AGRAPH

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Complementary Software for Axial-Line Analysis

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Abstract
The software AGRAPH, as presented at the Space Syntax Symposium in 2005, is a tool for analysing 'node-and-connection models', particularly aiming at 'easy-to-use-interface' and the possibility of doing modelling and analyses as well as making printable images within one program. The intention behind the version of AGRAPH presented in this paper, is to offer a similar tool for axial-line analyses, i.e. software that has an intuitive interface and that handles axial-map modelling as well as analyses without requiring external software. By being simple and by the option of easy and 'on-screen' modelling of bridges, tunnels, curved streets and 'barrier-like-traffic', the program represents a useful supplement to the existing stock of axial-line software. AGRAPH is no substitution for larger software when it comes to advanced space syntax analyses or studies of very large systems, but it should be a highly relevant tool in education and in doing basic axial-line analyses of complex but not too large systems.

Introduction

Fundamental to the development of space syntax in education, research and consultancy is the continuous improvement of software. In addition to the programs DEPTHMAP, CONFEEGO and AJAX from Space Syntax Lab and University College London, there exist useful tools such as MINDWALK that does axial-line analysis with the option of 'merging lines' and S-CUBE that handles modelling as well as analyses within one program. All together these programs offer most of the features one might request when doing axial-line analysis. However, a lesson learned from introducing space syntax to students, is that, regardless of all existing and advanced software, improvements of basic axial-line tools can still be made. It is straight-forward to teach students the basic theory of axial-line analyses, it is straight-forward for students to draw axial-maps of theoretical 'example-cities', but as soon as it comes to axial-line analyses of 'œreal situation' things become less obvious. After drawing just a few axial-lines, students become aware of the many relevant configurational properties of the real city-space that is difficult to capture by simple axial-line modelling. Many of the students'™ questions can be answered by referring to particular features of the different existing axial-line software mentioned above, but in courses where space syntax is only a minor part of the total teaching, little time is left for analyses if the students need to be taught numerous software. The intention behind this new version of the software AGRAPH is to help this, i.e. to offer software that has an intuitive interface, that provide some new axial-line modelling options and that combine useful features that so far do not exist in one software.

Kinds of space syntax analyses

From the beginning of space syntax research, the development of space syntax theory has been closely followed by evolution of software. The combination of theory, software and numerous analyses of real-life situations has been the fundament for the scientific success of space syntax. Space syntax software are of several kinds that can be distinguished in accordance with the spatial units applied in the modelling; there are 'node analyses', 'axial-line analyses' and 'visual-field analyses', the latter also termed 'visual graph analyses' (VGA). Figure 1 shows some images typical for these three kinds of modelling.

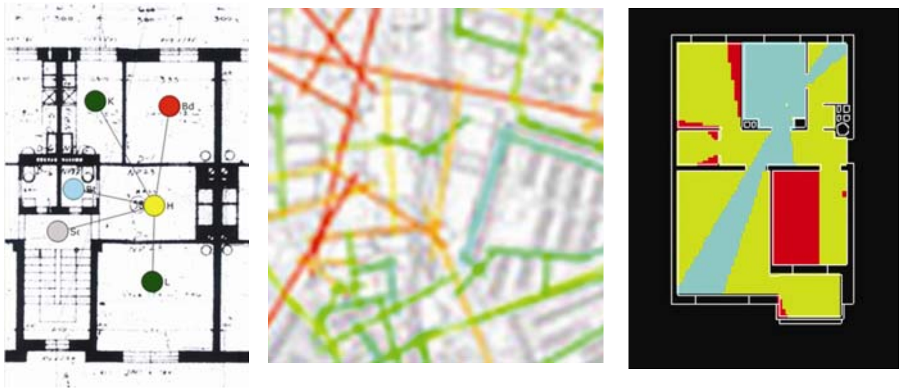


Figure 1
The three kinds of space syntax modelling
LEFT: node analysis (drawing a connectivity-graph)
MIDDLE: axial-line analysis
RIGHT: visual-fields analysis (here: "isovists" from a particular point)

In node analyses, the space syntax model consists in a 'connectivity graph' of nodes and lines (vertexes and edges in mathematical terms) where the nodes usually represent a room or a 'subspace' within a room (often a 'convex space'), while the lines (or edges) represent connections between the spaces. Node analysis is particularly useful for studying dwellings since they usually consist of enclosed spaces (rooms) connected by doors or door-like openings.

