SPATIAL POSITIONING TOOL:
a prototype software and some background correlation data

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Abstract

Spatial Positioning tool (SPOT) is an isovist-based spatial analysis software, and is written in Java working as a stand-alone program. SPOT differs from regular Space syntax software as it can produce integration graphs and intervisibility graphs from a selection of positions. The concept of the software originates from a series of field studies on building interiors highly influenced by organizations and social groups. These studies indicated a need for a tool to be developed that can produce graphs using a specific selection of position as starting point for the isovists. Now we have developed spot as a prototype, only for academic use. Basic SPOT operations use selections of positions and creations of isovist sets. The sets can be colour-coded and layered; the layers can be activated and visible by being turned on or off. At this point, there are two graphs produced in SPOT, the isovist overlap graph that shows intervisibility between overlapping isovist fields and the network integration analysis built on visibility relations. The graphs for correlation studies are made using workstations as origin for the isovists. We use data from an office case study regarding face-to-face interaction. The correlation study shows how central positions have more face-to-face interaction sitting at their workstations than the periphery positions. It also shows that walking face-to-face interaction is evenly distributed, and that organizational boarders sometimes work as strong as walls. The program aims to be used as a fast and interactive sketch tool as well as a precise analysis tool. Data, images, and diagrams can be exported for use in conjunction with other CAD or illustration programs. The first stage of development is to have a functioning prototype with the implementation of all the basic algorithms and a minimal basic functionality in respect to user interaction.

Introduction

The proposal of new software for spatial analysis is here motivated by the need to dig deeper into phenomena related to observation data originating from studies of spaces strongly influenced by organizational and cultural structures. In our studies, these phenomena have been problematic to grasp with correlation studies using regular space syntax software such as Depth Map (Turner 2001). For example, when an organizational border crosses the middle of open space offices, patterns of interaction are different than if the space was occupied by a homogenous organization. By using an uneven distribution of isovist and layering of subsets, it is possible to grasp these phenomena. Regular space syntax tools (such as Depth Map) create graphs of the occupiable space (UCL, ed. Turner 2004); however, the Spatial Positioning Tool (SPOT) creates graphs of the occupied. Therefore, SPOT is not strictly a tool for spatial analysis; it analyzes how organizational entities occupy space in relation to each other. The main difference from the regular space syntax graph is that SPOT produces graphs of the distribution in space where the former is an analysis of the distribution of space (Turner and Penn 1999). This shift is relevant when analyzing spaces occupied by a specific organization.

102-02 There are several basic specifications for building the software: the possibility to create an uneven distribution of isovists; layer systems with color-coding; and calculation of integration measures. During the process, new functions have been developed and other concepts of measures were added. Building the software has in itself been an investigation of how to create representations of social and spatial relations. In addition, we will use SPOT as a platform for further investigations of socio-spatial representations. The software was produced during a one-month period and work as a prototype, for academic use only.

To produce graphs with SPOT, we use isovists to represent space because the phenomena studied here are related to visibility. An isovist, having its origins in analysis of sightlines, is an attempt to represent what can be seen from one position or area in space (360 degree orientation) as represented by a two-dimensional slice of visibility (Benedict 1979). In the SPOT graph is both the origin of the isovist as well as the field part of the analysis both together and on their own. The isovist on its own can also be interpreted in different ways: position, internalized to a seeing subject, what is seen from one position, and externalized and interpreted as a field seen from the origin of the isovist. This double relationship within the isovist is about who or what is exposed and what who or what is exposed to. It tells us something about the spatial strategies used to form and inhibit social relations through space.

This paper provides a technical description of SPOT and example of how a graph is produced. We provide a short background to the creation of the program and show the data that gave rise to the concept. As the software is not complete, we will also discuss further development.

Background

It has been suggested that space syntax use a multiple combination of representations of the spatial system in order to make a spatial model work with the function of interest. Creating relevant maps for correlation studies combines different scales, sections, and measures (Hillier 1996). In our studies, we have found reasons to combine representations in new combinations. SPOT brings forth a new way of operating by choosing the position of the isovist according to spatial distribution of an organization's subjects/objects. Organization related through space has been used when building the Place Syntax Tool (PST). PST has taken a hold on these relations and can calculate configurative relationships between organizational data distributed in a spatial network, which makes it possible to show new relations. For example, GIS (Geographic information system) data related to each other show spatial capacity within a spatial network. PST has proven very useful in urban studies. It does, however, use axial lines in the same way as regular space syntax analysis does (Ståhle, Marcus, Karlström 2005). Regarding SPOT, the difference from existing space syntax graphs, lies in the uneven distribution of spatial entities. Thus, similar graphs have been proposed to understand human orientation in transportation terminals (Braaksma & Cooks 1980). To create these graphs, they used sightlines between different important destinations at the airport, putting the data in a matrix showing binary relations. The main aim was to present a graph that illustrates human orientation and to evaluate new designs or existing plan layouts. SPOT has not yet been evaluated to confirm this research. The background data giving rise to SPOT has focused on building graphs for analyzing face-to-face interaction in spaces highly influenced by organizational or cultural features.

