

APPLYING SOCIAL NETWORK ANALYSIS TO DESIGN PROCESS RESEARCH, A CASE STUDY

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Abstract. This paper presents a novel approach to analyse design project development demonstrated within a collaborative design case study. We present the limitations of the existing protocol-based design process analysis in analysing real design scenarios. Taking a complete set of regular meeting notes from a design project, the study translated the record of design discussions and decisions into a decision network. We then selected three Social Network Analysis (SNA) methods to apply to the network to analyse different aspects of the project development. Degree, betweenness and clustering focused on three different resolutions of the design process, offered quantitative ways to analysis and visualise the design decisions in both short term as well as over the whole design process.

Keywords. Social Network Analysis (SNA); data visualisation; tool development.

1. Introduction

The process of design in the built environment progressively becomes a more collective team effort, combining expertise from specialist designers and technical consultants (Spence et al 2001). It is vital that we understand what occurs during these collaborations so we can better support the change in the design practise of today.

Unveiling the cognitive process of collaborative design has been the focus of much scholarship. Protocol analysis, first applied to design processes by Eastman in 1968, was applied to collaborative design in the well-known 1995 Delft Protocol Workshop (Cross et al 1996). Classification of the protocol into a series of "design moves" and design reasoning "links" quantifies

the design process into a format for static analysis and visualisation, a method coined as Linkography by Goldschmidt in 1990. Kvan and Gao (2006) applied Linkography to protocols from collaboration in three different design settings.

A major shortcoming of the standard Protocol Analysis is that it is inaccessible for a real world design scenario. A comprehensive Protocol Analysis requires extensive observation including a complete transcript of interaction between members and detailed observation notes, making it difficult to apply to design processes that are more than a few hours long. For design scenarios of long durations researchers need an alternative data source and -analysis method that is practical.

One common practice in collaborative projects is the recording of minutes during team meetings. If the team meets regularly and minutes are recorded consistently, then it is fair to assume a complete set of meeting minutes contains the essential design decisions made throughout the project.

We propose a novel approach to examining the design process by extended the standard Linkography analysis to include parameters from Social Network Analysis (SNA). We will demonstrate this with a case study. We suggest that the selection of SNA methods and visualisations can give insights into different aspects of the collaborative activity such as idea convergence (Figure 3), critical discussion identification (Figure 6) and topic clustering (Figure 7).

In this paper we will first present the case study. The results from a careful selection of SNA methods will then be discussed in the context of design development. We will also speculate on ways to integrate SNA methods into the design process to inform design decision-making.

2. Case Study

A multi-disciplinary team was assembled to tackle a trans-disciplinary design problem: to prepare a design workshop that investigates an environmental phenomenon through digital and physical simulation. The set of meeting minutes used in the study documented the project discussions and decisions from the four months of weekly team meetings, covering the project development and delivery stage. The meeting items were reviewed for associations across consecutive meetings; each association was identified as a link and is stored into a database for further analysis.¹

There were 385 links extracted from the 206 items across the 15 meetings. The Goldschmidt Linkography representation is presented in Figure 1. This set of links had the link index of 1.87.

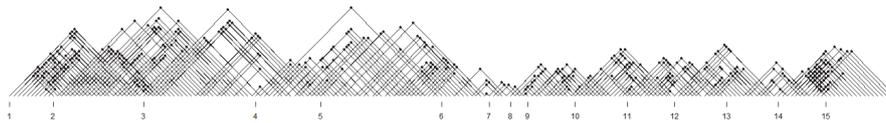


Figure 1 Linkography representation

As the items were naturally grouped into meetings and links were only considered across consecutive meetings, Figure 2 represented the items in 2D and mapped the link information accordingly.

