Debating about the Graphic Representation of the Spatial Distributions of points: 3-D vs. 2-D

Germà Wünsch
Maison René Ginouvès, Lab. d'Ethnologie Préhistorique.
21, allée de l'Université. 92023 Nanterre. cedex. France.
E-mail: wunsch@mae.u-paris10.fr

Introduction: graphic representation as a research tool.

The graphic representation of information is a basic tool of scientific communication. Its contribution to the application of quantitative methods is evident, because it makes understanding the study of phenomena easier. Nevertheless, the importance of the graphic representation of data has not always gone hand in hand, with an adequate reflection on its specific features.

In archaeological research, data quantification, basically centred on the application of statistical tests, is still in its initial stages (Barceló et al., 1994; Wünsch, 1996c). The confusion and the fascination, which new tools inspire (due to a lack of a training, for using statistical techniques correctly), have brought about different situations. At present, excellent applications of statistical techniques coexist, side by side, with displays of total ignorance. In general, we still are at an exploratory stage, and at this stage, new tools ought to be introduced into different working procedures. It should not surprise us, then, that there also exists great confusion, in relation to the use of graphic representation.

Skimming through handbooks and projects, devoted to the application of statistical tests in archaeology, one can gather a certain lack of reflection, on the characteristics, of the most widely used methodology for graphic representation (Doran and Hodson, 1975; Richards and Ryan, 1985; Shennan, 1992; Orton, 1988; Djindjian, 1991; Fletcher and Lock, 1991). Most of the works hardly pay any attention to this subject, with the exception of an interesting work by Chernokian (1986), that gives a suggestive appraisal on the advantages and disadvantages, of different forms of graphic representation for statistical results.

This situation is, indeed, curious. In principle, most researchers make use of statistical tests, only as mere working tools, and, as such, it is important to know how they work, as well as their technical features, in order to ensure their correct application. Basically, one assumes that this basic knowledge is what helps us to choose the tests, which meet the needs of archaeological research. Nevertheless, only in a few situations is the same reflection present, in the use of the graphic representation of data.

Moreover, we cannot set aside the implications, of new approaches in data processing. Then, without forgetting that the aim of graphic representation is to facilitate the understanding of phenomena in the framework of scientific research, it is also true that graphic representation can be regarded, in itself, as a research tool. This is the starting point for the exploratory analysis of data (Tukey, 1977; Everitt and Dunn, 1983), which uses graphic representations as tools for heuristic description and/or analysis of data sets. From this point of view, graphic representation is not conceived of, only as a complementary element for results illustration or communication, it is also conceived of as an independent tool. This change needs to be considered, and, what is more, a quest for new forms of data visualisation should be undertaken.

On the other hand, the lack of reflection, on the properties of the graphic representation of data, is more disturbing, when referring to fields of archaeological research, that use it as a central element. This can be seen, for example, in the study of the spatial articulation, of the archaeological record (Wünsch, 1991-92), in which the methodology of spatial interrelationships analysis is applied (Figure 1). It is clear, thus, the outstanding character of graphic representation, within the framework of an instrumental methodology, that seeks to gather information, from the spatial properties of archaeological contexts (distribution, arrangement and association).

In the elaboration of the operational methodology, of spatial interrelationships analysis (ANITES), we have tried to find an instrumental design, that could meet our needs and our theoretical expectations (Wünsch, 1991-92, 1992, 1996c). We devoted special attention, to the execution procedures of statistical processing. That is, we chose the most appropriate tests, for the handling of spatial properties, of the archaeological record (Figure 2). The selection of these tests was based on the search for a balance, between the potentiality and appropriateness of the statistical tests, and their simplicity and operability, for data management (Barceló, *et al.*, 1994; Wünsch, 1994, 1995a, 1996a). Furthermore, the most informative graphic representations were selected, initially, taking into account their features, and our interests.

