6

Improvements in intra-site spatial analysis techniques

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Resumeé française

Après un rapide historique des méthodes d'Analyse Spatiale de l'Habitat, replacées dans le contexte de l'évolution des techniques statistiques, une nouvelle methode d'analyse spatiale est proposee, comme une amélioration de la methode de R. Whallon 'Unconstrained clustering'.

La nouvelle méthode, intitulée 'Analyse de la structure spatiale de l'Habitat', comprend les etapes suivantes:

- enregistrement des distributions spatiales, par coordonneés de points, ou comptage,
- lissage des distributions et traitement des donneés manquantes,
- échantillonnage d'un tableau de vecteurs de densité,
- analyse des correspondances du tableau de vecteurs de densité et sélection des facteurs révélant des structures spatiales,—classification ascendante hiérarchique, soit classique, soit sous contrainte de contiguité, sur les facteurs,
- visualisation et caractérisation des structures spatiales.

La méthode a été appliquée au site esquimau *'Mask'* (L. Binford), à l'habitat magdalénien de *Pincevent* (A. Leroi-Gourhan) et au village néolithique lacustre de *Charavines* (A. Bocquet).

Les résultats des expérimentations sont enfin comparés, et la valeur de la méthode discutée.

6.1 Introduction

This paper describes the preliminary results of methodological work concerning the definition of an Intrasite Spatial Analysis method, the choice of data analysis algorithms

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and associated software, and the experiment on archaeological data to determine possibilities and limits of the method in comparison with the archaeological aim and the other intrasite spatial analysis methods.

6.2 The main existing methods of intrasite spatial analysis (ISA)

The study of the historical development of Intrasite Spatial Analysis methods allows the identification of three technical phases:

1. The first period (1950–1975) saw the influence in archaeology of quantitative ecology techniques, which appeared during the fifties, and which was applied to archaeology during the seventies (Whallon, Hodder); the applications were based on spatial distribution tests either on counting data (dimensional analysis of variance), or on coordinate data (nearest neighbour analysis).

2. The second period (1970–1980), an extension of the previous period, is based on association tests between spatial distributions. The best element of this set of techniques is the multi-response permutation procedures (Berry *et al.* 1984).

3. The third period saw the coming out after 1975 of data analysis techniques in intrasite spatial analysis:

   - local density analysis (Johnson 1977, Johnson 1984),
   - cluster analysis on spatial coordinates (Kintigh & Ammermann 1982; Simeck & Larick 1981),
   - correspondence analysis (Hesse 1984, Bouchet 1986), unconstrained clustering (Whallon 1984).

Hodder and Orton's book (Hodder & Orton 1976) and Orton's paper (Orton 1982a) give a good introduction, mainly for the the techniques of the first two periods. The book edited by Hietala (Hietala 1984), gives a good but non complete methodological review, and a set of archaeological applications.

6.3 Comparison of intrasite spatial analysis methods based on data analysis techniques

The *local density analysis* by Johnson (Johnson 1977, Johnson 1984) is based on the definition of an association index between two spatial distributions. The index matrix is then processed by data analysis techniques (multi-dimensional scaling in the first paper, correspondence analysis in the 1985 paper), which give a reduction of the distribution space (R-method).

Graham (Graham 1980) emphasized the impropriety of the association index, which is strongly linked with the pattern of the distribution: sometimes the value of the association index between two different distributions is greater than the value of the association index between the same distributions. The association index, based on the *nearest neighbour*, as proposed by Graham (Graham 1980), avoids the previous disadvantage, but the value of the association index is always dependent of the pattern of each distribution. The two methods, moreover, are R-methods, which give only a reduction of the space of distribution, and not a pattern of the archaeological area.

Cluster analysis on spatial coordinates (Kintigh & Ammermann 1982), is not a multi-dimensional spatial analysis technique, even if the method uses cluster analysis. The multi-dimensional approach is only given by a graphical superposition of the cluster variance circles. The method, more oriented to the research of superposition of artefact concentrations, is not, *sensu stricto*, an intrasite spatial analysis method.

