Press, 2006)

<sup>9</sup> It has not been possible to discern the exact relationship between Samuel Rainford and the other actors here except for his brother.

<sup>10</sup> For a good example of this see Kenneth Morgan (ed.), *The Bright-Meyler Papers: A Bristol-West India Connection, 1732-1837* (Oxford: Oxford University Press for The British Academy, 2007).

Table 1. Rainford's Percentage of Liverpool's Slave Trade to Jamaica 1779-1793.<sup>11</sup>

Figure 2 highlights Rainford's share of the Liverpool-Jamaica slave trade between 1779 and 1793. Rainford was used as the agent in Jamaica to sell approximately 13,000 slaves via thirty-seven voyages to over 350 customers.

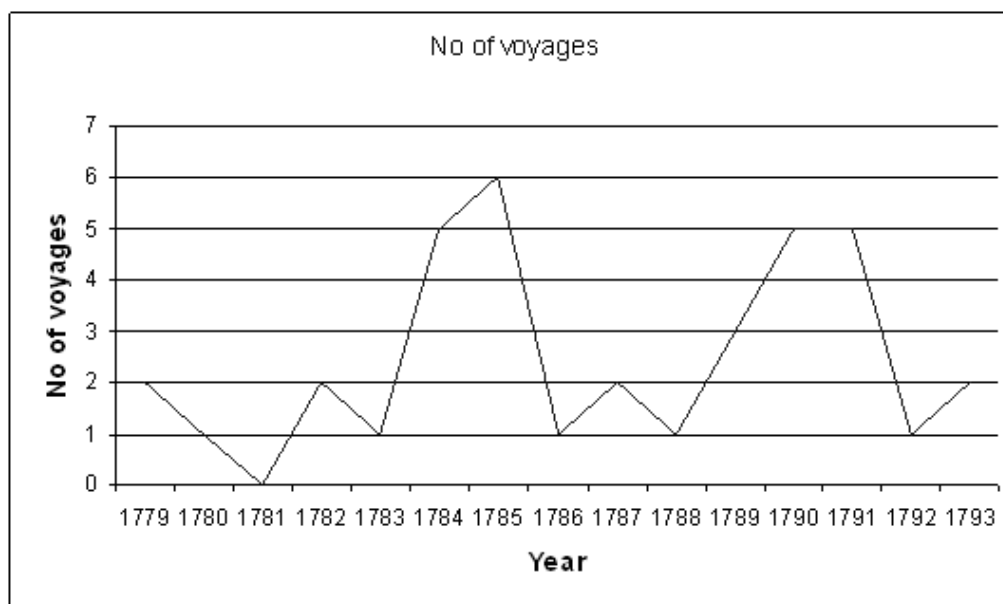


Figure 2. Number of voyages in which Rainford acted as agent for selling slaves in Jamaica.<sup>12</sup>

Rainford also exported sugar and other goods from Kingston to Liverpool and imported various manufactures in return for the almost monocultural economy. This mixing of various trades was a risk-reduction strategy employed by most merchants in Jamaica.<sup>13</sup> They were also vital in providing goods and credit facilities to the planters in the island. His records provide both qualitative and quantitative data. They form part of a wider collection and provide links with many other networks. Rainford is therefore a representative case study because the trades in which he was involved, the slave trade, sugar trade and importation of merchandise and groceries into Kingston, Jamaica, link him with some of the major ports and players of British-Atlantic trade at this time. This mix of quantitative and qualitative data is ideal for the purposes of this paper. The quantitative data

<sup>11</sup> Rainford, Blundell and Rainford Pocket Ledger MG-54, No 74, Library and Archives Canada; *The Transatlantic Slave Trade Database* at <http://www.slavevoyages.org/tast/index.faces>.

<sup>12</sup> Rainford, Blundell and Rainford Pocket Ledger MG-54, No 74, Library and Archives Canada.

<sup>13</sup> Sheryllynne Haggerty, "Liverpool, the slave trade and the British-Atlantic empire, c. 1750-75" in Sheryllynne Haggerty, Anthony Webster and Nicholas White (eds.), *The Empire in One City? Liverpool's Inconvenient Imperial Past* (Manchester University Press, 2008), pp. 17-34.

provided by a ledger of the firm provide the basis for the experimental part of this paper. This is correlated with a widely available quantitative data set which has been used to furnish further details on the slave trade networks of the voyages in which Rainford was involved.<sup>14</sup> We have also used secondary literature to provide context for the analysis. In the discussion of methodological issues in section four we have used qualitative data related to the case study to comment on the reliability and completeness of the results.<sup>15</sup>

The principal quantitative data used within this case study has raised an interesting issue within the methodology regarding the reliance on source-centric data. This issue is discussed in greater detail in section four. The source-centric data problem relates to the reliance on a single source in the analysis of social networks. The source of the data will inevitably be placed in the centre of the network and the analyst will invariably analyse the network from this point of view. However, this does not provide a true picture of the network as it can over-inflate the power or centrality of that actor in relation to the wider networks. Rather than analyse the networks *centred* on Rainford, it is more beneficial to identify and analyse the networks to which he had *access*. Therefore, in section three, we present results in which we have removed Rainford as the central protagonist.

