Social Network Analysis in Military Headquarters using CAVALIER

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Abstract

Social Network Analysis is a branch of mathematical social science (focusing on the relationships between people and/or groups) which we intend to apply to military organisations (in particular military headquarters). In this paper, we discuss the use of Social Network Analysis in analysing such organisations in order to make recommendations about work practices, and to suggest new placements of staff within a physical headquarters setting.

We demonstrate the utility of this technique to the military through a case study. We also describe a suite of tools for Social Network Analysis which we are developing, which we call CAVALIER (ChAnge VisuALIsation for the EnteRprise). We have included a number of diagrams which illustrate the operation of this tool suite.

1. Social Network Analysis: Introduction

Social Network Analysis is an approach to analysing organisations focusing on the *relationships* between people and/or groups as the most important aspect. Going back to the 1950's, it is characterised by adopting mathematical techniques especially from *graph theory* [Gibbons, 1985]. It has applications in organisational psychology, sociology and anthropology. A good summary is found in [Wasserman and Faust, 1994].

Social Network Analysis provides an avenue for analysing and comparing formal and informal information flows in an organisation, as well as comparing information flows with officially defined work processes. We are interested in applying Social Network Analysis to military organisations, and especially to military headquarters ranging from brigade to national strategic levels.

The universe of possible relationships between people in headquarters includes, for example:

(*i*) Person A is the supervisor or commanding officer of Person B (*yes or no?*)
(*ii*) Person A is a parent of Person B (*yes or no?*)
(*iii*) Person A delivers the result of their work to Person B (*yes or no?*)
(*iv*) Person A socialises with Person B away from work (*how often?*)
(*v*) Person A asks Person B for advice at work (*how often?*)
(*vi*) Person A says they respect Person B (*how much compared to other staff?*)
(*vii*) Person A has an office close to that of Person B (*how close?*)

Clearly some of these relationships (e.g. *i*, *iii*, *v*, *vi*, *vii*) are more important than others in studying the functioning of a headquarters. These relationships can each be represented as a network or *graph* [Gibbons, 1985] where the circles (or *nodes*) represent people and an arrow (a *link* or *edge*) is drawn between people if the relationship exists. For relationships (*iv*) to (*vii*), we would also associate a numerical *strength* of the relationship with each link. It is usually convenient to convert the numerical information to a score ranging from just above 0 (weakest relationship) to 1 (strongest relationship).

The first goal of Social Network Analysis is to *visualise* these relationships by means of diagrams (such as figures 1 to 5) which display the information in such a way as to give a good picture of how the organisation functions.

The second goal is to study the *factors which influence relationships* (for example the age, service, cultural background, and previous training of the people involved) and also to study the *correlations* between relationships. This can be done using traditional statistical techniques such as correlation, analysis of variance, and factor analysis [Cohen *et al*., 1996].

The third goal is to draw out *implications* of the relational data. These include:

- Bottlenecks where multiple information flows funnel through one person or section, slowing work processes and hence slowing the OODA loop.

- Cases where information flows does not match formal group structure, and where existing structures (for example the traditional J1, J2, J3 branches) may not be the best subdivision.

- Individuals who carry out key roles that may not be formally recognised by the organisation, for example as a source of advice on certain topics, as a bridge between sub-units of the organisation, or as a liaison to other organisations. Such analysis of implications often uses graph-theoretic techniques. Since the existence of these people often helps to improve information flow, it is also of interest to study the characteristics of these people (previous experience, training, etc.) which should be encouraged.

As an example of this kind of analysis, figure 1 is a diagram produced by the CAVALIER (ChAnge VisuALIsation for the EnteRprise) tool which we are developing which illustrates a social network extracted from discussions on the Internet neural-networks newsgroup (comp.ai.neural-nets). The diagram is laid out so that people who communicate extensively with others are located close to them, and people who communicate most are located closer to the centre of the circle. Three main *communities of practice* are visible: people who discuss beginner's issues on the left of the circle, people who discuss neural networks for forecasting on the right of the circle, and people who discuss software on the bottom of the circle. At the centre of the circle are two key people who participate extensively in most discussions.