Unconstrained clustering (Whallon 1984), is a method based on the computing, in a point of the area, of a multidimensional density vector. Results of the cluster analysis applied to the density matrix give a spatial pattern. Interpretation of clusters may induce the definition of specialized activities areas. The method, unfortunately, is a Q-method, which gives only a pattern of the archaeological area.

6.4 A new method: analysis of the intrasite spatial structure (ISS)

6.4.1 Critical examination

The critical examination of the existing spatial methods induces the following concluding remarks:

- Data analysis techniques supply a better solution to the problem of intrasite spatial analysis, in comparison with distribution tests, or association tests between two distributions.

  Data analysis techniques, nevertheless, need the following features:

  - the capacity for producing a R+Q multidimensional reduction (both on variables and points or cells),
  - the capability to be a non-linear multidimensional technique, as already pointed out by Whallon (Whallon 1984), concerning the problematic use of principal components analysis.

- Smoothing techniques allow simultaneous use of spatial data obtained both by cell counting and by coordinates measures.

- Informations of spatial distribution patterns (clustered, random or uniform distribution) must be keep apart from informations given by association between spatial distributions, by the following manner:

  - Multidimensional approach of intrasite spatial analysis is best explained by the definition, in a point of the area, of a multidimensional density factor.
  - Best structuring of the spatial area is obtained in considering also the information given by the contiguity of density vectors.

6.4.2

A new method called the the 'analysis of the intrasite spatial structure', which integrates the previous technical features, may be seen also as a structuration method in Archaeology (Djindjian 1980), especially in the main point of the choice of intrinsic informations (here the distributions), directly connected with the spatial analysis problematic.

The ISS method is constituted by the following steps:

1. Recording of spatial distributions, either by point coordinates or by cell counting,
2. Smoothing of spatial distributions (moving average, Symap...),
3. missing data processing (smoothing, krigeing,...),
4. Sampling of a density vector matrix,
5. Correspondence analysis on the density vector matrix,
6. Selection of factors supplying relevant spatial structures,
7. Hierarchical ascendant clustering applied on previous factorial coordinates,
8. Option: hierarchical ascendant clustering with contiguity constraints. In that special case, the method is called the analysis of the intrasite contiguous spatial structure (ICSS).
9. Visualization and characterization of the structures.

6.5 Technical improvements in the ISS method

Without considering the missing data processing which need not here particular explanations, improvements of Whallon's unconstrained clustering are defined by the introduction of two data analysis techniques.

6.5.1 Correspondence analysis

Discovered by Jp. Benzecri (Benzecri 1973) about twenty years ago, correspondence analysis has been introduced by Djindjian (Djindjian 1976) in archaeology, involving many applications in French archaeology (described briefly in section 6.7).

Correspondence analysis is employed here as a factor analysis for the multidimensional reduction of a density vector matrix. R+Q visualization allows to represent on the same map both the distributions and the sampling points. Non-linear analysis by the chi square distance, correspondence analysis can recognized local patterns, on the contrary of a linear analysis, like PCA, which shows trend patterns.

6.5.2 Hierarchical ascendant clustering with contiguity constraints

The cluster analysis, used here, is a hierarchical ascendant clustering algorithm based on chi square distance and intercluster variance maximizing aggregation.[1] The algorithm is applied not on the original density vector matrix, but on the coordinates of the sampled points in the selectioned factorial axis.

The hierarchical ascendant clustering with contiguity constraints is a specialized algorithm for applications in human geography. The algorithm allows to two points to be clustered only if they are spatially contiguous. Clusters, then, are both multidimensional density clusters and spatial clusters. An algorithm has been realized by Lebart (Lebart 1978), based on the recording of a contiguity table updated at each step of the algorithm, like the distance table. The same approach has been employed successfully

[1] Variance criteria are unanimously considered by the French school of data analysis as a better criterion than the archaic criteria of cluster analysis (single linkage, ward...).

in archaeology with a toposeriation method (Djindjian 1985) using a non-hierarchical clustering algorithm, to show the spreading steps of a cemetery, from both a seriation and a grave contiguity table.

