USING SOCIAL NETWORK ANALYSIS FOR VISUALIZING SPATIAL PLANNING DURING CONCEPTUAL DESIGN PHASE

ALI GHAFFARIAN HOSEINI, RAHINAH IBRAHIM
Department of Architecture, Faculty of Design and Architecture, University Putra Malaysia, 43400, UPM Serdang, Selangor, D.E., Malaysia
Email address:
Ali_ghaffarian_hoseini@yahoo.com
upm.rahinah@gmail.com

Abstract. Spatial diagramming exercises with clients are difficult when most clients are not able to visualize the end results of their requirements. This paper would like to introduce a computational tool—Social Network Analysis (SNA)—commonly used in the communications field to study relationships between people we believe can resolve this visualization problem. Our research intent is to affirm whether or not we can use SNA as a spatial planning tool during conceptual building design. We posit that since the nodes and structural relationships between the nodes may have similar architectural characteristics, the tool would enable architects to make changes by moving any spaces on a floor plan while safely maintaining their spatial relationships to other spaces. In this paper, we would like to develop a proof-of-concept model using an available SNA tool to facilitate spatial diagramming visualization during conceptual design phase. We tested the use of a SNA tool at four levels. The first level determined whether we could develop spatial relationship between functional spaces (such as the living room must be adjacent to the front entry). The second level is on setting priorities values for the different nodes and the linkages. The third level determined whether we could develop grouping relationship between several functional spaces that have a common characteristic (such as public versus private spaces) on one horizontal plane. The final fourth level determined whether we could develop multiple layers that are connected by one common connector (such as a staircase in a double-story house). Our models are validated intellectually by visual comparison between our model and another diagramming by Nooshin (2001) that was developed manually. We are most interested in the fourth level because complexity in the spatial diagramming exercises is caused by multi-layered spatial arrangements at the horizontal and vertical planes. We expect our study to provide us guidelines in developing a prototype for a spatial diagramming tool using SNA, which architects can use to resolve visualization problems when conducting the exercise with their clients.

1.Introduction

Conceptual designing is the phase where designers start developing ideas, proposing a scheme, and developing several alternative schemes before proceeding further into design development. Designers progress by iteratively changing their spatial layouts in order to obtain the best result for their conceptual idea. Sketching and conceptual designing are two inseparable acts (Akin, 1986; Lawson, 1990; Schon, 1983) for architects because for most, the design progresses through them. Sketching is a learned process during design education where architects learn to think with drawings, develop their ideas and solve complex problems with them (Zafer, Gero and Purcell 2006). Spatial diagramming helps architects to place the required spaces in such an order that embraces the overall design concept while ensuring the technical and functional arrangements of those spaces are met. However, it is quite a task trying not to change any spatial relationships while reworking on a new spatial arrangement. Here, we would like to test whether or not architects could use the social network analysis (SNA) methodology to facilitate the rapid spatial programming activities during the conceptual design stage of a building project. Social network analysis (Scott, 2000) has been used extensively by sociologists in the communication field as a set of methods for the analyzing social structures. The methods specifically allow an investigation of the relational aspects (called links) between people (called actors) in the tool.

Social Network Analysis is based on an assumption of the importance of relationships among interacting units. The social network perspective encompasses theories, models, and applications that are expressed in terms of relational concepts or processes. There is a growing interest and use of network analysis in studying the central principles underlying the network perspective (Wasserman and Faust, 1994). E.g. Hill and Dunbar (2002) state that the shape of the social network helps determine a network's usefulness to its individuals. Smaller, tighter networks can be less useful to their members than networks with lots of loose connections (weak ties) to individuals outside the main network. More "open" networks, with many weak ties and social connections, are more likely to introduce new ideas and opportunities to their members than closed networks with many redundant ties.. It is better for an individual’s success to have connections to a variety of networks rather than many connections within a single network. Similarly, individuals can exercise influence or act as brokers within their social networks by bridging two networks that are not directly linked called filling structural holes (Hill and Dunbar, 2002).

