



City Research Online

City, University of London Institutional Repository

Citation: Sathiyarayanan, M., Turkay, C. ORCID: 0000-0001-6788-251X and Fadahunsi, O (2018). Design and Implementation of Small Multiples Matrix-based Visualisation to Monitor and Compare Email Socio-organisational Relationships. 2018 10th International Conference on Communication Systems & Networks (COMSNETS), pp. 643-648.

This is the accepted version of the paper.

This version of the publication may differ from the final published version.

Permanent repository link: <https://openaccess.city.ac.uk/id/eprint/21111/>

Link to published version:

Copyright: City Research Online aims to make research outputs of City, University of London available to a wider audience. Copyright and Moral Rights remain with the author(s) and/or copyright holders. URLs from City Research Online may be freely distributed and linked to.

Reuse: Copies of full items can be used for personal research or study, educational, or not-for-profit purposes without prior permission or charge. Provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way.

City Research Online:

<http://openaccess.city.ac.uk/>

publications@city.ac.uk

Design and Implementation of Small Multiples Matrix-based Visualisation to Monitor and Compare Email Socio-organisational Relationships

Mithileysh Sathiyarayanan
City, University of London, UK

Cagatay Turkey
City, University of London, UK

Odunayo Fadahunsi
City, University of London, UK

Email: Mithileysh.Sathiyarayanan@city.ac.uk Email: Cagatay.Turkey@city.ac.uk Email: Odunayo.Fadahunsi.1@city.ac.uk

Abstract—One of the fundamental organisational questions is how organisations identify anomalies, monitor and compare email communications between staff-staff or staff-clients or staff-customers relationships on a daily basis. The tenacious and substantial relationships are built by the combination of timely replies, frequent engagement and deep interaction between the individuals. To watchdog this periodically, we need an interactive visualisation tool that can help organisational analysts to reconnect some lost relationships and/or strengthen an existing relationship or in some cases identify inside persons (anomalies). From our point of view, Social Intelligence (SI) in an organisation is a combination of self-, social- and organisational-awareness that will help in managing complex socio-organisational changes and can be interpreted in terms of socio-organisational communication efficacy (that is, one's confidence in one's ability to deal with social and organisational information). We considered a case study, an Enron Organisation Email Scandal, to understand the relationships of staff during various parts of the years and we conducted a workshop study with legal experts to gain insights on how they carry out investigation/analysis with respect to email relationships. The outcomes of the workshop helped us develop a novel small multiples matrix-based visualisation in collaboration with our industrial partner, Red Sift UK, to find anomalies, monitor and compare how email relationships change over time and how it defines the meaning of socio-organisational communication efficacy.

Index Terms—Email Communication; visualisation; social networks; anomaly detection; temporal features; D3;

I. INTRODUCTION

Though there are many social and professional networking sites such as Facebook, Twitter and LinkedIn, Organisational email communication is ubiquitous and is used in building business relationships and communication with partners and clients. Socio-organisational networking is rapidly evolving and profoundly changing the way people communicate and interact on a daily basis in an organisation setting [1]. This helps in building a strong business by improving communication between globally dispersed partners, clients and customers, and even measuring scientific impact. Although organisations solely depend on email system for business communication and have formed their own communication networks, email systems and/or web interfaces do not provide effective visualisation to quickly understand relationships between staff-staff or staff-clients or staff-customers. Especially, considering Social Intelligence (SI) in an organisation which is a combination

of self-, social- and organisational-awareness that will help in managing complex socio-organisational changes and can be interpreted in terms of socio-organisational communication efficacy (that is, one's confidence in one's ability to deal with social and organisational information) needs watchdogging. So, to find anomalies, monitor and compare various individuals relationships, and to explore characteristics of the socio-organisational communication have become increasingly challenging due to inextricable communication with the clients or customers over time. There are few email visualisation tools developed to visualise relationships between staff in an organisation but most do not consider the issue of effectively exploring interpersonal relationships from a single staff perspective.