6.6 Case studies

Three case studies has been chosen for the experimentation of the new method. The two first data sets, the Nuniamut Mask site from L. Binford, and the Magdalenian Pincevent camp-site excavated by A. Leroi-Gourhan, are now reference data sets for intrasite spatial analysis method tests. The last example, the Neolithic lacustrine village of Charavines from A. Bocquet is tested to verify the capability of the method on a Neolithic site.

6.6.1 Intrasite spatial analysis of the Nunamiut Mask site

The Mask site has been studied by L. Binford (Binford 1978), for the comparison between the archaeological interpretations from the artefact spatial distributions, and the real Nuniamut activities. The data published by Binford have been processed by Whallon (Whallon 1984) as a case study for the 'unconstrained clustering' method. The five spatial distributions are tools, projectile components, wood scrap, bone scrap, large bones. They show strong clustering. Correspondence analysis shows on the four axis an individual behaviour of each distribution:

- axis 1: Tools
- axis 2: Association of projectile components and wood scrap in opposition with bone scrap
- axis 3: Opposition between projectile components and wood scrap
- axis 4: Large bones

The activity areas are defined by only one artefact type, showing that the case study is a caricatural example, not able to be used to study the limits of different methods.

Three methods (UC, ISS, ICSS) supply, therefore, the same number of clusters (six) and the quite same spatial patterns (Fig. 6.1). The only practical conclusion of the experiments is the capacity of the three methods to recognize very clean activities area.

6.6.2 The Magdalenian camp site of Pincevent (area 36)

The publication of the 'area 36' of the famous Magdalenian camp site of Pincevent (A. Leroi-Gourhan and M. Brezillon (Leroi-Gourhan & Brezillon 1972) supplies a classical but very detailed spatial analysis of the occupation floor. Data sets have been used as a case study for the experimentation of their methods by Johnson (Johnson 1977, Johnson 1984) for local density analysis and by Kintigh & Ammermann 1982 for the analysis on spatial coordinates.

The twelve spatial distributions are lithic tools (endscrapers, burins and burin spalls, awls, backed bladelets), bone tools, cores, hearth stones and reindeer skeletal remains (five types). Most of the spatial distributions have a strong clustering. Correspondence

