

# A new tool for spatial analysis: 'Rings & Sectors plus Density Analysis and Trace lines'

## 1 Introduction

Intrasite spatial analysis of Stone Age sites has often involved the use of quite complex mathematical or statistical procedures (e.g. Blankholm 1991). The present authors felt that the output of such techniques is often unsatisfactory and difficult to interpret. Therefore, they wished to develop more transparent ways of dealing with horizontal distributions of artefacts. Out of this desire, the computer program 'Rings & Sectors' (R&S) was created; it is designed as a simple tool for intrasite spatial analysis.

R&S comprises four techniques: ring and sector analysis, trace lines, and density analysis. Furthermore, it offers many options for creating distribution maps. The program has been designed in such a way that non-specialists in the computer world can easily work with it without having to go through time-consuming learning processes. This has been achieved by applying two basic principles. The first is that it is a what-you-see-is-what-you-get program; the maps, graphs, etc. on the printer output are exactly as on your screen (except for some minor details). The second principle is that we have tried to keep the screen as clear as possible by removing all superfluous information and by applying a top-down order wherever possible, so that the user automatically encounters all possibilities of the program.

## 2 Ring Analysis and Trace lines

The Ring & Sector Method was especially developed for Stone Age sites with a central hearth, more or less in the middle of an artefact scatter. In principle, however, it can be applied to any site with a suitable central point (Stapert 1992). The idea behind the Ring & Sector Method is that the hearth was a focal point in the daily life of a small group of people. It attracted many activities, and also played an important role in social life. Therefore, using rings and sectors around the hearth centre seems to be a 'natural' way of charting spatial patterns in such situations (fig. 1).

An attractive aspect is that the method is closely related to Binford's 'hearth model', based on ethnoarchaeological research (Binford 1983). Binford described a characteristic pattern of 'drop and toss zones' around outdoor hearths.

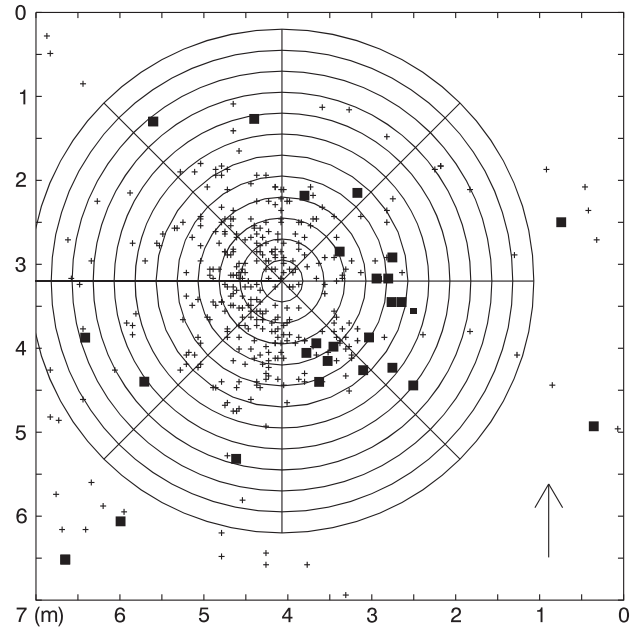


Figure 1. Distribution map of the tools (crosses) and the cores (squares) at the Magdalenian site of Pincevent, unit T112. The core symbols have been filled. A ring and sector system radiates from the centre of the hearth; in this case 8 sectors, and 12 rings of 25 cm width were employed.

The drop zone was located in the site-half where the people sat and worked most of the time, windward of the hearth in order to avoid the smoke. It can be shown that in the case of Late Palaeolithic sites with outdoor hearths, the drop zone was generally located in the tool-richest site-half.

In a ring analysis, the frequencies of artefacts are counted per distance class. One of the most important applications of the Ring & Sector Method relates to the question whether a hearth was located inside a dwelling or in the open. The ring distributions of tools from the analysed sites are found to be of two different types: unimodal and multimodal. Unimodal ring distributions point to hearths in the open (fig. 2). Artefacts that were tossed away were not stopped by tent or hut walls, with the result that ring frequencies gradually decrease away from the hearth.

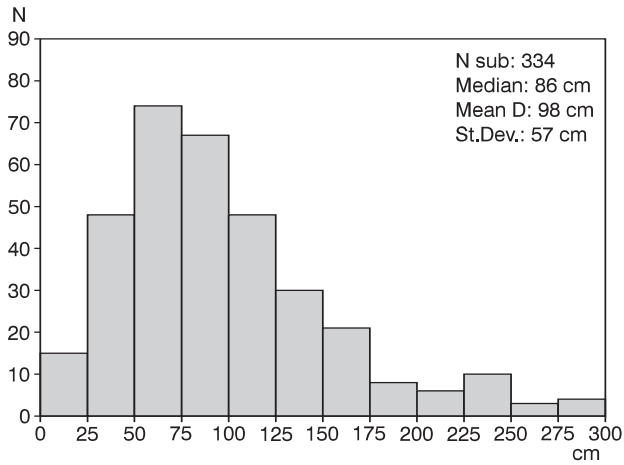


Figure 2. Ring diagram of the tools at Pincevent. The ring width can be changed to any size, so that the best resolution for any site can be found. Here rings of 25 cm have been used. The result is a unimodal graph which points to a hearth in the open air.