The network visualisations within this paper represent both *direct* and *indirect* business associations identified by the ledger and correlated with the *Transatlantic Slave Trade Database*. A direct association is where Samuel Rainford will have been in direct contact with the other actor, either in person or through written communications. For example, Rainford would have met the ships' captains on arrival in Jamaica during the process of selling slaves. The ships' captains will have been under written instructions from the ship's husband (the merchant who managed the voyage) in the slave adventure to meet with Rainford on arrival. Indirect associations within this network were the investors in the slave voyage who, whilst will have had direct association with the principal investor, were unlikely to have had direct contact (and therefore influence) with Rainford. However, through their relationship with the principal investor, they will have a relational tie with Samuel Rainford.

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<sup>14</sup> The quantitative data is derived from Rainford, Blundell and Rainford Pocket Ledger MG-54-No 74, Library and Archives Canada, and *The Transatlantic Slave Trade Database* at <http://www.slavevoyages.org/tast/index.faces>.

<sup>15</sup> The qualitative data here is all taken from Rainford Family Papers, Edward Chaffers Papers, 920 CHA/1, Liverpool Record Office.

## Quantitative analysis of Rainford's slave trade network

As mentioned above, the methodology used in this paper allows us to analyse both tangible evidence (Rainford's involvement in a slave trade network between 1779 and 1793) and intangible evidence (an examination of the relationships within that network). Rainford's complete slave trade network is illustrated in figure 3 showing the Liverpool slave trade networks in the top right and the customers in Jamaica in the bottom left of the network.