Social networks have also been used to examine how companies interact with each other (Wasserman and Faust, 1994), characterizing the many informal connections that link executives together, as well as associations and connections between individual employees at different companies. On the other hand, the basic factor that makes a society is the interaction between the actors. Therefore, it is possible to swap the role of actors into functional spaces, and the societal relationships into spatial relationships. By doing so, we posit that we can use SNA as a space planning tool during conceptual building design.

In mathematics and computer science, graph theory is the study of graphs and mathematical structures (Biggs, et al., 1986). A graph is a set of connections between objects. It is a set of objects called points or vertices connected by links called lines or *edges*, and is represented visually by drawing a dot for every vertex, and drawing an arc between two vertices (Hartmann and Weigt 2006).

We will make recommendations how we can further develop the use of the SNA tool for the conceptual design phase, discuss our limitations and validation methogology. We will conclude with some guidelines on how we can use SNA as a spatial planning tool.

2. Literature Review

In our literature review, we focus on selected literature on Social Network Analysis, conceptual design process, and spatial planning. We present a summary on how they can guide us in developing our spatial planning tool with an SNA tool.

It is for visualization purpose that we believe the SNA tool could assist us in our study. We believe that the structural network between the nodes could easily replace the references to functional spaces and the relationships between them. E.g. Ibrahim (2005) used SNA for the first time in the construction industry studying knowledge movements in a project team. Prior to that, most SNA studies only looked at social structures in a selected community (such as Everett and Borgatti, 1999; Krackhardt, 1988), with more recent studies looking at knowledge transfers within a selected networked group (such as Carley and Prietula, 1994; Levitt, 1994).

In order to have the ability to analyze architectural databases through certain tools and softwares, we need to prepare a suitable tool to computerize and automate the basic architectural phases. Here, Scott and Donald (2002) state that by applying the physics of motion to space planning elements, they are able to automate the conceptual design process. They pointed that, when a designer uses this approach, he creates a space plan by specifying and modifying graphic design objectives rather than by directly manipulating primitive geometry. It combines the speed of automated design methods with the flexibility of manual design methods, while adding a highly interactive quality and a sense of collaboration with the design itself.

Further, Liggett (2000) reviews the history of automated facility layout, focusing particularly on a set of techniques, which optimize a single objective function and also presents and evaluates applications of algorithms to a variety of space allocation problems. The author also reviews alternative formulations of the problem on how space is represented and methods of evaluating a plan.

Moreover, Haythornwhite (1998) declares that one of the most probable ways to improve the future opportunities of the nodes in a network is to improve the information routes between the nodes (the linkages in social network analysis graphs) but, she did not consider the actors' own special properties which is one of the most important factors in the network's future opportunities. It is our objective that we optimize the functional spaces, while knowingly being assured that we will never break the priority relationships that we want between the spaces.

Performing a social network analysis task is a complicated process hence the collaboration of some computer softwares is needed. Therefore, e.g. Gross (1996) proposed that computational representations could be used for conceptual designs, computer-supported editing, critiquing, analysis, and simulation.Gross's goal was to develop a computational drawing environment to support conceptual designing through computerizing the sketches; on the other hand, there are often some unwilling problems, which may happen during the computerized design process.

Since SNA analyses the relationships between individuals, we posit that the use of SNA can be extended to facilitate the design of functional spatial arrangement of a building project. E.g. Scott (2000) explains that there are two types of data that SNA uses for analysis: attribute and relational data. Attribute data relate to the properties, qualities or characteristics that belong to individuals while relational data relate to the contacts, ties and connections, the group attachments and meetings, which relate one individual to another. In building design, we can assign "wet" to kitchen and toilet as their properties and use variable analysis to develop their plumbing "tie". On the other hand, relational data uses network analysis, whereby the relations are treated as expressing the linkages that run between agents. In this case, we can group front porch, living room, and dining room as a "public zone" for a house as opposed to master bedroom, children's rooms and family room as a "private zone".