The first applications of the ANITES methodology on ethnoarchaeological data (Wünsch, 1995b, 1996b), shed light on the great volume capability, and, above all, the potential, of graphic representation, used as a heuristic research tool. Consequently, it has become necessary to consider further, the advantages and disadvantages of different graphic representations, used in data processing. In the following pages, we will direct the discussion towards the graphic representation of spatial distribution, and also, the arrangement of archaeological remains, treated as three-dimensional points, in graphic representation.

Visualising spatial distributions of points: comparing 3-D and 2-D graphics.

Within the framework of the ANITES operational design, we have established several, complementary analytical stages, that offer a forthright approach, to the spatial articulation of the archaeological record (Figure 3). We will focus our attention on the first stage, in which spatial distribution plots of different categories, are observed. In fact, this first approach process implies that the visualisation of three-dimensional remains, located through their Cartesian coordinates (x, y, and z), should be complemented with those of remains, which are not three-dimensional, located on a grid, as occurrence frequencies, by squares. Nevertheless, in this paper, we will only discuss the advantages and disadvantages of different visualisations, in 2-D or 3-D, of point distributions, and to do so, we will use graphic representations, resulting from the processing of several sites (Tunel VII, Tierra del Fuego, Argentina; Punta Baja, Patagonia austral, Chile; Ca n'Isach, Catalunya, Spain).

The most typical graphic representation in 2-D, of a spatial points distribution, is obtained from so-called, distribution maps (Meignen and Ducasse, 1985; Hodder and Orton, 1990; Ebert, 1992). These are two-dimensional graphics that permit us to visualise the distribution and the arrangement of points, located on the studied surface, through their coordinates, x, and y (Figure 4). These graphics are very simple to obtain, when using different software, and, moreover, they draw a good picture of the data's character.

As a general rule, points shpuld be expressed, preferrably, as symbols. By doing this, the graphics will not be affected by inevitable, size reduction, a consequence of the plans' multiplication, for saving space (when the graphic is published), or by the number of occurences represented. It is only advisable to use alternative symbols (squares, circles, triangles, crosses, etc.), when there are only a few occurrences, or when the distributions of two or more categories overlap, in the same graphic (Figure 5). Likewise, in order to maintain visualisation, always in relation to the number of occurrences in each case, it is important to avoid overlapping too many categories, and it is advisible to make one category plans. To overbudening the graphic representation often implies the loss of its informative potential.

Among the most positive aspects of 2-D distribution patterns, we must highlight the fact that they are, both easy to draw and manipulate. This simplifies, enormously, the overlapping of partial plots, and, above all, it simplifies the work, when comparing different categories from the same site (Figure 6). We have great freedom, when choosing the categories to be represented and, therefore, graphic representations can be multiplied. Consequently, user-friendliness and flexibility make this visualisation, a good working tool. For example, if there are many points (making the visualisation of certain details more difficult), it is very easy to use subdivisions, in order to obtain a clearer image. Moreover, taking the same scale, images can be complemented easily with graphic representations of the profiles (longitudinal or transverse) and a first glimpse, of the general distribution of data and its arrangement trends, is obtained (Figure 7).

Likewise, 2-D distribution plans result very operational when evaluating, for the first time, the character of different categories, in relation either to the location of elements associations, or to initial hypotheses (location of combustion areas, occupation units perimeter, etc.). Therefore, these plots do not only provide an adequate framework for the evaluation of distributions, based on observational criteria, but they also show scattering or clustering trends, concentration degrees, eventual alignments, empty areas, etc. (Figures 8 and 9). The negative aspects of 2-D distribution plots stem, exclusively, from their two-dimensional character, because the loss of visualisation, of remains depth (coordinate z), can lead to erroneous evaluations of clusters and/or dispersions.

Continuing the discussion on 2-D graphic representations, we find contour plots, which at present, are widely used (Haigh, 1987). For some researchers, as is the case with Chernokian (1996), these are the best tools, for the study of spatial distributions. Contour plots represent the density of archaeological remains, through curves that link identical values; this is done with a calculation, that entails a certain loss of information (Figure 10). These graphic representations are fairly easy to obtain, and if scales are observed, it becomes a good tool, for comparing different category distributions of a site (Figure 11).