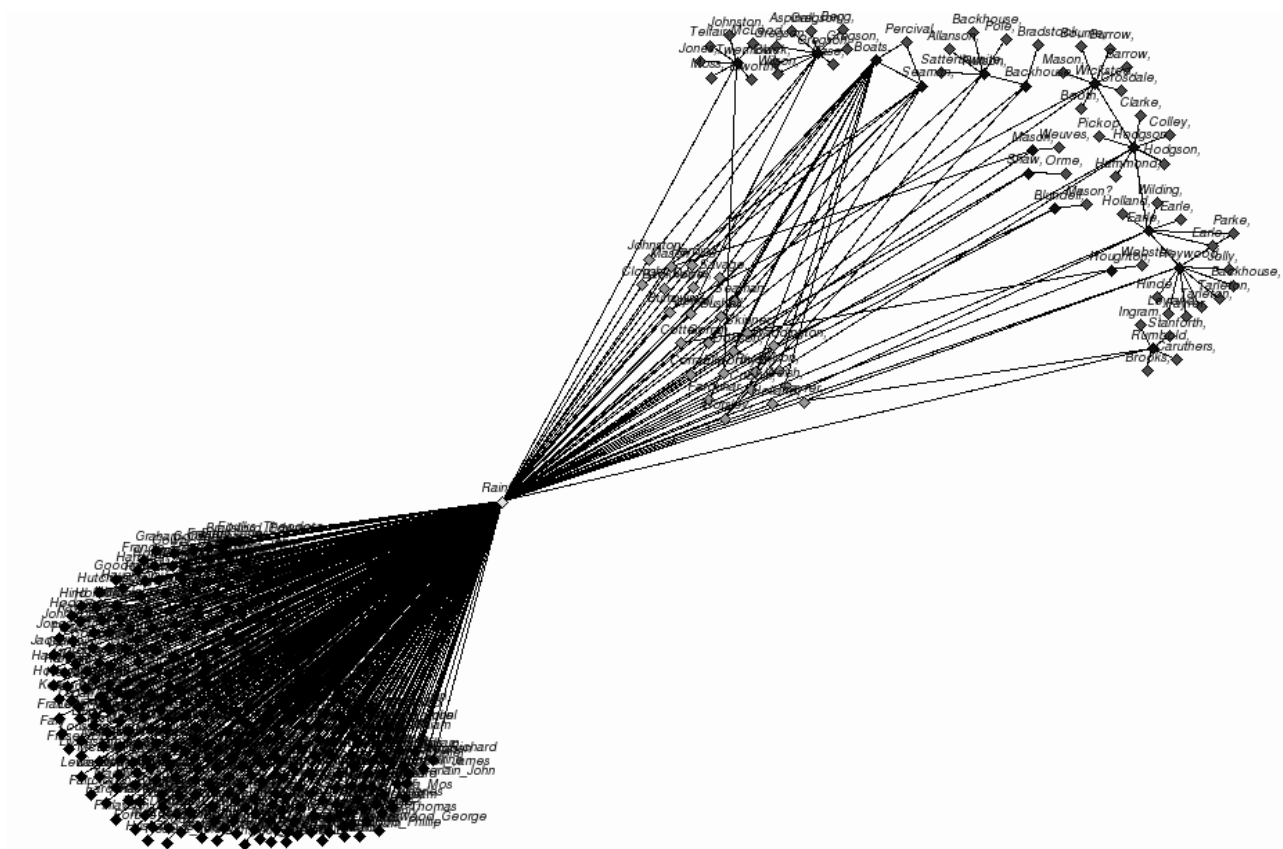


Figure 3. Rainford's complete slave trade network.<sup>16</sup>

For the purpose of this paper however, we are particularly interested in the organisation and dynamics of the trade. Therefore, we concentrate on the ships' captains, ships' husbands and the other investors in the voyages. Having removed Rainford from the network in order to avoid source centrality (see above), the slave trade business subnets in Liverpool that Rainford accessed are

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<sup>16</sup> All the figures in this section and the next are visualised through data in Rainford, Blundell and Rainford Pocket Ledger MG-54, No 74, Library and Archives Canada and *The Transatlantic Slave Trade Database* at <http://www.slavevoyages.org/tast/index.faces>.



The slave trade was considered to be an extremely risky undertaking, more so than other Atlantic voyages. This was due to the extremely high level of organisation and capitalisation required, the long time it took to receive payment for the slaves sold to planters, possible rebellions by the slaves on the ship and high mortality amongst the white crew and human cargo during the so-called ‘middle passage’.<sup>19</sup> It was usual therefore to spread the risk of a voyage by having several investors, usually somewhere between three and eight. In Figure 4, it is obvious that most of the network is involved in multi-investor voyages, whilst the Blundell, Shaw, Houghton and Mason subnets are in a minority as small investor groups. It was not only to spread risk that merchants came together. Access to information, skills and indeed further networks were an important factor too.<sup>20</sup> Often a slave merchant had come through the ranks, and had been a captain in the slave trade for some time, building up useful social capital.<sup>21</sup> Having invested in a voyage, or several voyages, trust could be built up through relational cohesion between the investor in Liverpool and the slave factor in the West Indies.<sup>22</sup> Therefore, we see that Thomas Hodgson was an investor in voyages organised by Thomas Earle in 1782 and Richard Wicksted in 1784. In 1793 he finally arranged a voyage himself in which he sent slaves to be sold by Rainford. The importance of spreading risk and lowering information and transaction costs meant that most people worked on expanding their networks, especially with people they felt they could trust based on past experience.

The fact that most people needed access to capital, skills and information means that it is important to know how many people, or indeed networks, to which Rainford had access. Figure 5 illustrates the out-degree centrality within the network. The actor with the most ties in the network is William Boats, followed by John Gregson, Thomas Earle and then Benjamin Heywood. However, the visualisation identifies a key difference in the business relationships that these actors utilised and ultimately their business operations.

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<sup>19</sup> Stephen D. Behrendt, “Markets, Transaction Cycles and Profits: Merchant Decision Making in the British Slave Trade”, *William and Mary Quarterly*, 3<sup>rd</sup> Ser., 58:1 (2001) 171-204; David Richardson, “Profits in the Liverpool Slave Trade: the Accounts of William Davenport, 1757-1784”, in Roger Anstey and P. E. H. Hair (eds), *Liverpool, the African Slave Trade, and Abolition* (1989 ed) (Liverpool: Historic Society of Lancashire and Cheshire, Occasional Series, Vol 2, 1976), 60-90; Richard H. Steckel and Richard A. Jensen, “New Evidence on the Causes of Slave and Crew Mortality in the Atlantic Slave Trade”, *William and Mary Quarterly*, 46, 1 (1986), 57-77.

<sup>20</sup> For a good description of the importance of partnerships see David Hancock, *Citizens of the World: London Merchants and the Integration of the British Atlantic Community, 1735-1795* (Cambridge: Cambridge University Press (1995), 104-114.

<sup>21</sup> Stephen D. Behrendt, “Human Capital in the British Slave Trade” in Richardson et al, *Liverpool and Transatlantic Slavery*, 66-97.

<sup>22</sup> Lawler, Edward J., & Yeongkoo Yoon, “Commitment in Exchange Relations: Test of a Theory of Relational Cohesion”, *American Sociological Review*, 61:1 (1996), 89-108.