Motivating Fictitious Example. Individuals in an XYZ organisation are connected with and have influence on each other. Discovering the strength of connections and how many emails individuals have sent/received between each other can help identify strong ties (i.e., people with high influence relationship). Stronger influence relationships can provide clue about information being transmitted. For instance, if a staff named Robin is influenced by his colleague Tom on 'Project 1' aspect and influenced more by his colleague Jack on 'Project 2' aspect, then Robin, Tom and Jack need to be investigated on a daily basis. If the emails sent/received are based on the organisation's development point of view, then it is good to foster more strong relationships between the individuals else if the project information are leaked, then the case has to be reported at the earliest.

Motivating Real Example. According to 2015 BBC report ¹, Tesco, a UK retailer suffered a big annual loss of £6.4bn and had to shut down many of the stores. They are one of the best when it comes to products, services and customer support. Unfortunately, the loss could have been as a result of a number of reasons, for example: Tesco has not kept up with competition in terms of their business strategy, non-clear communication and a minimal interference with the stores, and a problem of delivering products on time. From the various online articles, we understood one of the important factor is, non-clear communication within the department and external

¹<http://www.bbc.co.uk/news/business-32408661>

contacts led to the loss. Since, there are no tools to investigate individuals email communication patterns on a daily basis, we aim to exploit this space and develop a tool.

Email Socio-organisation Challenges. As the email data keeps increasing on a daily basis, one of the interesting question to be addressed in a socio-organisation communication is “How to establish a comparative visualisation in emails to understand individuals relationships over time in an organisation?”. As we know, email communication is used in building business relationships and communication with partners and clients, and this socio-organisational networking has evolved rapidly and transformed the communication world. To improve staff-staff or staff-clients or staff-customers relationships over time and to improve business, there is a pressing need for having an effective visualisation to compare individuals relationships over time.

Context. Email visualisation with interactions will enable an analyst to explore and understand the quantitative and qualitative features of the underlying data. Unravelling patterns of interactions will help to identify socio-organisational relationships in an organisation and will offer insights to formulate future action plans based on the visual and text results. Including interactions in the visualisation will provide a handy mechanism to handle massive and complex data to understand, explore data and make decisions. Our goal is to conduct workshops and develop a visualisation tool to detect the expected and discover the unexpected patterns in the data, and provide insights to the development of organisations.

Contributions. Our previous works on set visualisation for social networks have been part of COMSNETS series. Our work on socio-organisational email visualisation is a fundamental improvement from its conference poster version [2] and other other conference presentations [3],[4],[5],[6]. The paper contribution includes:

- 1) A real case study (Enron Fraud Case) was considered and workshops were conducted to understand analysts requirement in comparing relationships evolving over time. The Enron data itself, while well structured, is not easy to break down or represent in an human understandable or readable manner. This is a complex dataset, but the presented approach breaks down the data in a year over year format to make the data extremely manageable in order to study for insights.
- 2) Anomaly detection in social communication data is an important and a difficult problem. Various design sketches were considered to improve staff relationship analysis based on the case study and workshop outcomes.
- 3) After numerous iterations, small multiples matrix-based visualisation was proposed to watchdog staff relationships evolving over time in an organisation.

Paper Layout. The next section (Section II) is the related work which describes email visualisations developed till date including node-link diagrams and matrix-based diagrams. Section III is the preliminary work we conducted so far and explains the outcome of the workshops. Section IV describes

the small multiples approach in generating matrix-based visualisations. Section V concludes by considering future works.

II. RELATED WORK

Email Visualisations. There are many email visualisations developed by various researchers, but each has its own drawbacks, such as inconsistency, complexity and not very powerful tool for email monitoring and comparison of individuals in an organisation. Some of the well-known ones are EmailMap [7], EmailTime [8], EzMail [9], Re-mail [10], Themail [11]. From email organisation analysis point of view, relationships in email networks can be visualised using a node-link diagram or a matrix-based diagram to understand underlying information. There are drawbacks in both the diagrams and comparing them is not very easy because they are each subject to a variety of representation parameters with respect to socio-organisational relationships (that is, individuals email relationships). There are a very few research carried out in the field of email networks in organisations and they are mainly focused on analysing the clustering and density on an email network by visualising relationships between individuals and some metrics are available to compare graph layouts based on time.