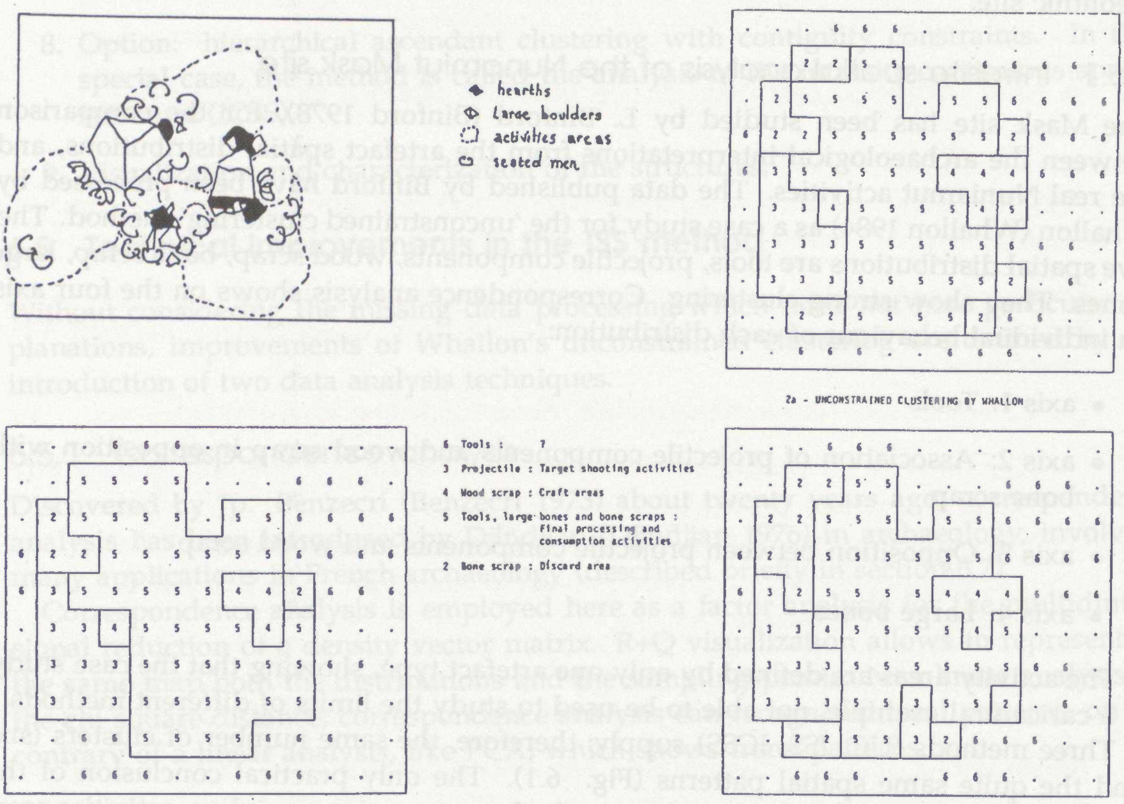


Figure 6.1: The Nunamiut 'mask' site

analysis shows an opposition between bone and lithic tools, core, hearth stones and faunal remain (Fig. 6.2a). The lithic tools shows a same behaviour in the reduced factorial space, *i.e.* similar spatial distributions, structure confirmed by the results of the cluster analysis on spatial coordinates which show superpositions of cluster variance circles (Fig. 6.2b). The faunal remains set, also clustered, shows nevertheless some variability among the first axis, characterizing a differential dispersal from the central area. The results are globally similar with the results supplied by the local density analysis (Fig. 6.2c). Cluster analysis shows a spatial structure, characterized by a tool cluster in the central area, around the hearths, a strong differential dispersal of faunal remains, and a globally uniform distribution of small hearth stones (Fig. 6.2d, e).

The interpretation of the spatial patterning cannot induce to specialized activity areas, but rather to a central area of non specialized activities, perhaps only resulting from a smoothing due to a long occupation time. Site maintenance activities may explain the dispersal area structures. Intrasite spatial analysis, realised on the whole 36 area of Pincevent, gives finally unsatisfying results. A complementary analysis, at a more detailed scale, is necessary to try to discover patterns inside the central area.

The main conclusions of the experiment are the strong sensitiveness of the methods to artefact dispersal patterns, directly associated with density measures, and the relative insensitiveness to smoothed patterns, which seem to limit the application of intrasite spatial analysis method to short occupation sites.

6.6.3 The Neolithic lacustrine village of Charavines

The Neolithic lacustrine village of Charavines (Isère) has been occupied twice during the late neolithic. The site, excavated by A. Bocquet since 1972 is not yet published.[2]

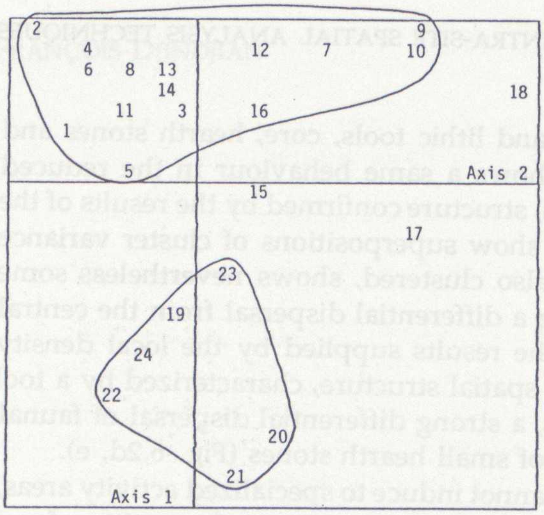
Processed archaeological data correspond to a 10×15 m^2 limited area from the first occupation floor (B3). The twelve spatial distributions are: large flint pieces, small flint pieces, fine ceramics, rough ceramics, quartzites, stones, charcoal, clay, nuts, burnt bones, coproliths, cereals. Data are counted or weighed by metric triangles.