The fourth and most important goal of Social Network Analysis is to make *recommendations* to improve communication and workflow in an organisation, and (in military terms) to speed up the OODA loop or decision cycle in the headquarters.

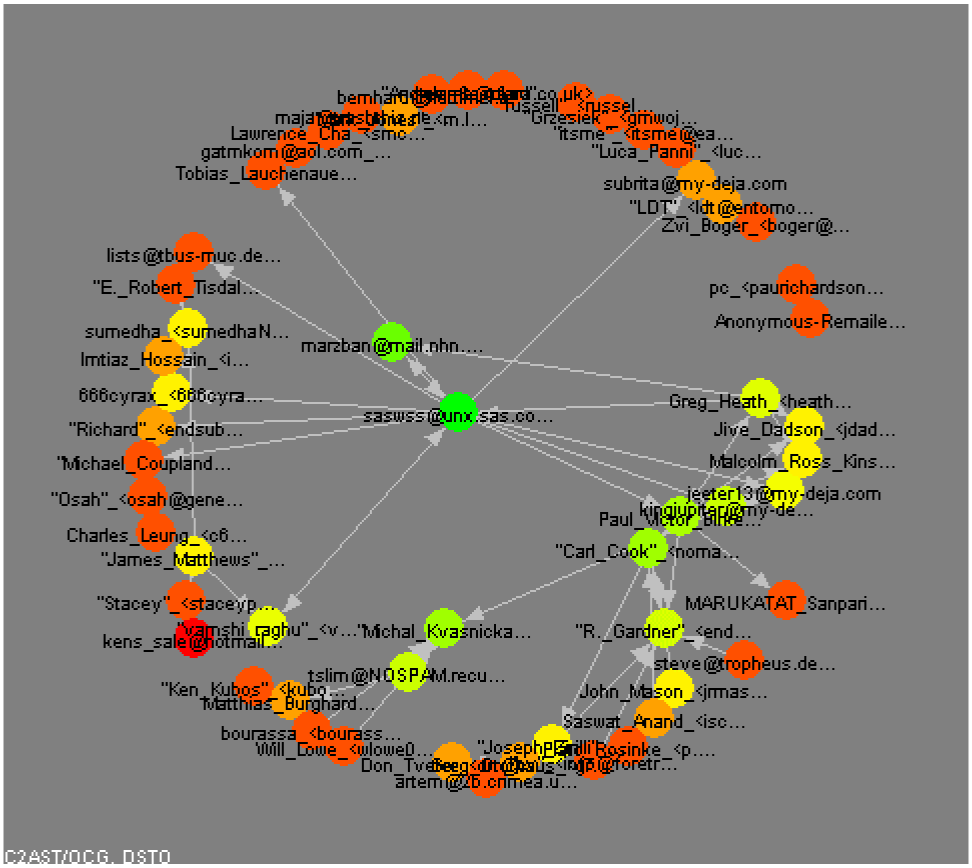

Figure 1. Social Network Extracted from Discussions on an Internet Newsgroup

The data required for Social Network Analysis can be collected by surveys, interviews, observation, staff diaries, and other techniques commonly used in the social sciences.

2. Previous Work

Several previous Social Network Analysis studies of the Australian Defence Force have been conducted by DSTO. Generally these have had a mostly descriptive character, focusing on the first two goals, but making few definite recommendations for organisational improvement.

This is partly because the literature of Social Network Analysis contains many mathematical and graph-theoretic techniques which are applied because of the existence of an *analogy*. For example, the numerical link between two people can be analysed as if it is a resistor in an electrical circuit (Cohen distance analysis), a spring (spring embedding as a technique for layout and visualisation), or a signal transmission channel (information centrality analysis). These analogies are not always compelling enough to act as a basis for firm recommendations.

Attempting to extend graph-theoretic techniques originally intended for yes-or-no relationships to numerical relationships also results in *instability* problems, where a slight change in the numerical data would have given a significantly different result. This is especially of concern since Social Network Analysis data, as is common in the social sciences, often contains a significant element of random noise. For example, our studies have found only a 60 percent correlation between two people's assessment of how much they talk to each other.