Multimodal ring diagrams are thought to be typical for artefact distributions created inside dwellings. Figure 3 shows the ring diagram for the backed bladelets in the NW quarter, up to 5 metres from the hearth centre, at the Magdalenian site of Gönnersdorf Concentration II. The first peak represents the drop zone near the hearth. The second peak is caused by the barrier effect of the tent wall. We concluded from a series of diagrams such as this that the tent had a diameter of about 7 metres (Boekschoten/Stapert 1993: fig. 10).

When a ring analysis is done for all 4 quarters, or even for 8 sectors, it will be possible to produce a reliable reconstruction of the tent wall. It should be noted that if a tent was not exactly circular, or when the hearth was located eccentrically, a ring analysis for all sectors taken together may produce an unintelligible diagram.

One of the advantages of the computer program Rings & Sectors is that one can establish the optimum level of resolution, by exploring the whole scale of measurements: from fine- to coarse-grained. In this way the best parameters for any site may be found. Our experience is that one should preferably choose a ring width between 20 and 50 cm, depending on the number of artefacts. Too narrow a ring will lead to fragmentation of the curve and obscure its character; too wide a ring may give a meaningless or even misleading picture.

An alternative way of analysing distance data is the trace line. The artefacts are ranked according to their distance from the hearth centre; in the bottom left corner the artefact closest to the hearth is plotted; in the top right corner the farthest one. This results in characteristic S-shaped curves for artefact scatters around fireplaces

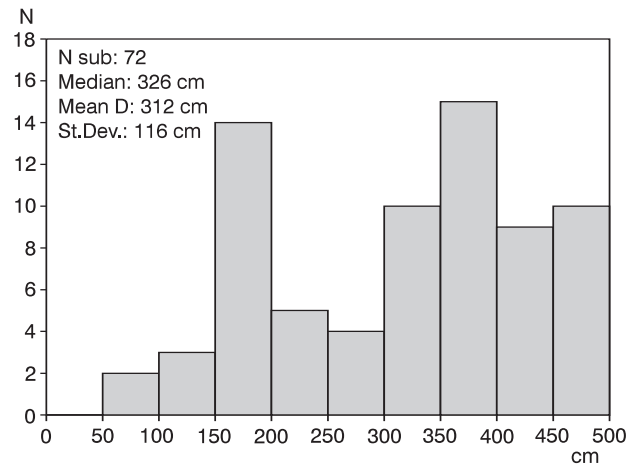


Figure 3. Ring diagram of the backed bladelets in the NW quarter of the Magdalenian site Gönnersdorf II. Bimodal or multimodal ring distributions indicate a hearth inside a dwelling. The first peak is the drop zone, where the people were sitting and working; the second peak is caused by the barrier effect of the tent wall. By executing a ring analysis for a series of sectors, a reliable reconstruction of the tent wall can be obtained (see also Boekschoten/Stapert 1993: fig. 10).

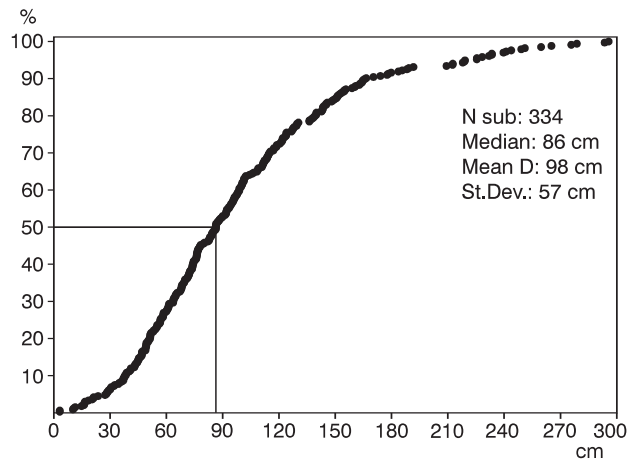


Figure 4. Trace line of the tools at Pincevent. The trace line is an alternative way of displaying distance data; the artefacts are ranked according to distance from the hearth. Characteristic S-shaped curves result for hearths in the open air. The advantage of trace lines over ring diagrams is that no class division is needed; they are therefore more precise. The median is indicated in the diagram.

in the open (fig. 4). The steep part of the S-curve coincides with the only peak in the corresponding unimodal ring diagram: the drop zone. At tent sites, 2 or 3 S-shaped curve-parts will follow each other in the trace line (fig. 5). The first 'S' reflects the drop zone. The second one is caused by the tent wall which will have been located just after the end of the steep part. The third S-shaped