Node-Link Diagrams. The most common depiction of socio-organisational relationships are through node-link diagrams (sometimes called as network diagrams or graphs). The email network can be visualized in terms of a node-link diagram to understand relationships information using nodes and links. The node represents each individual in the email network, and the link expresses a relationship between the nodes and visualises a characteristic of the email network. There are many papers related to graphs and their tools but we are restricting to email communication.

The positives are: compact and effective for small graphs and sparse graphs, not very difficult to identify cluster structures.

The drawbacks are: nodes overlap, edges cross, nodes are not always distinguishable, non-sequential way of representation, poor readability for large and dense graphs, manipulation is not easy, navigation is not very easy, poor graph layout, problems with nodes depiction and ordering, visual clutter as graph grows big, scalability, poor aesthetics, cognitive load on analysts, and difficult to interpret and compare relationships over time.

Matrix-based Diagrams. To visualise relationships between individuals and considering various drawbacks of node-link diagram, researchers introduced matrix-based diagram (sometimes called as connection matrix, adjacency matrix, reorderable matrix, co-occurrence matrix, or heatmap matrix). These diagrams can give information about the relationship, such as its strength, the roles played by various individuals and/or measurements. From email networks point of view, the relationships information can be visualised using matrix representation in the form of squared cells and with a dedicated matrix axes and cells where the nodes are ordered appropriately and the edges are represented with a coloured cell within

the matrix. This kind of representation helps in visualising a characteristic of a email network effectively.

The positives are: nodes are distinguishable, nodes have a dedicated matrix axes and cell, nodes depiction and ordering are easy, sequential representation, good linear form of layout, scalable, better aesthetics, no visual clutter, better readability, manipulation is easy, navigation is easy, easy to identify cluster structures and other patterns, and easy to interpret and compare relationships over time.

The drawbacks are: layout space is not compact for large graphs, and edges depiction are slightly difficult which might involve a little bit of cognitive load/effort on analysts.

III. PRELIMINARY WORK

Case Study. We considered Enron [12] scam as a case study for investigating emails exchanged between top executives. In just 15 years, Enron grew into one of America's largest company, employing 21,000 staff in more than 40 countries which later entered into a scam. Enron produced fake profit reports and company's accounts. As the depth of the deception unfolded, the firm went into bankruptcy in 2001 December. Most of the top executives were involved in the scam, as they sold their company stock prior to the company's downfall. Lower-level employees were prevented from selling their stock due to various restrictions and many subsequently lost their life savings. The emails exchanged between top-level and lower-level employees are publicly available to access. In our work, we used the Enron data as a test case for the design process.

Workshop. Based on the existing case study, we conducted a workshop with a legal team of six solicitors in Bangalore, India. In the workshop, we aimed at focussing "How do analysts/investigators gain insights from large and complex email data to understand individuals relationships?". In an effort to better understand, we collected suggestions, comments and feedbacks from the legal team, the Enron case was unveiled and couple of questions were presented to understand the general and specific requirements:

- 1) How will you investigate on the key players involved and their relationships (e.g. Enron case)?
- 2) How will you detect individuals relationships over time and on a daily basis?

From the workshop, we summarised the specific and general requirements of the solicitors for developing an information-rich email visualisation. They are as follows:

Specific Requirement(s). The solicitors are looking for a simple interactive tool that can help in finding anomalies, monitoring and comparing individuals email relationships on a daily basis. One of the important question was raised, "Are there any other visualisations other than node-link diagrams that can help in visualising individuals relationships?". This helped us exploit matrix-based diagrams.

General Requirements. The solicitors general requirements are very common to other workshops being conducted by various other researchers in various fields where visualisations are being used and they are as follows: Visualisations must be

- 1) simple, easy to use and quickly accessible

- 2) easy to understand, explore, search, detect and analyse
- 3) visually appealing (i.e. visual perception), readable and help in thinking (i.e. cognition)
- 4) a means to discover and understand investigative stories, and then to present them to others.
- 5) interactive and user-friendly (avoid animations/3D)
- 6) patterned well (aesthetically pleasing, simplified and systematically organised)
- 7) effective for displaying relationships and comparisons
- 8) easy to predict trends/future (to some extent).
- 9) presented with some visual cues about what to consider and what not to (temporal cueing).
- 10) time-saving (large amounts of search must be avoided)

The case study and the workshop outcomes helped us come up with various design sketches and we had several prototype iterations.

