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Fragmentation and Disruption: Ranking Cut-Points in Epistolary Networks at the Court of Henry VIII

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Keywords Cut-points; fragmentation; centrality; Tudor England; early modern history

Abstract As network analysis becomes more widely utilized amongst digital humanists to study connections between actors, so too grows the desire to quantify and measure importance and power within these interaction structures. Finding actors of structural significance holds implications not only in historical networks, uncovering people who link disparate communities or who lie at the center of information systems, but also has real contemporary applications, most significantly for security and defense agencies (Ahnert *et al.,* 2020). In his canonical paper 'The Key Player Problem' Stephen Borgatti suggested identifying cut-points – nodes which, when removed, separate one component of the network into two or more distinct components – as "the most obvious" means of finding those most likely to disrupt communication in the network (Borgatti, 2003).

This article develops Borgatti's fragmentation equations into re-usable Python code, assessing the nodes selected by the NetworkX cut-point function using three measurements: the number of new components created by the removal of a cut-point; the size of the remaining Giant Component; and the average length of the shortest path in the Giant Component. In measuring the impact of a cut-point's removal in several different ways, these experiments move beyond basic understandings of the cut-points as merely 'cutting' and demonstrates that these measures offer greater understanding, not only of individual actors but the structures around them as well.

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Introduction*

On 3rd March 1541, only seven months after the execution of Thomas Cromwell, Charles de Marillac, French Ambassador to the English court, reported back to France that Henry VIII had been blaming his advisors for the loss of his chief minister, complaining that "upon light pretexts, by false accusations, they made him put to death the most faithful servant he ever had."[1] The now infamous elegy of the fallen minister peppers biographical accounts of Cromwell: but why did Henry VIII lament this loss so much? Marillac's letter to the French advisor Anne de Montmorency implies that the English king's complaints stemmed from a fever and ongoing problems with his leg – "because he is very stout and marvellously excessive in drinking and eating," which caused a shortness in his temper and a temperamental, changeable mood.[2] Yet the ambassador's official report to the French king, Francis I, offers further insight, highlighting the disrepair of the coastal defenses at Dover and

> that, hearing that [Henry's] subjects in divers places murmured at the charges which, contrary to their ancient liberties, are imposed upon them, and at their ill-treatment [sic] for religious opinions, and having conceived a sinister opinion of some of his chief men, in his illness, [Henry] said he had an unhappy people to govern whom he would shortly make so poor that they would not have the boldness nor the power to oppose him, and that most of his Privy Council, under pretence of serving him, were only temporising for their own profit[.][3]

Though Henry's *vocalized* complaints about his advisors may have been a result of his recent illness, Marillac's reports make clear the very real governmental and administrative issues at the Tudor court and surrounding Henry after the fall of his chief minister. Cromwell's role and power at court was built on his administrative efficiency and access to critical information to aid his king, both of which were managed through his own personal correspondence and web of contacts. Many petitioners and other members of the court looked to him as a vital contact, the key means of reaching Henry VIII and the rest of his advisors. When Cromwell was removed from power, these avenues of access were disrupted, and many of these correspondents were cut off. Without this bounty of extra contacts

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1 J. S. Brewer, ed., Letters and Papers, Foreign and Domestic, of the Reign of Henry VIII, 1509–1547 (henceforth L&P), Vol. XVI, no. 590 (1898).

2 ibid.

3 L&P, Vol. XVI, no. 589.

placed at Henry's disposal by Cromwell, the king mourned more than just the loss of the minister himself, but all the extra information and administrative control that Cromwell brought with him.

In network terms, Cromwell was a *cut-point* – a node that, when removed, separates one component of the network into two or more distinct components, disconnecting one part of the network from another. Identifying cut-points offers a means of highlighting key members in a network, actors that link together disparate sections of a graph and act as bridges for communication and information. Finding actors of structural significance holds implications not only in historical networks, uncovering people who link disparate communities or lie at the center of information systems, but also has real contemporary applications, most significantly for security and defense agencies.[4] The role of – and possible problems in – using cut-points as a proxy for important nodes in a network is best explored by Stephen Borgatti in his paper 'The Key Player Problem', in which methods are explored to find the most influential nodes in a network.[5] Borgatti separates this into two distinct categories, selecting a node that will either "maximally disrupt communication" or "is maximally connected."[6] In highlighting cut-points as "the most obvious" possible solution to the first category of nodes (those that, if removed, would cause most damage to the structure of a network), Borgatti points to some of the initial problems with selecting all cut-points as key players in this first scenario.[7] Borgatti first introduces a measure of fragmentation, which counts the number of new components created by the removal of a node. However, Borgatti recognizes that this calculation does not account for different sizes in components; that is to say, a node would have the same fragmentation score if it separated a component of one node as if it separated a component of five nodes. Borgatti therefore introduces a second fragmentation measurement "that simply counts the number of pairs of nodes that are disconnected from each other," allowing for a closer idea of the impact of different cut-points.[8]

Whilst Borgatti's work means *identifying* cut-points has become a well-practiced aspect of network analysis, there still remain questions over *ranking* these nodes, and how to quantify or measure the impact of their removal on the network. In what ways and to what extent does a cut-point fragment or disrupt a network? How many new components does their removal create, and what 'damage' do they cause to the main component of a network? Though Borgatti's equa-

4 Ruth Ahnert et al. The Network Turn: Changing Perspectives in the Humanities. (Cambridge: Cambridge University Press, 2020), 3–4.
5 Stephen Borgatti, 'The Key Player Problem,' in Dynamic Social Network Modeling and Analysis: Workshop Summary and Papers, edited by Ronald Breiger, Kathleen Carley, and Philippa Pattison, (Washington: The National Academies Press, 2003), pp. 241–252.
6 ibid, p. 1.
7 ibid, p. 4.
8 ibid.

tions offer an introductory solution to ranking cut-points and quantifying their impact on a network, the problem remains that when using NetworkX – the coding library designed for network analysis with Python – cut-points are returned as a list, which does not measure the extent of fragmentation, either by number of nodes separated or size of new components created. Actors are selected as cut-points whether their removal disconnects one node or one hundred. This article therefore develops Borgatti's fragmentation equations into adaptable and re-usable Python code, designed to rank and evaluate the cut-points in a way that is accessible to more novice coders and applicable to case studies in the digital humanities. In doing so, this builds on pre-existing packages and ideas rather than creating something from scratch – as Dan Edelstein argued in a recent RHS roundtable on digital historical research, there is not always a need to create new tools or software, but to better utilize those which already exist; or, as he put it, sometimes we don't need the Bentley, we can take the Skoda and it will do the job.[9]

Whilst social network analysis has been increasingly adopted for historical and wider humanistic research in the wake of the 'network turn', barriers still remain in effectively 'translating' theories, equations, or code into constructs or concepts that can be used freely by traditional historical researchers.[10] Such is the case with cut-points: though, as shown, this concept is well-theorized in historical literature, little has been done to develop it within digital humanities to bridge the gap between mathematical equations, as Borgatti has done, to modes of analysis and understanding available for digital humanists, and in particular non-coding historians. The term 'network' itself is not foreign to humanistic scholars, who have long used this term to metaphorize systems of communications throughout history.[11] As Lindsay O'Neill argues, the network metaphor may be the most useful way to relate to these historical structures: "early modern invocations of friendship do not stray far from modern definitions of networks [...] So, while anachronistic, the word network encapsulates the ways [actors] envisioned their social worlds."[12] Quantitative network analysis, then, can be understood as the 'materialization' of qualitative concepts that have been regularly theorized and discussed, and cut-points are no different.[13] Importantly, whilst this article offers and analyses quantitative results on a given dataset (introduced below), its primary contribution is a novel means to understand and *replicate* network experiments in a way that is accessible and applicable to historical case studies.