The observation studies using come from studies of department stores and offices. Studies of department stores have contributed to SPOT by investigating spatial strategies that use intervisibility between certain positions of products to affect and reflect the costumers (Koch 2007). Spatial strategies are also used by management in an open plan office so as to place themselves in spatial positions giving high visibility within their spatial domains. To see and be seen was crucial for the management. In this study, we also used department borders to limit the VGA when correlating to face-to-face interaction (Markhede, Steen 2006).

This helped us form new survey studies regarding face-to-face interaction. The survey was formed to gather data related to each worker and their workstation. Furthermore, we use survey data and correlations studies to show the phenomena we aim to describe using SPOT. The survey was carried out at Posten Headquarters (Sweden) and comprises 600 workstations and employees on three floor plans. We made a series of different surveys and observations. The survey data presented here is just one of these. This survey asks questions about face-to-face interaction, during the two days the survey was performed. Each day each employee was given a paper with their floor plan and instructions for how to note their face-to-face interactions during the day. Each face-to-face interaction was noted on the plan layout on the spot where it took place. The instructions were tested in advance and changed several times to give correct information about the procedure. The answer frequency is significant and the similarity of the filled forms shows a great intelligibility of the survey. We have also compared the results of the survey with our snapshot observations showing where face-to-face interactions took place; we found similar patterns although the snapshots do not tell us anything about organizational belonging and who did what. The data is stored in an illustration program and layered by each workstation and color-coded according to organizational (department) belonging. Through this process, it is possible to combine each department's totals of face-to-face interaction during two days in one picture or all together in different colours. Figure 1 illustrates an example of the compiled data of one of three floor plans.

As SPOT did not exist at the time our preliminary studies were executed, the intervisibility graph used here is assembled manually by importing isovist from Depth Map into Adobe Illustrator. The isovists are stored in a related plan layout and assigned 10% transparency. The darker the colour represents more intervisibility; the lighter the colour represents less intervisibility. When building the intervisibility graph we used each workstation of each department as origin for the isovists. In this case, it is motivated as the workstations are used as a base for the individual worker and they spend most of their working day at the workstation. Also earlier studies of offices reveal that most face-to-face interaction is carried out at individual workstations (Steen 2001, Grajewski 1993).

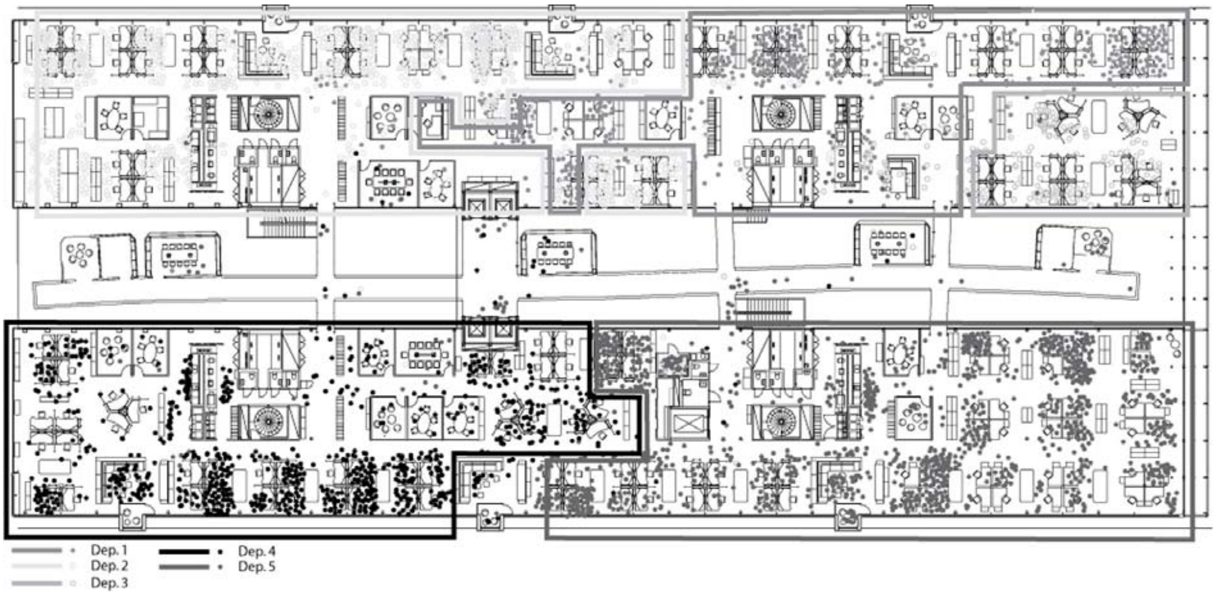


Figure 1:

This diagram shows data from a survey concerning face-to-face interaction during two days at Posten's Swedish HQ. The lines surround workstations belong to the same organizational department. The colours of the dots show the organizational belonging of the employee who interacted (top)

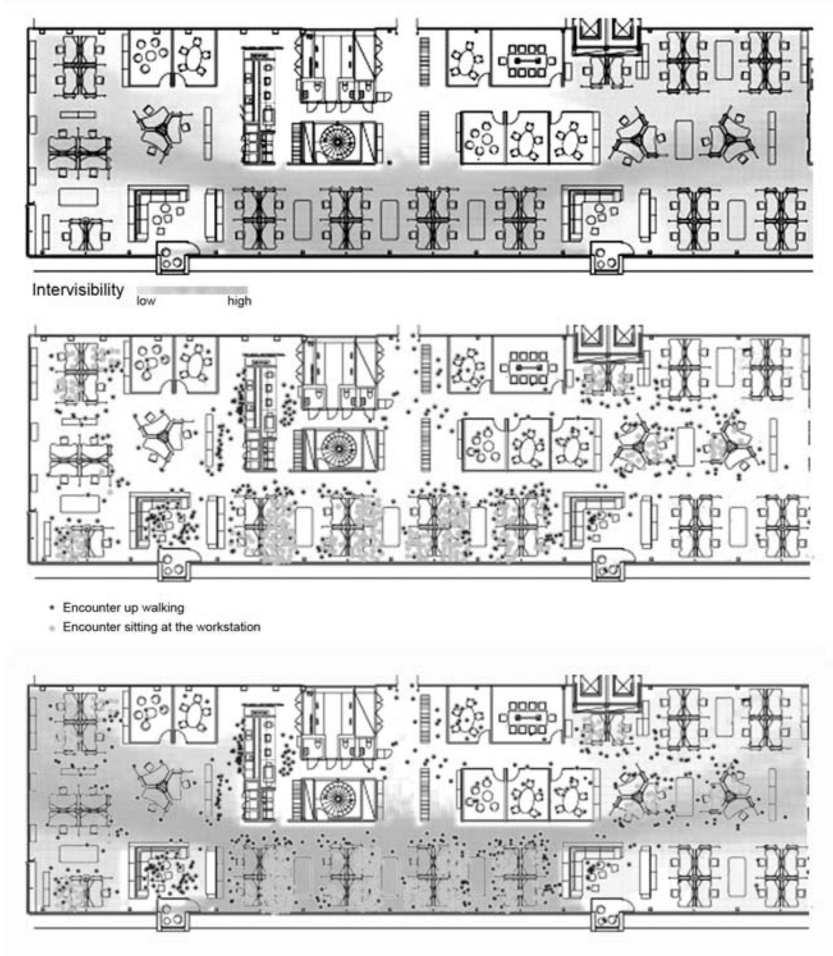


Figure 2:

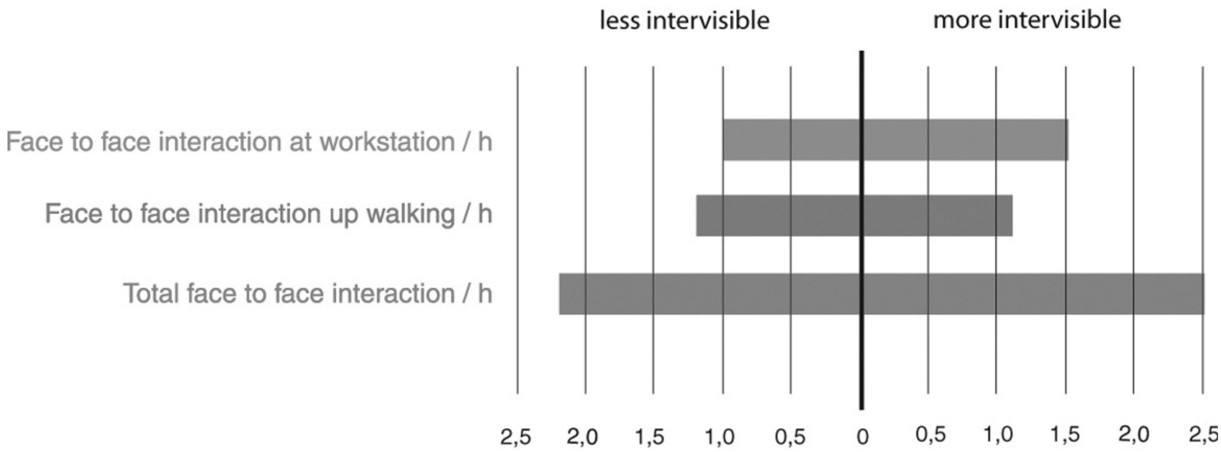
Example of how the data is stored and layered. On top is a manually constructed intervisibility graph, using positions given from workstations belonging to the present labour (present during the survey). In the middle is data from the survey, showing face-to-face interaction of two kinds. Encounters as a result up walking and encounters at a workstation. The lower picture shows information from the other two pictures, layered upon each other (right)