Design Sketches. After understanding the email socio-organisation challenges, case study, specific and general requirements of the solicitors, we came up with various paper sketches which will help analysts in investigating email communication relationships. We went through several iterations and had discussions with our industrial partner, Red Sift in London, to inform our design process.

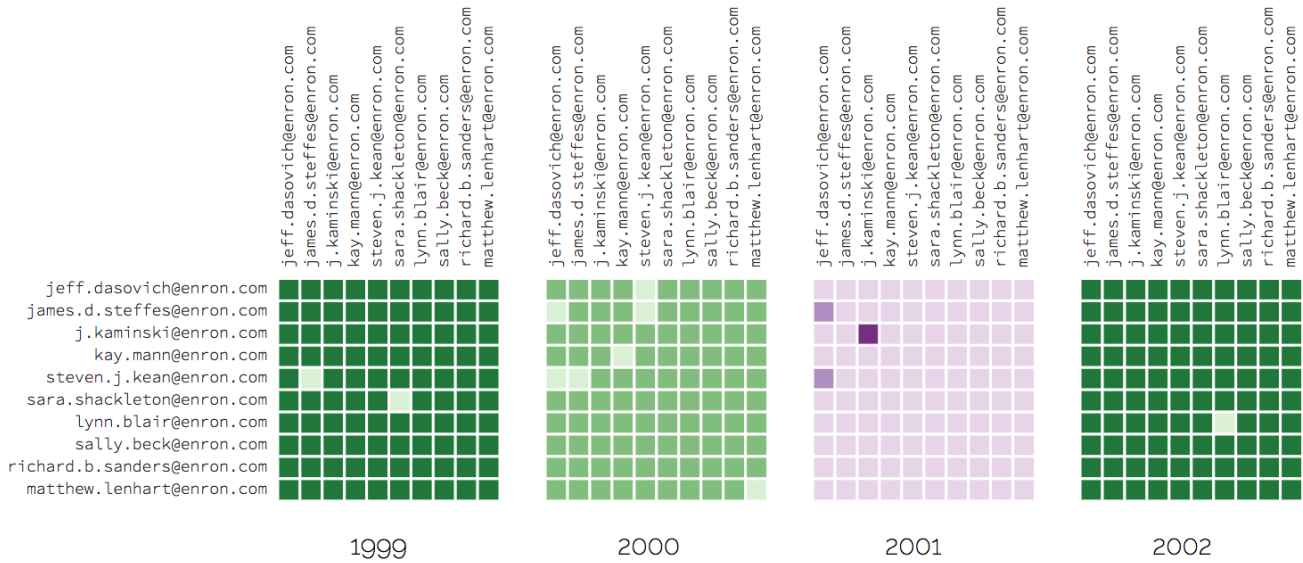
Prototype Iterations. We considered data-driven documents (D3) which is a JavaScript library for visualising data using web standards. This allows us to get full control of the web browsers and the freedom to design various visual interfaces that will be based on the data and fit the need of the users. So, based on the workshop insights, we developed D3 prototypes (discussed below).

IV. SMALL MULTIPLES MATRIX-BASED DIAGRAM

We considered small multiples approach using matrix-based diagrams established on the specific and general requirements of the solicitors. The reasons for using it in our work are explained below.

Design Approach.

Small multiples (sometimes called as trellis chart, lattice chart, grid chart, or panel chart) are a set of similar design or graphs or charts using the same scale and axes to display difference slices of a dataset and allowing them to be easily compared in horizontal and/or vertical direction (multiple views). The term was effectively used by Edward Tufte [13]. Small multiples are preferred because they can represent complex, multi-dimensional data into a simple comparison chart. For a wide range of problems in data comparisons, small multiples are one of the good design solution. In general, small multiples charts must be simple and have some logical order (for example, based on time) and must share the same measures, scales, size, and shape which will help analysts/users to quickly find the charts that are interesting to them and be able to process information across many of these charts. Allegedly, small multiples approach is used in plots, bars, lines and maps. In our work, we are using small multiples with matrix charts to visualise differences between them.