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9 Royal Historical Society Panel. 'Digital History and Collaborative Research: a Practitioners' Roundtable.' Recorded 23rd May 2023. https://royalhistsoc.org/digital-history-and-collaborative-research-a-practitioners-roundtable/

10 Ahnert et. al., Network Turn, 3.

11 ibid, 7; 13–24; Lindsay O'Neill, The Opened Letter: Networking in the Early Modern British World, (Philadelphia: University of Pennsylvania Press, 2015), 4–6.

12 O'Neill, Opened Letter, 3.

13 For networks as 'thought experiments' see Ahnert et al., Network Turn; 43.

As a case study, this article returns to the Tudor court, testing qualitative assessments of Cromwell's role therein. Though Henry clearly mourned the loss of his minister and the impact this had on governance, scholarly debate continues as to the *extent* of this impact: whilst G. R. Elton frames Cromwell as unique in his role as the "unifying factor in [the state's] multiplicity of departments", others have sought to minimize Cromwell's significance at court, describing him as "no great original thinker" whose work was merely a function of his role as Principal Secretary.[14] Where Elton's assessment – alongside Henry's complaint highlighted above – qualitatively outlines Cromwell's role as a cut-point at the Tudor court in the 1530s, these experiments quantitatively evaluate this role, demonstrating the extent to which the minister occupied this critical 'unifying' role at court and re-engaging with these historiographical debates in a novel way.

To do so, this article applies the experiments to an epistolary network using metadata from *State Papers Online* for 1534–1540 to consider how these measurements can indicate the most *destructive* cut-points, and what this reveals about particular roles in a network. Finally, comparing these rankings to commonly used network analysis centrality measurements – degree, betweenness, and eigenvector centrality – offers a means of considering whether these centralities can be used as proxies for cut-point impact, to what extent they differ, and why. Though this article does not dramatically shift understandings of the Tudor court – offering instead a fresh quantitative framework through which to engage with existing and ongoing scholarly debates around Thomas Cromwell – where the approach supports long-held qualitative statements, it suggests that if the network presents something 'new' or – more often – supports one side of a debate over another, this can be trusted as much as any other expected result. This paper is thus modest in its contribution to historiography, but in establishing these new cut-point measurements as another means of assessing structural importance in a network, and importantly by applying these to a historical context, this article will demonstrate how they can offer new perspectives and avenues of quantitative historical inquiry research, offering this for new and experienced coders and digital historians alike.

14 G. R. Elton, The Tudor Revolution in Government: Administrative Changes in the Reign of Henry VIII, (Cambridge: Cambridge University Press, 1953), 223; Diarmaid MacCulloch, '"Vain, Proud Foolish Boy': The Earl of Surrey and the Fall of the Howards,' in Rivals in Power: Lives and Letters of the Great Tudor Dynasties, ed. David Starkey, (London: Macmillan London Limited, 1990), 95; R. B. Wernham, review of The Tudor Revolution in Government: Administrative Changes in the Reign of Henry VIII, by G. R. Elton, The English Historical Review 71, no. 278 (January 1956): p. 95.

Methodology and Sources

Sources

The networks in this article are built from letter data taken from *Letters and Papers* on Gale's digitized *State Papers Online*. As part of their AHRC project, *Tudor Networks of Power, 1509–1603,* Ruth and Sebastian Ahnert collected the available metadata of over 130,000 letters (including sender, recipient, date, and place of writing), before extensively cleaning them in a laborious eighteen-month process, disambiguating and deduplicating letters, places, and names.[15] This article, focusing on 1534–1540, uses a subset of this considerable and large-scale work, containing 13,024 individual letters and 3,116 writers or recipients.

As a state archive, the State Papers of England represent a curated collection of documents related to the governance of the country, developed out of individual collections, both confiscated and consciously preserved, from the start of the sixteenth century. In the 1830s the State Paper Commission first sought to consolidate the papers of the Tudor reign as the *Calendar of State Papers,* bringing together the records of the State Paper Office and the confiscated papers kept in the Chapter House of Westminster Abbey. When the State Paper Office was subsumed by the larger Public Record Office in 1852, a more comprehensive collection of the papers of Henry VIII began, completed in 1920 as the first edition of *Letters and Papers, Foreign and Domestic, of the Reign of Henry VIII, 1509–1547*.[16] In this long history, the contents of the State Papers archives have been shaped by both contemporary and more modern archival processes: as Arnold Hunt phrased it, "the early modern archives that have come down to us are very often the product of a deliberate but largely invisible process of selection."[17] Whilst this invisibility certainly applies to contemporary processes for document survival, J. S. Brewer explicitly outlined the selection of material for *Letters and Papers,* a process more concerned with the inclusion of available material than exclusion. Brewer followed a different editorial process to that used by the rest of the Calendars; where these focus on one office or state department, *Letters and Papers*

> embraces an abstract of all Letters and Miscellaneous Papers, illustrative of the reign of Henry VIII, foreign or domestic, printed or in manuscript, preserved either

15 Ruth Ahnert and Sebastian E. Ahnert, Tudor Networks of Power, (Oxford: Oxford University Press, 2023).

16 Amanda Bevan 'State Papers of Henry VIII: the Archives and Documents.' State Papers Online 1509–1714, Cengage Learning EMEA Ltd., 2007; J. S. Brewer, 'Preface to the First Edition', L&P, Vol. I.

17 Arnold Hunt, '"Burn This Letter": Preservation and Destruction in the Early Modern Archive,' in Cultures of Correspondence, 191.

> in the different departments of the Great National Depository, or in the British Museum, the Bodleian and the Lambeth libraries, or the colleges of Oxford and Cambridge [... and includes] a complete index and summary of the French, the Scotch, the Patent and the Parliament Rolls, the Signed Bills and Privy Seals, the army, navy, ordnance, and wardrobe accounts of the same period, not omitting the transcripts made by the late Record Commission from foreign archives [... which] have now for the first time been brought together and arranged chronologically.[18]

Letters and Papers thus includes a broader range of material than other periods included in the State Papers archives, subject as it is to Brewer's various choices in terms of archival selection.

Network analysis offers an important means of exploring and analyzing this collection, focusing in particular on the letters contained in the archives. As Gary Schneider argues, "letters were *the* material medium, *tout court,* of early modern sociocultural exchange and, along with face-to-face conversation, a critical means of pragmatic communication."[19] With few other means of interacting, early modern letters also became fundamental indicators of relationships and displays of power. Understanding the significance of letters as social markers emphasizes the usefulness of correspondence when engaging in network analysis. Inherently containing 'to' and 'from' categories as part of the correspondence process, letters can be 'abstracted' into data for directed networks, in which relationships can be measured and explored in mutual and reciprocal terms.

Original Network

Using the subset of letter metadata from *State Papers Online* described above, an 'original' network (G) was created. This is a weighted directed network, containing 3,116 nodes and 4,543 edges, where the nodes are letter writers or recipients, and the edges are correspondence relationships. Before calculating the results of each cut-point experiment (detailed below), measurements for the original network (G) were calculated [Table 1]. The original network G contains 119 separate components (G_c), of which 118 are made up of 14 or less nodes. The giant component (G_1) contains 2,863 nodes, nearly 92% of the full network, and has an average path of 2.868. This is an important baseline against which measurements for each cut-point are compared. For this dataset, G_1 contains the core of Henry VIII's court and political connections, including the king himself, key advisors and their allies, as well as members and monarchs of other sixteenth century European courts.

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18 Brewer, 'Preface to the First Edition' L&P, Vol. I.

19 Gary Schneider, The Culture of Epistolarity: Vernacular Letters and Letter Writing in Early Modern England, 1500–1700, (Newark: University of Delaware Press, 2005), 13.

Original Graph (G) Measurements	*State Papers of England* **Network**
Number of Components (G_c)	119
Size of Giant Component (G_1)	2,863 nodes
Size of Second Component (G_2)	14 nodes
Average Shortest Path Length of Giant Component (G_P)	2.868
Number of Cut-Points (C)	300

Tab. 1 A table illustrating measurements for the original epistolary network using letter metadata from the State Papers of England, 1534–1540, as a base for further experiments.