The correlation study was made through layering the survey data and intervisibility graph on each other and making a manual count. The number of face-to-face interactions was counted for each person and hour divided into two categories: up *going* and *at the workstation* and on the amount of intervisibility. The occupied workstations were divided into two categories: high and low intervisibility. This rough division is motivated only by this study's preliminary character.

The organizational departments then have two kinds of relations to their neighbours: direct and indirect. The indirect relations are across the shaft or with another group in between, allowing a visual connection but inhibiting a physical connection. As can be seen in Figure 1, the floor plan is divided into two parts separated by a light shaft with bridges for pedestrian circulation (which also is a reoccurring design on all floors). Each of these parts is an open space only separated by functions such as toilets and coffee bars. The desks allow for direct relations only meters from the other departments but in the same open landscape. Here there are no physical boundaries separating them from each other. One of the most striking findings from these data lies in the lack of mix regarding face-to-face interaction between different organizational departments. Most face-to-face interactions are carried out within units despite the open plan solution. For the indirect neighbours there are 10 of 13 departments with no registered data of face-to-face interactions. For the other three departments, the interactions are 0.1%, 0.2, and 0.3% of the total face-to-face interaction carried out by the departments. With the direct neighbours, inter-department face-to-face interactions are much more common; the data show that the average value is around 3.4% for face-to-face interactions between direct neighbours. This data concerns only interaction at another department's workstation, which ensures that it is an inter-department act.

Figure 3:

The diagram displays data form 13 groups on three different floor plans. Each group is divided into more intervisible and a less intervisible depending on the workstation's position according to the intervisibility graph. The "h" stands for total present hours of the present labour



As we look within each department, the face-to-face interaction pattern is different than it is between departments. Face-to-face interaction is here divided into two categories: those that result from a movement and those that result from an interaction sitting at the workstation. We have compared these data with the models more intervisible and less intervisible parts. (Fig. 3) In 11 of 13 departments, the total face-to-face interaction is higher in the more intervisible parts than in the less intervisible parts. The intersection value is 2.5 face-to-face interactions per present hour for the more intervisible, compared to 2.2 in the less intervisible parts. For interactions resulting from when a person is walking about, the intersection value for the more intervisible parts is 1.1 and for the less intervisible parts it is 1.2. The distribution of face-to-face interactions carried out by someone walking about is very evenly distributed within the different departments. The intersection value for face-to-face interaction carried out at the workstation is 1.5 in the more intervisible parts and 1.0 in the less intervisible areas. There is 50% more face-to-face interaction at the workstations in the more intervisible areas than those placed in the less intervisible areas. In the less intervisible areas, 10 of 13 cases show more face-to-face interaction from walking than sitting at a workstation. This data are confirmed when we look in detail as well in the overview of the data.

Summing up, in this case interdepartmental face-to-face interaction is rare between indirect neighbours, with direct neighbours is it slightly higher but still relatively low, this show on the strength of organisational boarders. Within each department face-to-face interaction is much more common in the more intervisible areas regarding encounters sitting at ones desk. Encounters as a result of up-moving are more evenly distributed.

The data presented here together with other research in our group (Koch 2007) has illustrated phenomena that need further attention. We have also noted the same kind of phenomena discussed in earlier research (Grajewski 1993, Allen 1977, Hanson 1998). To dig deeper into this data, we need spatial analysis software that can make graphs based on occupied positions and sorted by organisational belonging. Therefore, we see a clear potential for using the features of SPOT to create graphs that help us investigate these phenomena.

Platform and Technical Specification

SPOT is written in Java, and thus it is platform independent; it runs in Windows, Mac and Unix machines. Because it is written in Java, and therefore it is strictly Object Oriented, it is intended to be modular and easy to re-use, allowing the specific modules for calculating isovists, their graphs and topological relations, to be used in different contexts and in combination with other Java packages. The intention of SPOT is to build a platform that will allow future expansions and research, not merely to provide a solution to a specific problem.

SPOT also implements a simple user interface, and it is the intention keeping it simple and easy to use, if necessary to divide functionality in to different programs (which its modularity allows) instead of adding features to the existing basic program.