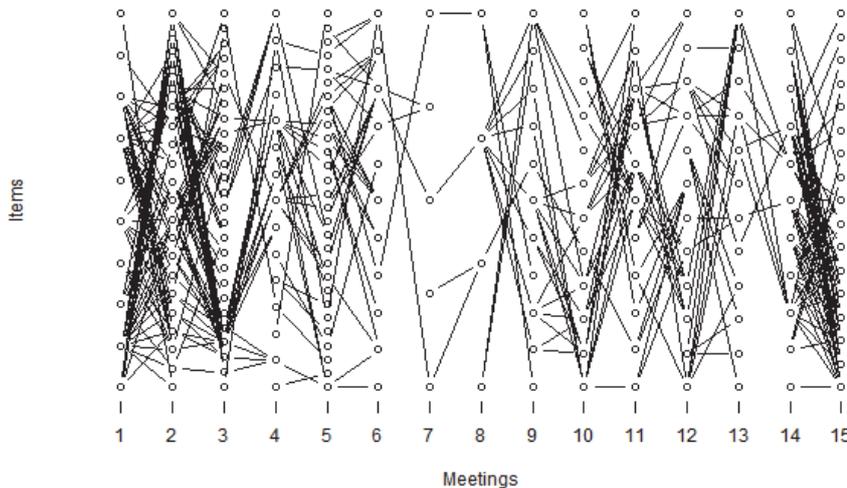


Figure 2 2D link representations

If we observed only the Linkography, it was easy to draw the conclusion that the project had two phases that divided at Meeting 7 or 8. Looking at the 2D network representation it became clear that this appearance was the result of having fewer items discussed during these two meetings. There were no Linkography "chucks" observed from our case study; this could be explained that all the links were only recorded across meetings thus not possible to observe large sections with little overlapping. This nature of the links meant it was also not possible to observe "sawtooth track". "Webs" could be observed between meeting 1-2, and 14-15, but from the 2D network we could see that there were also a concentration of links between Meetings 2-3, which was less obvious from the Linkography representation.

From the above comparison we could see the limitations of the Linkography method to analyse the discrete sets of meeting items. For this we proposed to introduce quantitative methods from SNA into the design process research.

3. Application of the SNA measures

SNA is a branch of Network Science, which considers the discrete objects as social entities (nodes) and focuses on the relationship between the objects. In context of this case study we defined the meeting items as *nodes* and the identified associations of the items across consecutive meetings as the *links*. We have applied a selection of SNA methods and measures² to the meeting item association dataset. These measures covered analysis over multiple scales, from the local node level to the global-network level.

3.1. DEGREES

Degree is the number of links that belong to each node; it is a measure of the local connectivity of the node. For a directional network, the distinction can be made from in-degree (number of direct links that arrive at a node) and out-degree (number of links that are originated from a node). In the context of our study, the degree measure gives indication of how an item is explored between two meetings. To enable the measures from different meetings to be comparable, the definition degree values were normalised by the number of items in the corresponding meetings.

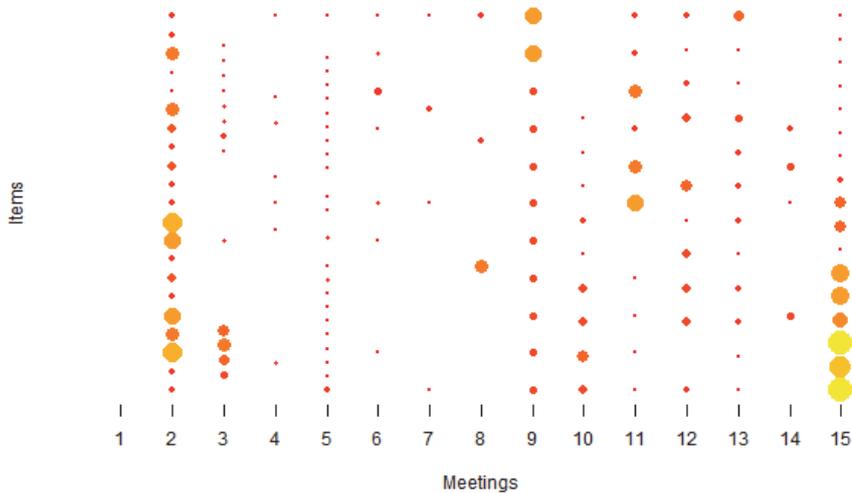


Figure 3 Normalised in-degree measures

The in-degree measures gave an indication of how well the current meeting item is considered from the discussions in the previous meeting. Observed from Figure 3, it was not surprising that the final meeting (Meeting 15) contained many high in-degree items, as they were summarising discus-

