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Abstract
Spatial Positioning Tool (SPOT) is an isovist-based spatial analysis software written in Java that works 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. SPOT was originally developed for a series of field studies on building interiors highly influenced by organizations and social groups. These studies needed a tool that could produce graphs using a specific position as starting point for the isovists. Now, we have developed SPOT as in several steps, although this paper focuses mainly on the first iteration. In this version, basic SPOT operations use selected positions to create isovist sets. The sets can be colour-coded and layered; the layers can be activated and made 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 the origins for the isovists. We use data from an office case study regarding face-to-face interaction. The software 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 with respect to user interaction. We will also briefly discuss recent developments of SPOT, and we furthermore provide a theoretical background for its development.

Keywords: Spatial analysis; Software; Organizations; Interaction; Isovist; Space syntax

1. Introduction
This paper reviews the background and properties of the spatial analysis software SPOT, software that can be used to analyse relational properties in space. It has gone through a number of iterations, and since the last publication (Markhede and Miranda, 2007), it has developed into two different applications doing two different kinds of analysis. This paper briefly introduces the background to the software development, a methodological approach we have come to loosely label “positioning analysis” (Markhede and Koch, 2007), and the research on which it was based. The herein presented version of SPOT is the most empirically tested: it is software that analyses configurations in space using isovists and isovist relations (Benedikt, 1979). Another recent development will be covered only briefly as it still remains to be tested. Finally, we will briefly discuss on ongoing and future research and their inclusion in existing or future projects to demonstrate how the software will be tested against empirical data.¹
Before addressing the software, we will briefly introduce the ideas behind “Positioning analysis” as was discussed in the method paper from the 6th International Space Syntax Symposium where Positioning analysis was discussed as a methodology to analyse spatial relationships between organisational subjects/objects distributed in space as different from relations of space (where the latter can be considered the focus of most space syntax modelling). Although some recent studies focus on the spatial relations of organisations, workers, or positions, some authors note differences between our argument (2007) and their arguments (e.g., Heo, et al., 2009; Lu, et al., 2009). Our point of departure comes from studies of building interiors strongly influenced by organisational and cultural features: our analysis examines the ways in which such features inhabit spatial configurations. In this sense, positioning analysis addresses question of programme as translated into spatial distribution. Basically, positioning analysis studies configurations in space of certain sets of elements of social or cultural significance to see how this relates to behaviour and organisational properties. These sets of elements can consist of workplaces such as in offices (Steen, 2009; Steen and Markhede, 2008; Steen and Markhede, 2006) or commodities and brands such as in libraries or department stores (Koch 2007, 2009a). The starting point of these studies, however, stems from the difficulties presented in trying to understand aspects of these buildings using regular space syntax analysis. It can be understood as analysis of buildings with strong programmes (Hillier and Hanson, 1984), but also as analysis of how a programme configurationally inhabits space to establish and communicate itself (see Markus, 1993). It should be noted that while the positioning analysis discussion was an integration of findings from office, library, and department store research, the SPOT software presented has consistently been developed primarily within the workplace environment studies conducted by Steen and Markhede with input from other studies.

2. The Software

The proposal of new software for spatial analysis is 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 DepthMap (Steen 2009; Steen and Markhede 2008; DepthMap: See 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 DepthMap) create graphs of potentially occupied space (UCL, ed. Turner 2004); however, the Spatial Positioning Tool (SPOT) creates graphs of the occupied space. 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.
There are several basic specifications for building the software: the possibility to create an uneven distribution of isovists; layer systems with colour coding; and calculation of integration measures. During the process, new functions have been developed and other concepts of measures were added, a process that has continued after the Istanbul Symposium. Building the software has in itself been an investigation of how to create representations of social and spatial relations. In addition, we have and will use SPOT as a platform for further investigations of socio-spatial representations. The initial software was produced during a one-month period and has been used as prototype for academic use only. The software has been further developed and used in two slightly longer projects in cooperation with AEDAS's Research and Design Department.

To produce graphs with the first versions of 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). The SPOT graph represents both the origin of the isovist as well as the field analysis both together and on their own. The isovist on its own can also be interpreted in different ways: the position, the position internalized to a seeing subject, the view from one position, the externalized position, and the interpreted position 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. In the latest iteration of the software, the isovist has been abandoned in favour of angular and metric distances because, in part, it aims to answer other questions. However, this should not be seen as a replacement but rather as a parallel development.