In axial-line analyses, the space is represented by straight lines, so-called axial-lines. In brief, the space to be examined is modelled by 'fewest and longest straight lines covering all convex spaces'. (Hillier and Hansson, 1984, p. 91-92) Each line is considered as a node in a connectivity graph and for crossing lines the respective nodes are defined as connected. Axial-line modelling captures basic features of continuous spaces such as the outdoor space between buildings in a city, a space that is a 'net' of long and intersecting 'street-spaces'. Therefore, axial-line modelling is often applied in urban analyses.

In visual-field analyses, the spatial elements on which the calculation is based are 'visual-fields' or 'isovists'. For spaces not known in advance by the persons being present (spaces where 'what you know is what you see') or spaces where people's movements have the character of 'free-float', visual-fields as well as axial-lines are likely to be relevant kinds of modelling. Visual-field analyses are often applied for studying spaces that are complex and overlapping but not 'street-alike', for instance public squares in cities and indoor space of buildings like museums or shopping malls.

Most real spaces can be analysed by any of these three kinds of modelling. However, as the different kinds of modelling capture somewhat different aspects of space, some modelling is likely to be more relevant than other. Which kind of modelling that might be best in a particular study, depends on the kind of space that is examined as well as on the subject of interest. In urban analysis, the field of research and consultancy where space syntax has been most important, axial-lines is the kind of analyses most frequently applied. This is particularly the case when studying large systems as entire cities, which usually consist of thousands of streets.

Tools for axial-line-analysis

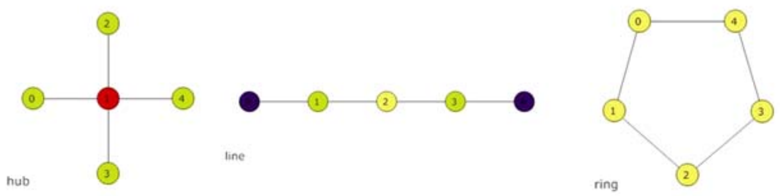
When doing axial-line analysis in practice, trying to represent the continuous 'street-space' of a real city by 'drawing fewest and longest straight lines covering all convex spaces', numerous questions arise. How to handle a crossing by bridge or tunnel? How curved can a road be for still being modelled as one axial-line, - and how long? With a two-kilometre long road, the axial-line analysis tells that the two ends are equally integrated as the midpoint (half-way) of the street, - can this be a relevant analysis? If you cannot see the end of a straight road because the road goes over a hill, is it still one axial-line element? How many axial-line segments are needed for modelling a serpentine-curved road down a hill? Does it make sense to model streets as linear elements being either connected or not-connected, - neglecting the angles at crossings and at streets' bends? These kinds of questions have been driving the continuous improvement of axial-line software. All useful axial-line software have an 'unlink'-option in order to model bridge- or tunnel-like crossings. The software MINDWALK handles the challenge of continuous but slightly bended roads by the option of 'merge lines'. (Figueiredo and Amorim, 2005) Turner (2005) has been working on taking the angle between intersecting lines into consideration by introducing other 'connection-values' than only the integers 0 and 1. AJAX handles the 'long line problem' by combining axial-line-modelling with a kind of 'node-analysis' (a so-called 'dual-analysis') where junctions between lines are treated as a kind of nodes. (Batty, 2004)

In addition to this development of modelling and analyses of axial-lines, progress has been made on user-interface, on computing capacity (needed for handling large systems), on doing statistical analyses and on combining space syntax analyses with analyses of other kind of data. Due to the increasing complexity of the software, it is advantageous to make software that leans on external and specialised program-modules. For optimizing speed of calculation, space syntax programs apply separate mathematic-modules. In order to combine space syntax analyses with analyses of other kinds of data, CONFEEGO is designed as a plug-in to the GIS software MAPINFO. The software PLACESYNTAX works as an addition to CONFEEGO and is particularly developed for combining analyses of geographical accessibility and space syntax axial-lines.

All together, these space syntax programs offer most of the features one might request when doing axial-line analysis. However, regardless of all this existing and advanced software, at least two lessons are learned from introducing space syntax to students. First, the possibility of doing all operations within one program is appealing. Second, improvements of software for very basic axial-line analyses can still be made. The axial-line version of AGRAPH attempts to help this.