In our work we are attempting to refine Social Network Analysis techniques to provide a more solid basis for recommendations about organisational change.

3. Social Network Analysis using CAVALIER

We have addressed the issues raised in the previous section by viewing visualisation and analysis problems within Social Network Analysis as general optimisation problems, i.e. problems of finding the best answer subject to constraints.

A proven technique for solving very difficult optimisation problems of this kind (or at least of finding near-perfect solutions) is *simulated annealing* [Hecht-Nielsen, 1990]. This technique has its origins in mathematical analysis of metals which are heated and very slowly cooled, resulting in a near-perfect crystal structure. However, it has proved to have considerable generality as an optimisation technique, tackling the same kinds of problems as are addressed by genetic algorithms, but generally using much less computer time. For example, modern chip-design software uses simulated annealing to minimise chip area and maximise clock speed.

We are developing a suite of tools called CAVALIER (ChAnge VisuALIsation for the EnteRprise) which integrates a number of analysis and visualisation techniques for Social Network Analysis (many of them based on simulated annealing). The tool suite also includes:

- Electronic questionnaires (which headquarters staff can complete at their leisure), to reduce the impact of the Social Network Analysis process on the workplace, and to allow re-evaluation after changes to work practices have been made. These questionnaires use automatically generated web forms on an intranet, and can include questions about communication, questions about rank etc., and questions that identify differences in culture by asking about past experiences and assessing agreement/disagreement with statements of philosophy (such as the role of the military). Figures 2 to 5 show a social network which was automatically constructed from electronic questionnaires.

- A data acquisition package which can extract social networks from a wide variety of data sources, including network traffic, Internet newsgroups, Lotus Notes databases, and military message repositories. Figure 1 shows a social network which was extracted from discussions on the Internet neural-networks newsgroup (comp.ai.neural-nets). Information about electronic communication extracted by this package supplements the information collected by questionnaires.

- A flexible network editing and visualisation tool which allows the definition, editing, and visualisation of an unlimited number of new attributes and properties for both people and relationships. Networks can be visualised in both two and three dimensions, utilising a toolkit of network layout and visualisation routines, which allows highlighting of key attributes. Figures 1 to 4 show two-dimensional visualisations of social networks, and figure 5 shows a three-dimensional visualisation, obtained by exporting to the POV ray-tracing package (export to VRML for viewing by web browsers is also possible).

- A toolkit for analysis of networks, including statistical and graph-theoretic techniques, and techniques for suggesting groupings of staff which would keep together staff which communicate extensively. This toolkit can also suggest placement of staff within a physical headquarters building to optimise information flow. This optimisation is done using self-organising neural networks and simulated annealing optimisation techniques. Figure 3 shows a hypothetical staff placement for the social network in figure 2, assuming a rectangular grid layout.

4. Case Study: Visualisation

The case study we describe here (illustrated in figures 2 to 5) involved a military C3I-related organisation seeking scientifically based advice to a reorganisation process. Data was collected during March/April 2000 using electronic questionnaires which included questions on communication and areas of interest.