Alongside these, the NetworkX function [nx.articulation_points(G)] was used to find the number of cut-points in the network, a total of 300. Having established the cut-points, they could then each be tested to quantify the impact of their removal from their respective networks. For each cut-point, a test graph was created, in which the cut-point was removed, the network was re-constructed, and the measurements used on the original graph were re-calculated. For each measurement, the new result was assigned to the cut-point as a score, which could then be sorted and ranked. The raw score allows for a comparison with the original graph *G,* and to determine the impact of each cut-point. In these experiments, if two cut-points received the same score in any measurement, they were assigned the same rank as one another. Each cut-point was tested in the following three experiments, all designed to meet Borgatti's equations. All code for measuring the original network and the following cut-point experiments can be found in a dedicated GitHub repository [see Bibliography].

Number of New Components

The first experiment (F_1) reflects Borgatti's first measure of fragmentation, establishing and ranking the number of components in the graph after the removal of a cut-point. In order to rank this using Python, a test graph was created for each cut-point, wherein the test node was removed and the number of components re-calculated. This was then assigned to the test node as a value in a dictionary, which was sorted and ranked. In this measurement, the node with the highest number of components ranked first.

Size of Giant Component and Second Component

The second experiment (F_2) again builds on Borgatti's idea that the initial fragmentation measurement does not quantify the size of the new components, or the damage done to G_1. Rather than counting disconnected nodes, as Borgatti's second fragmentation does, the experiment in this article measures the new sizes

of the Giant Component (G_1) and Second Component (G_2). Whilst measuring the size of G_1 determines how many nodes are 'lost' when a cut-point is removed, measuring the size of the Second Component – and comparing it to the size of the Second Component in G – means it can be assessed whether G_1 has been split into many smaller components, or if a large cluster has been separated but remains intact. As in F_1, a test graph was created for each cut-point, and the size of the Giant and Second Components re-calculated after the cut-point's removal. For this experiment, nodes were ranked by the smallest remaining Giant Component but the largest Second Component.

Average Path Length

The third experiment (D) explores Borgatti's final consideration of a key player, which rather than assessing the impact of a node's removal on dis*connection,* focuses instead on a cut-point's dis*ruption*. That is to say, though a node's removal may not significantly fracture the network structure, it will disrupt efficiency and communication within the remaining graph. Though nodes are still able to reach one another without this cut-point, it takes longer for them to make these connections. This measures a different type of impact than the first two fragmentation experiments, and to a lesser extent establishes the destructive nature of a cut-point, but rather assesses the *overall* impact of a node on the surrounding structure. To compute this final measure, the average path length was measured for each test graph. Here, the top-ranking node holds the longest new average path.

Results and Discussion

'Not-Cuts'

Sorting and ranking the cut-points from their scores in the experiments listed above creates an immediate and easy way to highlight the most impactful cut-points in each network. It also means the lowest scoring nodes – those with minimal impact when removed – can be identified. In this way, the experiments are able to address one of the fundamental problems with the cut-point function established in the introduction: the standard NetworkX code cannot distinguish between nodes that isolate one other node, or one hundred. Though this is not necessarily an issue with smaller datasets, this can pose a bigger problem for larger datasets with a much greater number of cut-points to assess. To account for this, additional code was written to separate these 'not-cuts' – nodes which, whilst technically cut-points, have minimal impact on the network when removed – from the rest of the cut-points. In order to account for the size of the original networks by using percentages rather than raw numbers, this code used limits for scores, set at 10% for F_1 and 1% for F_2, which deal with whole numbers. This selected any cut-point that created less than 10% more components than the

original network, or cut less than 1% of the original G_1, and created a list of nodes that fulfilled both conditions. Some nodes fulfilled only one of the conditions and therefore were left in the list of cut-points. Here, the code identified 196 (65%) of the original cut-points as 'not-cuts', causing minimal impact or damage to the graph. Though these have been left in for the remainder of the experiments as useful context, they can be isolated for further, more specific research interests.

Fragmentation

Having returned the results of the two fragmentation measures (F_1 and F_2) as both raw scores and ranks, these can be compared against one another for a more nuanced consideration of important or destructive cut-points. In Figure 1, the ranks for the two measures are plotted against one another, along with a line depicting perfect similarity: that is to say, where cut-points hold the same rank for both fragmentation measures. Here, it is important that the cut-points with the same score are ranked the same, as this allows for easier comparison between ranks in each measurement. For the most part – and certainly for higher ranking cut-points – these two figures have a high degree of correlation. This is largely not all that surprising: other quantitative measurements in network analysis tend to correlate, implying that having power or importance in one form normally draws

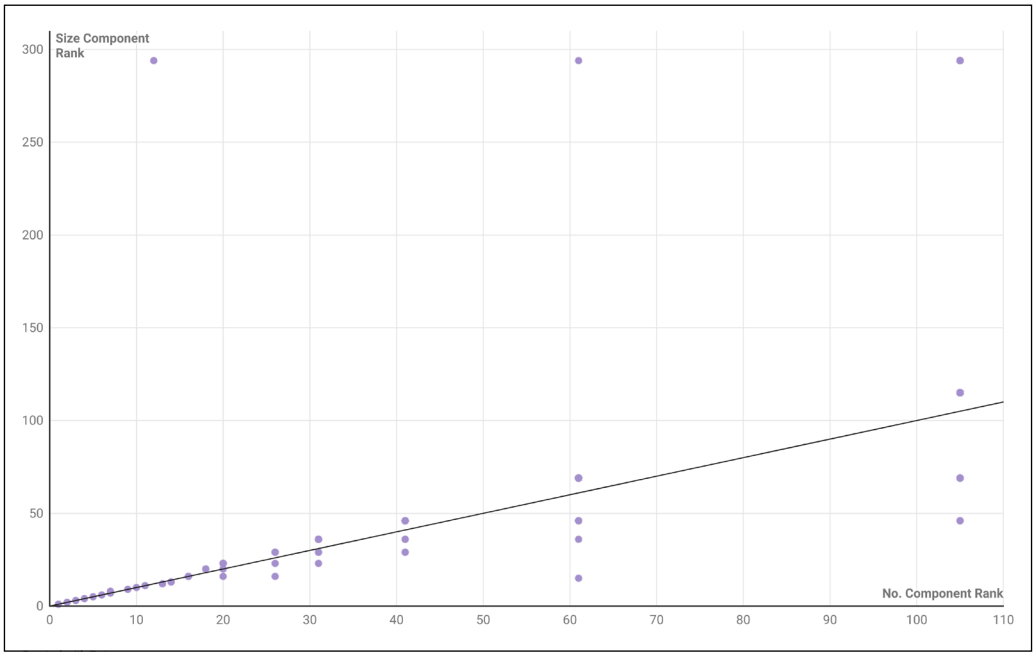


Fig. 1 A scatter graph with the rank for F_1 (number of components after removal) plotted against F_2 (size of remaining giant component after removal) to demonstrate the correlation between fragmentation measures. A line of similarity indicates where nodes rank the same in both measures.

influence in others, in a self-fulfilling and socially self-reinforcing manner, so it might be expected that these fragmentation measures would follow a similar pattern. This still leaves three loose groups of cut-points, however: those on or close to the line of similarity; those above the line; and those below it.

The first group are cut-points which rank the same or similar in both measures, sitting close to or on this line of perfect similarity. Most of the top-ranking nodes hold similar ranks for both ranks, and therefore sit close to the line on each scatter-graph. This indicates that these are the most impactful cut-points. Not only are they high ranking in both fragmentation measures, but by having a similar or the same ranking score for both, it suggests that they are not only separating nodes from G_1, but fragmenting and causing a disconnect between these removed nodes as well.

High-ranking cut-points within this network are thus likely to hold greater sway in court business, given that they also have an ability to severely disrupt business by fragmenting the structure. As such, they are removing maximal nodes at the same time as creating maximal new components within the results possible for the cut-points in the network.

