Place as a Constituent for Social Networks

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Abstract. Social network analysis has traditionally ignored the role of place and geographic space in forming social bonds and networks. Here we introduce a richer model by introducing the notion of co-placement as a factor for social bonds. A hierarchical categorization of co-placement and the inferred strength of relations at different scales and granularity are discussed. This research shows that the geography of places is instrumental in determining the strength of social bonds, which is studied using the case of academic collaborations in form of published papers between researchers in the GIScience and COSIT conference communities.

1 Introduction

Places are said to originate and contain activities in space and also determine behaviour in the real world. Places are also said to be the containers in which communications and connections in real world take place, connecting similar characteristics, behaviours and activities. This research proposes that places also underlie social networks and are indicative of connections and communications across a social network- one that does not exist in the real geographic space. As opposed to hyperspace, we are interested in investigating the effect of real places and co-placement in space and in time as a measure for social cohesions and networks. Social network analysis has previously indicated that social friendships are independent of real world geographies. In this case, we demonstrate that the real world geographies, not as real world spatial proximity, but as a place-based geography is instrumental in formation of social networks and of determining and maintaining the strength of connections in these networks.

A social network has geography-real or virtual. Urry [13] has pointed out how important physical co-presence is to keep social connections alive. But social network analysis has traditionally ignored the role of geographic proximity or spatial operators in determining the cohesion or strengths of links in social networks. Especially in this global, digital and world wide web age where spatial proximity is often not necessary to develop social links and proximities and communications can happen in digital environments, this research is an attempt to identify the role of geographic place-based proximities in development of social networks and connections.

The general view is that in this age, context of work and collaboration is changing from a stable, physically located model to one where collaborations happen between people who never meet in traditional work environments. But, is this really true? Is
place becoming obsolete in forming social connections? In this paper, researcher biographies are studied. Biographies describe place-based trajectories, which enables to talk about co-placement in space and time. It is demonstrated that place has played an important role in determining connections and links within a research community. So, is research collaboration determined by co-placement? And are there barriers of geographic separation that determine the nature of collaboration?

With these research questions we aim beyond current research. Social network research started with links between people and topological concepts of distance in the social network. We postulate that a strong constituent for social links is co-placement, and distance has to be based on this bi-modal network of people and places. Hence, this research is also instrumental in development of scale-based notions of ‘placeness’ and of co-placement in space and in time. Here the term co-placement is proposed as an extension to co-location to consider the overlapping of trajectories at some point in time and to allow for a range of granularities and spatial scale. The hypothesis is that the higher the degree of co-placement, the stronger the links in terms of social connections and collaboration. The emergence of global social networks, and the growing interaction with global information networks impacts the sense of place of users and on processes of place production. Halbwachs [7, p. 134] proposed the terms ‘implacement’ and ‘displacement’ for social reactions to urban changes. By the same token, the simultaneous sensing of places may be termed ‘co-placement’. The major aspect in this regard is the growing tension between the distant and the local, the absent and the present, or between disembedded space and place, expressed in distanciation and time-space compression [see 6].

The research presented in this paper explores and analyses the influence of geographic space and the places that we inhabit and share in shaping the social connections and links that we form. In this paper, we demonstrate that geographic space—not as geometry of spatial proximity, but as geography of places is instrumental in formation of social networks and of determining and maintaining the strength of connections in these networks. Our case study considers a social network that is typically perceived as highly independent from geography and strongly relying on electronic communication-networks between university researchers. Our objective is to understand the role of space and time in forming landscapes of collaboration between university researchers and to express and understand the relationships between sharing and experiencing space and forming social bonds. Thereby, the networks considered here are between individuals rather than at the organizational, societal or community level. Although the study makes the knowledge flows in the community visible through mapping the collaboration landscape, prolific and active organizations and individuals, it is more explicitly targeted at understanding whether the places that these individuals share and experience have an impact on their choice of who these researchers share their information and knowledge with.