Correspondence analysis, realised here on complete disjunctive coded variables, shows complex associations between the modalities of variables and Guttman effects: the two first axis, with flint, ceramics, bones and nuts associations, are interpreted as human activities. The third axis, with stones, clay and charcoal associations, is interpreted as building material remains.

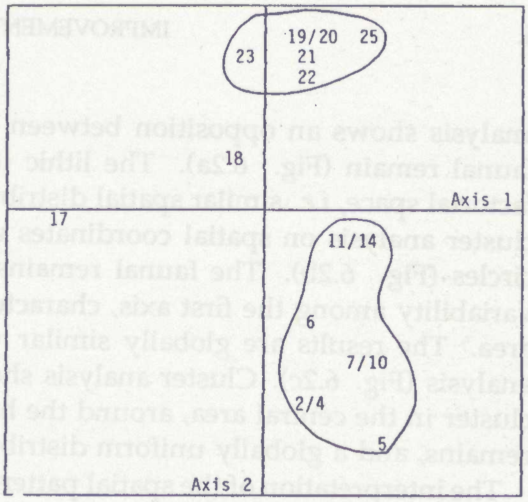
Cluster analysis shows a three cluster structure and a five cluster structure, visualized by Fig. 6.3. The comparison with the restored map of the houses from wood posts dated by dendrochronology, clarifies the interpretation of the clusters. Cluster D corresponds to the outside of the houses, and clusters A, B, E to the inside, while cluster C corresponds probably to a porch or an enclosure alongside the house. Inside, clusters A and B are activity areas, around the hearth, while cluster E is more probably a rest area or a circulation area.

The results of the spatial analysis find, spectacularly, the house map confirming the map obtained by dendrochronology. The determination of activities areas inside is nevertheless too vague, to be related, perhaps, with the small number of variables, or their limited relevance.

[2]The spatial analysis has been realised under our direction by A.M. Christien in a work carried out at the University of Paris X Nanterre.

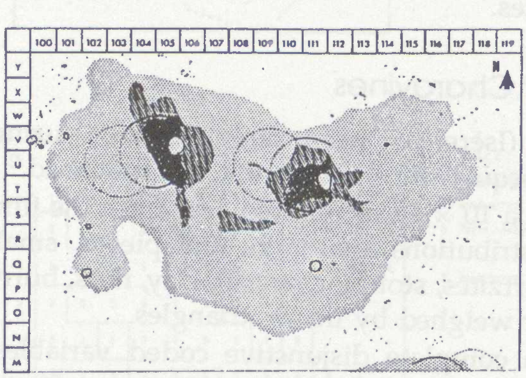


a - Correspondence analysis of local density association indices (JOHNSON, 1984, fig. 5)



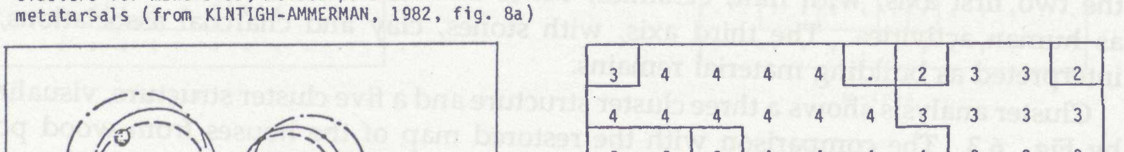
b - Correspondence analysis of density vector matrix