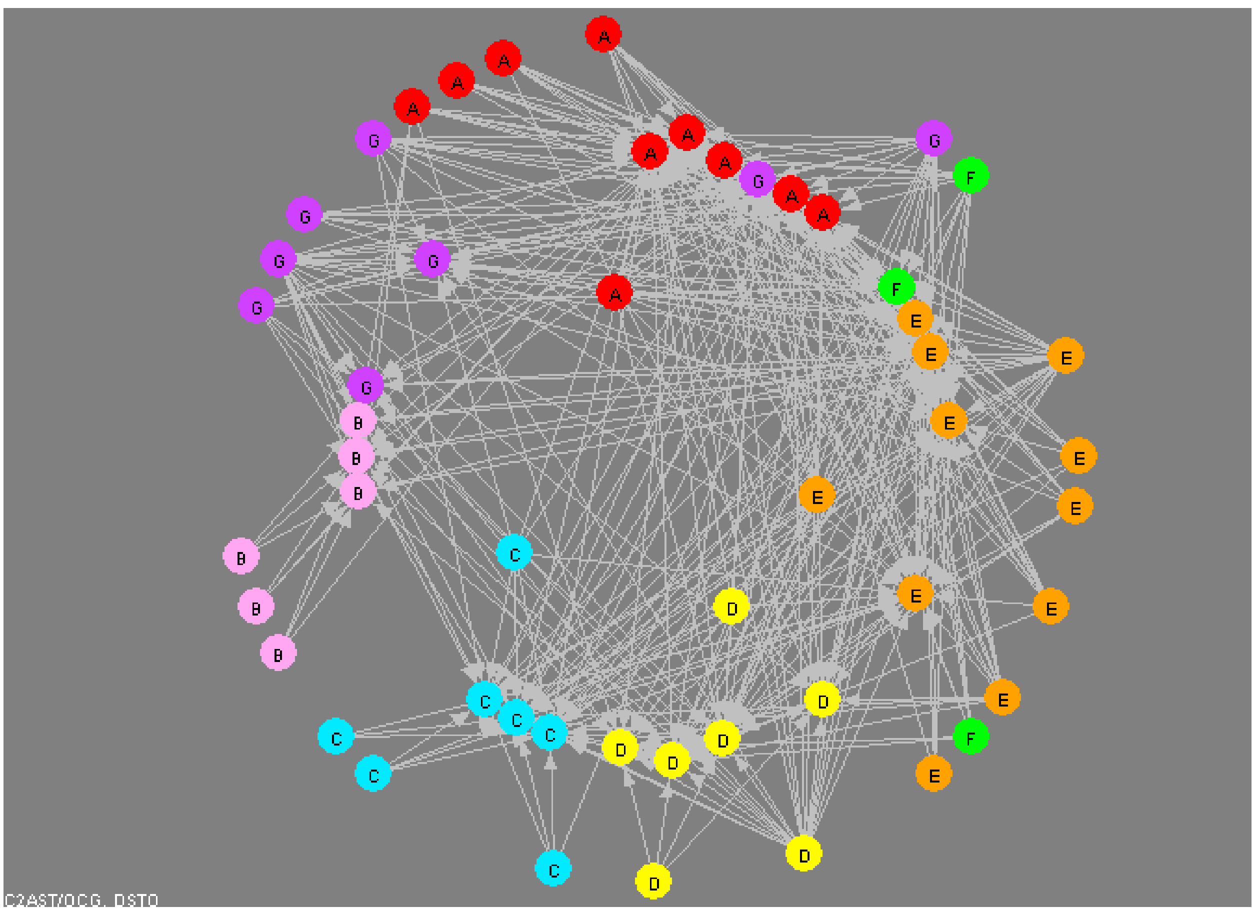

Figure 2. Social Network for a Military Organisation: Circle Layout

Figure 2 visualises communication between people in the organisation. Staff are placed in a circle with senior staff central and junior staff towards the outside. Simulated annealing was used to find a configuration which placed together staff who communicated most with each other. The organisation consisted of six main sub-units (labelled A to F in the figure) as well as a number of special executive and liaison staff (labelled G in the figure). Extensive communication took place between all groups, but the strongest communication links were between the three groups A, E and F. Moderately strong links also existed between the four groups C, D, E and F. Weaker, but still significant, links were A–B, A–C and A–D.

This communication was found to be largely consistent with the interests of staff. This is of course not surprising, but helps to confirm the accuracy of the results. An extension to figure 2 was constructed which placed together staff who communicated with each other and/or staff with similar interests, and this resulted in substantially the same diagram.