Space syntax integration

The theoretical basis of space syntax calculations consists of some parts that are elegant in their simplicity, some parts that are clear but somewhat more complicated and some parts on which even specialists do not agree. The deduction of basic space-syntax parameters, from counting 'depths' between elements to the formula for RA, which is a 'relativised' measure of integration, is straight-forward and clear. When it comes to further parameters of integration, things are less obvious and subjects for discussions.



hub	TDn	MDn	RA
0	7	1,75	0,50
1	4	1,00	0,00
2	7	1,75	0,50
3	7	1,75	0,50
4	7	1,75	0,50
TD (total) 32			

line	TDn	MDn	RA
0	10	2,50	1,00
1	7	1,75	0,50
2	6	1,50	0,33
3	7	1,75	0,50
4	10	2,50	1,00
40			

ring	TDn	MDn	RA
0	6	1,50	0,33
1	6	1,50	0,33
2	6	1,50	0,33
3	6	1,50	0,33
4	6	1,50	0,33
30			

Figure 2
The space syntax parameters "total depth" (TD), "mean depth" (MD) and "relative asymmetry" (RA) for three 5-noded-graphs. The nodes are coloured by RA where red is maximum and dark blue is minimum possible integration. (Figure from Manum (2006), graph-images as well as tables are direct output from the software AGRAPH.)

Figure 2 illustrates the parameters total depth (TD), mean depth (MD) and relative asymmetry (RA) for the elements of three basic configurations; a 'hub', a 'line' and a 'ring'. The nodes are coloured in accordance with space syntax integration in the way that red represents the highest integration possible (which means RA=0.0) and dark blue the lowest integration possible (which means RA=1.0). By introducing the inverse parameter called 'integration', i = 1/RA (or i=1/RRA, see next paragraph) the scale becomes more logical in that a high value means high integration. What is described here is 'global integration', which means that the calculation 'counts' the distances between all elements in a complex. By counting distances only to elements within certain numbers of 'space syntax steps', integration of other radii is determined. Integration of different radii correlate to different kinds of activities in the city, but this will not be elaborated here.

In spite of the 'relativisation' with respect to system-size captured by the RA, RA-values are not directly comparable across systems of different sizes. In order to handle this, the parameter RRA (Real Relative Asymmetry) has been introduced. (Hillier and Hanson, 1984, p. 109-113) The definition is RRA=RA/D, where the scaling factor D depends on the number of elements in the system and is found by table or by calculation. Exactly how levels and distribution of RA-values vary by system-size, which is the problem intended to be solved by the RRA, or why this is solved by the D-values, is not easy to find out. Space syntax literature usually refers to Kr'ger (1989) on this, while Kr'ger's proposals are not absolutely clear. What Kr'ger has done, is to propose a scaling factor being RA of the 'root-element' in a 'reference configuration' of same size (size in terms of number of elements) as the case being analysed. He has described two alternatives, one where the scaling factor is RA of the root-element of a 'diamond shaped pattern' and one where it is RA of a 'corner of a grid', as shown in figure 3. His proposal is to apply the latter on 'node-grid-graphs', while the one to apply on 'axial-line-graphs' is not straight-forward but depends on the 'significant level of the difference of their mean RA'. (Kr'ger, 1989, p. 33) Several have questioned RRA being the best proposal for scale independent parameter of integration and have instead proposed other kinds of 'normalisations'. For instance Thaler (2005) applies normalisation according to Teklenburg (instead of the RRA according to Hillier/Hanson and Kr'ger), while Park (2005) more in detail discusses integration measures in space syntax.

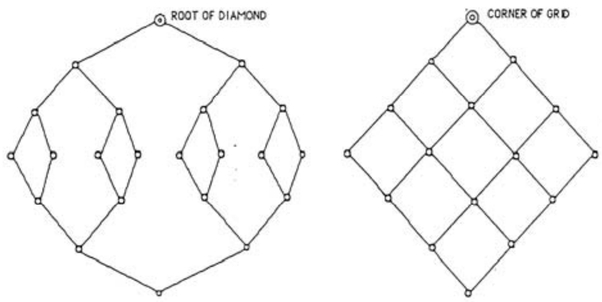


Figure 3

The two kinds of "reference configurations", where the "D-value" in calculating RRA=RA/D is derived from the "diamond-shaped-pattern" on the left. (Krüger, 1989)

The conclusion from this brief review of space syntax integration, is that an 'explanatorial step' occurs when developing more advanced measures of integration than RA and i=1/RA. So far, the software AGRAPH handles integration as RA, but normalisations of RA might be added.