The calculation process in SPOT starts by reading a file of dxf format which contains a description of the two dimensional geometry we want to analyse (sections or plans, for example) , and then it breaks that geometry in two ‘wall’ components , made of simple lines. This geometrical description is stored in to an ‘Environment’ class which all isovist objects share and can interrogate.

The most important component of the program is the Isovist class, which uses the operations available through the java.geom. Area class, part of the standard Java libraries, to manipulate 2D polygons. The calculation of an isovist is done quite simply, by generating an initial rectangular polygon that covers the total area of the specified drawing, and by subtracting the polygons of the ‘shadow’ areas produced by the position of the isovist. Because of the speed of these calculations isovists can be added, deleted, moved in real time or organised in layers which can be turned on or off.

Below is shown a part of the code regarding the process of calculation.

```
Isovist (Environment enviro, float cx, float cy)
 {
  this.enviro = enviro;
  vpt = new Point2D.Float(cx, cy);
  isopol = new Area(enviro.perimeter);
  rangex = enviro.perimeter.width;
  rangey = enviro.perimeter.height;
  maxrange = rangex > rangey ? rangex : rangey;
  int nw = enviro.walls.size();
  for (int i = 0; i < nw; i++)
  {
    Area shadow = calcShadow(enviro.walls.elementAt(i));
    isopol.subtract(shadow);
  }
```

Code snippet: Constructor method of the Isovist class, showing the process of calculation. The constructor takes 3 arguments: an object of type Environment, which is the class that stores the description of the 2d geometry from which to calculate the isovists, and the x and y of the centre of the isovist. The Environment class has a field consisting of a rectangular polygon called ‘perimeter’, which is taken as the initial polygonal area of the isovist (an Area object called isopol). Then the constructor iterates through all the ‘walls’ of the Environment object (enviro) and subtracts their shadow areas from its polygonal area. The resulting Area object is the polygonal boundary of the isovist.

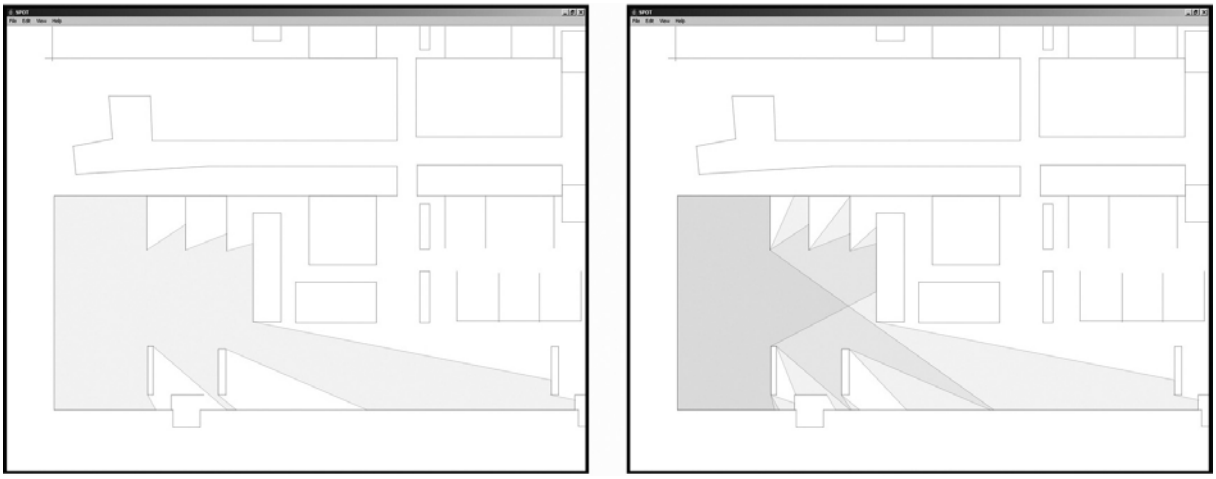
A number of calculations can also be performed in these isovists; a particularly interesting one is the difference between the point from which it is calculated and the centroid of its area. This shows a certain directionality of the space from where it is being perceived, which seems to intuitively relate to a certain directionality feeling of that space. More in depth studies on how this measure may relate to actual empirical data needs to be done, but at this stage it suggests a possible interesting measure, combined with other geometrical properties of isovists.

The interface is based on windows with four menus: file, edit, view, and help. Under file is the open and store functions. Under edit is the operative commands, add and delete isovist, delete all, and the layer manager. In the layer manager it is possible to create and delete a layer and assign colours to the set of isovists within the layer. Layers can also be turned on and off. Under the view menu it is possible to choose which information to view in the work area. Graph features can be turned on and off. Under the help menu is this paper to be found. When creating the graphs in SPOT, one can move around, delete, or add positions and see the graphs change in real-time.