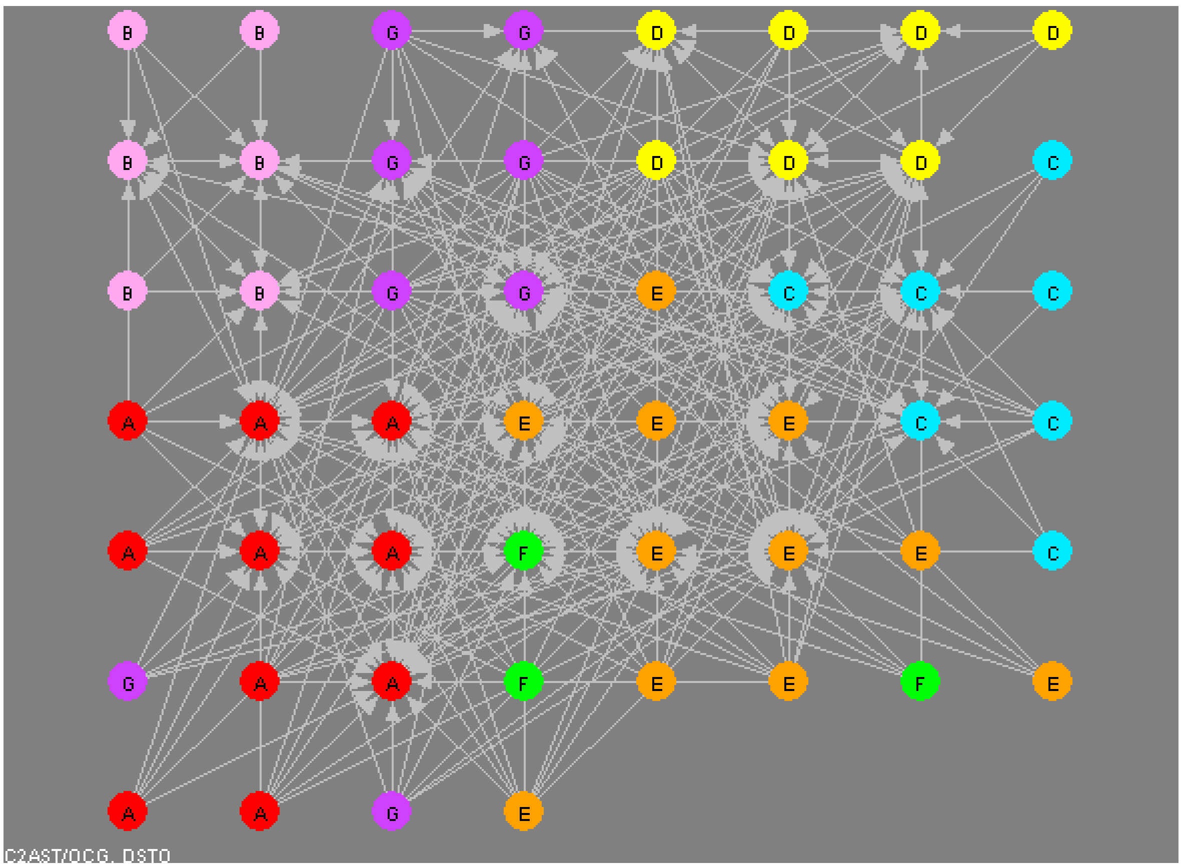

Figure 3. Social Network for a Military Organisation: Grid Layout

Figure 3 shows an alternative visualisation which places together staff who communicated most with each other, but constrained to a rectangular grid. This could suggest a physical placement of staff within a headquarters building to optimise information flow (actual staff names are, of course, omitted here). The simulated annealing process used here can also be used to fit staff to a non-rectangular building floor plan.