After reviewing these articles we conclude that there are some similarities between SNA process and architectural conceptual design phase. We are proposing that the SNA tool can be reconfigured for use as an architectural space-planning tool during the conceptual design phase. The following section describes how we can test the SNA tool to ascertain its feasibility.

3. Research Method and Results

We used UCINET version 6.26 (developed by Borgatti, Everet, and Freeman 2002) in our study. We will test the use of UCINET at four levels to determine whether the tool is suitable for architectural spatial planning. We first need to develop a matrix consisted of the information about the different nodes as the input. Here, we refer the nodes as representatives for the functional spaces. We set the matrix to symmetric mode because all of the relations between the spaces in a building are symmetric (two-way). In the symmetric mode, the relation between two nodes is set once, for instance, when you set the amount of relation between Node A to Node B as 'Yes' then automatically the amount of relation between Node B and Node A is set as 'Yes'. In the asymmetric mode you can set 'Yes' for Node A to Node B and 'No' for Node B to Node A. We will try to gather architectural spatial planning databases and use it as the input for UCINET. The analysis through this software can assist architects to optimize spatial planning.

3.1. Test case (I)

Test purpose: To determine whether the relations between various spaces in a normal architectural residential designing project, can be represented and analyzed using UCINET or not.

Implementation: We replaced the different spaces of a normal house as the nodes of the network and documented the relationships between those spaces as the links between the nodes in the graph. We created a matrix of binary amounts. In this matrix "1" means "yes" and "0" means "no". We set the matrix to the symmetric mode and entered the desired data for the different spaces.

Results: The resulted graph was able to represent the relationships between the spaces but the linkages and spaces have no priorities between and among them.

3.2. Test case (II)

Test purpose: To determine whether the different values can be set for the various nodes and vectors to show linkage and space priorities in the resulting diagram?

Implementation: Using the same matrix for test case I, we now set up a graph consisting of different link priorities and different actor sizes as the input data. In this matrix, the highest value for nodes and lines varies from 3 to 0. Three means that the node has the highest level of importance or the linkage has the highest priority among others.

Results: The resulted graph (shown in figure 1) can represent the relations between the spaces including different priorities for the linkages and spaces.

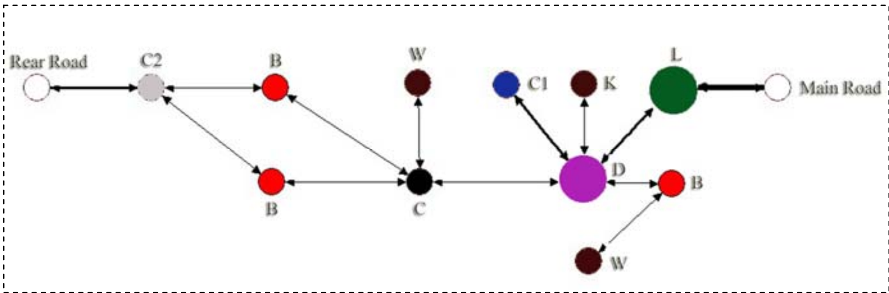

Figure1. **The graph with different node and linkage priorities.**

3.3. Test case (III)

Test purpose: To determine whether we can set some rules for establishing functional or spatial groupings.

Implementation: We divided the spaces into public and private areas. Any group that is presented as a single node (for instance the public area and the private area groups) has a sub-matrix including the group details. We made a parent matrix (the first matrix of the hierarchical order of matrixes including the most general data) for the base and two sub-matrixes (private area sub-matrix and public area sub-matrix) for each group.

Results: For the next step, the groups are further divided into specific detailed matrixes that could produce a detailed graph for each group.

3.4. Test case (IV)

Test purpose: To determine whether SNA can prepare multilayered graphs?