The domain of study that exemplifies our approach is the semantic network formed by the scientific community intimately related to Geographical Information Science. Social network analysis is being used to understand patterns of collaborations in this field, and to what degree locations of researchers at different points of time and the way that their trajectories intersect impact the formation of a network of communities.
To illustrate the approach we consider two major international conferences of the field: the Conference on Spatial Information Theory (COSIT) and the GIScience Conference from 2001-2006. The components that constitute the elements of the network are researchers having full papers published at these conferences as joint collaborative work, and connections given by the strength of these collaborations, i.e., the number of papers, etc. The objective of the study is not to study individuals and their networks, but rather to analyse the composite network of collaborations and the respective affiliations of these researchers. We also consider the attendance at these conferences as a measure of sharing a specific event in a specific space and time, and thereby as a measure of co-placement at a specific spatio-temporal granularity.

The paper starts with a review of the relevant background literature in Section 2. In Section 3, the different co-placement relations and categories (and hierarchies) proposed in this research are outlined. The nature of social bonds resulting from co-placement and the role of space and time in determination of the strength of these social connections is discussed in Section 4. The experimental design, analysis and results are presented in Section 5, and Section 6 presents the conclusions and future work.

2 Background

A social network is commonly defined as a set of people who share a common interest and have connections of some kind [14], and in doing so, provide useful insights into ways that the social communities are formed and interact. Social networks have been widely studied over the past years, particularly from the applied mathematical and statistical research [10; 12], and have been applied to many application domains such as epidemiology [9], environment [5] and scientific citation [11].

The spatial dependence of social links is a quite recent area of interest in social network analysis. Butts [3], for example, studied the relationship between distance and the probability of (the emergence of) a social tie. His argument is related to the one in the present paper, although there are significant differences: (i) the measure of distance in this paper is place- or granularity-based, and hence discrete and logarithmic, and (ii) in this paper there is a claim that people far from each other do not form ties, but there is no claim that people close to each other will form links. [2] reverse this perspective by investigating the relationship of existing social ties and the willingness of people to travel over distances to the end of the ties. Again, the present paper uses the same argument: that people interested in forming a social tie are bared by distance.

Related to this paper is also the work studying the social networks of scientists. Prominent in this regard is for example the Erdős Number Project\(^3\), introducing a social distance between scientists by co-author relationships. The present paper argues in the same way: social ties in the case study-researchers of a research community-will be observed by their joint publications. Less strict ties are formed by influence connections\(^4\), or simply by citations\(^5\). Also in this category is previous work [1] studying social ties in the research community that this present paper will focus on as well. However,

\(^3\)http://www.oakland.edu/enp/
\(^4\)http://mike-love.net/
\(^5\)http://scholar.google.com/
these previous studies have neglected the spatial aspect of co-placement, or any spatial condition for the ties in the social network. Since the hypothesis claims exactly such a relationship between collaboration and co-placement (as one example of the relation between social links and geographic nearness), the next step will be to identify and categorize the relationships considered, and then to formalize them for a formal social network analysis.

3 Complementary Structures of Social and Geographic Space

Since the hypothesis claims a relationship between social networks (of collaboration) and geographic space (or co-placement), the first step of investigation is to identify and categorize the relationships considered in this paper.

3.1 Person-Person Relationships

Although people form social bonds for many reasons and in various contexts, the links considered in this paper are formed between researchers by collaboration. In the current climate of pressure to publish (‘publish or perish’), collaboration can be observed by joint publications.

Collaboration is a purely social bond, and not bound to physical encounter, geographic nearness or co-placement. Two (or more) researchers can find each other by references from other members of their community, or by encountering previous publications of the partner researcher. These encounters are nowadays supported by means of electronic communication and search in electronic databases, which is possible with access to the Web from anywhere anytime. Cairncross [4] coined the term death of distance when characterizing this ubiquity of access and contact.

Two (or more) researchers can also find each other by occasional encounters at academic meetings. More generally, physical encounter—an explicitly spatial event—of researchers can lead to collaboration, too. Other examples of spatially formed interpersonal relationships are sharing an office, being neighbors at work or at home, or participating (physically) at the same event.