AGRAPH

AGRAPH, as presented at the Space Syntax Symposium in 2005, is a tool for analysing 'node-and-connection models', particularly aiming at 'easy-to-use-interface' and the possibility of doing modelling and analyses as well as making printable images within one program. This version of AGRAPH is free download from http://www.ntnu.no/ab/forskning. The intention behind the new version of AGRAPH, the version described in this paper, is to offer a similar tool for axial-line analyses; a software that has an intuitive interface, that does not require any external CAD- or GIS-software and that offers some very useful modelling options. AGRAPH is developed in C# using VisualStudio.NET and runs on PCs operated by WINDOWS. The axial-line version of AGRAPH is made as a 'line-mode' in the existing AGRAPH software. The menu is simple and should be manageable without detailed instructions. Therefore, this paper concentrates on describing the software's main features rather than being a complete manual.

The axial-line modelling

Axial-line modelling consists in abstracting a real and often complex space into a model of linear elements being connected or not. This is a work that consists in numerous interpretations. These interpretations require knowledge about space syntax and axial-line analyses in general, about the possibilities and limitations of the particular software to be applied, about the subject of interest (such as kind of traffic or movements to be examined) and not at least knowledge about the particular city or site. AGRAPH is developed particularly for 'site- and subject-specific' axial-line modelling.

Drawing the axial-map

The basis of any axial-line analysis is the axial-map. Before starting drawing the axial-map in AGRAPH, a city-map or a floor-plan of the case to be analysed is set as background image by 'set background'. The background image can be turned on/off by the 'show/hide-background' button. Drawing axial-lines is done by turning on the draw-function and then simply left-click the endpoints for each line. Moving or deleting lines is done by switching off the draw-function and then picking the particular line with a left-click. Figure 4 shows a screen image of drawing axial-lines in AGRAPH.