The main function of the program is to import line drawings and position isovists within the line drawing. The isovists are positioned by using the pointer and clicking within the drawing area. When doing this is an isovist field expanded, limited by the imported line drawing and the drawing area box which gives an outer limit for the isovists.

Figure 4:

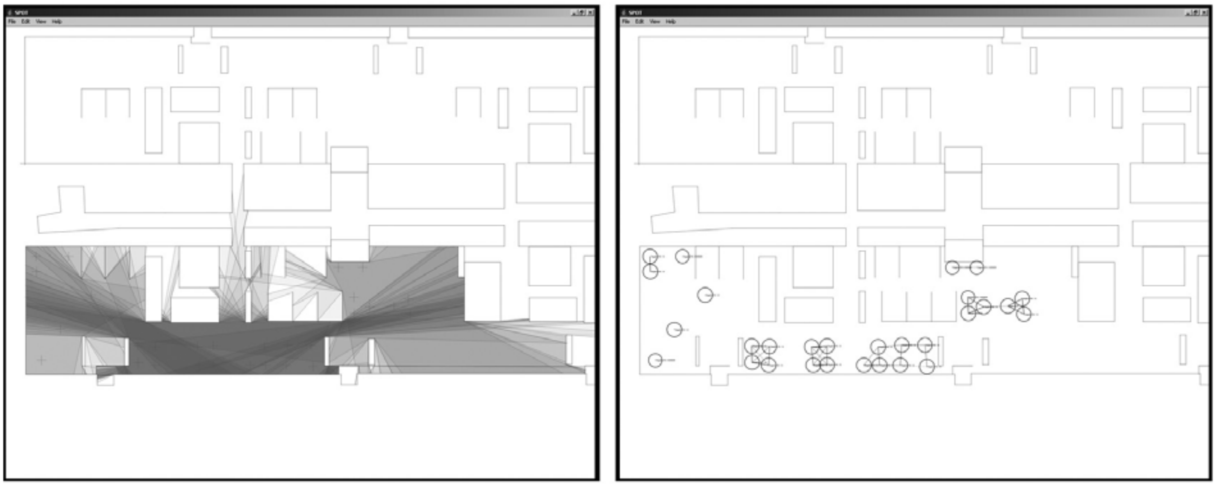
Screen print showing Spot windows with imported dxf line representation, and two examples of positioning isovists



The application of several isovists with different positions but with overlapping fields gives rise to a differentiation in colour among the overlaps due to the gamma transparency. There are two kinds of graphs produced in this version of SPOT. Intervisibility which is an overlapping isovist fields graph, and network graph showing relative asymmetry (RA) integration. The graph of overlapping isovist fields is very crude and is not yet possible to calculate with any space syntax integration measure. The gamma structure of the isovist field creates a visual effect giving the range of the graph. The range depends on the amount of layered isovists, where there are many overlapping isovist the graph becomes darker and where its fever it becomes lighter. The graph can be said to show the visual situation created by the selected positions.

Figure 5:

An example of intervisibility graph and network integration graph, generated from the same positions



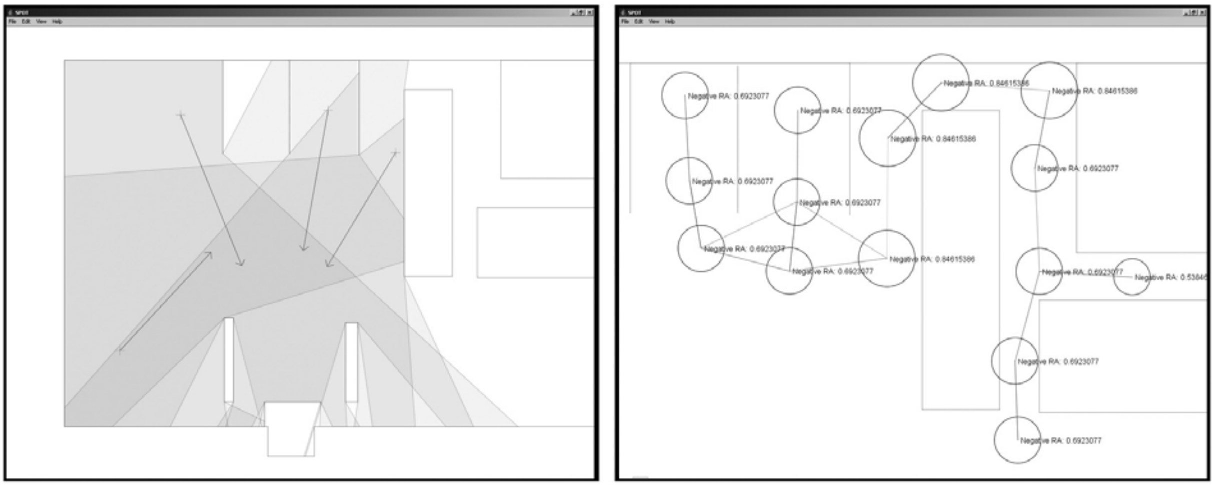


Figure 6:

The left picture show centroids and to the right is a close-up of a visibility network graph

When choosing the *show centroid* command (fig.6) is an arrow within the isovist lit. The arrow goes from the isovist's starting point to the centre of the isovist. This feature is added only for further evaluation and is not backed up with any systematic studies.