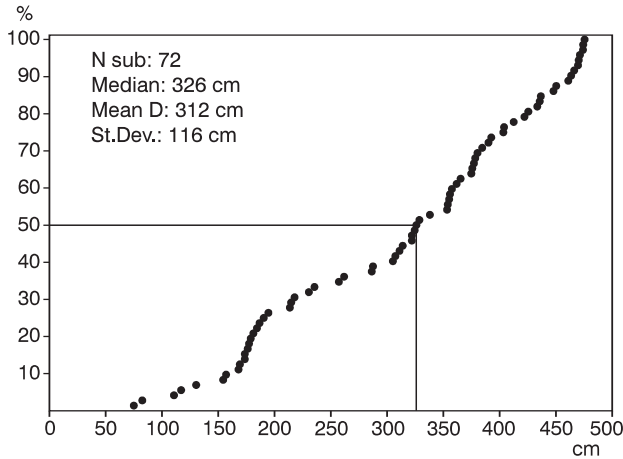


Figure 5. Trace line of the backed bladelets in the NW quarter of Gönnersdorf II. At tent sites, three S-shaped curve-parts follow each other. The first steep part, between 150 and 200 cm, represents the drop zone; the second, between 300 and 400 cm, is caused by the barrier effect of the tent wall; the third, between 450 and 500 cm, may indicate a door dump.

curve-part, if present, represents the door dump, outside the tent entrance. The advantage of trace lines over ring diagrams is that no class division is needed. It is therefore a more precise method for establishing the position of the tent wall.

### 3 Sector Analysis

Once it has been established whether the hearth was in the open or in a tent, a new series of questions may be approached. Figure 6 immediately makes it clear that in Pincevent (T112) the western site-half contains most of the tools. As stated above, in the case of outdoor hearths the tool-richest half is the half where people were sitting and working most of the time. We can therefore now reconstruct the prevailing wind direction during occupation: from the west. We call a diagram such as figure 6 a sector graph, which in fact is a combination of a bar graph and a pie chart. The centre of the circle represents the hearth, around which, in this case, 16 sectors are positioned. The frequencies of the artefacts are counted for each sector. The centre has the value zero; the circle represents the mean number per sector. Sectors with a frequency higher than average are given a black bar protruding outwards. Sectors below the mean have a bar protruding inwards. In this way a powerful visual presentation of the data is achieved.

One may wish to perform an analysis of the richest half only. The program is then able to calculate the position of this richest half. It will count the tools in 72 sectors of 5 degrees, and establish the richest site-half.

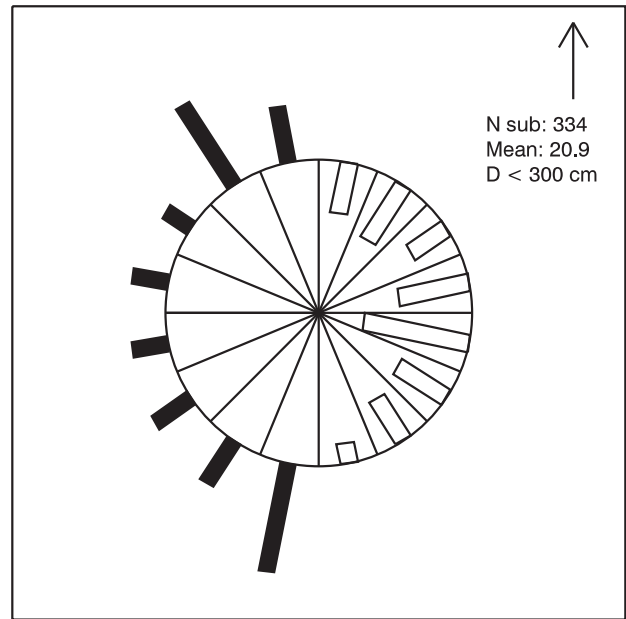


Figure 6. Sector graph of the tools at Pincevent. The centre of the circle represents the centre of the hearth. Sectors with frequencies higher than the average get black bars protruding outwards; sectors with frequencies lower than the average get a white bar protruding inwards. The circle represents the mean. It is immediately clear that in Pincevent the western half is the richest site-half.

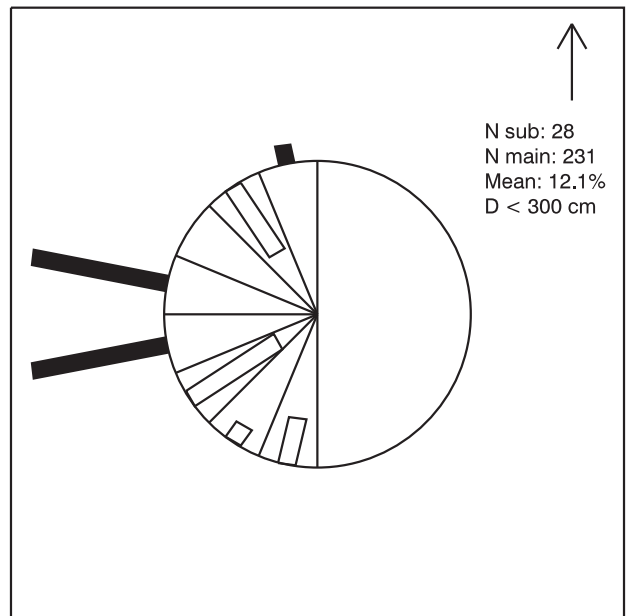


Figure 7. Pincevent, comparative sector graph of the scrapers, shown here as a percentage of the tools. The "mean" is the percentage of the scrapers in the richest site-half only.