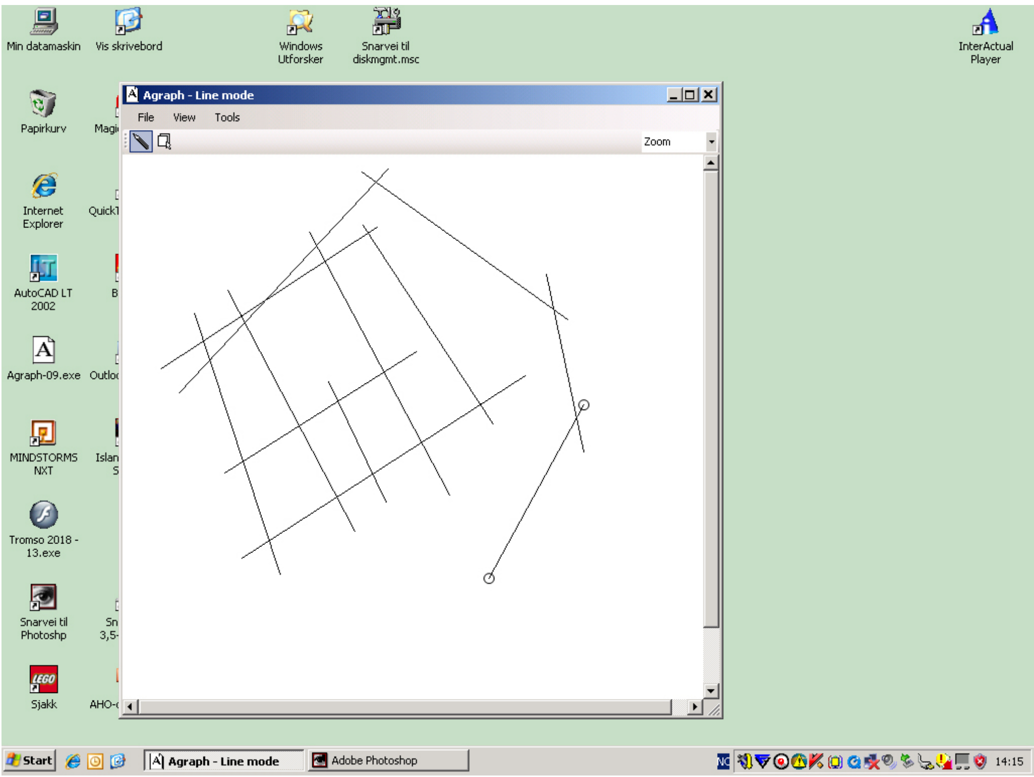


Figure 4

Drawing axial-lines with AGRAPH

Disconnect

A basic request in axial-line modelling is the need to disconnect lines. One road crossing another by a bridge is a typical situation where 'unlink-' or 'disconnect'-function is needed. In AGRAPH this is done by selecting a crossing (by mouse-click) and then clicking at the 'disconnect'-button, similarly to the merge command showed in figure 6. AGRAPH shows 'unlinks' as red circles if 'show disabled links' is switched on. (See figure 5)

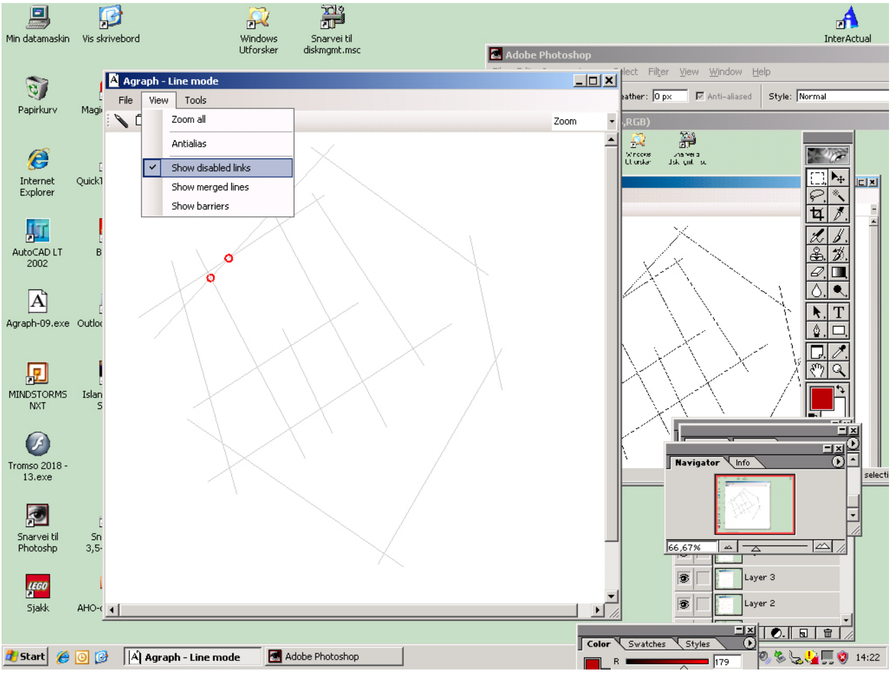


Figure 5
Example of showing "disabled links" (= "unlinks")