All graphs are related to layers that can be turned on and off. Each isovist position carries information about its relation with other isovist positions. When using the *show graph* command, a visibility network between the isovist positions is selected. Each node of the network shows an RA (relative asymmetry) value and a circle; the size of the circle depends on the RA value.

There is also a line shown between those positions seeing each other. (fig.6) The thickness of the line indicates the distance between the positions, following a ten grade scale depending upon the size of the line drawing. The RA describes the integration of a node by a value between or equal to 0 and 1, where all low values describe high interactions. RA is calculated by the formula RA=2(MD-1)/ (k-2).

When using the *move isovist* command, it is possible to click and drag the isovist to any position in the drawing area. The isovist, centroid, and network graph changes in real-time and along the transportation between the positions.

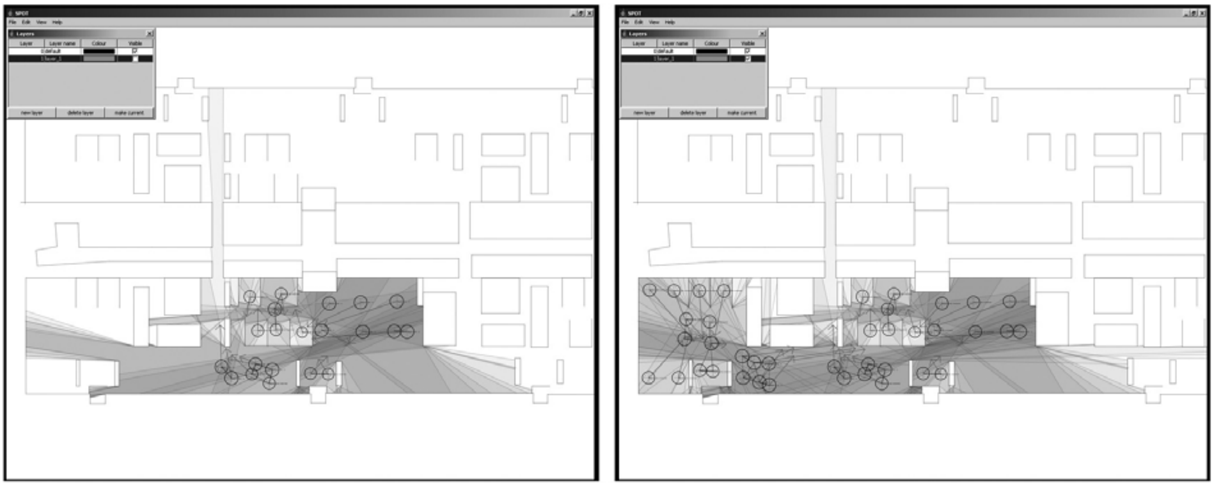


Figure 7:

Layers can be turned on and off in the layer manger

The isovists can be divided into different sets that can be put in different layers. All layers have an assigned colour that is also seen on the isovists. Each layer can be turned on and off. When a layer is turned on its set of isovists automatically becomes a part of the graph.