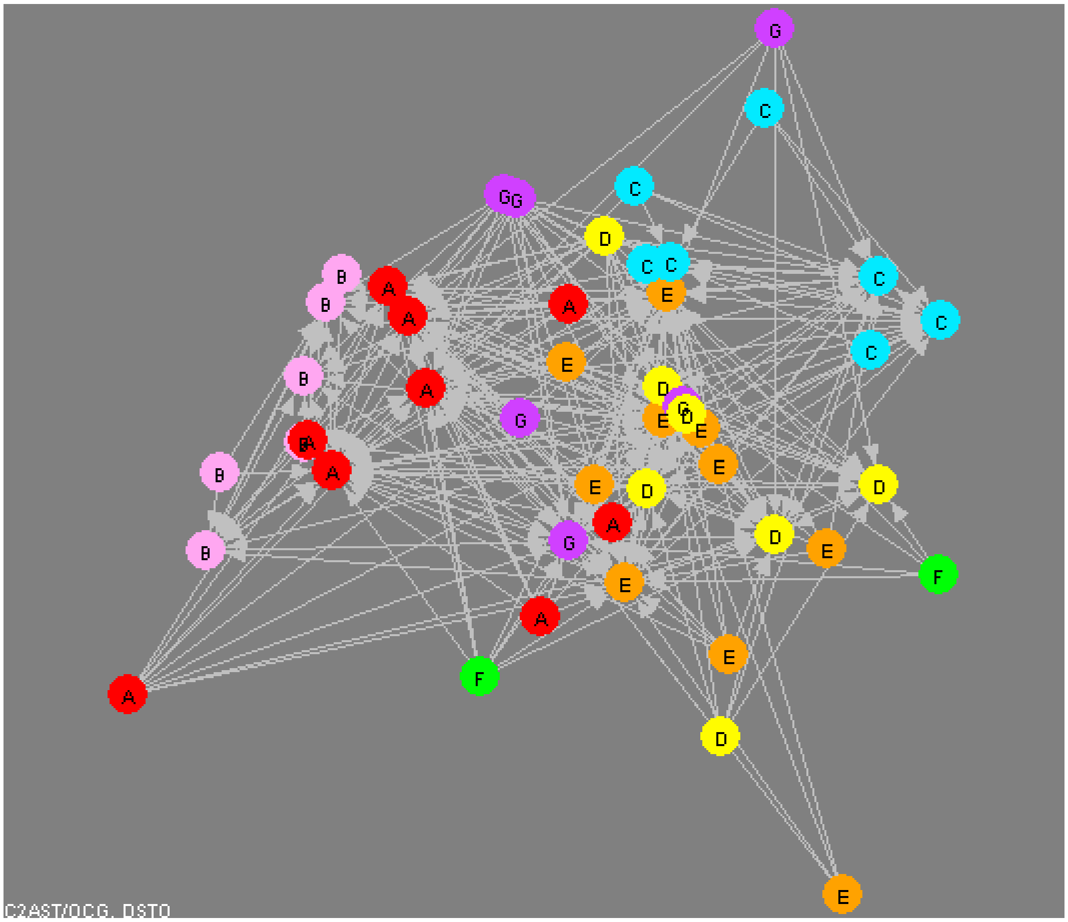

Figure 4. Social Network for a Military Organisation: Principal Components for Interests

5. Case Study: Statistics

The electronic questionnaire in this case study included information about 15 topics of interest, many of which were found to be highly correlated with each other. For example, the topics of intelligence, reconnaissance & surveillance (ISR) systems, geo-spatial information, and imagery were considered by staff to belong together, as were communications & network infrastructure, information security, and interoperability. Factor analysis (principal component analysis) on these topics found that 4 main factors (principal components) explained 73 percent of the variation in data about interests. Figure 4 illustrates the two most important principal components: people are located in two-dimensional space according to the numerical values of these two principal components. In other words, the location of people in this diagram is based on their interests. From the diagram we can see that groups A and B share a common interest, as do groups D, E and F, although there is also considerable overlap in interest between groups.

Figure 5 illustrates the three most important principal components in a three-dimensional visualisation, obtained by exporting to the POV ray-tracing package (export to VRML for viewing by web browsers is also possible). This diagram illustrates the differences in interest between groups as well as the considerable communication between them.