Select the year

- 2002
- ✓ 2001
- 2000
- 1999

Select 10 Individuals of Interest

- jeff.dasovich@enron.com
- james.d.steffes@enron.com
- j.kaminski@enron.com
- kay.mann@enron.com
- steven.j.kean@enron.com
- sara.shackleton@enron.com
- lynn.blair@enron.com
- sally.beck@enron.com
- richard.b.sanders@enron.com
- matthew.lenhart@enron.com



Select 10 Words of Interest

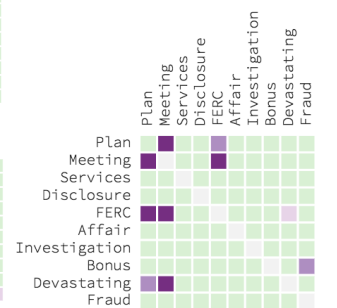


Fig. 1. Small Multiples Matrix-based Diagram representing Enron company's individuals email relationships

Matrix-based diagrams are a closely packed small squares (cells) arranged in a horizontal and vertical direction forming a big square or a rectangular shape. These diagrams have a dedicated matrix axes and cells where the nodes are ordered appropriately and the edges are represented with a coloured cell within the matrix. Matrix-based diagrams help in visualising relationships between nodes. The diagrams helps in nodes and edges depiction easily and aids in fast navigation to quickly interpret and compare relationships over time.

Small multiples matrix-based diagram are a matrix-based diagrams represented in a small-multiples form. In email communication analysis, individuals relationships changes very quickly over time, resulting in the need for dynamic graph visualisation supporting fast exploration of data. Dense graphs cannot be visualised quickly, especially using node-link diagrams. From the preliminary work, we use matrix-based diagram in small multiples form which facilitates the comparison of relationships/clusters/patterns over time. This helps in finding anomalies and monitoring the “growth of email communication between individuals”.

Why small multiples approach? Small multiples can represent complex, multi-dimensional data into a simple comparison chart which is generally a good solution as they are used with plots, bars, lines and maps. As a novel approach, we are using matrix charts to visualise differences between them.

Positives and Drawbacks. Small multiples are used in displaying many variables with less risk of confusing users/analysts, enable comparison across variables and reveal the range of potential patterns in the charts with less cognitive efforts. There are some possibilities of misinterpretations caused due to visual comparisons of sub matrices in different blocks. In general,

- Helps in comparing individuals relationship
- compare changes over time
- compare changes across different groups
- comparison (within) in comparison (between)

Advantages of Small Multiples

- 1) Increased productivity
- 2) Flexibility
- 3) Easy to compare
- 4) Easy to understand patterns
- 5) Easy to browse and navigate

Disadvantages of Small Multiples

- 1) Potential for distraction
- 2) Can take considerable space though individual charts are being small.

The uses of Small multiples are as follows [14]:

- Informs the steps involved in a comparison task analysis
- Creates a narrative visual story (storytelling) [15]
- Creates a copacetic presentation
- Visual elucidation of cardinal/ordinal relationships
- Visual elucidation of cordial relationships
- Visual elucidation of rhetorical relationships
- Visual elucidation of temporal, non-temporal/non-spatial, and/or spatial relationships [16]

- Visual elucidation of adjacency, patterns, comparisons, associations and trends
- Visual elucidation of dynamics
- Visual identification of anomalies

Visualisations were developed by collaborating with the company, Red Sift UK and they provided a core infrastructure required for the research work and the only need was to focus on the actual email visualisation and interaction models using D3 JavaScript library. Red Sift company is enabling smart decision making in email communication by delivering actionable insight from emails. As a preliminary method, Enron email archive (real dataset) was set-up in the Red Sift platform and the user requirements for individuals emails were prepared. We developed the matrix-based visualisation using D3 for visualising email relationships.