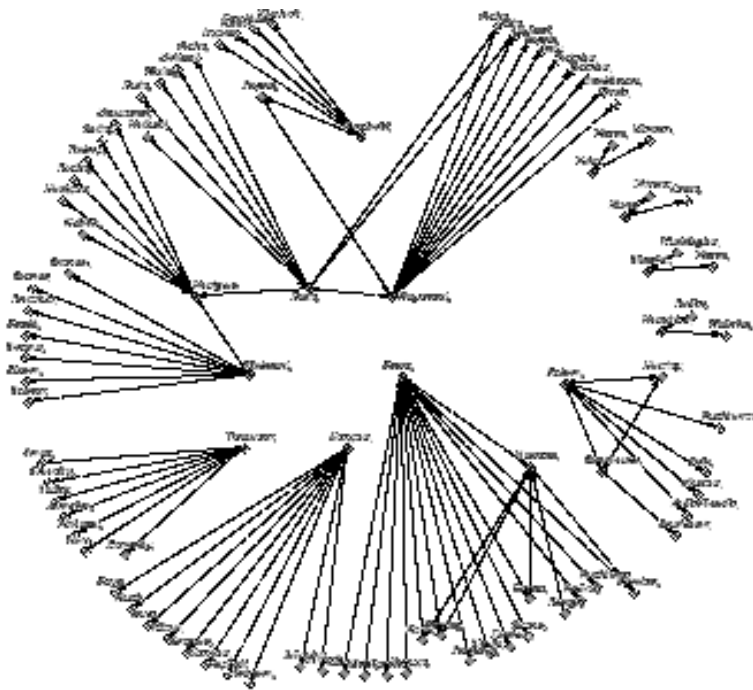


Figure 5. Out-degree centrality of investment networks associated with Rainford.

William Boats worked either independently, or in partnership with only two other investors, Thomas Seaman and James Percival between 1782 and 1793. Mostly, he was the lead investor. During the period 1788–1790, Seaman acted as the principal investor before Boats again took on this role from 1790–1793. Boats did not therefore fit the general pattern of investors. By taking in fewer investors he was maximising his risks, but potentially also his profits. Boats' extensive ties were mostly amongst the ships' captains. This is a reflection of the fact that he used a group of fewer investors, and also that he was involved in many voyages that involved Rainford using many different captains, because he invested in several voyages per year. Another reason for the importance of Boats within this network is that from 1787 the Boats, Seaman, Percival investment group were (with one exception), the only merchants to send slaves care of Rainford in Kingston.

The other actors with the highest out degree centrality were Benjamin Heywood, John Gregson and Thomas Earle. John Gregson organised one voyage independently and the other with an extensive number of investors, including three members of his family. Thomas Earle and Benjamin Heywood both used an extensive number of other investors in the voyages that they organised. In the case of Earle and Heywood, this involved each other as well as Thomas Parke and William Earle junior in over-lapping subnets. Therefore, these traders appear to have wanted to share the risk of the slave

adventure amongst others within the Liverpool business community. It may also be that they had access to better networks than William Boats, although it is worth noting that all of them, including Boats, were involved in the same Liverpool cultural institutions in the late eighteenth century.<sup>23</sup> There could also be other factors involved here such as reputation, personality and familial ties. Certainly the Earles and the Heywoods were major families within the Liverpool business community. Boats was notoriously an orphan – allegedly named after the vessel in which he was found.<sup>24</sup>

In-degree centrality identifies the key facilitators within the network, those to whom that other actors most want access. In this case, those actors with the necessary trust, reputation and ability to organise a successful slave trade voyage. Figure 6 illustrates the in-degree centrality within the trade networks.

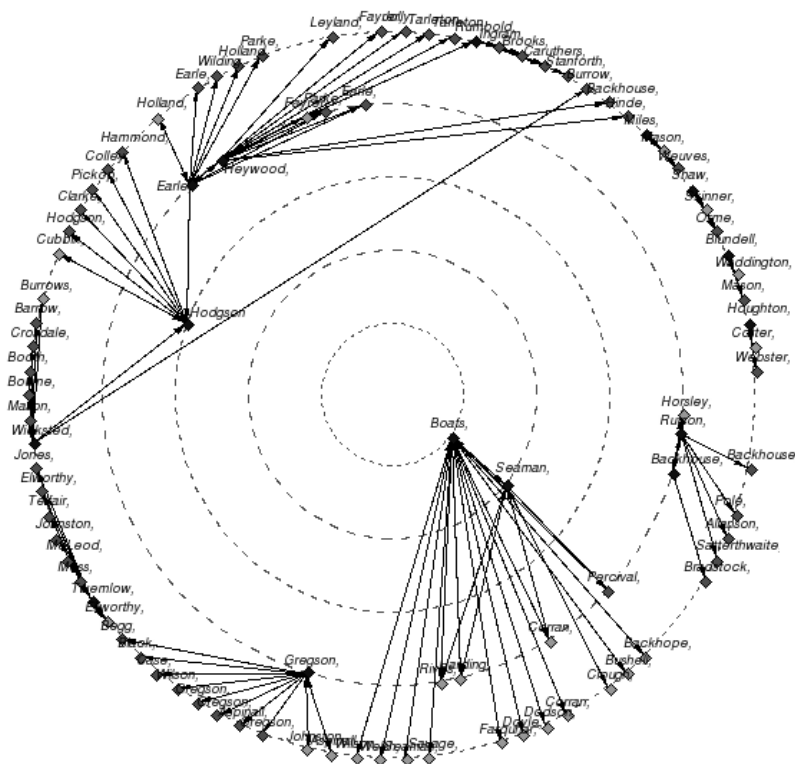


Figure 6. In-degree centrality of investment networks associated with Rainford.