It is clear from the discussion above that spatially formed relationships are not a pre-condition for collaboration, and social networks formed by collaboration between researchers can be studied by classic social network theory alone [1]. However, our hypothesis suggests a dependency of collaboration and spatially formed relationship (co-placement). The rationale behind the hypothesis is that interpersonal relationships, although they can be established by virtual encounter, are stronger if they are supported by face-to-face encounters or bodily experience. While people do form links in electronic spaces such as chat rooms, virtual worlds, or per email, they typically do want to meet physically if they want to intensify their relationship. The hypothesis states that it needs in fact these stronger ties formed by face-to-face encounters for researchers to collaborate.
3.2 Person-Place Relationships

Data about physical encounters between researchers is not available to us (and for many other types of social network analysis). What is available for researchers and for many other types of social network analysis, are biographies. Researcher biographies show their employment history, and their list of accepted conference papers. Research homepages as well as conference websites also provide data on conference participation. Being at the same place at the same time creates the opportunity for physical encounters. Limiting to researchers working in the same domain (otherwise they would not collaborate), means they have an interest to meet, and will take the opportunity at least if they intend to collaborate. A spatially formed relationship between two researchers is then constructed by being at the same time at the same place, or co-placement: the more specific this place is, the more likely is that the two collaborating researchers have met physically.

Time geography introduces space-time paths to describe the movements of individuals in space over time [8]. Such paths can be represented with various spatial and temporal granularities. Biographies do provide space-time stations—phases of space-time paths characterized by the absence of movement, because the place provides resources for stationary activities—in different, but generally small scale spatial (departments, universities, cities, countries) and temporal granularity (years, months, down to days of conference visits).

Formally, a relationship between a person and a place is established between a start time and an end time (Figure 1). Note that overlapping or nested time intervals are allowed in biographies, caused by circumstances such as shared appointments, or visits during an ongoing employment (time intervals of Place 2 and Place 3, Figure 1). Some biographies also contain gaps.

Within this paper, place and co-placement shall refer exclusively to geographic places. Hereby, places in semantic space—i.e., in any domain that can be spatialized, or has a concept of distance—are deliberately excluded. In the landscape of conferences, for example, COSIT (as a conference series) is a place. COSIT is close to the GIScience Conference, if one considers the overlap of the participants. In semantic spaces, co-placement exists as well. For example, two researchers are co-placed in the landscape of conferences when both of them went to a COSIT, maybe in different years. Going to the same conference means that these researchers must share some interests. Now,
instead of including semantic co-placement in the current investigation, an alternative perspective will be studied: the perspective of a semantic relation between geographic places (Section 3.3).

3.3 Place-Place Relationships

Co-placement can be established by being at the same geographic place at the same time. However, other relationships between the places of person \( A \) and person \( B \) exist that still support some affordance to meet physically. These relationships are here identified and characterized by strength of co-placement.

In particular, these relationships will be investigated:

- co-placement from equal place references,
- co-placement from neighborhood or nearness, relations between place references,
- co-placement from partonomic relations between place references, and
- co-placement from semantic relations between place references.

The most primitive relationship between places is equality\(^6\). Yet the nature of the places, i.e., their spatial granularity, influences the strength of co-placement. Two equal place references can be at levels such as office numbers or countries. With a hierarchical organization of space, strength of co-placement can be linked to the level of granularity. Two researchers working at the same university department are more likely to meet than two researchers in the same city.

A second type of relationships between places is given by neighborhood or nearness. The distinction is made for extended and bounded conceptualizations of places—which may have a neighborhood relation—and point-like conceptualizations of places, which may be near to each other. References to neighboring or near places form co-placement, but weaker than by equal places. While two people working in institutions near to each other may still realize their desire to meet and collaborate, the physical and mental barrier to do so is higher than in the case of being colleagues at the same institution.

A third type of place relationship is partonomy, as reflected in hierarchical cognitive conceptualizations of space, or map series of different level of granularity. Partonomy also provides a weaker form of co-placement. Two persons may refer in their biographies to places of employment at different levels of granularity. If these two places hold a partonomy relation, the two persons still have the opportunity to meet and collaborate, although their nearness is only specified to the level of the super-ordinate place. The larger the area of the super-ordinate place the higher is the likelihood of a physical or mental barrier for a meeting and collaboration. – This type of co-placement holds for example when one researcher reports an employment at University College London and another researcher reports employment in London.