This paper provides a technical description of the first iterations of SPOT (still using the isovist as its base) and an example of how a graph is produced. We provide a short background about the creation of the program and show the data that gave rise to the concept. As the software is under continuous evolution, we will also discuss further development.

3. Background
It has been suggested that space syntax uses many representations of the spatial system to make a spatial model work with respect to a particular outcome. Creating relevant maps for correlation studies combines different scales, sections, and measures (Hillier, 1996). In our studies, we combine representations in novel combinations. SPOT allows researchers to choose 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, see Ståhle, et al., 2005). PST 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. Although PST has proven very useful in urban studies, it uses axial lines in the same way as regular space syntax analysis.
Unlike traditional space syntax analysis, SPOT allows for an analysis of uneven distributions of spatial entities. Thus, similar graphs have been proposed to understand human orientation in transportation terminals (Braaksma and Cooks, 1980). To create these graphs, they used sightlines between different important destinations at the airport, placing the data in a matrix that reveals 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 that gave rise to SPOT has focused on building graphs to analyze face-to-face interaction in spaces highly influenced by organizational or cultural features.

The observation studies used 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 management. In this study, we also used department borders to limit the VGA when correlating to face-to-face interaction (Markhede and 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 correlation 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 ensure 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 colour coded according to organizational department. Through this process, it is possible to combine each department’s total face-to-face interactions 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 initial studies were executed, so 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 the origin for the isovists. In this case, 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).

The correlation study was made by 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 the time (hour) of the interaction was noted. This information was divided into two categories: interaction at the workstation and interaction elsewhere, analysed in relation to 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, a design feature that is found 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. Strikingly, the data revealed few face-to-face interactions between 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 interactions 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 reflects only interaction at another department's workstation, a limitation that ensures that it is an inter-department act.
The face-to-face interaction pattern within each department is not the same as 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 (Figure 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.

In this case, interdepartmental face-to-face interaction is rare between indirect neighbours. For direct neighbours, interdepartmental face-to-face interaction is slightly higher but still relatively low, reflecting the strength of organisational borders. Within each department, face-to-face interaction is much more common in the more intervisible areas regarding encounters sitting at one's desk. Encounters as a result of 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.

4. Platform and Technical Specification

SPOT is written in Java, and thus it is platform independent - it runs on 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. SPOT builds a platform that will accommodate expansion and future research because it provides more than a solution to a specific problem. Since the Istanbul conference, we have split SPOT into different packages - isovist relations and angular/metric distance clustering - rather than creating one large software program that included all different analyses. SPOT implements a simple and dynamic user interface with the goal of making it user-friendly, simple and easy to use. This desire for simplicity of use is one reason for the division into different programs (modularity) instead of adding features to the existing basic program.

The calculation process in the isovist-position analysis package of SPOT starts by reading dxf format file that 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 an 'Environment' class that all isovist objects share and can interrogate. The most important component of the program is the isovist class, which
uses the operations available in java.geom. Area class, part of the standard Java libraries, is used to manipulate 2-D 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, and moved in real time or organised in layers that can be turned on or off.