Nevertheless, there are several handicaps to contour plots' usefulness. For example, they are very sensitive, to the threshold of chosen occurrences. This means that any change in the threshold is translated into a different visualisation, and this can give way to significant information losses (Figure 12). Depending on the numerical threshold that is chosen, data visualisation varies notably, and this implies the appearance and/or disappearance of concentrations. This variability in visualisation is serious, because the concentration of remains is, precisely, the main source of information, regarding the distribution character of the remains. Furthermore, contour plots are neither useful, to carry out overlapping plots, nor do they offer a good visualisation, of the scattering of remains. Other alternative visualisations, based on the same densities calculation principle, do not seem to solve the outlined problems either (Figure 13).

When considering these problems, we realise that it is more sensible to use this type of graphics, only as an alternative representation method, of frequency distributions, by squares. In any case, it is important to pinpoint out that this type of visualisation, only permits us to catch a brief glimpse of general distribution trends. It is not the most appropriate, if the idea is to work at higher resolution, or in greater detail, because it entails a loss of information.

As is the case with statistical tests, the availability of powerful software has given way to the outbreak of 3-D graphical representation use, in various lines of archaeological research. The rapid expansion of these images, as a means to visualise spatial distributions, is due, undoubtedly, to the fact that they are spectacular (Figure 14). Nevertheless, if we set aside the fascination that three-dimensional images, which are closer to archaeological reality, hold for us, we find that there is not reflection, on their real potential, as a data communications tool.

A certain parallel can be drawn, between 3-D representations and the use of very sophisticated, statistical techniques, that, in the end, are unnecessary, for the attainment of the pursued objective. On many occasions, the use of this type of graphics does not answer to previous reflection, that would justify their appropriateness, but, simply, to factors, which are beyond the research. Among these factors, there is the availability of such representations, in the most common software, and the visual fascination, that 3-D graphics hold for us. Consequently, these graphic representations of showy colours have taken priority over other, simpler, but not necessarily less informative, types of visualisation. This means, once again, that aesthetic questions prevail, over scientific and operational criteria.

It is important to analyse, in depth, the performances of 3-D graphic representations. As for distribution graphics, it is evident that 3-D plots offer an image, which is closer to the three-dimensional reality of the site. This type of graphics provide a more realistic picture of distributions, by means of the three Cartesian coordinates (x, y, and z). And so, the stratigraphic dimension is recovered, in a way, and it can be incorporated into previous evaluations, on the features of distributions. As in the cases we have seen, always in relation to the number of occurrences, we obtained images that were adequate, to have a first comparative view of the distribution, and the arrangement of the different categories (Figure 15).

The accomplishment and manipulation of 3-D images is not difficult thanks to the user-friendliness of the software. However, some transformations in the data are needed, especially for **z** coordinates, since they have to be inverted, in order to obtain correct graphics. Nevertheless, the resulting image is too general, to be useful to study details. When the number of occurrences is high, and more complex views of the data character are obtained, these graphics become difficult to read. Therefore, aside from graphic appeal, 3-D representations do not always provide better visualisation of data.

Their greater contribution can be seen, in the use of three-dimensional representations, as heuristic research tools. In this case, it is necessary to complement 3-D static graphics, which offer us an specific view of the data, that it is not necessarily the most informative, with spin three-dimensional representations. The tools, used in three-dimensional animation, allow us to carry out controlled rotations of the axes of a spatial distribution, and to seek the most informative perspective. This work is difficult to capture in only one image, either in 2-D or in 3-D.

Finally, it is important to outline the interest of new 3-D graphic representations, which grant greater realism to the spatial distributions visualisation than 2-D graphics. A good example is the use of plots, based on Kernel density estimators (Baxter, *et. al*., 1997). In fact, this type of graphic representation, barely used in archaeological research, offers a false three-dimensional visualisation. The representation is based on a two-dimensional distribution of the data, and provides, in a three-dimensional form, a view of remains densities. As in the previous examples, these graphics provide us with an overall view, of general spatial trends, and make possible the comparison, between the distributions of different categories (Figure 17).