<sup>23</sup> See for example Records Relating to Ye Ugly Face Club 1743-1757 (367 UGL, LivRO), Records of The Mock Corporation of Sephton 1753-1829 (367 SEF, LivRO), the Liverpool Library, Lyceum (027LYC/1 and /2, LivRO).

<sup>24</sup> Arline Wilson, *William Roscoe: Commerce and Culture* (Liverpool: Liverpool University Press, 2008), p.13. Whilst Boats did not have extensive family ties himself, by 1775 he sat on the Liverpool Council with many that did, such as William Gregson and Ralph Earle, see Richard Brooke, *Liverpool as it was 1775-1800* (1853) (Bristol: Liverpool Libraries and Information Services, 2003) p. 195.

Boats is again identified as the most central to Rainford's network and this is due to his connections with ships' captains and the many voyages for which he uses Rainford as a factor in the West Indies. In addition, Seaman, Boats' partner, is also identified as central, as he is part of the same small investor group. Note that the third actor in the small subnet, Percival, is not ranked highly. This is because he is only an investor, and never a ship's husband of a voyage, and therefore has no direct contact with Rainford or the ships' captains conducting the voyages. The third most central actor is Thomas Hodgson. Due to his earlier investments with Wicksted and Earle, Hodgson was no doubt seen as someone with the ability to organise a successful voyage in his own right despite the fact that this voyage was over ten years later. Of course, he could have easily invested in the slave trade in other networks, building up trust and reputation independently of the Rainford networks.<sup>25</sup> In addition, a number of ships' captains, such as Thomas Rives, William Horsley, and Joseph Fayrer, were as equally important as investors. This reflects the fact that they conducted more than one voyage and would have current knowledge of the trade. Furthermore, they would have had direct contact with Rainford whilst in Jamaica and so would have built up their relationship with him whilst in the British West Indies. Ships' captains were therefore important not only in terms of their skills and knowledge of the trade itself, but were often the only people to have regular contact with the factor in the West Indies.

Betweenness centrality identifies potential points of control within the trade network due to an actors' central role over information or investment flow. These actors may not only have control over the investors and ships' captains that they work with, but the decision of whether to use Rainford as their agent in Kingston. They would therefore be key actors for Rainford to know and trade with during this period. Figure 7 illustrates betweenness centrality within the trade groups.

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<sup>25</sup> Indeed, Thomas Hodgson was involved in a total of 149 slave trade voyages from Liverpool. *Transatlantic Slave Trade Database*.

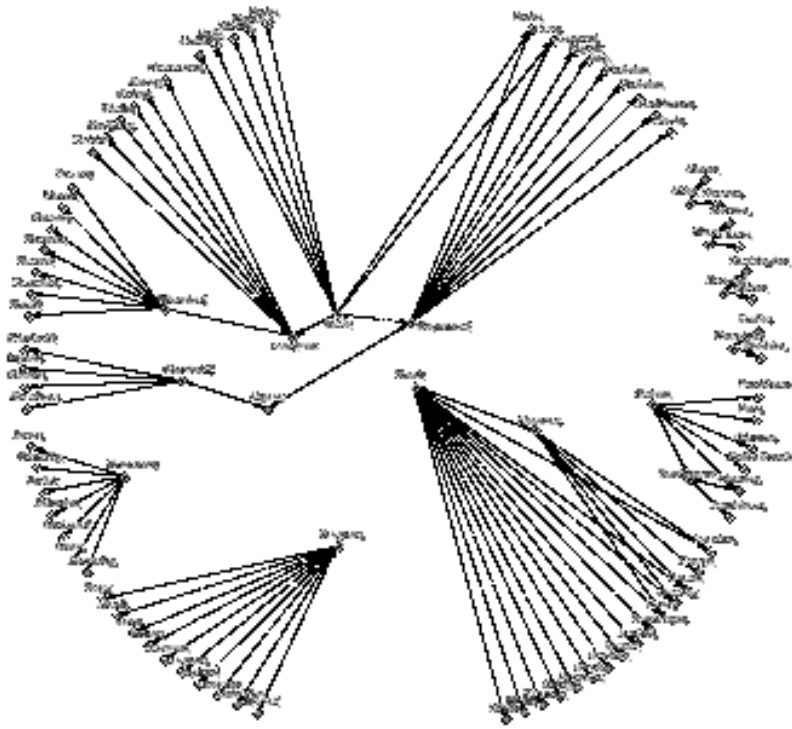


Figure 7. Betweenness centrality of investment networks associated with Rainford.