Implementation: We developed a matrix for a multi-story building by setting the vertical junctions such as (stairs, elevators, and escalators) as a hub that connects two main matrixes with each other. We used the relationships between spaces of a double-story house for this purpose. The parent matrix is a very general matrix representing the major spaces of the building consisted of five major nodes (main road, ground floor, first floor, rear road, and stairs). Each floor was assumed as a major group and has its own sub-matrix and is represented as a single node (as represented in figure 2).

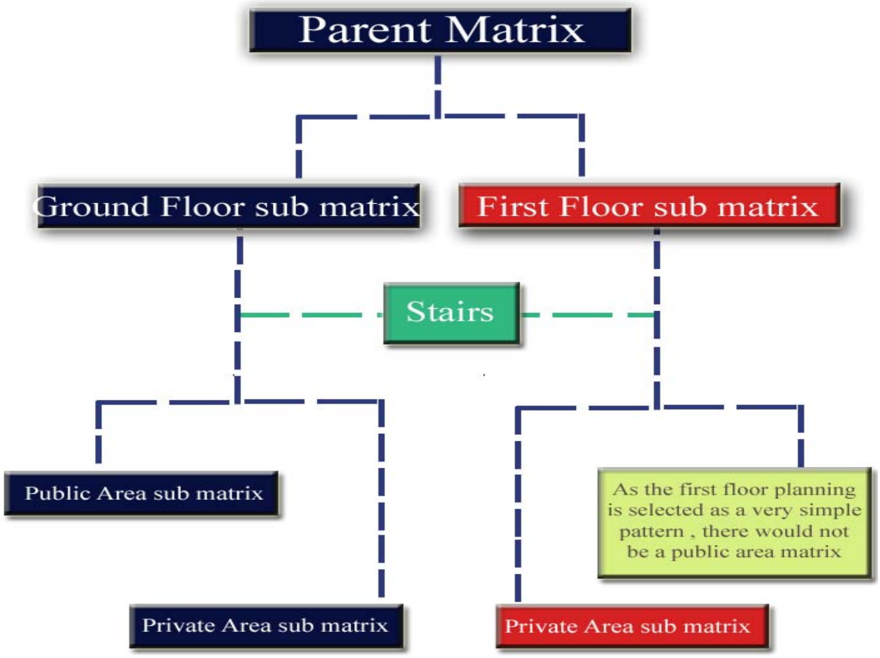

***Figure*2. The hierarchical order of the matrixes.**

Results: The resulted graph from the parent matrix is a very general diagram consisted of first floor and the second floor nodes as the major actors (each group is mentioned as a major actor). The second level consists of more detailed graphs for first and second floor matrixes, following the grouping pattern (mentioned in test case III), including major nodes such as public and private areas. The final graphs are detailed graphs including no major actors, expressing the situations of various nodes and their linkages in each separate floor.

4. Spatial relationship development

In our study, we examined the use of UCINET at four levels. Firstly, we determined that we are able to develop spatial relationship between spaces. Secondly, the SNA tool allowed us to set up different priority values for each node and linkages. Thirdly, the SNA allowed us to group spaces with common relationships or having a common characteristic. Finally, the SNA tool allowed us to develop multiple spatial grouping on individual layers that are joined by a common connector such as a staircase. **The incremental conceptual spatial planning test cases allow us to develop and recommend a methodology to develop an SNA matrix as described:**

a. **Determine the functional spaces according to the building program requirements.**
b. **Create a matrix consisting of similar number of rows and columns for the total of required functional space.**
c. **Create phantom functional space for a walking path if needed.**
d. **Ascertain the relationships among functional spaces in the matrix.**
e. **Assign priority values for each linkage and space based on their importance and other characteristics.**
f. **Creating the spatial network by using the matrix as the input for UCINET that will simulate the spatial graph.**
g. **Determine the effectiveness of the spatial graph (to be determined in future study).**

5. Limitations and Validation

Our research is limited to testing the present SNA tool at four levels intellectively (Thomsen, et al., 1999). We compare the results of the simulated graphs with the spatial diagram manually developed by Nooshin (2000). The manual and simulated **graphs are exact duplicates hence validating our study.**