A fourth sense of co-placement can be derived from geographic places that have a semantic relationship. For example, the places of Ittingen, Switzerland, and Ellicotville,

\(^6\) Note that in this paper a place is merely a reference to a place, i.e., a symbol. Equality between places means equality of symbols, not equality of the conceptualizations of the places by different people.
NY, have a semantic relationship: they both hosted COSIT once (in 2003 and 2005, respectively). In the given context, semantic relations can form a weak co-placement: two people participating in one type of event, but in different geographic places, share some experience, and hence, may share some interests, and may have a desire to meet and collaborate. A person participating in COSIT’03 and a person participating in COSIT’05 most likely share some interests, but their physical chance to meet is not specified by these references to different events.

While equality, neighborhood and nearness, and semantic relationships are all symmetric (but see Worboys [15] for a more detailed study of nearness), partonomic relationships are directed (1 : n) relationships: a person or an event in Ittingen is at the same time in Switzerland, but a person or event in Switzerland is not necessarily in Ittingen. Figure 2 characterizes the latter three types of co-placement by different symbolizations.

![Fig. 2. Semantic, neighborhood/nearness and partonomic place relationships, with different line symbols.](image)

### 4 Social Bonds from Co-Placement

Co-placement was introduced in Section 2.1 to develop a conceptual model of links establishing a social network. The reasoning was that co-placement gives a motivation, and in case of strong co-placement also the chance to meet physically. For researchers working in the same domain, for example, this could be the motivation to seek collaboration. With the identified types of place relationships, some notion of strength of co-placement came up. This strength will now be formalized. For the purpose of this paper, given only textual resources (biographies), an ordinal measure of strength will be favored over any continuous (ratio) measure of place similarity.

Let us assume that the context of each social network analysis defines a range of relevant spatial and temporal levels of granularity. Then the strictest, and hence, strongest case of co-placement is equality of places at the in this context highest level of granularity (Figure 3, left). Strength decreases in order of the level of actual granularity.

The temporal aspect of co-placement can also be used for modeling strength: the longer the period of co-placement, one could argue, the stronger the co-placement. This aspect is neglected here. Another temporal relation is depicted in Figure 3, right: two biographies referring to the same place may refer to different time periods. Although this may form a (weak) social bond (“You just moved to Vienna? I was living there a
Fig. 3. Two persons X and Y are at the same time at the same place (left), or visit the same place at different times (right).

Fig. 4. Partonomy relations can be ranked only by the granularity of the super-ordinate place.

Nearness or neighborhood shall be considered only for places at the same level of granularity. Then a simple condition for nearness or neighborhood is their containment in the upper level of granularity. For example, University College London and Kings’ College London are both in London, and hence, are counted as being near or neighbors according to this condition. With this definition, it becomes clear that the strength of co-placement for near or neighboring places (Figure 5) should be the same as for equality at the next lower level of granularity. In the given example, two researchers, one of them working at the University College London and the other one at Kings’ College, have a co-placement at the level of London.

Finally, semantic relations (Figure 6) form clearly the weakest form of co-placement, since they do not relate directly to a chance of a physical encounter. Both persons have to make an effort to meet, and this effort is not correlated with their semantic co-placement. Hence, if this type of relationship should be considered at all, then it should be ranked last in the order of co-placement relationships.
Fig. 5. Placement at near places means co-placement at the upper level of granularity.

Fig. 6. Co-placement at semantically related places affords least chance of physical encounter.

The discussion from the previous sections can be summed up through this following example. Researcher A and B were both in London at the same time, although at different universities. This affords them a lesser chance of a true physical encounter (and hence a meeting instrumental in initiating a discussion and collaboration) than working at the same university. But the notion of co-placement allows to consider the notion of London as a place at some level of granularity. This means that these two researchers have a higher sense of co-placement (and possibly a greater potential for social connectivity) than A has with another researcher C who was in UK at the same time but in Nottingham. However, A has a higher chance of collaboration with C than with researcher D, who was at A’s university but at a different time than A. A and D therefore will have a weaker co-placement than A and C. If it is seen that A and B have co-authored more papers together than A and C or A and D, then the hypothesis is validated that scale-based place geographies play a significant role in social networks, especially in case of research collaborations.