The program Rings & Sectors offers the possibility of selecting two groups of artefacts for analysis; a 'main-selection' and a 'sub-selection'. The actual analysis is carried out on the sub-selection, which preferably should be part of the main-selection. One can compare the two sets of data, both in ring and sector analysis, and in density analysis. The frequencies of the sub-selection are then presented as percentages of the frequencies of the main-selection. This 'comparative option' may be very useful in bringing out locally occurring high proportions of, for example, tool types. Figure 7 shows the tool-richest half at Pincevent T112 (calculated by the program), with the scrapers presented as a percentage of all tools per sector. It is immediately clear that there are proportionally many scrapers in the two sectors in the middle, while they are underrepresented in most of the remaining sectors. In this case, the circle indicates the percentage of scrapers in the richest site-half (called 'mean' in the diagram).

For sector analysis, several optimizing techniques have been included in the program. Apart from the possibility to calculate the richest site-half (see fig. 7), the program also offers options to calculate the 'richest sector' and the 'highest contrast', by rotating the sectors. These calculations can be done both 'absolutely', on the basis of the sub-selection only, and 'comparatively', in which case the sub-selection is presented as a percentage of the main-selection.

With a given number of sectors, the richest sector option seeks the sector system in which (at least) one sector has the highest possible frequency (or percentage). The option 'highest contrast, absolute' seeks the sector system that maximizes the sum of the squared numbers of artefacts in the sectors:  $\sum(n^2)$ . The 'comparative' option maximizes the sum of the differences between the observed percentage and the overall percentage in all sectors (fig. 8).

#### 4 Density Analysis

Density analysis is a generally applicable technique not requiring a central hearth. Over the excavated terrain a system of square cells is positioned, which can be of any size. Grids with cells of  $50 \times 50$  or  $100 \times 100$  cm are most common as such cells often form the basic excavation units. Inside these cells black circles are placed, the size of which reflects the relative frequency of artefacts in the cells. Figure 9 shows a density map of the tools at Pincevent (T112); a grid size of 50 cm was used.

Just as in the case of the Ring & Sector Method, the program offers the possibility to establish the optimal resolution for density analysis. In figure 10 the same data have been used as in figure 9, but here the density map is based on a grid size of 25 cm. This clearly gives much more detail.

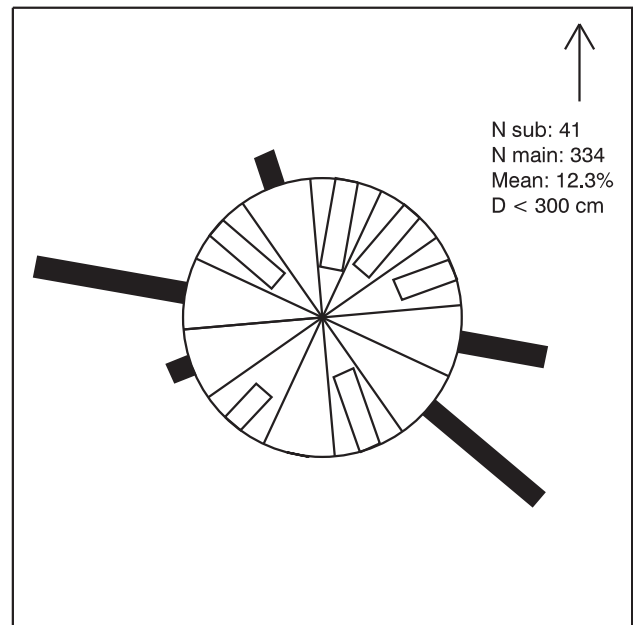


Figure 8. Pincevent, sector graph of the scrapers as a percentage of all tools. The graph has been optimized by rotating the sector system, so that the highest possible contrast is obtained.

The program includes several options for the parameters of density maps, in order to make these maps more analytical. It is possible, for example, to use three different systems of class division (Cziesla 1990):

1. the linear class division, which simply divides the highest cell frequency by the number of classes (fig. 10);
2. the peripheral class division, which emphasizes the lower frequencies; class intervals grow according to a square power function (fig. 11);
3. the central class division, which emphasizes the higher frequencies; class intervals decrease according to a square root function (fig. 12). All detail is lost in the latter case, but it may be useful for stressing certain activity areas characterised by high local densities, such as flint-knapping locations or dumps.

Cziesla (1990) advocates the linear option for class division. The visual effect of density maps, however, depends on the surface areas of the circles and not on their radius. Therefore, the surface areas of the circles in the peripheral option are in fact linearly proportional to the cell values (or to be more precise: to the maximum values of each class). Consequently, the linear option results in a 'central' display of the data (and the central option is in fact super-central; see Stapert/Boekschoten in press).