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

```java
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 three arguments: an object of type Environment, which is the class that stores the description of the 2-D geometry from which to calculate the isovists, the x of the centre of the isovist, and the 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 are 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. By doing this, an isovist field is expanded, limited by the imported line drawing and the drawing area box that gives an outer limit for the 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 a network graph, which shows 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; where fewer, it becomes lighter. The graph can be said to show the visual situation created by the selected positions.

When choosing the show centroid command (Figure 6), an arrow within the isovist is highlighted. 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 to 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 (Figure 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 \( RA = \frac{2(MD - 1)}{k - 2} \). 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.

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 or off. When a layer is turned on, its set of isovists automatically becomes a part of the 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 all data elements in the file are 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.

5. Use and Future Development

The result in the example implies that both the artefact of space and artefacts of organizations significantly influence 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; Sailer and Penn, 2009).

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 and ongoing research at SAD (Spatial Analysis & Design) aims to evaluate the different SPOT analyses through ongoing studies of hospital environments as well as by using data sets from earlier
studies of office buildings made within our research group. Within the confines of this paper, we primarily study open plan offices and department stores. The testing of different kinds of office layouts is crucial to prove the usefulness of the software.

The version of SPOT primarily presented in this paper is an evaluation prototype. The development of SPOT has since handled many of these bugs as well as developed new graphs and measures. The originally perceived objectives (Markhede and Carranza, 2007) - 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 - have after initial improvements and ironing out of some bugs been somewhat abandoned in favour of developing angular/metric clustering analysis. The reason for this is because a concern for methodology, a desire to investigate new foci of analysis, and a decision to develop new questions rather than to provide software that basically reproduces to existing software.

The reason behind the intent to implement an integration measure to the isovist field graph was that it would make it possible to create simplified VGA graphs. As this would make it possible to compare different sub-sets of distribution in space with the super set of the total distributed space, it is still an interesting development. It would open up a process of matching the occupiable to the occupied and use the layer manager for testing different combinations and solutions. Although a different operation, this is a similar approach as found in the analysis of the local in global measure, a measure that is common in both researchers' and practitioners' analysis. This way of measuring has been successfully used when analyzing pedestrian movement in offices (Grajewski 1993) and movement in cities (Spacescape, 2007). In these cases, the analysis was of axial line maps used for correlations. A similar implementation would also provide a possible step in the analysis of spaces with a disjunction between visibility and accessibility as discussed by Koch (2009b).

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, et al., 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 such as Halls’ (1966) social distances. This line of thinking is part of the move from isovist studies to angular/metric distance and clustering analysis.

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).
Since the first publication of SPOT (Markhede and Carranza, 2007), many of the shortcomings of the software have been ironed out, some of the theoretical and empirical findings have been studied closer, and implications from the original approach have been developed (Koch 2009b, 2009c; Steen, 2009; Steen and Markhede, 2008). Furthermore, in the latest development stage of the software, working together with AEDAS Research and Development, isovists have been discarded in favour of distance measurements in terms of either (absolute) changes in degrees or metrics. The focus on this iteration of the SPOT software has been clustering measured in a number of different ways. While looking promising when it comes to the study of creation of contexts or identities, it remains to be tested in which way it can be said to correspond to social or cultural structures, organisational strategies, or to behaviour.

One such investigation relating directly to recent research within the space syntax field would be to focus on how SPOT relates to curatorial strategies in museums (Zamani and Peponis, 2007; Zamani 2009; Tzorti 2009). Other investigations could revisit studies done on department stores and

Figure 9. Visibility from (a) the expected regularly frequented spaces (own room, ‘day-room’, and the corridor in-between) of a single patient and (b) the ‘documentation spaces’ of the personnel, where nurses and doctors have their shared desks. Pictures from a research project funded by FORMAS on the Karolinska University Hospital in Huddinge, gastronomy section.
libraries or study the relation between clustering in space and organisational borders or face-to-face interaction patterns. Within current research projects, however, we are mainly focused on consolidating what has been learned from the developed version of SPOT as it is presented in this paper. These studies include studies of hospitals (Figure 9), in which comparisons between regular space syntax analysis, the analytical methodology worked into SPOT, and the work done by Heo, et al. (2009) and Lu, et al. (2009) are made. The latter two have similarities to what we proposed as “positioning analysis” or to SPOT properties, but there are also significant differences both in questions and methodology, both concerns that can be further developed and understood. All 'packages' of SPOT are also available for non-profit academic research by request, in order to facilitate further testing and development.

It is our conviction that the development of SPOT has significantly contributed to our research not only directly by making a number of analyses feasible and showing new problems and potentials, but also indirectly. The questions of how to develop analytical software, in which ways to represent space, which relations to study, and in which way to study them, becomes specific in a way they rarely do otherwise. We believe that while remaining still in early stages of empirical testing, the continuous development of software, even in applications that are later discarded, ensures a continuous development of theory and methodology, at least in as far as the software development is tasked with trying to answer something other than questions addressed by existing software.

6. Notes

1. This paper is an update of Markhede and Miranda (2007), which includes parts of the discussion of Markhede and Koch (2007), information about software development since then, and a reworked final discussion on SPOT. All of these have been a major part of much of the ongoing configurational building studies at KTH School of Architecture.

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