Validation. In this analysis, we considered Enron company’s top individuals’ email communication (relationship), based on the literature [17], they are Jeff.Dasovich, James.D.Steffes, J.Kaminski, Steven.J.Kean, Sara.Shackleton, Lynn.Blair, Sally.Beck, Richard.B.Sanders and Matthew.Lenhart@enron.com. Different set of individuals can be selected and dragged in for comparison. As mentioned earlier, the small multiples matrix-based diagram was developed using D3 library. The Fig.1., linear small multiples, represents manually selected individuals’ email communication (relationship) from 1999 to 2002. The year 1999 was considered as a baseline for comparison to compare the rest of the years – the baselines can be changed based on users’ interest – we considered the year 1999 since the data is available from this point of time. The diverging colours (dark green to dark purple) help users/analysts to compare relationships between the years. Dark green represents “low-level communication” and dark purple represents “high-level communication”. So, from the Fig.1.(above), the year 2001 is of interest (as most of the connections were involved). The visualisation allows user to select a particular year for comparing individuals’ relationship over the months, which are in small multiples matrix form spread in horizontal and vertical direction - as shown in the Fig.1.(below). Since the year 2001 is of interest, this is considered as a baseline for comparison to compare each of the month in the year 2001. That provides signals that are of interest. Interestingly, we identified, inside persons in their organisation (Jeff and Kaminski), many individuals had self cc’d emails (anomalies) and other relationships were confirmed based on the available reports and literature [17].

Furthermore, we conducted analysis on the words exchanged between the top individuals selected (again based on the literature [17]). We identified Plan, Meeting, Services, Disclosure, FERC, Affair, Investigation, Bonus, Devastating and Fraud (extracted these words using Python code). The matrix view gives the combination of words being used by the selected individuals demonstrating the socio-organisation of the company. The small multiples matrix-based visualisation helps in email communication analysis, find anomalies, monitor and compare socio-organisational changes in individuals

over time. Thus, the design is useful to the best of our knowledge. The examples/evidences of using our approach and further discussions with the organisation experts helped us demonstrate the usefulness of using small multiples matrix-based visualisation.

V. CONCLUSION AND FUTURE WORKS

Forefront. Generally, an email organisation network (aka professional network) is a socio-organisational structure between individuals who are connected by a set of relationships, such as friendship, collaborations, co-working and etc. Based on the case study and the workshop outcomes for finding anomalies, monitoring and comparing individuals email relationships in an organisation over years and months, small multiples matrix-based diagrams were developed by collaborating with the company, Red Sift UK using D3 JavaScript library and Enron email archive to understand the growth of individuals email relationships such that it will help organisations to re-connect some lost relationships and/or strengthen an existing relationship or in some cases identify inside persons. As we know, Social Intelligence (SI) in an organisation can be interpreted in terms of socio-organisational communication efficacy and through our visualisation.

Furthermore. We have some interesting goals to be achieved in the next few months by collaborating with the Red Sift company in London.

The short-term goal is to introduce more interactions for easy navigation which will help analysts to order matrices based on email frequencies, size and alphabetical order of individuals. The visualisation can be further extended to drill down relationships comparison to weeks, hours and parts of the day. The proposed system is not completely scalable, the approach can only be applied to a small subset of employees. However, for a large subset of employees, the individuals can be broken down into departments they work in an organisation. We will be developing a well tested automated method using different email datasets. We aim to carry out further workshops and empirical studies (comparisons with existing work) with organisations and legal experts to get more insights and improve the current version.

The long-term goal of the research is to develop right methodologies to unravel the “interesting” information within email data. We aim to find “interesting” structures by integrating node-link and matrix visualizations [18]. The challenging tasks will be delivered by considering visual analytics and algorithm analysis in combination which will be highly useful in the Electronic Discovery (E-discovery) domain. In this domain, electronic data from emails, Google chats, Facebook chats and other social media chats can use our visualisation tools with an intent of using it as evidence in legal cases or help organisational analysts to re-connect some lost relationships and/or strengthen an existing relationship or in some cases identify inside persons in their organisation [19],[20],[21].

ACKNOWLEDGMENT

We would like to thank Rahul Powar and Randal Pinto of Red Sift Research for their insightful comments and enlightening us with their corporate knowledge and supporting us by funding. We would also like to thank people from the giCentre, City, University of London, UK for their timely guidance.