As a result, it is unsurprising that in the top ten [Table 2], all of whom rank the same in both fragmentation measures, there are three European monarchs – Henry VIII, Francis I, and Charles V – and a number of key administrators in England – Thomas Cromwell, Arthur Plantagenet, and Thomas Wriothesley. They not only reflect historically influential actors, but also indicate that these nodes are most responsible for bringing and holding together parts of the network. The strong correlation between rankings in each fragmentation measure suggests that these actors are the most likely to be in correspondence with people who in turn are *not in contact with anyone else*. This is not to say that these nodes do not have any contacts beyond the surviving State Papers collection, but rather that these cut-points are their only link to the bulk of the administrative work at court. The cut-points in this network are important patrons at court, perceived as the most effective way to reach G_1 and the center of the royal court. Those outside of this pattern – namely Cardinal Reginald Pole and Philip Melanchthon – though not core members of the court, are clearly valuable in the wider network, offering uniquely significant links into English epistolary circles. The now isolated nodes are most likely to be petitioners seeking patronage or other aid from influential correspondents.

The second group are the nodes above this line, who score higher in the number of new components created than in the number of nodes removed from G_1. For the most part, this suggests that they are *not* part of G_1 to start with. As such, they create new components only from within their own, smaller grouping. Those with significantly higher results in F_1 are likely to be leaders or key brokers within their groups: these are the nodes holding together the smaller components and

Rank	Fragmentation: Number of Components and Size of Giant Component
1.	Thomas Cromwell
2.	Arthur Plantagenet, Lord Lisle
3.	Henry VIII
4.	Honor Plantagenet, Lady Lisle
5.	Thomas Wriothesley
6.	Thomas Cranmer, Archbishop of Canterbury
7.	Francis I, King of France
8.	Charles V, Holy Roman Emperor
9.	Cardinal Reginald Pole
10.	Philip Melanchthon

Tab. 2 A table to show the top ten ranked nodes in both fragmentation measures. For the top ten, all nodes score the same rank in both measures.

acting as a bridge between the other nodes. As such, when they are removed, they entirely disconnect the smaller components and create multiple isolated node components. For example, in this network, Jehan Lange ranks 12th for F_1, but ranks last (at 294th) for F_2. In fact, considering the raw score of this second fragmentation measure, Lange removes no nodes at all from G_1. Nodes above the trendline in this dataset are often isolated groups of correspondents that appear in the State Papers by accidental preservation, or for other reasons. In the case of Lange, his letters survive because of interception.[20] Lange was a French merchant and broker from Paris, visiting the English court in January 1537, meeting with the king and facilitating the sale of "my image, Jacques Poullain's image, [Thibault Comtet's] mirror, a hat of Mons. Caillot, and a collar and vizor (*cachenes*), and a martin (*une martre*), and some linen worth 400 cr. which belongs to Jan de Gran."[21] Writing only to his family, friends, and fellow merchants at home in France, Lange is not only completely disconnected from G_1 but also solely responsible for the presence of his correspondents in the State Papers archives. As such, whilst he does not impact G_1, he creates twelve new components from each of his intercepted correspondents. Nodes above the trendline offer instances for case studies into anomalous additions to the State Papers.

The third and final group is those cut-points that sit below the similarity line, and therefore score higher in damage done to G_1 than in the number of new

20 L&P, Vol. XII, no. 47–48 (1890).
21 ibid, no. 47.7.

components created. These are most likely to be leaders of or representatives for smaller, well-connected groups who are a part of G_1, but likely on the edge of the graph. The cut-point is the only link between this small cluster and the rest of the component, meaning that when the cut-point is removed, they are detached. However, the people in this cluster remain in contact with one another: as such, though the cut-point may remove a large number of nodes, because these isolated nodes remain in contact with one another, they create one new component together. These are also the nodes most likely to create a new second largest component. Whilst no node creates a new component larger than the pre-existing Second Component from *G* in this particular network, these cut-points below the trendline are those that are creating components of clusters, rather than just individuals. Unlike the monarchs and patrons listed above who are corresponding with individuals looking for personal favor, this second group of outliers are more likely to be leaders of cohesive groups, who rely on the cut-point to represent them in corresponding with the rest of G_1. Perhaps the most recognizable of these is Robert Aske, ranking 16th in F_2 but only 26th in F_1. One of the leaders of the Pilgrimage of Grace rebellion in Yorkshire and Lancashire in 1536–37, Aske was elected by the rebels to treat with the king in London, and correspondence was regularly passed between the court and Aske as a representative and negotiator. Correspondence was also shared *within* the group Aske was leading, however, meaning that they remain in smaller clusters when Aske is removed. Whilst creating only four new components, Aske's removal separates eleven other nodes from G_1. Other examples below the trendline include Sir William Weston, Prior of St Johns; Laurence Copferler, Master of St. Thomas Acres; Sir Anthony Windsor; and Brethren of Watton. All of these cut-points create only one new component, but each component is made up of three to four nodes separated from G_1. In each case, these cut-points are the link between a smaller grouping and the main body of the State Papers correspondents.

Disruption

The final experiment *D* measures the extent to which a network is disrupted by a cut-point's removal, measuring the new average path length for each test graph. Whilst Borgatti includes disruption alongside fragmentation for his assessment of 'key players', it is important to note here that these measurements are quantifying two very distinctive characteristics. Though *D* does not consider the damage done by *completely* separating nodes in a network – and therefore is not a *primary* measure of cut-point impact – measuring the new average path is a means of considering the *overall* impact of the cut-point's removal on the surviving structure. Given the relative similarity already established between F_1 and F_2, Figure 2 shows the ranks for F_1 and *D* plotted against each other, again with a line of perfect similarity to indicate where a cut-point is performing the same in both measurements. Unlike in Figure 1 comparing the two fragmentation measurements, there is almost no correlation between a cut-point's fragmentation and disruption ranks, with only a handful sitting close to the line of similarity.

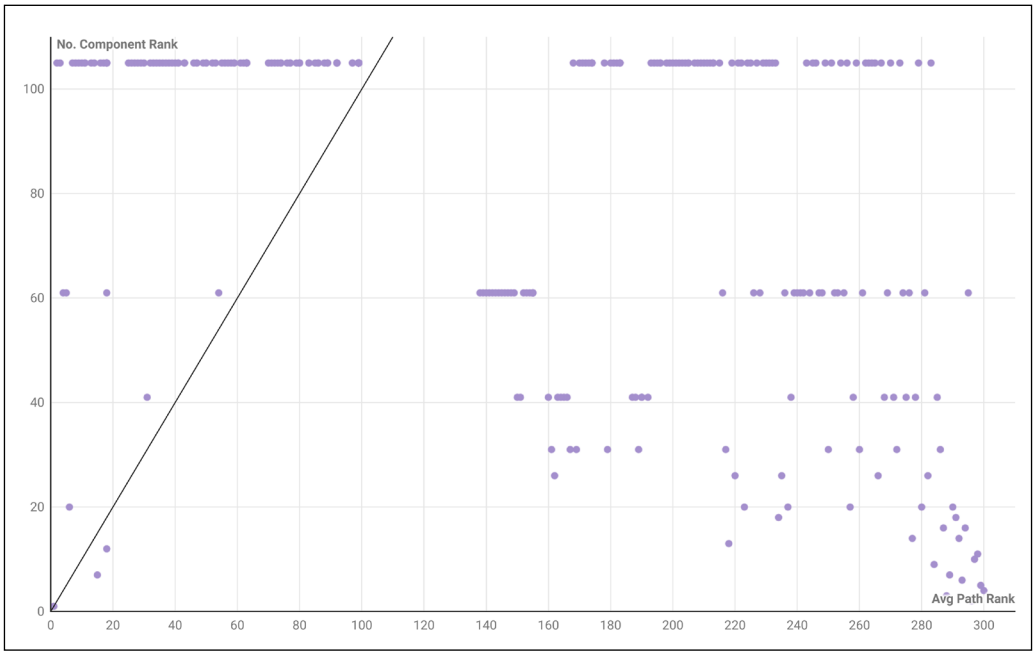


Fig. 2 A scatter graph with the rank for F1 (number of components after removal) plotted against D (average shortest path length of giant component) to demonstrate the correlation between fragmentation and disruption. A line of similarity indicates where nodes rank the same in both measures.