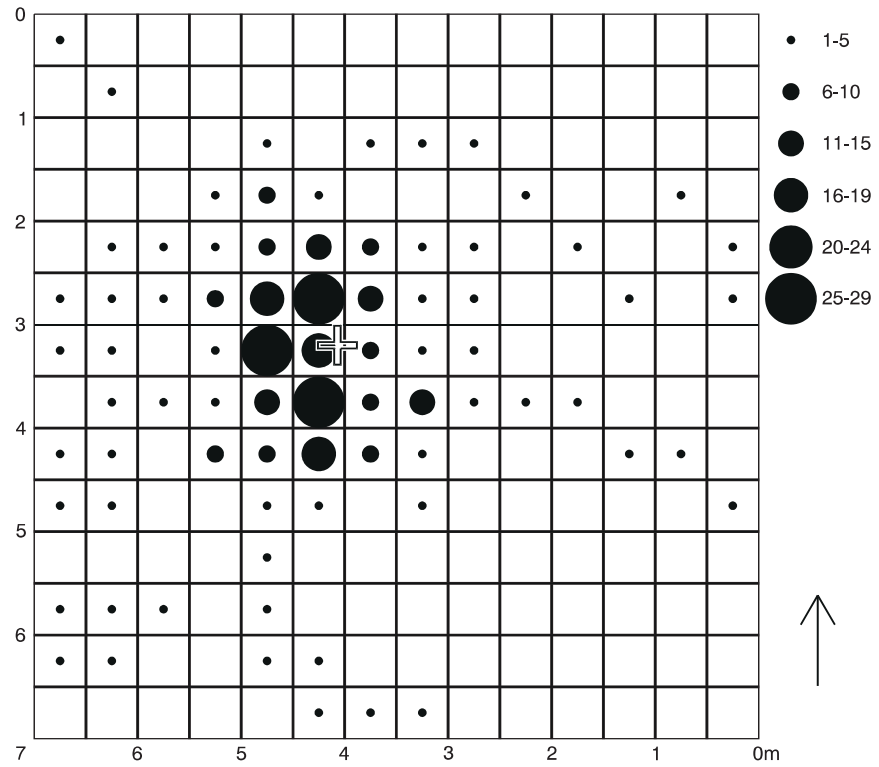


Figure 9. Pincevent, density map of the tools. The cross indicates the centre of the hearth. A grid size of 50 cm was used. Note that with a linear class division, a maximum cell value of 29, and 6 classes, there will be always one class with an interval of only 4, instead of 5.

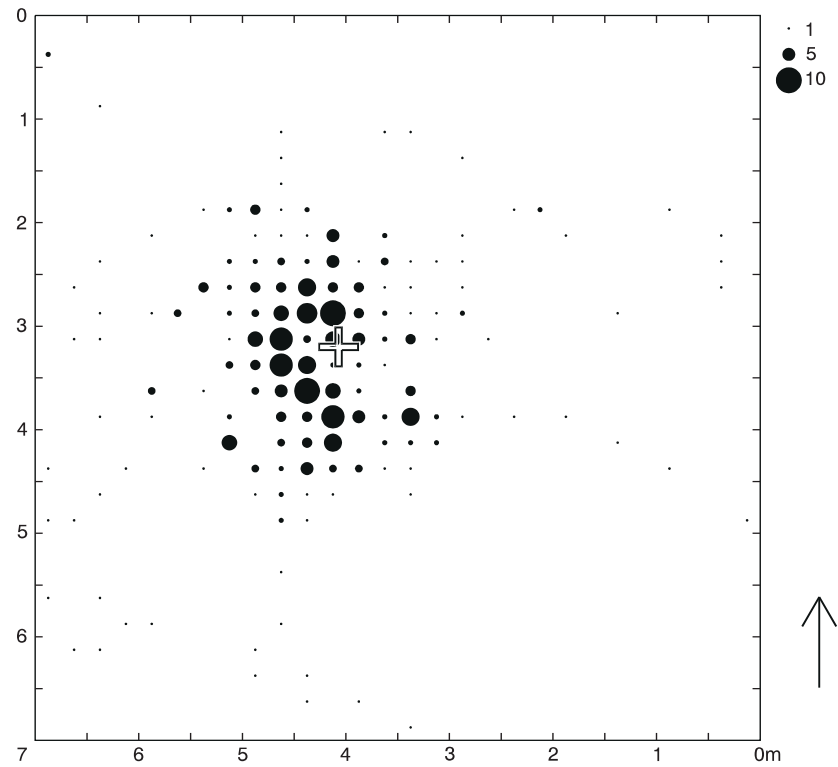


Figure 10. Pincevent, density map of the tools, based on a grid size of 25 cm. The program Rings & Sectors allows the use of any grid size for density maps, so that the optimum level of resolution may be established. Note that the grid lines were omitted in this picture. No classes were used in this case. Linear.