5 Geographic Space as a Constituent for Social Networks

To validate our hypothesis regarding co-placement and collaboration patterns between researchers, as indicative of social bonds and networks in the GIScience community, a study is carried out, results of which are presented here. The collaboration networks between academic researchers is extensive and for the purposes of our study, we focused on the Geographic Information Science community and their collaborations as represented by two major biennial conferences in this domain, i.e., the International Conference of Geographic Information Science (GIScience) and the Conference on Spatial Information Theory (COSIT). The collaborations were considered to be the full papers published at these conferences from 2001-2006. The data for authors and their
affiliations at the time of publication was collected from the conference websites and proceedings, authors’ own web pages (where available) and from the DBLP publication server. Data was also collected and validated by personal email communication, where necessary. As the focus was the map the collaboration patterns, each author was assigned equal importance irrespective of the order of authorship.

The primary parameters considered for the purposes of the study were:

- What is the strength of co-authorship, i.e., how many papers have they co-authored together?
- Where were the authors located at different stages of their career?
- Where were the authors located at the time of collaboration (university, city, country, etc., where available)?
- Who were the authors co-placed with? Where and when, for how long?

Amongst the patterns and trends to explore, the ones we consider are the key conferences in the research area of interest, the collaborations at these conferences, and degrees of compactness versus spread of the collaboration network to identify the clusters, isolates and peripheral players. The primary purpose of this experimental work was to address the question: can we deduce a direct co-relation between social cohesion and proximity/links and geographic proximity or strength of co-placement? It is expected that the analysis of the graph and geographically-based emerging properties of this semantic network should help in making apparent and for qualifying the degree of integration of the research community.

Figure 7 is a snapshot of the nature of the collaborations between the researchers active in contributing to these two conferences between the six year period from 2001 – 2006. Network analysis shows strong composite nature of the collaboration network,
with a few tight-knit clusters lying as isolates to the larger more central community. The nodes are the researchers collaborating and the ties demonstrate the collaborations/papers co-authored at COSIT and GIScience conference published as full papers in the Springer series from 2001 – 2006. In this figure, the ties are the papers published together by these authors, and in this particular illustration, the relative strength of these connections (in terms of number of papers co-authored) is not considered significant, instead focusing on the nature of clustering and a relatively closely knit community that these collaborations indicate. Figure 8 illustrates the relative strengths of links between the different actors in the network, with most links having a weight of 1 (1 paper co-authored) ranging to a maximum of 4.

Key player metrics and centrality analysis on the collaboration network in Figure 9 shows the nature of the collaboration bonds and the roles that the individual researchers play in maintaining the composite nature of this collaboration network and in maintaining a sense of the community. The key player metrics and the centrality measure when mapped to the nodes are indicative of the researchers that afford the maximum connectivity in the network and enable maximum connectivity between the different individual clusters in the network.

**Fig. 8.** Strength of ties illustrates the value of collaborative bonds (number of papers co-authored) Here the values of ties range from 1-4.

Following the exploration of the nature of the collaboration network in general which shows the composite nature of the collaboration landscape in this particular research community, the analysis and mapping of between groups and within groups in Figure 10 shows the existence of a large central social group composed of researchers connected to each other through collaboration. This analysis shows that the social proximities between the different authors in the network are relatively high, and collaboration ties are well-distributed between the researchers. The lack of well-defined clusters and isolates is also evident from this analysis with the clusters of individuals that are collaborating only within their particular group (blue ties) shown to be relatively few.
Fig. 9. Centrality network and key connections are shown as being instrumental in forming a dense collaboration network for the 6 conferences- also showing key player metrics.

Fig. 10. Composition of collaboration network shown here with between groups and within groups collaboration ties shown in red and blue respectively.
Figure 11 shows the 2-mode network of collaboration showing person-person and person-place relationships. The circular nodes represent the individual researchers and the academic institutions are represented by the square-shaped nodes. The ties (red) represent the academic affiliations extracted from authors’ biographies; these include the academic affiliation at the time of collaboration as well as current academic affiliation. In a large number of cases, these have not changed. The other ties (in blue) show the collaboration links as in previous figures, joining the researchers that have collaborated and published a full paper together at these conference series proceedings.

In Figure 12, the proximities are mapped between researchers illustrated by the relative thicknesses of the ties that represent the number of collaborations resulting in full papers. Here it can be seen that the researchers that show a higher level of collaboration have all been affiliated to the same academic institution (as a measure of co-placement).