However, the comparisons between these two measures are more revealing – and more interesting – when we compare the fragmentation ranks to the raw score, i.e. the new average path length, which also highlights the value of the code returning both rank and original 'score'. In Figure 3.a the top scoring disruption node, Thomas Cromwell, has been removed for a clearer visualization of the remaining scores and the line indicates the original path length rather than a line of similarity. Those sitting on the line itself are those that are not actually part of the giant component and therefore do not impact the path length at all, like Jehan Lange, discussed above. Others close to this line – though ranking somewhere in the middle of this measure – in fact have a minimally 'disruptive' impact. For the most part, these measures follow a loose bell curve distribution, where those to the left of the original path line instead return an average path that is *shorter* than the original, and where a large number of nodes with high fragmentation ranking – such as important English administrators and European monarchs, including Henry VIII himself – cluster closer to the graph's point of origin. In these instances, these cut-points are responsible for connecting a large number of nodes to the giant component. As such, when these actors are lost, the overall diameter of the network itself is reduced, meaning that the average path length is also lessened when the maximum distance across the network is shortened.

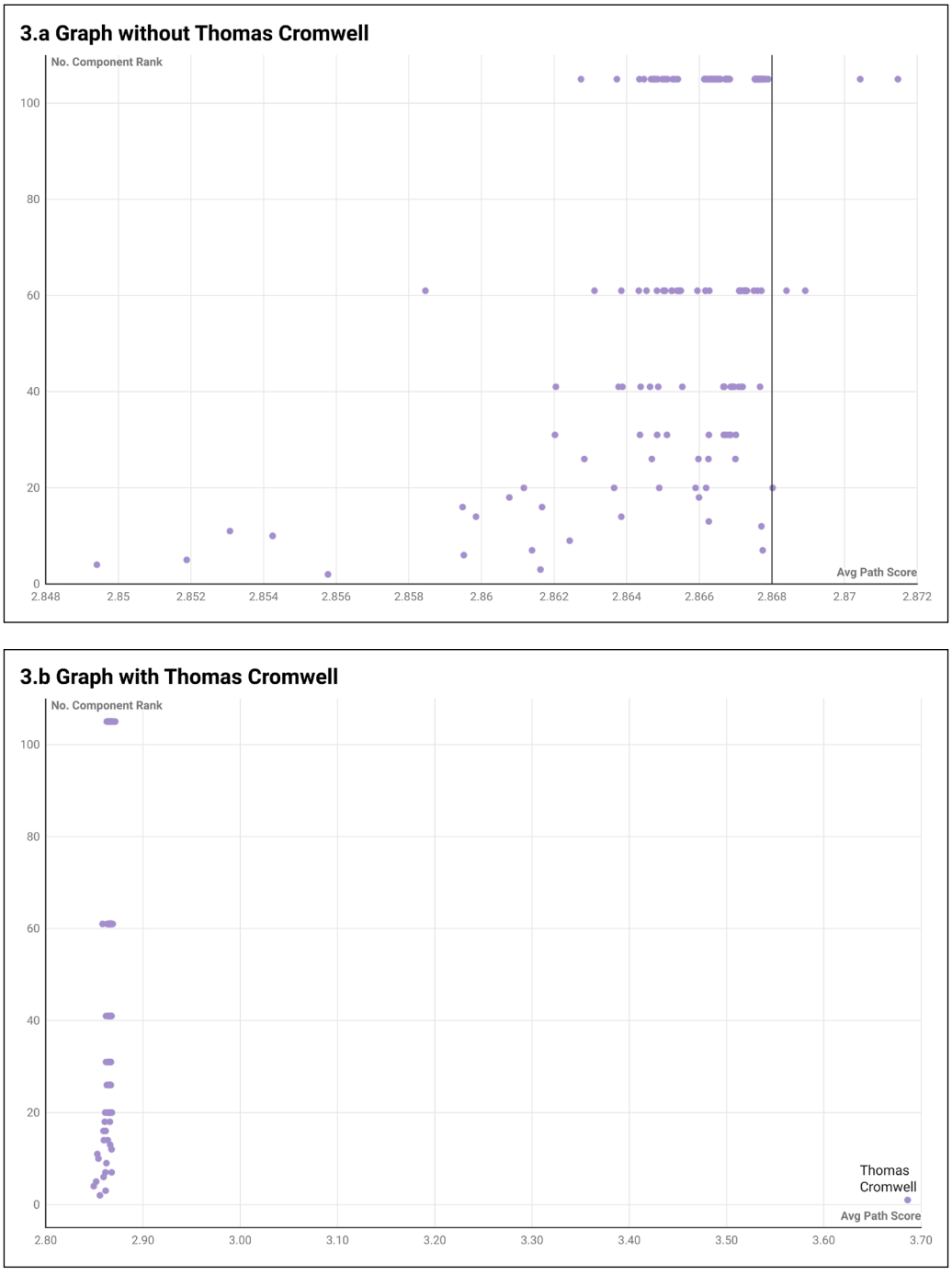


Fig. 3 A scatter graph with the rank for F_1 (number of components after removal) plotted against raw score D (average shortest path length of giant component) to demonstrate the correlation between fragmentation and disruption. A line in Fig. 3.a. indicates the average shortest path length of the original giant component, for comparison.

This tells us much about the role of cut-points in a structure. Whilst high-ranking fragmentation cut-points isolate a large number of neighbors, they are often on the edge of a network or, if they are part of the internal structure, are redundant there: that is to say, another member of the network can act as an alternative for their connections. In contrast, some high-ranking disruption nodes may only disconnect a minimal number of nodes, yet are more critical to internal connections. As such, whilst this article focuses these measurements only on the given cut-points, it is likely that the most 'disruptive' node may not be a cut-point at all. This is not to say that disruption and fragmentation measures *always* rank in opposition to each other, but rather that they consider two different qualities. In fact, as can be seen in Figure 3.b, Cromwell scores distinctly higher than the rest of the cut-points in average path length, meaning the minister holds the highest rank in all three experiment measurements. This extension of average path length – by almost one – after Cromwell's removal causes a significant change to the internal workings of the network, given that the fragmentation rankings indicate that his removal also isolates a large number of nodes on the periphery of the graph as well.

This article considers fragmentation and disruption as two distinct measures. However, it is worth noting, as Mark Newman, Duncan J. Watts, and Albert-László Barabási argue, that beyond a certain point, disruption can become destruction: this is to say that a path longer than a certain number of nodes is in fact infeasible and should be considered a destroyed path, rather than a disrupted one.[22] As such, it may be suggested that cut-points which disrupt a path to such an extent, making it so long that it is, in reality, unusable, should instead count these disruptions as fragmentations. Whilst this is possible to compute – deciding on a maximum usable path length and removing any paths that are longer than this after a cut-point's removal – the bigger issue is deciding on what qualifies as destroyed or merely disrupted. To decide this, a limit on the *effort* required to travel a path must be assigned to a network. How much effort one is willing to put into reaching another member of the network is likely to differ from node to node, let alone network to network, and as such cannot be given an arbitrary measure or limit. These measures thus reflect one of the perpetually problematic elements of digital history, namely the attempt to assign quantitative measurements to human nature and agency. This issue is often at the heart of contemporary social network analysis, and is only complicated further as greater historical distance between source and researcher is introduced. Given these complexities – both technical and theoretical – the disruption measurement is not developed any further in this experiment, but is acknowledged as offering an alternate means of considering importance in a network.

22 Mark Newman, Duncan J. Watts and Albert-László Barabási, The Structure and Dynamics of Networks, (Princeton: Princeton University Press, 2006), 556.