As in the case of contour plots, these pseudo-three-dimensional, graphic representations, obtained by means of Kernel density estimators, are not especially adequate to work with greater resolution, or to deal with details. They do offer a good view of remains concentrations, but they do not inform clearly, about dispersion, or about arrangement. Their most positive feature is that they are easy to carry out, and, above all, if the calculation procedure is maintained, it is possible to draw comparisons, between the remains distributions, of different sites.

By and large, three-dimensional representations grant greater realism, to the visualisation of spatial distributions, but they do not make easy, the heuristic handling of information. For instance, they only allow us to overlap distributions, when working with a very low number of occurrences; otherwise, it is impossible. Moreover, it is very difficult to assess the relationships of remains distributions, with respect to significant elements associations. This procedure is technically possible, but it takes a lot of time, and it is an effort that cannot be rewarded with the results. The same observational procedure can be carried out, more easily, with two-dimensional representations.

Some conclusions and remarks.

Some interesting conclusions can be drawn, from a combined evaluation of the advantages and disadvantages, of 2-D and 3-D graphic representations, of spatial remains distributions.

* First, there is the need of combining different graphic representations, because they show us different, but complementary, aspects, about the character of spatial distributions.

* It is also important not to forget, that graphic representation must be informative and accurate, eliminating, whenever possible, redundant or irrelevant data. In the case of spatial distributions visualisation, simplicity and clarity should take priority, over complicated representations.

* Although, on this occasion, we have not dealt with the problems related to the use of colour, we have to take into account that, usually, colour representations are attractive at first glance, but this does not necessarily make them more informative. Colour helps to clarify the reading of 2-D graphics, especially if two or more categories overlap, and it improves the visualisation of 3-D graphics. However, colour is not used in publications, yet. Therefore, it is worthwhile, to continue using black and white graphic representations.

* In practice, 3-D representations provide greater visual realism, but they are more difficult to read, and, consequently, concentrations can be misread (Figures 18 and 19). They seem to be good tools, when comparing characters of different categories, but they are not adequate for spatial overlapping. They should be restricted, to elaborate realistic visualisations, of the distributions of general categories. Their real potential lies in their power to create animated manipulations, with the computer, which make them excellent, heuristic tools.

* 2-D distribution plots strike a balance between their advantages and their disadvantages (Figure 20). These graphics are easy to use, very flexible, as far as the handling of data is concerned, and they allow spatial overlapping. Their only great disadvantage is their two-dimensional nature, that in some instances, can lead us to an erroneous evaluation of spatial concentrations. Furthermore, they provide a good-weighted visualisation, of the concentration

or dispersion degree of remains, in relation to elements associations. They are good working tools, that can be enhanced, by adding symbols or colour.

* Contour plots show a great imbalance, between their advantages and their disadvantages (Figure 21). Although they are easy to obtain and manipulate, they are not adequate for spatial overlapping, and details are difficult to deal with. Therefore, the obtained images are maintained at a low resolution level, and they must be complemented with other graphic representations. It is especially worrying, the great effect that the occurrences threshold has, in the visualisation of density curves. Variability in the precision, of graphic representations of spatial distributions, makes it a tool of delicate handling.

References

BARCELÓ, J.A. et *al.* (1994), "The easier, the better. The role of statistics in archaeological research", in: *Methods in the Mountains, Proceedings of UISPP, Comm. IV meeting, Sidney (Australia), 1993.* Johnson, I. ed.. *Sidney Univ. Archaeological Method Series,* 2, pp. 43-48.

BAXTER, M.J., BEARDAH C.C. & WRIGHT R.V.S. (1997), "Some archaeological applications of Kernel density estimates", *Journal of Archaeological Science,* 24, pp. 347-354.