Merge / unmerge

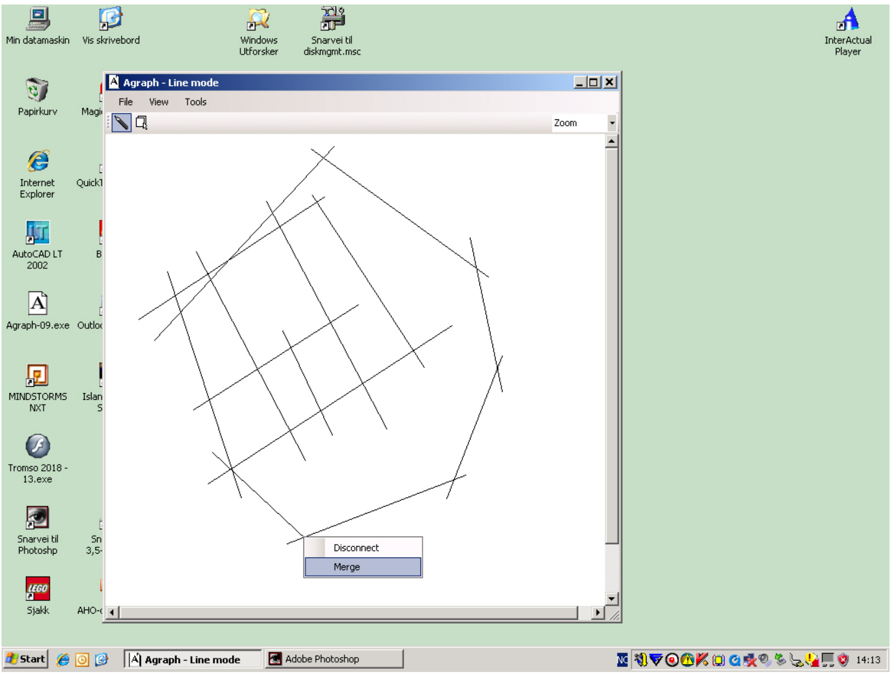


Figure 6
Merging two lines, - by clicking a connection, and then clicking "merge"

A challenge in axial-line analyses is how to model an element that is not straight but that still, in reality, is perceived as one element. Examples of such situations are ring-roads or a curved paths. Figueiredo and Amorim (2005) have proposed what they call 'continuity-maps' where sequences of axial-line segments can be considered as one element in terms of space-syntax distances. They have included this feature in their software MINDSTEP with a 'merge-function', a function where several axial-lines can be merged into one single element (i.e. one element with no internal distance). In MINDSTEP, the lines are automatically merged at all connections where the 'bend' is smaller that a certain chosen angle. In AGRAPH, the merge-function is somewhat different; the merge-function is 'manual' in the way that any two interconnected axial-lines can be merged by clicking at their intersection and selecting 'merge'. Figure 6 shows how to merge two lines, while figure 7 shows the entire merged-line-element that here consists of 6 axial-lines (shown by turning on 'show merged lines'). The example could in principle be a city-centre where a surrounding ring-road is modelled as one element by this merge option.

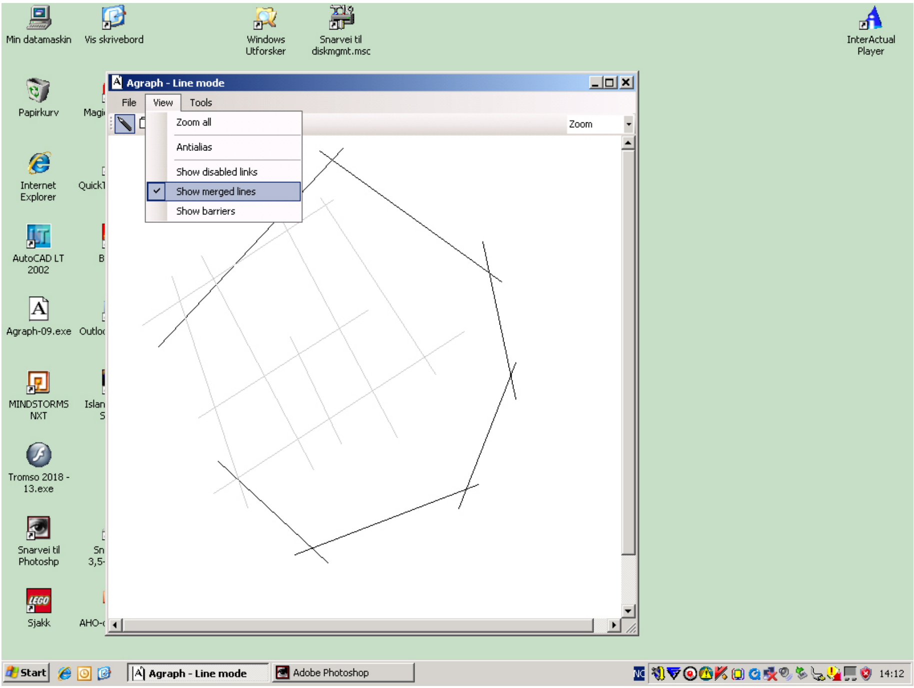


Figure 7

Showing merged lines, - by turning on “show merged lines” in the view-command

'Barrier-lines'

In space syntax, the basic conception of roads and streets is their potential for being elements in continuous spatial structures. In reality, roads and streets can be as much borders as they are connectors. In AGRAPH, a road that due to heavy traffic works as a barrier on crossing streets, can be modelled adequately by the barrier-line function. This function does two things. Firstly, it disconnects the barrier-line from all crossing lines. Secondly, it cuts all these crossing lines at their intersections with the barrier-line; each of the crossing lines becomes two axial-lines that are not directly connected. Then, finally, the barrier-line must manually be 're-connected' at appropriate crossings. Barrier-lines are not a special kind of element; it is an option of 'disconnect' and 'cut crossing lines' that can be applied on any axial-line element.