1. Antlers and fragments	11. Metatarsals	16. Hearth stones (+ 7 cm)
2. Maxilliaries	12. Metacarpals	17. Hearth stones (- 7 cm)
3. Mandibles	13. Metapodials	18. Cores
4. Isolated teeth	14. Phalanges	19. Burins
5. Ribs	15. Hare bones	20. Burin spalls
6. Scapulae and pelvises		21. Backed bladelets
7. Humeri	25. Worked bones	22. Awls
8. Femurs and rotules		23. Endscrapers and truncated blades
9. Tibias		24. Artefacts in brown flint
10. Ulnas and radii		



c - General plan of Area 36 (from JOHNSON, 1985, fig. 3)

d - Spatial coordinate cluster Analysis: Clusters for mandibles, metacarpals and metatarsals (from KINTIGH-AMMERMAN, 1982, fig. 8a)



e - ISS on area 36

Cluster 4: 40% hearth stone, 30% tools, 30% faunal remains
Cluster 3: 35% hearth stone, 5% tools, 60% faunal remains
Cluster 2: 50% hearth stone, 50% faunal remains, essentially ribs

Figure 6.2: The Magdalenian camp site of Pincevent

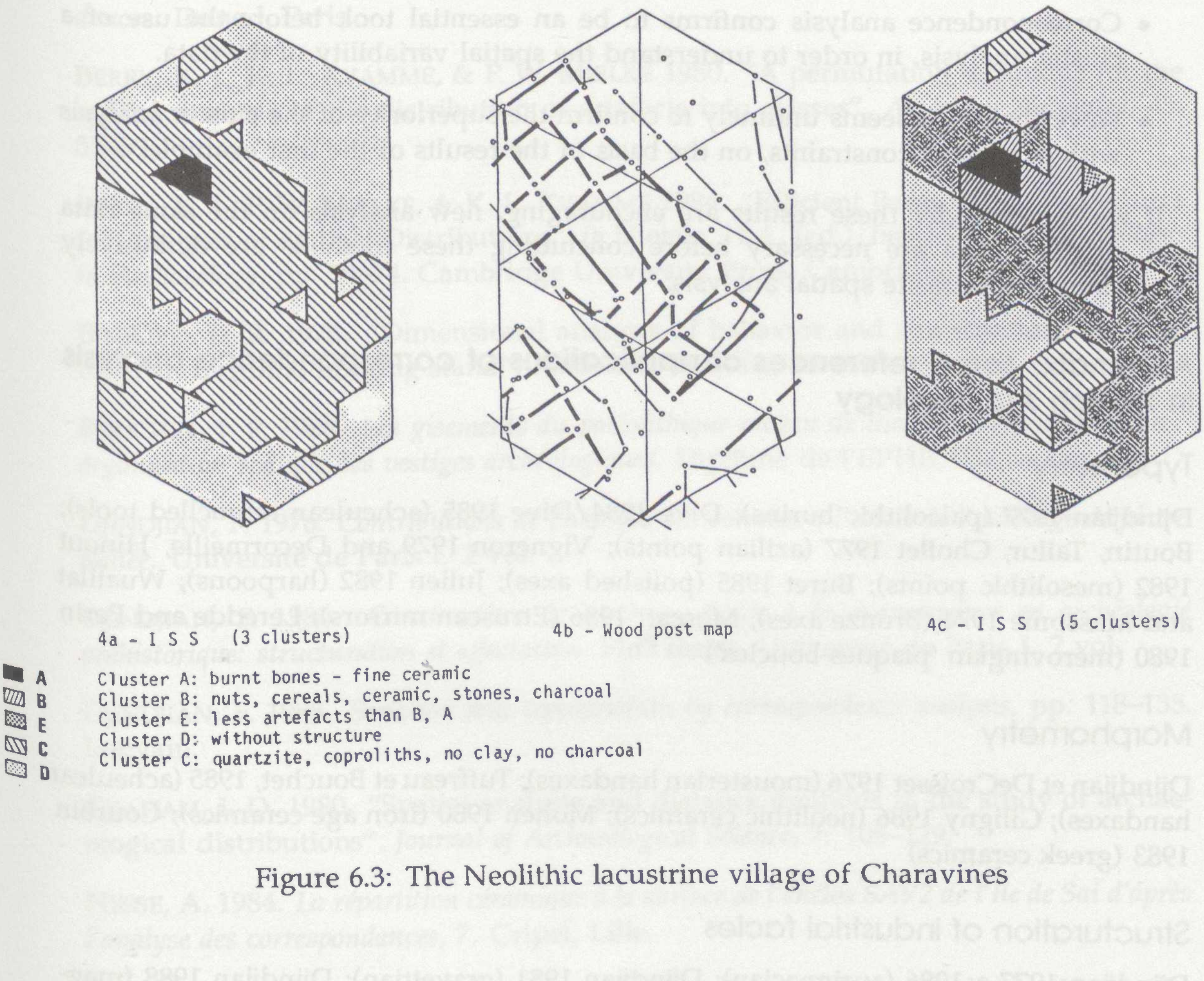


Figure 6.3: The Neolithic lacustrine village of Charavines

6.7 Conclusions

The experimentations on the three case studies demonstrate the following conclusions:

- The ISS method realizes an intrasite spatial analysis more efficiently than the local density analysis, or the cluster analysis on spatial coordinates, and more analytically than the unconstrained clustering.

- The ISS method proves its capacity to recognize strong spatial structures (examples 1 and 3), but its limits are unknown when applied to fuzzy structures (example 2).

- Correspondence analysis confirms to be an essential tool, before the use of a cluster analysis, in order to understand the spatial variability of the data.

- Nevertheless, it seems untimely to confirm the superiority of the cluster analysis with contiguity constraints, on the basis of the results of the first example.