sions that concluded the project. Meeting 2 also contained many high measure items. This was the meeting that the concept of the project was being consolidated, after the group members had a chance to consider the project post the introductory meeting (Meeting 1). This measure also highlighted interesting items in the intermediate meetings. For example the two high measure items in Meeting 9 were discussions on the limitations of the system and setting a deadline for one component of the project to be completed by the next meeting.

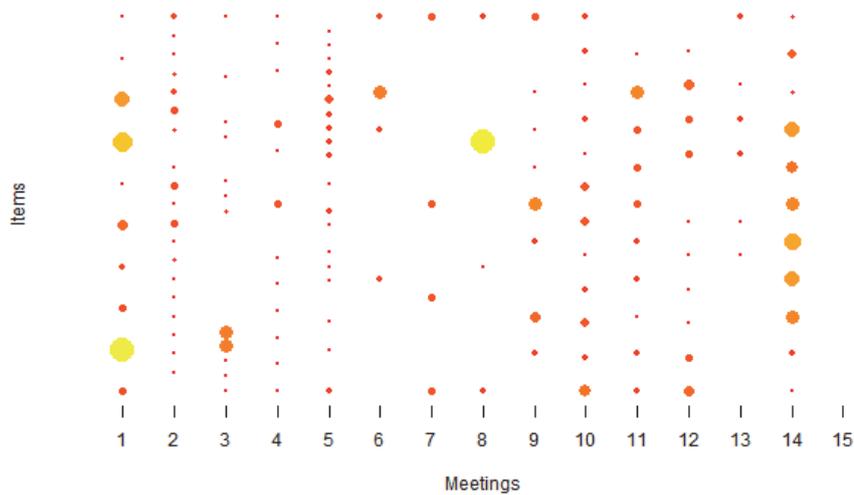


Figure 4 Normalised out-degree measures

The out-degree measures gave an indication of the influence of the current meeting item to the discussions in the next meeting. For example the highest measure items from Meeting 1 corresponded to the decision to have three foci in the project (physical, digital and theoretical); the item from Meeting 8 recorded a discussion on the project delivery schedule and plan (What needed to be resolved in the next 5 weeks.). (Figure 4)

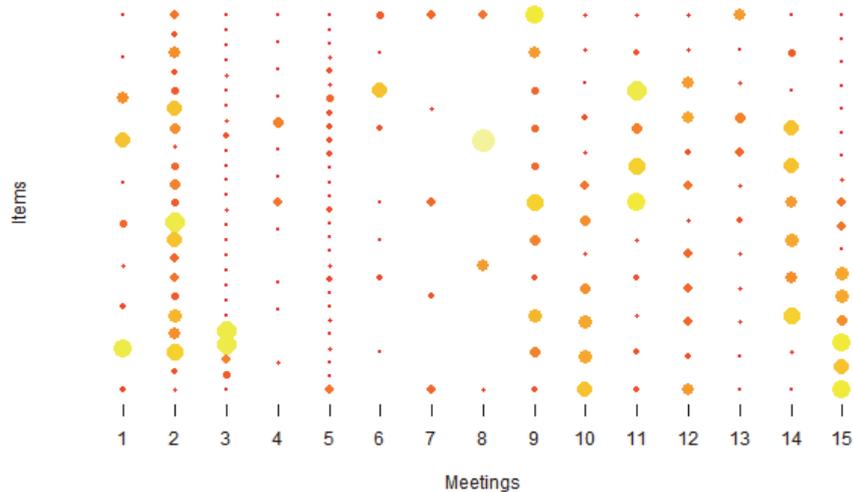


Figure 5 Normalised un-directional degree measures

The combined un-directional degree measures indicated the importance an item played in the short term, considering both the convergence and divergence of discussions. Presented together in Figure 5, the visualisation demonstrated the dynamic aspect of the project progress for this case study: Meeting 5 was a more balanced set of discussions, compared with Meetings 10 and 11 where less connected issues were discussed alongside more connected ones. When we referred to the notes from the Meetings 10 and 11 we found that the low degree measure items were discussions around alternatives to one aspect of the design, and the higher degree measure items were discussions on the development of the overall project.