The centrality measures are analysed and mapped in Figure 13 and shows the key players (indicated by the larger node sizes as relative to their measure of centrality in the network) in the network that are forming the most links with other researchers and/or affording the connectivity in the network to maintain a sense of integrity in the collaboration network. This figure also shows the relative proportion of researchers that have collaborated with other researchers outside their own groups as compared to the ones that have only collaborated with researchers within their group. The square nodes represent the academic institutions as in previous figures and the centrality measure mapped to these nodes (also shown by relative sizes of the nodes) indicate the Universities that have played the major role in supporting the most collaborations with other clusters in the network. The centrality measures give us an indication of the key actors, researchers and academic institutions that shape the composite nature of the network, maintaining the density of the network, affording maximum links between groups, and thereby being instrumental in preventing isolates and several disjointed clusters.
Fig. 12. Strength of collaboration ties shown between researchers indicating the number of collaborations (ranging from 1 to 4)

Fig. 13. Showing the key players in the collaboration network that have collaborated with researchers outside their immediate affiliated academic institution, and key universities that have supported these between-group collaborations
Thereafter, the heterogeneity indices for the network are mapped out and the researchers and academic institutions with higher heterogeneity index are shown as square nodes in Figure 14. Here, these nodes indicate the key actors that have afforded the between group links- person-person relationships with other individuals outside their own academic institutions, and place-place relationships between universities that have hosted such partnerships enabling links between researchers that have not been affiliated to the same academic institutions. The red and blue ties indicate the between groups and within groups collaborations respectively, and the thickness of links show the number of collaborations. Figure 15 show only these ‘cut-points’ from this analysis, showing the low number of researchers and academic institutions that do not satisfy the hypothesis that ‘collaborations have been enabled by co-placement’ by providing links to other academic institutions and/or other researchers.

This kind of analysis provides us an indication of the relative incidence of within-group and between-group collaborations showing that the majority of collaborations have occurred between researchers that have been co-placed at some point of time.

![Figure 14. The network showing relative incidences of between group and within group links as well as the cutpoints and the actors that validate the hypothesis.](image)

Figure 16 shows just only the network of researchers as nodes with the collaborations as ties. In this case, however, the centrality measures are combined with the affiliation measures over all the nodes between collaboration and academic association (both at time of publication as well as current association). Here, it is clearly visible that the number of researchers who have formed significant academic collaborations with other ‘similar’ researchers (those that have been associated with the same academic institutions in the past and/or currently) far outnumber those (blue nodes)) that have formed significant academic links with researchers that are not co-placed with
Fig. 15. The network showing the links between researchers that have collaborated with not co-located individuals and/or have moved away from the academic institution that their collaboration occurred.

them. Again, these results emphasize upon the role that place and co-placement has played in forming collaborations and academic networks in the GIScience community.

These figures and analysis have shown that there is a higher likelihood of co-placement leading to collaborative links, as indicated by past research from 2001 – 2006 for the GIScience community. The collaboration network for this community is integrated and dense, and there are fewer researchers that have collaborated with individuals that they have not been co-located with in the course of their academic trajectories, as compared to the ones that have collaborated mostly with other researchers that they have been co-located with at the time of the collaboration. To further validate our hypothesis leading from this person-person and person-place relationships, we performed significance tests to test the significance of links between co-placement and collaboration. Table 1 and 2 show the results of these significance tests, showing a high significance of correlation between collaboration and co-affiliation.

Table 1. Anova test showing significance of relationship between co-affiliation and collaboration.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SSQ</th>
<th>F-Statistic</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>1</td>
<td>0.00</td>
<td>0.0349</td>
<td>0.9998</td>
</tr>
<tr>
<td>Error</td>
<td>86</td>
<td>0.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>87</td>
<td>0.99</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Further to testing out hypothesis with person-place relationships as represented by academic associations, we also considered conference attendance as representative of an event co-placement. Academic collaborations, as considered in our analysis for the purposes of this paper, did not take into consideration whether co-placement was in
Fig. 16. Blue nodes representing researchers that have significant collaborative links with researchers not co-placed out-numbered by those in red that represent the ones that have collaborated primarily with researchers that have been co-placed with them.

Table 2. T-test showing significance between the collaboration and affiliation networks.