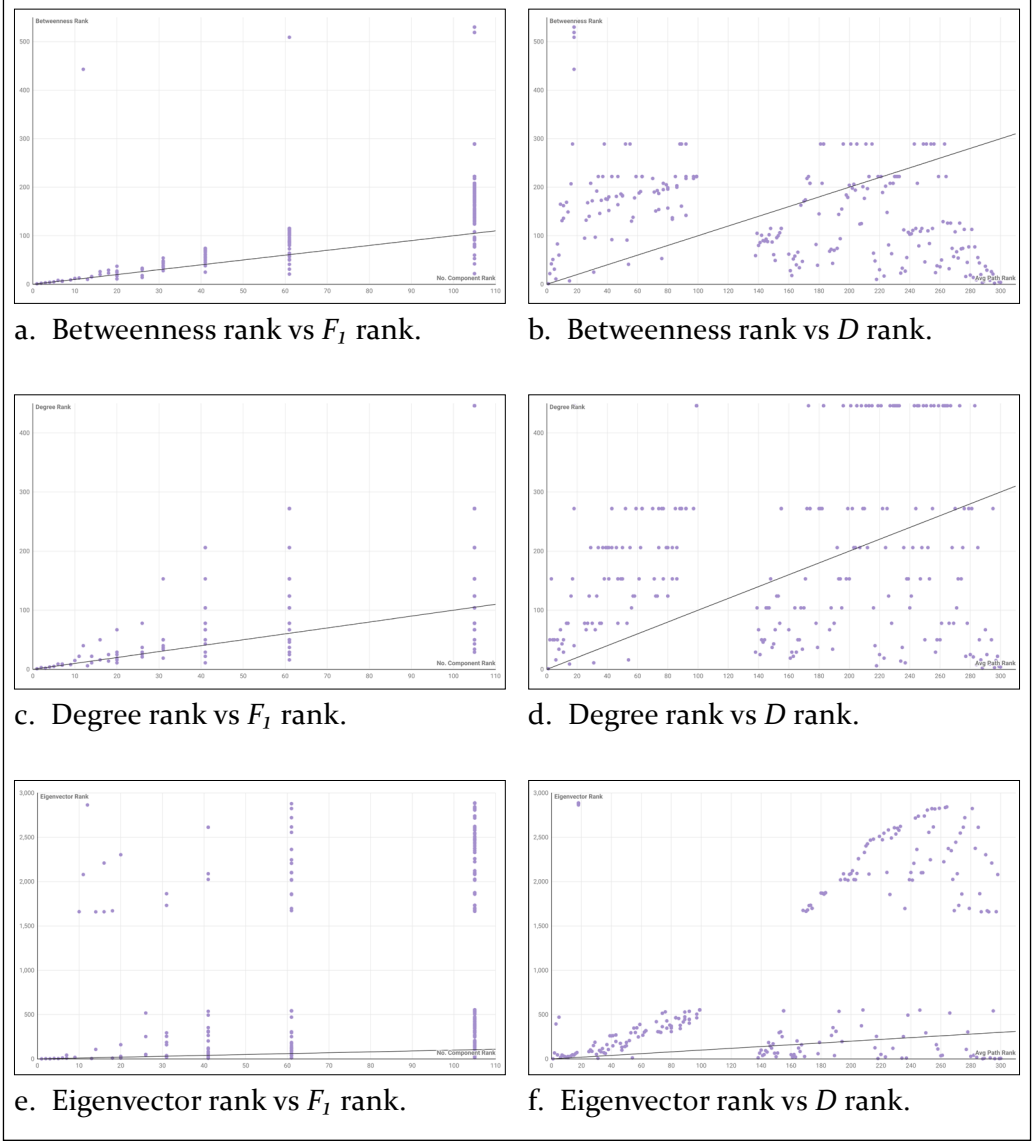
Centrality Measurements

These experiments are a means of ranking the cut-points and in doing so become another measurement for influence or structural significance in a network, evaluating the impact of a cut-point in a number of ways beyond simply establishing a state of basic fragmentation, as the original function does. Whilst this is useful, it is also worth examining whether these measures hold a unique value: that is to say, do these cut-point measurements offer any new insights into a network, or can a pre-existing measurement be used as a proxy for assessing cut-point impact? Given the desire to reduce unnecessary duplication or complication in new methods, it is important to understand if an existing measure is already able to replicate these results.

In order to assess this, this article compares the cut-point measurements with three centrality measurements as alternative proxies for power and structural importance in the network. As the name suggests, these measurements consider how central or essential a node is to the functioning of the network. Betweenness centrality measures how often a person can act as a go-between or intermediary on paths in a network. Degree measures the number of connections each node holds, or their 'busyness'. Though the network here is directed and weighted – counting the individual number of letters and the reciprocity of each relationship – the degree here is unweighted and undirected, counting only the individual number of relationships. Finally, eigenvector measures the extent to which one person can influence others who are themselves highly influential. As Borgatti himself has argued, "the idea is that even if a node influences just one other node, who subsequently influences many other nodes (who themselves influence still more others), then the first node in that chain is highly influential."[23] A high eigenvector score indicates nodes that are near other nodes of power at court and in the network. Like betweenness, eigenvector indicates perceived influence, reflecting how being close to other actors of power could itself put someone in a significant position of influence. As commonly used proxies for importance and power, these can be compared with cut-point rankings, both to offer context for the new measurements in the network and to establish their usefulness as a new value.

Having acknowledged the common similarity between ranks for both fragmentation measures, the ranks for the centralities were compared with just the first fragmentation measure, F_1, and the disruption measure D. As before, these were then plotted against one another to assess correlation, with a line of similarity, shown in Figure 4.

23 Borgatti, 'Centrality and network flow,' Social Networks, 27 (2005): 61.



a. Betweenness rank vs F_1 rank.

b. Betweenness rank vs D rank.

c. Degree rank vs F_1 rank.

d. Degree rank vs D rank.

e. Eigenvector rank vs F_1 rank.

f. Eigenvector rank vs D rank.

Fig. 4 Scatter plot graphs showing the ranks of each centrality measurement tested (betweenness, degree, and eigenvector) plotted against F_1 and D to test the correlation between pre-existing measures and the new cut-point experiment measures. A line of similarity indicates where nodes rank the same in both measures.

Betweenness

It is perhaps unsurprising that betweenness centrality offers the closest set of results: given that betweenness measures the frequency with which a node is used on paths, and cut-points are the *only* connection on a path between at least one node and the rest of the network, it may be expected that betweenness would be able to accurately predict high-ranking cut-points. Whilst the closest match, however, it is not fully accurate, returning only a 90% match between nodes appearing anywhere in the top twenty ranked betweenness centrality and top twenty for F_1, with only seven nodes holding the exact same rank for both measures.[24] Although betweenness is moderately capable of predicting high-ranking cut-points, this diminishes against lower ranking fragmentation cut-points: at its most extreme, though all rank 105th in F_1, William Popley ranks 22nd in betweenness, while Hugh Latham, William Thomlyngson, and Edmund Atkynssun rank 530th. Beyond high-ranking individuals, betweenness is less able to assess the impact of cut-points. The problem in using betweenness as a pure fragmentation proxy is, of course, that fragmentation only ranks highly when a connection is void without a cut-point, whereas this will still contribute towards a betweenness score even where there are other options, and a replacement path remains intact. In short, an impactful cut-point will always have a relatively high betweenness rank, but a high betweenness rank does not guarantee that a node is an impactful cut-point, or indeed even a cut-point at all.