3.2. BETWEENNESS

Betweenness of a node is defined as the number of shortest paths that cross the given node (Freeman 1979). This is a global measure indicating how well situated a node is in the network. This measure can be used to identify bottlenecks or gate-keepers in a network. In our study we expected the betweenness measure to reveal critical moments in the project development.

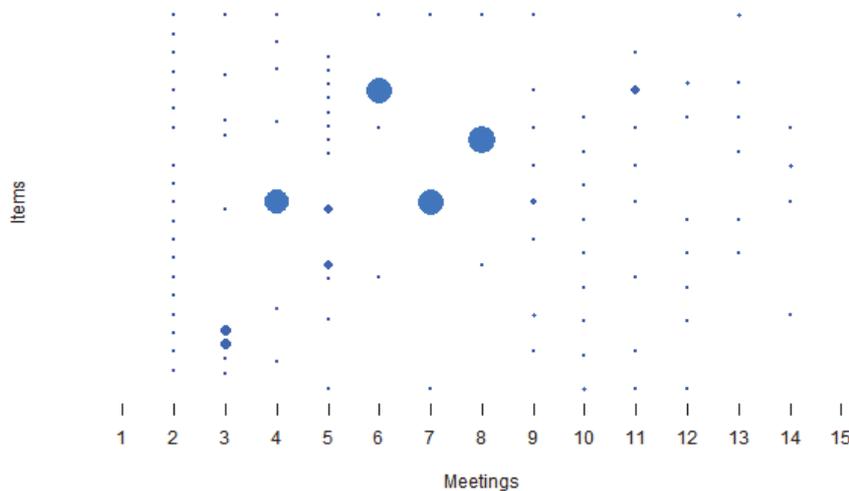


Figure 6 Betweenness measures

The higher betweenness measures from Meetings 4, 6, 7 and 8 corresponded to the following item discussions (Figure 6):

1. Design criteria (what scenario and materials?), need to give the workshop participants a clear brief (Meeting 4)
2. Prepare the workshop brief and schedule (Meeting 6)
3. Compile a factsheet for the participants (Meeting 7)
4. What needs to be resolved in the next 5 weeks? (Meeting 8)

Item 1 was a major discussion that set the approach of the project development. Item 2 and 3 were task setting discussions that pushed the progress of the project. Item 4 was a major stock-taking discussion where the team focused on the setting of a timeline and priorities to get the project to completion.

3.3. CLUSTERING

In SNA clustering and community detection are the optimisation tasks of grouping similar nodes according to a set of features and criteria. We have selected the Girvan and Newman (2001) link-betweenness algorithm to group the nodes based on the betweenness, or criticalness, of the links. This algorithm looks at the importance of the links in the context of the overall network and groups together nodes that are more densely linked. The link-betweenness algorithm detected 21 groups within the meeting item network (Figure 7).