REFERENCES

- [1] C. R. Seal, R. E. Boyatzis, and J. R. Bailey, “Fostering emotional and social intelligence in organizations,” *Organization Management Journal*, vol. 3, no. 3, pp. 190–209, 2006.
- [2] M. Sathiyarayanan and C. Turkay, “Design of small multiples matrix-based visualisation to understand e-mail socio-organisational relationships,” 2017.
- [3] M. Sathiyarayanan and C. Turkay, “Is multi-perspective visualisation recommended for e-discovery email investigations?” 2016.
- [4] M. Sathiyarayanan and C. Turkay, “Determining and visualising e-mail subsets to support e-discovery,” 2016.
- [5] M. Sathiyarayanan and C. Turkay, “Challenges and opportunities in using analytics combined with visualisation techniques for finding anomalies in digital communications,” 2017.
- [6] M. Sathiyarayanan, “Improving visual investigation analysis of digital communication data within e-discovery,” 2017.
- [7] S. J. Luo, L. T. Huang, B. Y. Chen, and H. W. Shen, “Emailmap: Visualizing event evolution and contact interaction within email archives,” in *Visualization Symposium (PacificVis), 2014 IEEE Pacific*. IEEE, 2014, pp. 320–324.
- [8] M. E. Joorabchi, J.-D. Yim, and C. D. Shaw, “Emailtime: Visual analytics of emails,” in *Visual Analytics Science and Technology (VAST), 2010 IEEE Symposium on*. IEEE, 2010, pp. 233–234.
- [9] M. Samiei, J. Dill, and A. Kirkpatrick, “Ezmail: using information visualization techniques to help manage email,” in *Information Visualization, 2004. IV 2004. Proceedings. Eighth International Conference on*. IEEE, 2004, pp. 477–482.
- [10] S. L. Rohall, D. Gruen, P. Moody, and S. Kellerman, “Email visualizations to aid communications,” in *Proceedings of InfoVis 2001 The IEEE Symposium on Information Visualization, IEEE*, vol. 12, 2001, p. 15.
- [11] F. B. Viégas, S. Golder, and J. Donath, “Visualizing email content: portraying relationships from conversational histories,” in *Proceedings of the SIGCHI conference on Human Factors in computing systems*. ACM, 2006, pp. 979–988.
- [12] B. Klimt and Y. Yang, “The enron corpus: A new dataset for email classification research,” in *Machine learning: ECML 2004*. Springer, 2004, pp. 217–226.
- [13] E. R. Tufte, “Envisioning information,” *Optometry & Vision Science*, vol. 68, no. 4, pp. 322–324, 1991.
- [14] D. B. Stringham, “The efficacy of small multiples in the visual language of instructional designs,” 2012.
- [15] R. Kosara and J. Mackinlay, “Storytelling: The next step for visualization,” *Computer*, no. 5, pp. 44–50, 2013.
- [16] M. Farrugia, N. Hurley, and A. Quigley, “Exploring temporal ego networks using small multiples and tree-ring layouts,” *Proc. ACHI*, vol. 2011, pp. 23–28, 2011.
- [17] C. W. Thomas, “The rise and fall of enron,” *Journal of Accountancy*, vol. 193, no. 4, p. 41, 2002.
- [18] A. Abuthawabeh, F. Beck, D. Zeckzer, and S. Diehl, “Finding structures in multi-type code couplings with node-link and matrix visualizations,” in *Software Visualization (VISSOFT), 2013 First IEEE Working Conference on*. IEEE, 2013, pp. 1–10.
- [19] M. Sathiyarayanan and N. Burlutskiy, “Design and evaluation of euler diagram and treemap for social network visualisation,” in *Communication Systems and Networks (COMSNETS), 2015 7th International Conference on*, Jan 2015, pp. 1–6.
- [20] M. Sathiyarayanan and T. Mulling, “Wellformedness properties in euler diagrams: An eye tracking study for visualisation evaluation,” in *Human Factors in Computer Systems (IHC), 2015 14th Brazilian Symposium on*, Nov 2015.
- [21] M. Sathiyarayanan and T. Mulling, “An eye tracking study on the wellmatchedness principles in euler diagrams,” *Journal of Usability Studies*, 2015.