This similarity is further reduced when comparing betweenness with the disruption measure *D,* where there is only a 15% match between the nodes in the top twenty ranks for both, and only one node with the same rank for both: Thomas Cromwell, who ranks first. Again, this is unsurprising considering the lack of correlation between the fragmentation and disruption measures: if betweenness and fragmentation are fairly similar in rankings, it is unlikely that betweenness and disruption would then correlate in any significant way. The relationship between fragmentation and betweenness and disruption and betweenness confirms general conclusions about cut-points in this network, but can also more specifically speak to a cut-point's location and role in the graph structure. Those with high betweenness and high fragmentation ranks – the more common correlation – are on the periphery of the network; those with high betweenness and high average path, though less likely to disconnect actors, are more involved in the internal connections of the graph. This can be seen again with the abovemen-

24 This is calculated by sorting by betweenness rank first, and then comparing to other measures; this therefore allows for multiple nodes ranking the same in F1, where this does not occur in betweenness rankings. The same method is similarly applied to other centrality rankings.

tioned William Popley, who while ranking low in F_1 actually ranks 2nd overall in disruption. Those that rank highly in all three measures hold a balance of being a frequent intermediary both to nodes in the center of the graph and those at the periphery; this is best exemplified by Cromwell ranking top in all three measures, which will be explored in more depth below.

Degree

The second most accurate of the three pre-existing measures tested, degree returns an 85% match with the top twenty ranked nodes in fragmentation, with only four nodes ranking the same in both measures. Like betweenness, the further the graph moves away from the point of origin, the further scores move away from the line of similarity. Again, low F_1 scores hold relative extremes in degree ranks, where ranking 105th in fragmentation can rank anywhere between 29th and 446th in degree. There is a smattering of odd scores, where a low degree score ranks (relatively) high in fragmentation: Albert Duke of Mecklenburg, with a degree of only 5, ranks 31st in F_1. This suggests that whilst the *most* impactful cut-points will have a larger number of contacts that they are able to disconnect from the network, those ranking somewhere in the middle of the fragmentation may have a higher F_1 score than those with higher degree ranks if those with a large number of contacts are redundant in their epistolary communities. There is of course a cap on this, however: all those with a degree score of only two rank last (105th) in number of components. In the State Papers, there is a limit on the damage that can be done to the network by a cut-point with a smaller number of connections. This says much not only about the cut-points themselves, but the overall robust nature of this scale-free network: the hubs are dominant and embedded at the center of the network, whereas the less-connected nodes are only at the periphery, and their removal is less significant in terms of overall effectiveness and communicability, i.e. there is no one node with a low degree that acts as a central bridge across the network. In other networks, a high ranking F_1 node with a very low degree score – and very high betweenness – would indicate such a bridge.

Once again like betweenness, degree also only matches 15% of the top ranked nodes in disruption, with one the same rank, again Cromwell. The other two nodes ranking in the top twenty for both – Charles V and Anne de Montmorency – are again the same as those in betweenness, and also rank in the top twenty for F_1. To a lesser extent, they mirror what Cromwell is able to bring to the epistolary network, and are similarly important in bringing unique connections to the network – those that are then isolated without them – as well as creating short paths and increasing efficiency in the internal network. Both, however, are *foreign* members of the English State Papers: Charles V, emperor of the imperial court, and Anne de Montmorency, resident ambassador from France. In many ways, their high rankings across cut-point and pre-existing measures reflects both their influential positions in early modern European politics, as well as the

fragmentary and eclectic collection practices of the English State Papers of this period.[25]

Eigenvector

Whilst neither betweenness nor degree are able to entirely replicate the rankings of the fragmentation measures, this disparity is even greater in the eigenvector scores: with the lowest similarity of only 60%, two of the top twenty eigenvector nodes – Sir Anthony Browne and James Butler, Earl of Ormond and Ossory – are not cut-point nodes at all. Given that eigenvector reflects the influence potential of an actor's connections – rather than their quantity, or whether they are unique in intermediary value – these nodes are almost more likely to be redundant in a network, and therefore not a cut-point. This is not to say that there is zero similarity between eigenvector and fragmentation rankings: the highest-ranking cut-points are significant players in the network and therefore are still likely to have a high eigenvector score. However, eigenvector scoring alone is less able to identify impactful cut-points. Where eigenvector centrality measures proximity to other nodes of influence, a high-ranking eigenvector score in this network indicates a close link with Henry VIII and Thomas Cromwell, themselves the most influential nodes in this 1534–1540 graph. Here, they form core members of Henry's advisory council or other influential ministers. Where a large volume of these nodes with high-scoring eigenvector centrality measurements do *not* rank highly in fragmentation, this suggests two things. First, it implies that Henry's inner circle – those closest to him in the network – were a tight knit cluster; removing them does not disconnect large swathes of the network, as other advisors and ministers hold similar or the same neighbors and would therefore prevent the network from fracturing. At most, when these nodes are removed, the Giant Component may lose a family or household member not involved in court business. Second, as a result of this, it implies that any of them may be easily replaced. Again, these nodes are structurally redundant: they offer the same contacts and information to Henry as other nodes in the network, as they do not isolate nodes that others in the network could not access in their absence. Concentrating as it does on proximity to nodes of power, rather than what – or *who* – they can offer these actors, eigenvector centrality has limited similarity with the structural roles of cut-points, and therefore is least suitable as a proxy for fragmentation.

Though still limited in its accuracy, eigenvector is however the most likely of the three to find disruptive rather than destructive cut-points, relying as it does on more internal structural importance: eigenvector has a 20% overlap with top

25 For more see Amanda Bevan 'State Papers of Henry VIII: the Archives and Documents.' State Papers Online 1509–1714, Cengage Learning EMEA Ltd., 2007.

twenty ranking nodes in *D,* though again only Thomas Cromwell ranks the same, in first place. Along with Anne de Montmorency once more, this overlap includes two others – Captain John Jefson and Thomas Manners, Earl of Rutland – who rank significantly lower in degree and betweenness, and last (105th) in F_1. Though historically less studied than other actors ranking lower across these measures, nodes with high eigenvector and high disruption ranks imply actors that are able to disrupt the paths that surround and are potentially important to influential actors in the network. Identifying actors in such positions may offer possible insight into previously undervalued actors of influence.

Thomas Cromwell and the Tudor Court

Though betweenness centrality offers the most similarity to the fragmentation rankings, none of these three centrality measurements can accurately recreate the results from any of the new measures developed to score and rank cut-points in a network. As a new measure, both fragmentation experiments and disruption thus offer not only a means to identify new nodes of potential interest and importance (such as William Popley, Albert Duke of Mecklenburg, and Thomas Manners, Earl of Rutland), but also act as a lens to round out our understanding of actors' roles in networks that have already been quantitatively or qualitatively identified as significant, on which the remainder of this paper will focus.

This is exemplified in this dataset by Thomas Cromwell, ranking first across all six measures tested in this paper and standing as the most destructive *and* disruptive cut-point in the network. Although, as shown, his function at the core of the Tudor court has long been discussed by historians, these experiments offer a new means to demonstrate the extent of this role. It is not merely Cromwell's top-ranking position that demonstrates his importance in the network, but the raw numbers as well: Cromwell's removal creates 1000 more new components than Henry's, reducing the giant component by more than 40%, and increasing the average path by just under one more than any other cut-point. The extent of destruction that Cromwell's removal as a cut-point would cause in turn indicates the role he held in holding the network together: in fact, arguably, according to these measures, Cromwell was of greater value to the internal operations and functioning of the English court in the 1530s than the king was.

Cromwell's removal from the network amounts to 1,204 nodes unable to remain in contact with the giant component – those who relied on the minister for access not only to the king but to the rest of court and government as well. This represents a large amount of business only in contact with and solely managed by the king's chief minister. To some extent, this relies more on Cromwell's set of surviving correspondence than the overall structure of the network: 1,009 (63%) of Cromwell's incoming correspondents hold a degree score of only one, meaning that they are connected *only* to Cromwell in the network, and are 'lost' without

him.[26] This remains a significant number, however, and it is important to not only acknowledge the volume of contacts lost by Cromwell's removal, but the contents of the correspondence as well. To understand this, a category was manually assigned to each set of letters to Cromwell, in order to quantify the role these correspondents played both in Cromwell's inbox and the wider giant component.