Bridge/tunnel-elements

The bridge/tunnel-option is an 'automatic disconnect function'. When a selected line is set to be a bridge/tunnel-element, AGRAPH 'disconnects' all intersections between the line and crossing lines. The line's connections must then be selected manually, - very similarly to the 'barrier-function' just described. A 'bridge/tunnel' can be changed back to en ordinary line (connected at all intersections) by selecting the line and the applying the 'connect at all intersections'-function.

Calculation

So far, line-mode in AGRAPH calculates the same space-syntax-parameters as the node-mode of AGRAPH do, which are control-value and global integration. Figure 8 shows the model example from figure 7 coloured by integration.

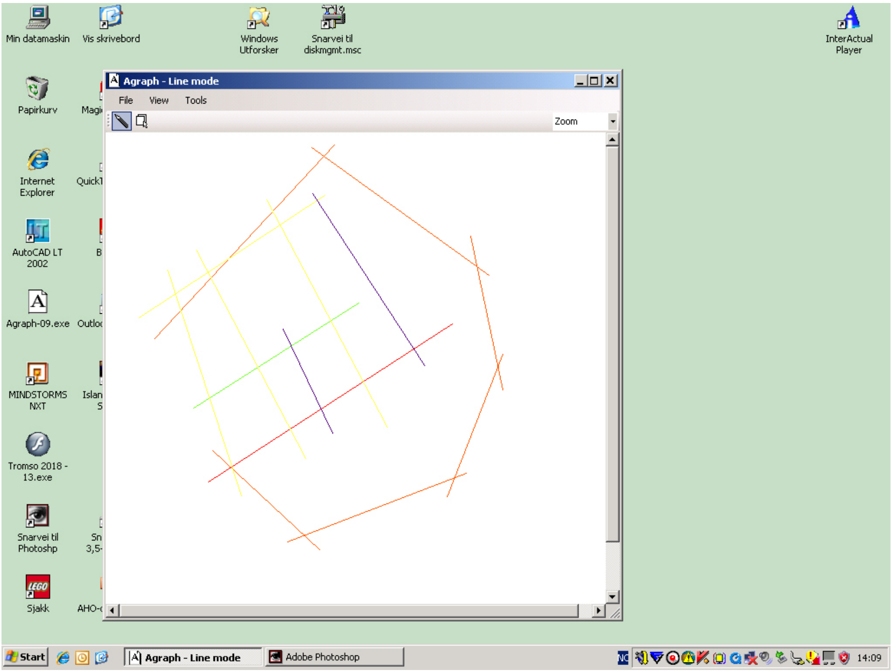


Figure 8

Integration (RA), - showing how the "merged-line" is one space-syntax element consisting of 6 axial-lines with no "internal distance"

Output data

The axial-line image shown on the PC-screen can at any moment be saved as image-file by the 'export'-command. Further output in terms of tables is to be selected by the 'output options' under the 'tools' command.

Optional features

Among useful options not yet made, is the possibility to import and export axial-maps in the .DXF ' format. We would also like to test combinations of node- and line-modes, similarly to the dual-analyses of AJAX. Furthermore, in order to analyse different kind of traffic/movement without making several axial-maps, a kind of layer-structure should be developed.

Conclusion

AGRAPH is a space syntax software that, by being simple and offering easy and 'on-screen' modelling of bridges, tunnels, curved streets and 'barrier-like-traffic', intends to be a useful supplement to the existing stock of axial-line software. The option of combining 'manual merge' with 'disconnect/unlink' and 'barrier' offers potentials of applications that are not yet examined, for instance in modelling 'super-grids' that overlay smaller-scaled city-grids. AGRAPH is no substitution for larger software when it comes to advanced space syntax analyses or studies of very large systems, but it should be a highly relevant tool in education and in doing basic axial-line analyses of complex but not too large systems.

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