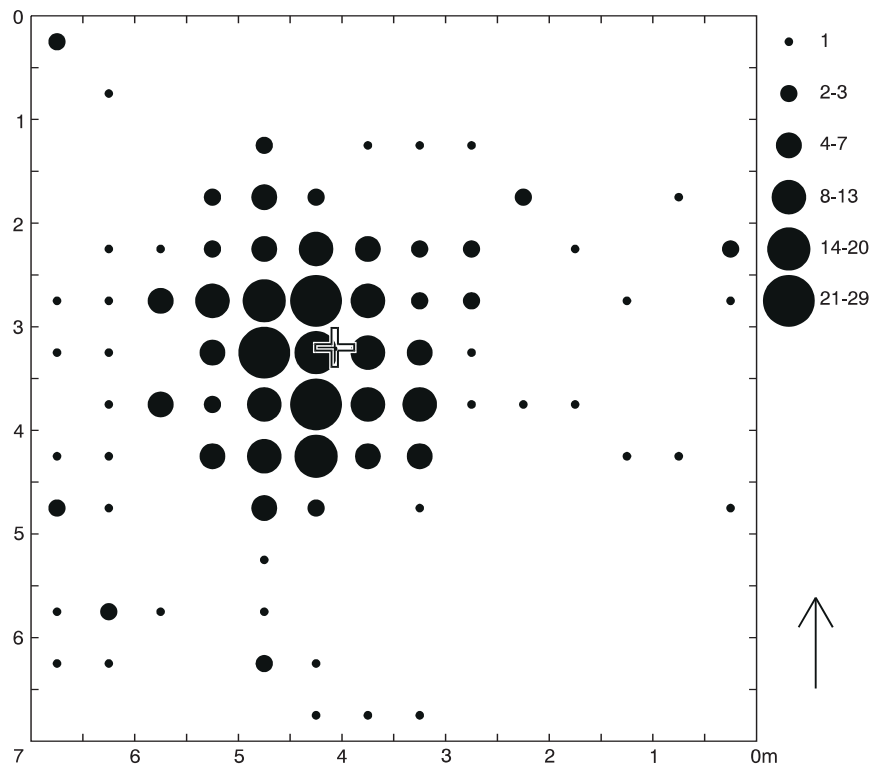


Figure 11. Pincevent, density map of the tools, based on a grid size of 50 cm. In this case a peripheral class division is used, resulting in relatively many classes for the lower frequencies and relatively few for the higher frequencies; this makes the map relatively "black".

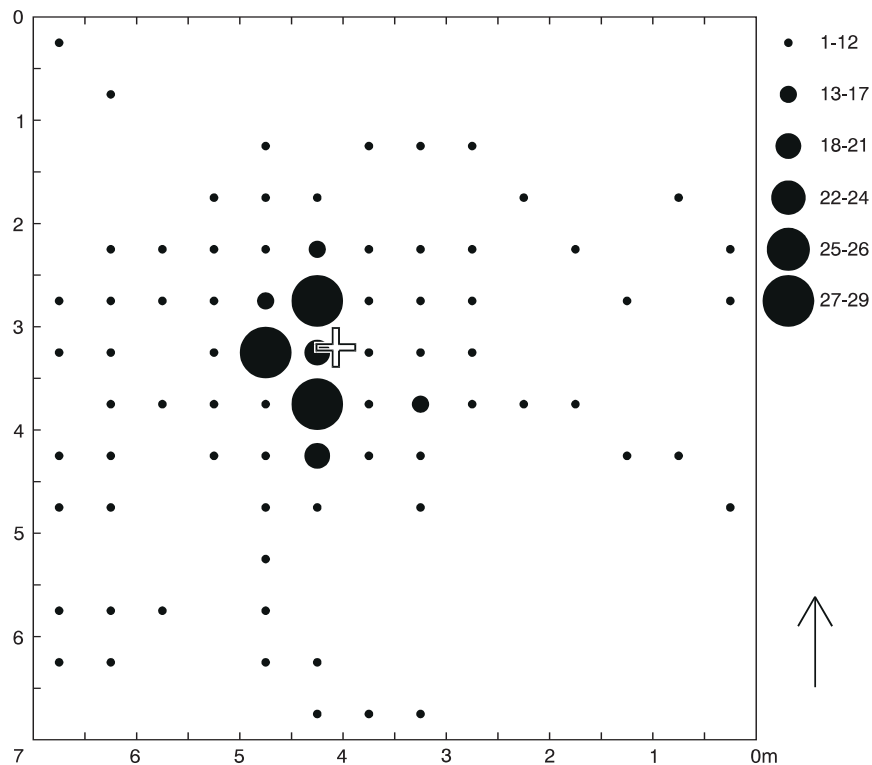


Figure 12. Pincevent, density map of the tools. In this case the size of the circles is defined by the central class division which emphasizes the higher frequencies.