<table>
<thead>
<tr>
<th>Difference in Means</th>
<th>One-tailed test</th>
<th>Two-tailed test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1 &gt; 2</td>
<td>Group 2 &gt; 1</td>
</tr>
<tr>
<td>0.034</td>
<td>0.965</td>
<td>1.000</td>
</tr>
</tbody>
</table>

exact moment of time, instead focusing on co-placement at a higher level of temporal granularity. Although it did consider location of researchers at the time of collaboration, it was very difficult to zoom into details of whether the academic trajectories of these researchers did indeed coincide and did they actually physically meet while being associated with the same academic institution at the same time. For the purposes of considering this temporal granularity and the possibility of actual physical co-placement as a factor in collaboration, event attendance provided the necessary constraints. Conferences such as COSIT and GIScience provide focussed forums with many social opportunities for interactions and two people attending the same conference have a much higher likelihood of meeting face to face and sharing ideas and opinions. Numbers are not huge and moreover these are at a specific spatial scale (such as a particular hotel in Maryland or a retreat in Ittingen) with the conference lasting between specific dates. So, it was considered that the attendance at these conferences provided a good indication of co-placement within a specific temporal and spatial scale. Considering conference attendance, therefore, helps in putting constraints on the time frame and the granularity of spatial location.

Data for this analysis was collected from conference websites, mailing lists, and individual researchers’ own webpages. Conference attendance for COSIT 2001, 2003, 2005 and GIScience 2002, 2004 and 2006 was only collected for the sample researchers included in our previous analysis for academic association. The conferences (places) are shown as square nodes and the researchers as circle in Figure 17. Ties between person-
person represent collaboration and between person-place represent attendance at that particular conference. The graph in Figure 17 shows the relation between collaboration and co-placement in time, showing the layout with lengths of ties indicating the attractiveness of the nodes assuming equal weightage to all ties. Presence of a core central tight-knit group demonstrates the affiliation between collaboration and numbers of conferences attended, with the innermost layer of researchers being most affiliated and the outer layer of relatively few researchers are those that have collaborations but not co-placement at these conferences. Figure 18 shows the 3 ‘cut points’ that show the nodes that connect outside actors (those who were not present at any of these events) to the collaboration network. The relative proportion of the cutpoints to the other nodes in the network is indicative of the fact that the co-location at these events has helped in maintaining and establishing the connectivity and density of the collaboration network in this research community.

**Fig. 17.** Graph showing repulsion and attractivity measure for the different nodes as related to collaboration and co-placement at specific scale and time.

6 Conclusions and Future Work

In the current digitally connected age, the degrees of separation are becoming lower every day. The proliferation of email and other networking media such as blogs, chat rooms, video messaging, etc. have enabled us to form links and collaborations across the world without meeting face-to-face. The notions of familiarity related to social groups have transformed from physical proximities to digital proximity and connectivity. This research tests the hypothesis that despite the loss of physical connectivity in forming social networks, space and more significantly ‘place’ enables the strengthening of links in a network. The research introduces a richer model for social network that links space,
Fig. 18. Graph showing that there are only three ‘cut-points’ in this network that represent the actors that have collaborated with other actors that have not been co-placed with the rest of the network at the conferences.

and more specifically place as a vessel for forming the social bonds. A new notion of co-placement is introduced in this paper, and the hypothesis tested using the case of researchers forming academic collaborations in form of full papers in Springer series for the GIScience and COSIT community from 2001 – 2006. The analysis has shown evidence of co-placement as being a significant factor in forming academic collaborations. Spatial and temporal scales were tested with the consideration of academic associations and conference attendance respectively. Significant correlations and affiliations were shown from a range of graph-based and statistical analysis between the strength of collaboration and co-placement at specific spatial scale, i.e., academic association, and specific temporal scale, i.e., attendance at same conferences lasting for a specific period of time at a specific spatial location.

This model provides further proof of the way places structures our behaviour, activities and the way that we share information and knowledge. It also shows that geography plays an important role in forming social networks and bonds.

Further analysis will include time-specific snapshots to consider specific time granularity as well as taking the particular spatial granularities into account to see the affect of scale based co-placement. Also, the length of co-placement has not been taken into account in this paper and future work will look at the correlation between length of co-placement and strength of network ties. The analysis will also be extended to take into account a wider network of collaborations in the community to validate the results from this analysis as well as to test out hypothesis further.
Bibliography