CHENORKIAN, R. (1996), *Pratique archéologique statistique et graphique*, ERRANCE, Paris.

DJINDJIAN, F. (1991), *Méthodes pour l'archéologie*, Armand Colin, Paris.

DORAN, J.E. and HODSON F.R. (1975), *Mathematics and computers in archaeology,* Edinburgh Univ. Press, Edinburgh.

EBERT, J.I. (1992), *Distributional Archaeology*, Univ. of New Mexico Press, Albuquerque.

EVERITT, B. and DUNN G. (1983), *Advanced methods of data exploration and modelling,* Heineman Educational Books, London.

FLETCHER, M. and LOCK G.R. (1991), *Digging numbers. Elementary statistics for archaeologists,* Oxford Univ., Oxford.

HAIGH, J.G.B. and KELLY M.A. (1987), "Contouring techniques for archaeological distributions", *Journal of Archaeological Science,* 14, pp. 231-241.

HODDER, I. and ORTON C. (1990), *Análisis espacial en arqueología,* Ed. Crítica, Barcelona.

MEIGNEN, L. and DUCASSE H. (1985), "Distribution plots as microcomputer graphics: an example from a prehistoric excavation", in: *To pattern the past. Proceedings of the Symposium on mathematical methods in archaeology, Amsterdam, 1984,* A. Voorrips and S.H. Loving, eds., PACT, 11, pp. 45-49.

ORTON, C. (1988), *Matemáticas para arqueólogos,* Alianza Editorial, Madrid.

RICHARDS, J.D. and RYAN N.S. (1985), *Data processing in archaeology,* Cambridge Univ. Press, Cambridge.

SHENNAN, S. (1992), *Arqueología cuantitativa*, Ed. Crítica, Barcelona.

TUKEY, J.W. (1977), *Exploratory data analysis,* Mass. Addison-Wesley, Reading.

WÜNSCH, G. (1991-92), "La organización del espacio interno de los asentamientos de comunidades cazadoras-recolectoras: revisión crítica y alternativas", *Xama,* 4-5, pp. 161-218.

(1992), "Aproximación a las estrategias organizativas de las comunidades cazadoras-recolectoras", *Archidiskodon* II, pp. 1-36.

(1994), "Modifying the nearest-neigbour analysis for 3D", *Archaeological Computing Newsletter,* 39, p. 9-15.

(1995[a]), "The spatial interrelationships analysis and its simple statistical tools", in: *Computer applications and quantitative methods in archaeology, CAA'94, Glasgow,* J. Hugget and N. Ryan, eds., *BAR International Series,* 600, pp. 75-80.

(1995b), "De la articulación espacial del registro arqueológico a la gestión del espacio social: un ejemplo de aplicación del análisis de las interrelaciones espaciales (ANITES)", in: ESTÉVEZ J. and VILA A. (coords.), *Encuentros en los conchales fueguinos,* Treballs d'Etnoarqueologia, 1, UAB-CSIC, Bellaterra, pp. 127-142.

(1996[a]), "Reflexiones sobre la aplicación de instrumentos cuantitativos en el análisis de la articulación espacial del registro arqueológico: una propuesta alternativa", *Arqueología Espacial,* 15, pp. 103-146.

(1996b), "Aplicación del análisis de las interrelaciones espaciales (ANITES) sobre datos etnoarqueológicos: el sitio Túnel VII (Tierra del Fuego, Argentina)", in: GÓMEZ-OTERO J. (ed.), *Arqueología. Sólo Patagonia. Ponencias de las Segundas Jornadas de Arqueología de la Patagonia, Puerto Madryn (Argentina), 1993,* Centro Nacional Patagónico, Puerto Madryn, pp. 231-240.

(1996c), "Thinking about the spatial articulation of the archaeological record: the role of statistical techniques", *III Convegno Internazionale di Archeologia e Informatica, Roma, 1995,* P. Moscati, ed., *Archeologia e Calcolatori,* 7, pp. 327-335.

All Figures in CD-ROM.