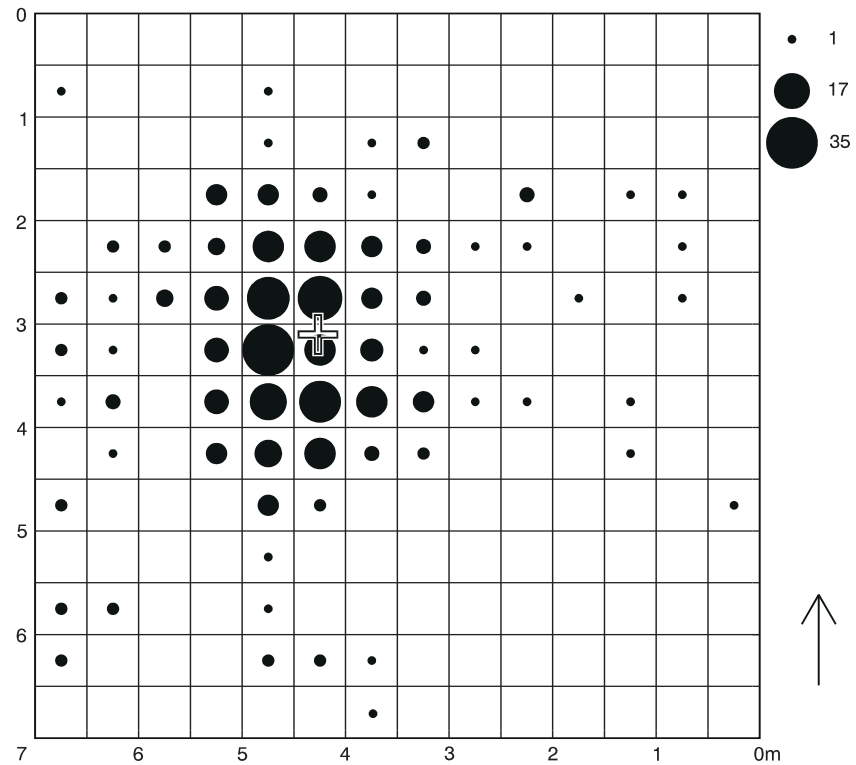


Figure 13. Pincevent, density map of the tools. In this picture, the richest cell option was used. The richest cell now contains 35 artefacts instead of 29 as in the standard position (see fig. 9). In this case no classes were used. To the right the minimum, median, and maximum cell values are shown. Peripheral.

In the computer package Rings & Sectors one can choose from 0 to 10 classes. In case one or more classes are used, the radius of the circles changes in a linear way, but the class intervals (contents) may vary, depending on how the class boundaries are calculated (linearly, peripherally or centrally). If, however, one chooses to use no classes, the diameters of the circles are calculated as a proportion of the highest cell value, for each frequency. Again, one can choose between the linear, peripheral and central options; in the latter cases the diameters of the circles are transformed by square root or square power functions, respectively. Figures 10, 13 and 14 are density maps without a class division.

In our opinion, the peripheral option without class division results in the clearest, and — more importantly — the most ‘honest’ pictures.

As in the case of sector analysis, the program offers several options for optimizing density maps. It is possible to move the grid freely over the excavated area; this of course only makes sense when artefact locations were measured individually. The most straightforward optimizing technique included in the program is the richest cell option: the grid is moved by the program so that the richest possible cell is found. This can be done either with absolute frequencies of the sub-selection, or comparatively (the sub-selection

expressed as a percentage of the main-selection: see below). Figure 13 presents the same data as in figure 11, but using the richest cell option (absolutely). The richest cell now contains 35 artefacts, instead of 29 as in the standard grid position; an increase of 21 %. This procedure results in ‘standardizing’ a density map, so that different sites can be compared in a more meaningful way. One could also say that in this way a density map is ‘focused’, so that the sharpest picture is obtained (in fig. 13, there is only one cell in the highest class, in figure 11 there are three). When using the ‘highest contrast option’, the program calculates the grid system for which the sum of squared cell frequencies is maximized.

The program offers several alternative ways to calculate class divisions. For example, one can suppress extreme values, as advocated by Cziesla (1990), or one can manually define class intervals in whichever way one desires.

A special utility is the frequency map (fig. 14), which is a numerical representation of the density map.

## 5 Proportion maps

One may wish to know not only the frequency distribution of the artefacts (of a specific group) over the cells, but also their proportion, relative to a greater population (for example, the percentage of scrapers, relative to the

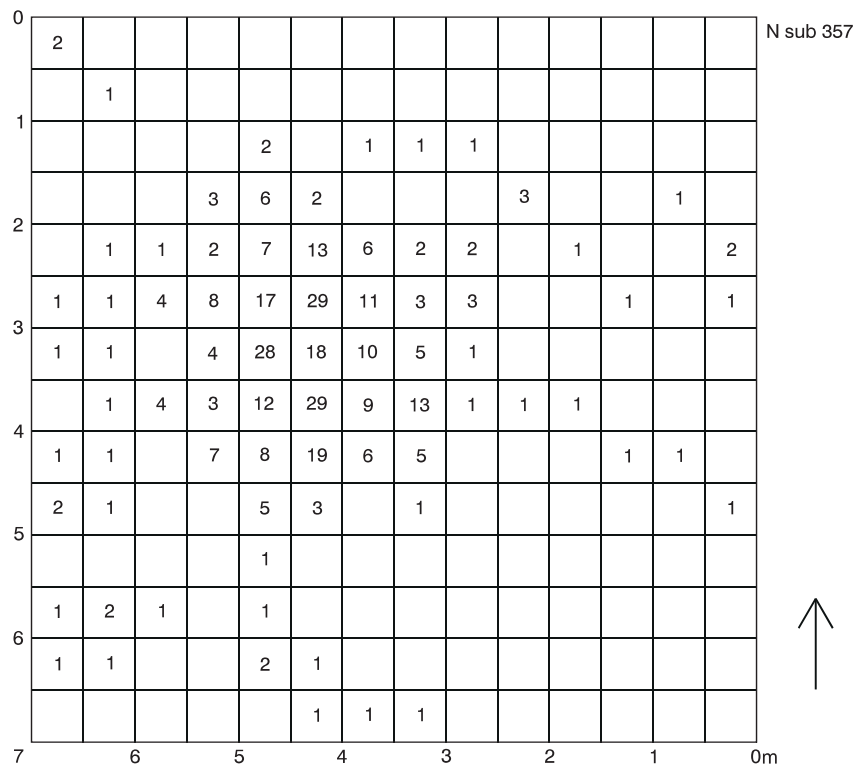


Figure 14. Pincevent, frequency map of the tools. The actual cell values which form the basis of density maps are shown.