Boats is again identified as a key actor with much control within the network. Benjamin Heywood and Thomas Earle are also identified as having a greater influence within the network due to their links with one another and their respective networks of investors. Of interest is ship's captain Joseph Fayrer, who is also identified as having relatively good betweenness centrality within the network, being far more important than some principal investors. Fayrer is incredibly well-connected in the network because he works for Thomas Rumbold, one of the early principal investors, but more importantly, because of his links to the Heywood subnet. His importance in this network may also be reinforced by the fact that he is one of the ships' captains that used their knowledge and profits as a captain to become an investor themselves, in this case in the Heywood subnet.

Finally, Figure 8 visualises the closeness-centrality. This measure analyses how close an actor is to the other actors within the network. If they are closer to information, they can act more efficiently and are also more independent. This means that they can also avoid the control of other actors, whereas those on the periphery must relay messages or investment. In this case study, these actors will be able to control the terms of any business conducted.



Figure 8. Closeness centrality of investment networks associated with Rainford.

As illustrated in Figure 8, the key actors in this measure were those that operated in very small networks; Richard Miles, John Shaw, Henry Blundell and John Houghton. These actors have more independence as they were able to directly control their investments within the slave trade. At the next level of closeness centrality are the ships' captains that worked for these investors; John Mason, Jno Skinner, Jas Waddington and John Cotter. Their centrality in this measure demonstrates their importance in the successful completion of a slave trade investment, especially within a small network.

The key actor in the larger networks identified by the Rainford ledger is Thomas Hodgson. He is well connected with his own and other sub-networks, but he has the ability to operate as an independent actor without being influenced by other important controlling actors identified above such as Thomas Earle and Benjamin Heywood. Other central actors, such as Thomas Twemlow and John Gregson operated with their own investment networks and it would be their own decision to use Rainford as an agent. John Gregson worked with Rainford on more than one occasion during this period. William Rutson worked within a subnet with John Backhouse, but using this analysis, it could be suggested that he was a more independent actor than Backhouse.

To summarise the quantitative analysis provided in this section, Table 2 provides an overview of the main actors by centrality measure. Table 2 demonstrates that by using different quantitative measures of the network, the historian is provided with different viewpoints of the relationships between actors.

<b>Centrality Position</b>	<b>Actor - AODC</b>	<b>Actor - AIDC</b>	<b>Actor - ABC</b>	<b>Actor - ACC</b>
1	William Boats	William Boats	William Boats	Richard Miles, John Shaw, Henry Blundell, John Houghton
2	Benjamin Heywood	Thomas Seaman	Benjamin Heywood	John Mason, Jno Skinner, Jas Waddington, John Cotter
3	John Gregson, Thomas Earle	Thomas Hodgson	Thomas Earle	Thomas Hodgson

Table 2. Overview of main actors by measure.

The quantitative analysis has provided results which identify the dynamics of the network that are not available from an analysis of the tangible evidence alone. First, it has provided a visualisation and measurement of the Rainford slave trade network. This provides historians with a graphical representation of business records. Second, it identifies those merchant groups that were able to spread their risk at the expense of profits compared to those in a more risky position by being in smaller networks. It is possible that this second group were able to mitigate their risk by the choice of ships' captains who had current knowledge of the trade. Third, it identifies those actors that had greater levels of control over investments and information in the network at this time, both in terms of access to investment and choice of agent. Finally, through their access to investors or contacts, the key facilitators of slave trade voyages in Liverpool may be identified.

## Methodological Issues

The analysis and visualisations discussed in the previous section provide the historian with a valuable tool in quantifying the unquantifiable; measurement of the dynamics of historical social networks based on even limited datasets. However, this experiment, whilst providing valuable quantitative analysis supported by the secondary literature, has identified a number of methodological issues. These issues, both positive and negative, should be taken into account in future case studies by historians using this approach. The key issues with the methodology are as follows:

*Failure to identify key players in quantitative source analysis:* The main problem with using finite material such as the quantitative data analysed here is that it does not provide the whole story. The surrounding qualitative data (held in a separate archive) demonstrates that four key actors are absent in this analysis. The first is Rainford's friend and attorney in Liverpool; Edward Chaffers. Chaffers was Rainford's main contact in Liverpool throughout the period and was the reason Rainford first went to Jamaica. Importantly, he also acted as a mentor to Rainford's errant family in Liverpool.<sup>26</sup> Also absent are Robert Rainford, Samuel Rainford's brother and business partner in Kingston, and Jonathon Blundell junior, a second business partner in Kingston.<sup>27</sup> Most importantly, Jonathon Blundell senior is completely absent. The qualitative sources demonstrate that it was Blundell senior (the father of Jonathon Blundell junior) who first introduced Rainford into the slave trade network through his extensive contacts in Liverpool, especially Thomas Rumbold.<sup>28</sup> The reason that Blundell senior is absent here is that he withdrew from the slave trade during the American War of Independence.<sup>29</sup> He therefore does not show up in the quantitative sources even though he obviously was extremely important to Rainford's business through the extension of credit and recommendations. The qualitative data also demonstrates that Rainford and his brother had disagreements with Jonathon Blundell senior's firm, which eventually led to arbitration and the exit of Jonathon Blundell junior from the Kingston business.<sup>30</sup> There is also a link between the reliance on the Boats, Seaman, Percival investment group from 1788 onwards and the increasing problems between Rainford and Blundell senior, although the causality is not clear. What is obvious is that

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<sup>26</sup> See the letters between Samuel Rainford and Edward Chaffers at 920/1/10, 11 & 12, PEC.

<sup>27</sup> Memorandum of Agreement (copy), 13<sup>th</sup> Jul 1789, 920 CHA 1/36 PEC.

<sup>28</sup> Jonathon Blundell Senr to Samuel Rainford, 23 Nov 1778, 920 CHA 1/1 and *passim*, PEC.

<sup>29</sup> *The Transatlantic Slave Trade Database* at <http://www.slavevoyages.org/tast/index.faces>.

<sup>30</sup> See Jonathon Blundell Senr to Rainford, Blundell & Rainford, 20 Feb 1784; The Accounts of Rainford, Blundell and Rainford with Jonathon Blundell Senior, 6 Nov 1779 to 6 Nov 1791, 920 CHA/1/21, PEC; Berry & Parke to Edward Chaffers, 22 Mar 1804, 920 CHA 1/34, PEC.

once Blundell junior returned to Liverpool from Kingston in 1789, he had far better access to information, credit and importantly, gossip, than did the Rainford brothers in Kingston.

*Source-centric data:* The main source of the data used within the case study is Samuel Rainford's account ledger, which provides a snapshot of his network from *his* point of view. Therefore, we can only visualise the network from a source-centric viewpoint. Although this was partly allowed for by taking Rainford out of the measurements once the network was constructed, the network is still skewed. Thus, Rainford's contact is overrepresented and his role exaggerated. We have no access to the actors themselves to ask questions of the results as would be the case with a modern study and correlation with other data sources is not necessarily available. Therefore, we are unable to assess other actors' centrality in Rainford's wider business dealings, the centrality of Rainford in the other actors' business networks or of Rainford's centrality in the wider slave trade of this period.

This problem is not unique to the analysis of historical case studies. For example, in the study of contemporary social networks identified through computer forensics investigations, it is recognised that an analyst cannot solely rely on one source of data.<sup>31</sup> An investigation of social networks identified by computer data would correlate information from a variety of sources, such as email, mobile phone records, files resident on the computer, etc. to provide a full picture of the suspect's activities. In the examination of historical data, it is recognised that the historian rarely has multiple data sources with which to provide a correlation.

*Reliability of results:* As we are relying on a source-centric viewpoint, it leaves the question of reliability of the results. Rainford's centrality skews the figures so that certain actors will have small figures associated with them; yet "significant evidence is not evidence of significance".<sup>32</sup> The importance of Rainford is highlighted because the source is centred around him. The way in which we addressed this in this experiment was to remove Rainford from the network before calculating our four measures. This mitigates the source-centric issue discussed above to enable the

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<sup>31</sup>A computer forensics investigation will typically rely on evidence from a variety of sources. For example, a case would involve the collection and analysis of evidence from the suspect's hard drive, computer memory, storage media, network logs, cell phone, etc. For further details, see for example G.G. Richard III & V. Roussev, "Next-Generation Digital Forensics", *Communications of the ACM*, 49 (2) (2006) pp. 76-80; X. Li & J. Seberry, "Forensic Computing", *Proceedings of INDOCRYPT*, New Delhi, India, 8-10 Dec 2003, LNCS 2904, Springer, (2003) pp.18-35; J. Haggerty & M. Taylor, "Managing Corporate Computer Forensics" *Computer Fraud and Security*, 6: (2006) pp. 14-16.

<sup>32</sup> Graeme J. Milne, *Trade and Traders in Mid-Victorian Liverpool: Mercantile Business and the Making of a World Port* (Liverpool: Liverpool University Press, 2000), p. 6.

identification and analysis of key actors within the Liverpool slave trade community during this period.

*Visualisation:* Using social network analysis and visual analytics has allowed for the visualisation of a quite complicated network. Visual analytics facilitated not only the representation of the network (and sub-nets), but also the complicated and inter-related nature of them. This in itself is beneficial to historians working with complex networks and could easily be adapted to larger networks than the one analysed here. The analysis of subnets has also demonstrated that whilst this dataset is source-centric, the relationships between other actors can easily be highlighted.