If we can consider these results are encouraging, new analysis on the same data and on other data are necessary before concluding these methods are definitively operational for intrasite spatial analysis.

Appendix: some references of applications of correspondence analysis in French Archaeology

Typometry

Djindjian 1977 (paleolithic burins); Dive 1984/Dive 1985 (acheulean retouclled tools); Boutin, Tallur, Chollet 1977 (azilian points); Vigneron 1979 and Decormeille, Hinout 1982 (mesolithic points); Buret 1985 (polished axes); Julien 1982 (harpoons); Wuaillat and Massonie 1974 (Bronze axes); Moscati 1986 (Etruscan mirrors); Leredde and Perin 1980 (merovingian 'plaques-boucles')

Morphometry

Djindjian et DeCroisset 1976 (mousterian handaxes); Tuffreau et Bouchet, 1985 (acheulean handaxes); Giligny 1986 (neolithic ceramics); Mohen 1980 (iron age ceramics); Courbin 1983 (greek ceramics)

Structuration of industrial facies

Djindjian 1977 a 1986 (aurignacian); Djindjian 1981 (gravettian); Djindjian 1988 (magdalenian); Hours 1977 (Middle-East epipaleolithic); Decormeille et Hinout 1982 (mesolithic); Slachmuylder 1984 (mesolithic), Mohen et Bergougnan 1984 (neolithic)

Seriation

Audouze 1984 (bronze age pins); Djindjian 1980 (Munsingen!); Djindjian, 1985 (merovingian cemetery); Desachy et Bourgeois 1987 (greek cemetery); Brunet et alii, 1985 (bronze and iron age cemetery)

Intrasite spatial analysis

Bouchet 1985; Hesse 1984

6.7.1 Paleoecoloy

Djindjian et Marquet 1985 (rodents); Laurin, Rousseau 1985 (molluscs); Villette 1984 (birds); Blanc-Vernet 1976 (foraminifera); Ozouf 1983 (sedimentology); Gasse 1980 (diatoms), etc...

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