6. Conclusion

We have introduced a computational tool—Social Network Analysis (SNA)—commonly used in the communications field to study relationships between people to solve visualization problem during spatial planning exercises. We posited that since the nodes and structural relationships between the nodes can have similar architectural characteristics, the tool would enable architects to make changes by moving any spaces on a floor plan while safely maintaining their spatial relationships to other spaces. We tested the use of UCINET at four levels. We have determined that we are able to develop spatial relationship between spaces and able to set up different priority values for each node and linkages. Further, the SNA tool has allowed us to group spaces with common relationships or having a common characteristic. More importantly, it has allowed us to develop multiple spatial groupings on individual layers but are joined by a common connector. **The incremental conceptual spatial planning testing also provided us insights to develop and recommend a methodology to develop a programming matrix that we could input into an SNA tool.** **Further study will be conducted to develop its ability to visualize architectural space planning in exact and definite shapes and**

sizes. We expect **the results to guide us in developing** a computational prototype for a spatial diagramming tool using the SNA concept.

References

Akin, O: 1986, Psychology of Architectural Design Pion Ltd, London

Biggs, N.; Lloyd, E. and Wilson, R.: 1986, Graph Theory, 1736-1936 Oxford University Press.

Carley, K., and M. Prietula: 1994, Computational organization theory.

Caroline Haythornthwaite: 1998, Social Network Analysis-An Approach and Technique for the Study of Information Exchange. LISR 18, 323-342.

Everett, M.G. and S.P. Borgatti: 1999, The centrality of groups and classes. Journal of Mathematical Sociology. 23 (3): 181-201.

Hartmann and Weigt: 2006, Phase Transitions in Combinatorial Optimization Problems, Section 3: Introduction to Graphs.

Hill, R. and Dunbar: 2002, Social Network Size in Humans. Human Nature, Vol. 14, No. 1, pp. 53-72.

Ibrahim, R., M. Shumate, R. Levitt, and N. Contractor: 2005, Discontinuity in organizations--Knowledge flow behaviors in sequential workflow processes. CRGP Working Paper No. 17, Stanford University.

Krackhardt: 1988, Predicting with networks-Nonparametric multiple regression analysis of dyadic data. Social Network. 10: 359-381.

Lawson, B: 1990, How Designers Think? (2nd Ed) Butterworth Architecture, London

Levitt, R. E., G. P. Cohen, J. C. Kunz, C. I. Nass, T. R. Christiansen, and Y. Jin.: 1994, The Virtual Design Team: Simulating how organization structure and information processing tools affect team performance. Edited by Carley, K. M. and M. J. Prietula.

Mark D Gross: 1996, A computational environment for working with design diagrams. Design Studies Volt 17 No 1, pp 53-69.

Robin S. Liggett: 2000, Automation in Construction 9, pp 197–215

Sakineh Nooshin Nahid: 2001, Accommodating the Muslim women privacy (Hijab) requirements with ventilation needs in Malaysian terrace houses, pp 160-183.

Schon, D A: 1983, The Reflective Practitioner-How professionals think in action Basic Books, New York

Scott A. Arvin, Donald H. House: 2002, Modeling architectural design objectives in physically based space planning. Automation in Construction 11 Ž. pp 213–225.

Scott, J. : 2000, Social Network Analysis: A Handbook 2nd Ed. Newberry Park, CA: Sage.

Thomsen, J., R. E. Levitt, J. C. Kunz, C. I. Nass, and D. B. Fridsma: 1999, A trajectory for validating computational emulation models of organizations. Journal of Computational and Mathematical Organization Theory 5 (4) Dec: 385-401.

Wasserman, S. and K. Faust: 1994, Social Network Analysis, Cambridge University Press.

Zafer Bildai, John S Gero and Terry Puecell: 2006, To sketch or not to sketch? That is the question**,** *Key Centre of Design Computing and Cognition, University of Sydney, NSW 2006, Australia*