Unsurprisingly, given that they were only communicating with Cromwell, over 50% of these nodes wrote petitions for aid or promotion, or sought patronage from the minister. Whilst the majority of these were generic requests for help, some can be categorized further. Despite the existence of the Court of Augmentations, designed specifically to manage the dissolution of the monasteries, thirty-eight of these letters of petition asked for Cromwell's help to protect a religious house from dissolution, or thanked the minister for his personal intervention, sometimes circumventing Richard Riche in his role as Chancellor of Augmentations. Whilst these perhaps support Cardinal Reginald Pole's depiction of the evil Cromwell seeking to destroy religion in England, sixty-six petitioners wrote to Cromwell in this period to seek promotion in religious offices, and to thank him for his aid in religious intervention and progression, perhaps reflecting a more balanced view of Cromwell's approach to and involvement in religious changes during this period. A further thirty-one people wrote to Cromwell to seek possession of dissolved monastic lands, both as secular petitioners and former members of these monastic houses. This speaks to Cromwell's assumed role as being in charge of the dissolution of the monasteries, as well as his – clearly well-known – experience with managing lands.

This management of lands, so important in his early years serving under Cardinal Thomas Wolsey, is further reflected in the forty-seven petitions for aid with other types of secular land disputes, whilst another eighteen wrote to discuss specific legal issues or wrote from prison seeking aid. A further fourteen wrote to Cromwell in the hope that he would settle expenses still owed to them by the king, reflecting Cromwell's control over the crown's purse strings. It is interesting to note that of these petitioners, eighty-two are female writers, sixty-five of whom sought Cromwell's help outside of monastic or religious problems. Many were in fact widows, seeking to keep their former land or possessions without the protection of their husband, painting an interesting – and perhaps overlooked – image of the minister as a defender of ill-disposed women, both at court and beyond.

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26 To some extent this supports arguments that Cromwell only holds importance in the network because the State Papers are predominantly made up of his letters; as I have argued elsewhere, however, this is not the case, and the State Papers are an amalgamation of overlapping collections, within which Cromwell is simply the most important. Caitlin Burge, 'Mapping the Archives: Epistolary Networks and the State Papers of England, 1523–1540', International Journal of Humanities and Arts Computing (IJHAC) vol. 18, no. 1 (2024): pp. 95–108.

Whilst some of these petitioners looked to Cromwell to intercede with Henry, many acknowledged Cromwell's role as a patron as separate from that of the king's and sought his aid as an individual of influence and legal knowledge. These petitioners and patronage seekers, whilst interesting case studies for Cromwell's role in aiding those in different forms across the country, do not speak to a wider loss in the administrative effectiveness of the main component, nor would they have drastically impacted the king's relationships, and perhaps reflect the topics that would be expected to be lost with the removal of any central node in the network.

In contrast, the remaining portion of these lost contacts represent a more significant issue for court, governance, and information gathering. Over 400 of these lost correspondents sent reports to the minister, often responding to explicit instructions from Cromwell and the king and sharing important information about governance across the country and further abroad. Again, these can be broken down into smaller categories. Seventeen discussed Irish affairs and twenty-eight were from foreign agents outside of official ambassadorial roles. A further seventy-nine reported specifically to Cromwell on religious dissention across the country, both from officials in the role and other individuals seeking to inform on neighbors and local priests. Again, despite the Court of Augmentations, eighteen of these reports referenced visitations to monasteries, addressed to Cromwell alone. As they supplied important information, these correspondents would represent a real loss to court administration and Henry's intelligence gathering in the network. The wealth of these writers, communicating – at least in surviving material – only with Cromwell, speaks not only to the supposed network of informants that Cromwell had both at home and abroad, but emphasizes the extent to which this relied on and was built around Cromwell alone.[27] Though in many of these cases – as with religion, the monasteries, and foreign affairs – there were other avenues of communication explicitly set up to manage this information, their exclusive relationship with Cromwell establishes the minister's pivotal role in the network and at court.

In reality, the damage done by Cromwell's removal depicts the substantial growth of the network by virtue of his own administrative work. This work may also be responsible, in turn, for the remaining robustness of the core component. Where the number of nodes remaining in the giant component – and their connectedness – are reduced significantly by Cromwell's removal, it indicates the

27 For Gary Schneider and Seth Lerer, Cromwell's primary objective was to create a spy system, the scheme of a "man charged with procuring information on dissent;" instead, however, this intelligence network reflects Schneider's own argument that "in general, the exchange of news was a duty, particularly in political administration and in patron-client relationships." (Seth Lerer, Courtly Letters in the Age of Henry VIII: Literary Culture and the Arts of Deceit, (Cambridge: Cambridge University Press, 1997), 98; Schneider, Epistolarity, 40; 153).

extent to which he conducted business through himself, independent of official means. That the main component remains able to communicate, however, implies an administrative system that was able to function without Cromwell, as the minister had designed. The removal of these influential nodes still leaves other foreign monarchs and ambassadors, but also the Privy Council and its members, including Thomas Cranmer, William Fitzwilliam, and Thomas Audley. This is not to say, of course, that all the remaining letters and edges in the network were focused solely on court administration; however, the network still evidences a robust – if diminished – main component of correspondents able to continue without the leaders and hubs. This robust main component in some ways reflects the centralization of court by the early Tudor monarchs, who sought to bring security to their legacy after decades of fragile reigns. More importantly, however, it offers early indications of Cromwell's administrative plans, both in the work he did himself and the administration he created. Elton was correct, then, to suggest that Cromwell orchestrated court management through himself and his personal office, and that this personal control was unmatched by anyone else in the 1534–1540 network, although given the relative stability of bureaucracy in this period, Cromwell's removal would not have been a complete administrative failure. But by dominating the network in such a way and ensuring that such a large proportion of correspondents looked to the minister as an intermediary, Cromwell established a sense of reliance on his administrative skills and network contacts, cultivating influence and power.

Conclusion

Cromwell's rankings as the most impactful cut-point may come as little surprise to Tudor historians or, indeed, to members of the Tudor court, and these measures go far towards supporting Elton's account of the chief minister as the "unifying factor" of the Tudor court, in itself a valid and sometimes overlooked act of the digital humanities.[28] It also offers a better understanding of his role in the epistolary structure and the potential impact of his removal, introducing more complex and interesting layers to the cut-point construct. Yet in 1540, Cromwell's removal from the network changed from a 'what-if' to a reality. The test network designed to model Cromwell's impact as a cut-point is not merely a hypothetical, then, but a prediction of the potential network in the 1540s. As Ahnert *et al.* have argued, "the predictive power of networks is a new horizon for cultural studies. In general, we tend to study artefacts or practices that are already in existence."[29] Understanding the ways in which modelling cut-point removals can offer insights into potential points of weakness in a network can be significant not only for historical studies, but may have wider ramifications for contemporary structures and organizations as well.

28 Elton, Tudor Revolution, 223.
29 Ahnert et al., Network Turn, 31.

Importantly, however, cut-points offer a fresh way to investigate specific roles in social networks. By designing measures that can distinguish impactful cut-points from those that are limited in their abilities to significantly destabilize communication in the network, these experiments not only advance the usefulness of cut-points as indicators of importance, but offer a means to establish actors of structural importance in more developed and nuanced ways across historical and social networks. Comparing measures that are able to rank the impact of removal in terms of fragmentation and disruption against more commonly used proxies for importance – betweenness, degree, and eigenvector – demonstrates that whilst the most impactful cut-points tend to also rank highly in these centrality measures, they are not the same and, most importantly, establishes the value of designing these new measures to concretely quantify this as a different quality.

Finally, this article not only seeks to evaluate the role of cut-points in a network, but also to demonstrate how this can be fruitfully used as part of a historical case study and 'translate' social network theories into applicable and re-usable code that is accessible to the wider and less experienced digital humanist research community. In doing so, it looks to promote how quantitative methodologies can formalize qualitative theories and offer new frameworks of understanding structural significance in historical networks.

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All custom-written code and the data for the experiments in this paper can be found at https://gitfront.io/r/user-8399541/J6jRC6PpHWAM/CutPoint/.

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