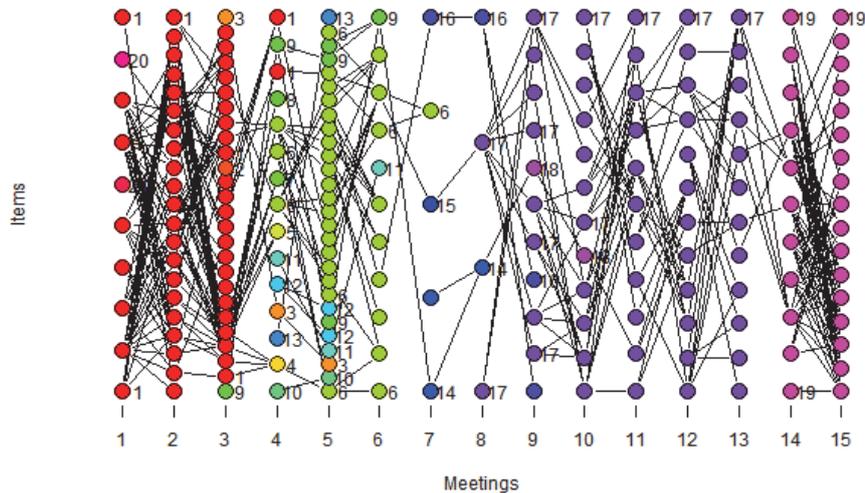


Figure 7 Clustering

As an analysis tool for project progress tracking, this algorithm indicated sections of the project or stages of the project that could be potentially delegated to a sub-team. Looking at the examples from our case study: Group 3, contained single item discussions that spanned across Meetings 3 to 5, was the discussion around locating a testing chamber; Group 11 (Meetings 4 to 6) was on participant selection; Group 9 (Meetings 2 to 7) was about communication with project sponsors.

Looking at the diagram as a whole the project could be divided into 4 phases: Phase 1 (Meeting 1-3), Phase 2 (Meeting 4-6), Phase 3 (Meeting 7-13) and Phase 4 (Meeting 14-15). These matched the project's concept exploration, concept development, fabrication, and delivery phases.

4. Discussion and Future work

By only considering the effect from the most recent meeting to the current meeting, this minimised the workload required to produce item association network that enabled analysis on the complete design process. This set-up prepared the system to be extended into an in-process project management tool that aimed to provide the design teams with up-to-date project information, such as presenting issues covered in the project ranked by importance (degree and betweenness), advice on task allocation and team structuring (clustering) and other numerical and graphical information.

The major shortcoming of this meeting by meeting association was that this ignored item associations within a meeting as well as the discussions that "leapfrogged" meetings. The former could be resolved by an additional

link association process with each meeting that looked at only the items with in the current meeting. To accommodate latter required a much more complex process: the numbers of possible links grows exponentially as the project progresses, if all past items are to be considered when producing links for the new item then. For this to be feasible part of the process it must be automated through an ontology based text association system and/or a recommendations based on machine learning system. Once the links are extracted the same analysis can be applied.

Looking at meeting notes is only one approach to analysis project process, we are planning to apply SNA to other the design process observations scenarios, such as tracking the physical interaction in a face-to-face collaboration workshop. It will be an opportunity to apply similar set of measures to a different setting. From this we hope to better understand the generality of the measures as well as investigate patterns in project developments.

Other SNA literature on clustering coefficients, multi-mode network and dynamic networks (comprehensively summarised in the 2011 book edited by Scott and Carrington) are also relevant for the context of design process research. Further work is required to extend these and develop new SNA measures to build a set of analysis tools for the investigation and applications of the design process management research.

In other aspects of architectural design we believe SNA has the potential to be integrated into the adaptable system design and interaction design. SNA offers new approaches for understanding and learning user behaviour as well as calculating recommendations for system responses.

5. Conclusion

This paper is the early stage of research into multi-disciplinary design processes. The aim of this study is twofold. Firstly considering real-world design scenarios, investigating ways to track and analyse the dynamic of the project development; secondly to extend the current design process analysis methodologies with quantitative methods.

The standard Protocol Analysis process is laborious and not suitable for real world projects. We utilised existing project development records in the form of meeting notes to investigate a long term project. The link extraction procedure is also simplified.

The three measures presented here are only a small sample of the existing and expanding social network research. By introducing SNA into design research we hope to expand the quantitative research tools that are available to the predominantly qualitative based discipline. At the same time we offer the

existing social network literature with fresh context to investigate and expand.

Endnotes

1. The procedure of the study was as follows: As a team member in the presented case study, the meeting minutes were taken by the First Author and recorded in a shared Google spreadsheet. Each team member was able review and edit the recorded meeting minutes. The minutes were available to be referred to during meetings. The analysis was conducted after the conclusion of the project. The link association was done by the First Author based the item description, assisted by personal recollections.
2. The SNA measures presented here are based on the set of R scripts developed by McFarland et al (2010).

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