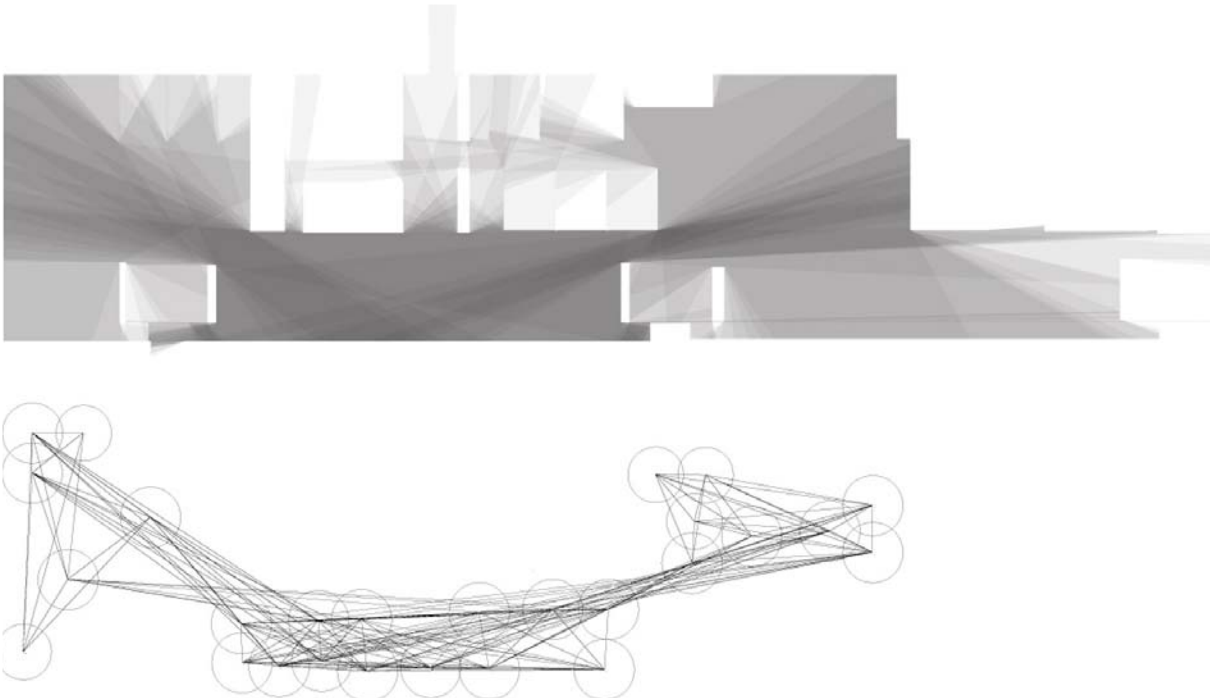


Figure 8:

Examples of outputs of network integration graph and intervisibility graph

Drawing interchange format (DXF) is the only drawing format importable. The DXF format is a tagged data representation of all the information contained in an AutoCAD drawing file. *Tagged* data means that each data element in the file is preceded by an integer number that is called a *group code*. A group code's value indicates what type of data element follows. Virtually all user-specified information in a drawing file can be represented in DXF format (Autodesk 2007).

The program was built during a one-month period and finished during the production of this paper. There are some minor bugs regarding importing and exporting data and sometimes in the order of appearance of the layers and graphs; however, it works for academic use and will be available when this paper is published.

Use and Future Development

The result in the example implies that both the artefact of space and artefacts of organizations have a deep impact on how face-to face relations are performed in the studied office. Despite the lack of a wide range of cases, we find it possible to explain the potential ways SPOT can be used. Earlier research in space syntax has highlighted that organizational structures and spatial structures influence the use of interior spaces that are strongly influenced by organizations (Hillier 1996, Grajewski 1993, Hanson 1998).

SPOT creates a possibility to examine the dynamics between the occupied space and the occupiable space as well as dynamics between organizational relations and spatial relations. The graphs made in SPOT can be correlated to data sets and show user patterns related to these dynamics. Future research at SAD (Spatial Analysis & Design) aims to evaluate SPOT through using data sets from earlier studies of office buildings made within our research group. So far, we only looked into open plan offices and department stores. The testing of different kinds of office layouts is crucial to prove the usefulness of the software.

Because this version of SPOT is an evaluation prototype, it has many bugs and lacks graphs and features that could make it even more useful. The development of SPOT will primarily handle these bugs as well as develop new graphs and measures. There are mainly three features to focus on: to implement integration measures to the isovist field graph; to implement fixed metric distance to the visibility integration network graph; and to make the line drawing editable in a real-time sketching process.

To implement integration measure to the isovist field graph would make it possible to create simplified VGA graphs. This would make it possible to compare different sub-sets of distribution in space with the super set of the total distributed space. This would open up a process of matching the occupiable to the occupied, and use the layer manager for testing different combinations and solutions. A similar but different operation is local in global measure, a measure that is common in both researchers and practitioner's analysis. By multiplying the local measure into the global measure, one can create graphs handling spatial phenomena originating from different scales. This way of measuring has been successfully used when analyzing pedestrian movement in offices (Grajewski 1993) and movement in cities (Spacescape, Markkontoret 2007). In this cases were axial line maps used for correlations. Such measure could be automatically generated in SPOT.

In addition, it would be useful to develop a visibility network node graph to calculate both integration measures and use fixed metric measures, which have successfully been used in other programs (Ståhle, Marcus, and Karlström 2005). We could then investigate small differences in for example offices. When analyzing face–to–face interactions, one could consider behaviour related to the range of human performance, for example such as Halls´ (1966) social distances.

The possibility to move isovists already exists in SPOT. This feature gives a possibility to experiment in real-time to test different solutions. We aim to develop the possibility to edit the line drawing in real-time. This feature would have a pedagogic value and be useful for the practitioner when evaluating small changes in their design. The tool would be able to design both the occupied and the occupiable at the same time, or 'Designing fields directly' as Benedikt puts it in his classic paper (1979).

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