*Measurement of relationships:* the measurements provided here are, in some ways, problematic due to the source-centric nature of the data. However, key players in the Liverpool networks were highlighted. This gives a clear starting point for further research. We know from this analysis that if we want to find out more about the slave trade networks in Liverpool, we need to look for further information on William Boats, John Gregson, Thomas Earle, Benjamin Heywood, Thomas Hodgson as well as Thomas Seaman, Thomas Twemlow and William Rutson. By no means are all the major players in the Liverpool slave trade highlighted here, not surprising from such a small dataset. However, William Boats, John Gregson, and Thomas Hodgson are all important in the slave trade and active in 396 slave trade voyages between them.<sup>33</sup> Thomas Twemlow was involved in 43 voyages. More importantly, the Earles and the Heywoods are two of the most important families in not only the slave trade, but Liverpool more generally.<sup>34</sup> Therefore, we have been able to analyse and quantify the centrality of the other actors within this trade network to provide a representation of wider slave trade networks in Liverpool, and who was central (and influential).<sup>35</sup> This means that given a limited dataset, using this methodology highlights important avenues for further research, even if we do not have much contextual information about the actors.

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<sup>33</sup> Figures from the *Transatlantic Slave Trade Database*, available at <http://www.slavevoyages.org>. William Boats was involved in 149 slave trade voyages, John Gregson 98 slave trade voyages and Thomas Hodgson (senior) 149 slave trade voyages, either as principal investors, independently or within investment groups.

<sup>34</sup> Earle Collection. Merseyide Maritime Museum; Arthur Heywood & Sons. Barclays Group Archives; see also H. A. Ormerod, "Extracts from the Private Ledger of Arthur Heywood of Liverpool, Merchant and Banker", *Transactions of the Historic Society of Lancashire and Cheshire*, 103 (1951), 103-111; Dawn Littler, "The Earle Collection: Records of a Liverpool Family of Merchants and Shipowners", *Transactions of the Historic Society of Lancashire and Cheshire*, 146 (1997), 93-106.

<sup>35</sup> This technique has been used in computer forensics investigations where more data is available to identify influential nodes. See Haggerty *et al*, "Determining Culpability in E-mail Investigations", *Proceedings of the 3<sup>rd</sup> IEEE Annual Workshop on Digital Forensics and Incident Analysis (WDFIA)*, Malaga, Spain, October 2008, pp. 12-20.

*Predictiveness*: Linked to the measurement of relationships is the predictiveness of this methodology. It is noted above that key actors are highlighted. William Boats is highlighted as very important, and it is true that a traditional approach would have highlighted him as such. In a straightforward frequency analysis he appears fifteen times as principal investor and twenty-one times by total investments. Thomas Seaman and James Percival are also highlighted under such an analysis. However, both Boats and Seaman organised voyages whilst Percival did not as he was an investor only. Therefore, even within their small investment network, their roles were not equal; a key issue that would not be identified by a frequency analysis but is identified using this methodology. Other key players within the Liverpool business community during this period and identified in the Rainford network would have been ignored using a frequency analysis. Thomas Earle and Thomas Ruston appear twice by total investments but only once by principal investor. John Gregson appears twice as principal investor and by total investments. Thomas Twemlow only appears once under each frequency. Importantly, using a traditional historical approach such key figures as Arthur Heywood, Henry Blundell, John and Thomas Tarleton appear only once and therefore would have been assessed as insignificant players in the Liverpool business community at this time, which is not the case.

This methodology also provides predictiveness in other ways, for example, in trying to determine actors' roles if they were not known. The case study has highlighted that using measures such as closeness centrality, ships' captains can be discerned from investors, despite many of these actors having the same frequency as each other. Therefore, the predictiveness of this methodology and its advantages over more traditional techniques is a significant contribution to the analysis of historical networks.

## **Conclusions**

This paper has examined an eighteenth-century slave trade network identified through the ledgers of Samuel Rainford, a merchant based in Kingston, Jamaica with ties and access to Liverpool merchants. The ledgers provide tangible evidence of Rainford's business activities between 1779 and 1793, and the resultant analysis provides intangible evidence regarding dynamics and centrality within the network.

The aim of this paper is to disseminate the results of an inter-disciplinary experiment in the application of social network analysis using visual analytics to an historical case study. The results

show that there are some problems with using this methodology, such as source-centric data and the omission of some key actors in a wider context. However, this methodology enables the visual analytics of large networks and the measurement of the relationships within them. The measurements also highlighted key actors within the network for further research which would not have been identified using traditional historical techniques. We have therefore been able to highlight not only the finite set or sets of actors within this network, but the relations therein, which are the defining feature of a social network.

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