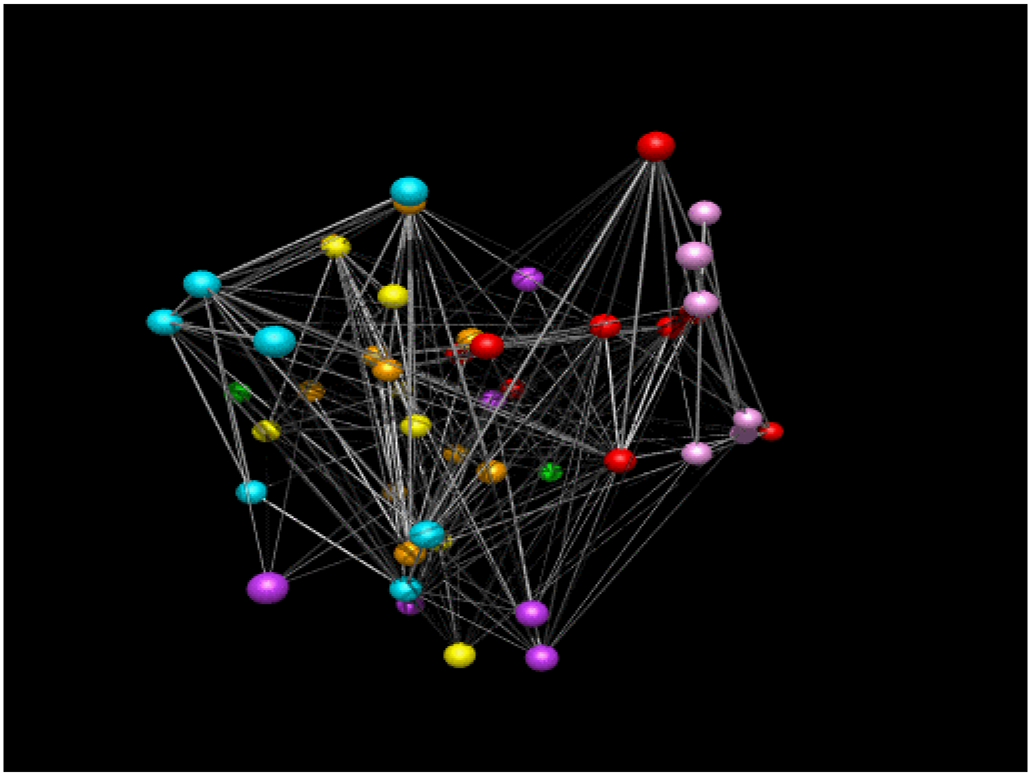

Figure 5. Social Network for a Military Organisation: Three-dimensional View of Principal Components

Statistical analysis also demonstrated that the service from which staff came did not affect their communication in any way, i.e. the organisation was (at least to some extent) successfully acting jointly. To be more precise, analysis of variance showed that there was no statistically significant effect of the service of staff (Army, Navy, Air Force or civilian) on the degree of communication between staff, and chi-squared analysis showed that there was no statistically significant effect of the service of staff on the existing group structure.

6. Case Study: Grouping

Simulated annealing was also used to suggest possible new groupings of staff. The algorithm used constructed groupings such that:

(*i*) Staff who communicated extensively with each other were in the same group
(*ii*) Groups were approximately the same size
(*iii*) There were about 3 to 12 groups

Constraints (*i*) and (*ii*) alone resulted in placing everybody into one group, and constraints (i) and (*iii*) alone resulted in one large group with six people in groups on their own, but all three constraints together worked well in grouping staff intelligently. For this case study, simulated annealing recommended four groups:

(Group 1) Staff in existing groups C and D

(Group 2) Staff in existing groups E and F
(Group 3) Staff in existing group A
(Group 4) Staff in existing group B

This is consistent with the visualisation in figure 1.

Putting all the information from this case study together would suggest a group structure with the above four recommended groups, and strong cross-group links, particularly between groups 1 & 2, groups 2 & 3, and groups 3 & 4. Such cross-group links can be fostered by management using the physical location of staff, programmes of regular meetings, and other techniques.

Clearly this recommendation would have to be integrated with information from other sources, and in a more complete study the statistical and graph-theoretic analysis we have performed here would have been supplemented by more complex surveys, interviews, workflow analysis and other action research techniques (indeed the organisation described here conducted some of these techniques as part of its own internal processes).

In future work we will be studying military headquarters using CAVALIER and applying techniques of this kind. As in the case study, we will be able to make recommendations about workflow, group structure, and physical placement of staff.

7. Conclusion

We have discussed the use of Social Network Analysis in analysing military organisations, and demonstrated the utility of this technique through a case study. We have also described a suite of tools for Social Network Analysis which we are developing, called CAVALIER (ChAnge VisuALIsation for the EnteRprise). We have included a number of diagrams which illustrate the operation of this tool suite.

8. Acknowledgements

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The CAVALIER software included the JAMA linear algebra module from the US National Institute of Standards and Technology (NIST) which has been released to the public domain.

9. References

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