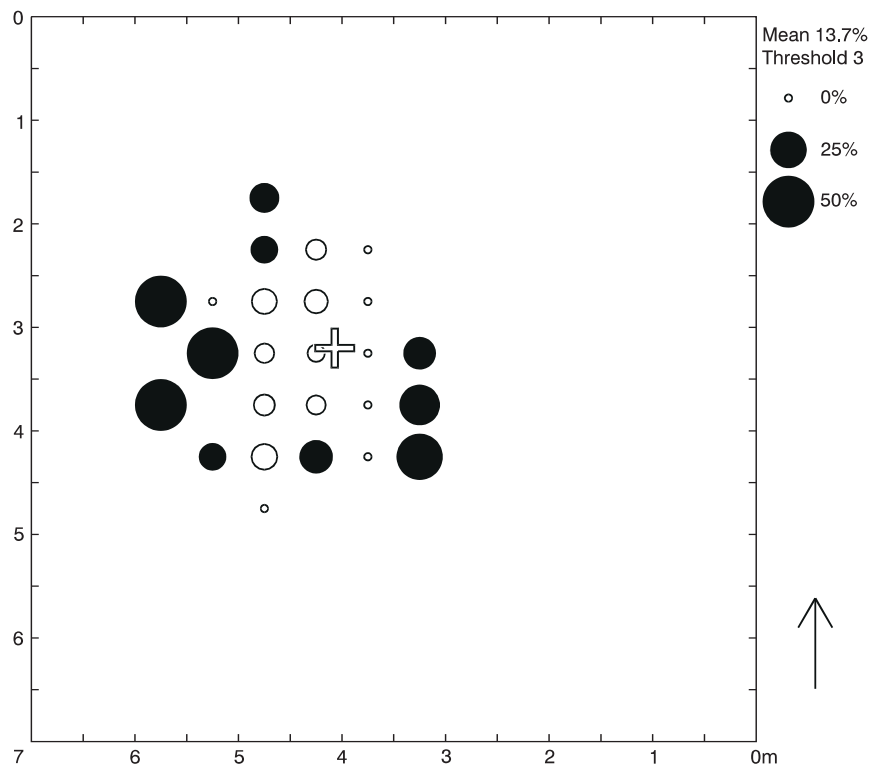


Figure 15. Pincevent, proportion map of the scrapers shown as a percentage of the tools. Black circles represent cells in which the percentage is higher than that over the whole site; open circles represent cells with a percentage lower than average. This map makes it clear that the scrapers occur particularly at some distance away from the hearth. In this case a threshold value of 3 was chosen; this means that only cells with 4 or more tools (in the main-selection) are shown. Again, the peripheral option without classes was used.



total number of tools). As noted before, the program allows 2 selections. These selections can be compared to each other in a so-called proportion map (fig. 15). In such maps, cells with black circles have a percentage that is higher than the proportion over the whole site. Open circles indicate cells containing less than the overall percentage (indicated to the right of the map: 'mean'). In this way, areas with higher or lower percentages than average are immediately visible.

A problem of proportion maps is that cells with low frequencies easily dominate the whole picture; all cells with only 1 artefact will result in either 0 or 100 percent. To avoid this problem, the program allows you to give a threshold value. Cells with a number of artefacts (in the 'main-selection') equal to or lower than this threshold value are not shown on the map. As can be seen in figure 15, only cells close to the hearth pass the threshold (and contain at least 4 tools).

The program is able to optimize proportion maps by moving the grid. For example, it can find the grid position with the highest possible proportion in one (or more) cells. It is also possible to calculate the grid in which the sum of the difference between the percentage over the whole site and the observed percentage in all cells is maximized. The result will be that cells with a low percentage of an artefact type and cells with a high percentage contribute more to the position of the grid than cells with a value around the mean.

## 6 Cartography

Cartography is, of course, the most basic tool for the analysis of any spatial distribution. The program always starts with a distribution map as a basis for all subsequent

analyses, so that one remains aware of the raw data that are being analysed.

There are several options for producing distribution maps. Three selections can be made:

- a. The sub-selection, to which only one symbol (out of 19) can be attached; in this way any group of artefact types can be given the same symbol.
- b. The main-selection; here one can assign symbols within a record field (artefact type, burnt/unburnt, broken/unbroken, etc.). Every category of artefacts within any field may have its own symbol. One can easily switch between several fields.
- c. The fill selection, in which artefact types can be selected that must have filled symbols in the map. For example, all tools may be selected in the main-selection, with a different symbol for each tool type; in the fill selection one can then choose those artefacts that are burnt. Many other combinations are possible, so that clear and analytical maps of different types can be produced.

## 7 Summary

The program Rings & Sectors supports four techniques for spatial analysis that are considered by the authors to be transparent: ring and sector analysis, trace lines, and density analysis. Furthermore, it offers many options for creating distribution maps. The program makes it possible to explore the whole scale of measurements from coarse- to fine-grained. In this way the optimal level of resolution for any site can be established, a prerequisite for meaningful quantitative approaches.

All results, whether maps, tables or diagrams, can be printed out on laser printers.

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