Multidimensional Spatial Analysis in Archaeology: Byond the GIS Paradigm

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Towards a general definition of "archaeological site"

An archaeological site is the place where social action "was" performed. This is a right definition, but probably an oversimplified definition. Social action is never performed isolated or in an abstract vacuum. Social action is produced *in* physical space, and this is not a neutral container, but the result of myriad of natural and social processes performed *before* the social action that originally constitutes what we have called a *site*. On the other hand, each individualized social action is influenced by other social actions and natural events, both *simultaneously*, and also *after* the original one. In this sense, an archaeological site is a complex relational framework in which social action and natural processes are related in a complex, dynamic and dialectical sense. It is a sequence of changes and modifications acting over the consequence of former changes and modifications (Estévez 2000, Barceló *et al.* 2005).

To understand the diversity and variability of social actions responsible of the formation of *archaeological space*, we should understand that social action varies according three different dimensions: *space*, *time* and *quality* (Engels 1883, Kondrashin 1997). According to an ordinary definition quality is the essential determination of any action due to which it is just this action but not any other one and it makes certain difference with other actions. Hence, each social action has its own definite composition of peculiarities and signs which it reveals while relating with other actions (social or natural, collective or individual) and their material consequences. Such an external revealing of qualitative characteristics of an action in a presumed system of relations is its *function*. That is why with a change of qualitative characteristics of some action its functional characteristics are changing as well (Kondrashin 1997).

Functional features of any social action can be revealed only in a framework of relations with other similar actions. A single, isolated social action cannot reveal its functional peculiarities and be used for material development. Thus the possession of quality or a functional definition dictates to every action the necessity to be dialectically related with other actions made by the same agent or other agents.

The change in quality is also tightly linked with the change in *time* and in *space*. The key aspect is here the "*location* of quality changes". *Location* should be understood in its spatiotemporal signification. We understand by it, a characteristic of a concrete event that defines how the quality of the event has changed from state 0_1 to state 0_2 at two different places E_1 and E_2, and at two different moments of time T_1 and T_2. Therefore, when there is some regularity in the changes of quality of social action across space *and* time, we say that there is a certain degree of *dependence* between locations, and this dependence, is exactly what gives its appearance of unity to the archaeological site. What we are looking for are the causes of this location, and we are trying to explain them in terms of the "influence" that another event located in the space-time has on the events located in the proximity. The assumption is that *space* is a system of concrete relations between physical objects, and *time* is some function of modifications which are going on in these objects. I am defending here a relative theory of *space* and *time* (Vieu 1997).

Spatiotemporal "location" can only be understood in functional terms, that is, according to what changes at each place and at each moment. Consequently, to understand what an archaeological site is, we require knowledge about how social action has changed, and about the specific changes generated by social and natural processes. In other words, our analysis of the spatiotemporal variation of social action will remain incomplete if not coupled with an explanation based on the nature of the event. Therefore, an archaeological site should be explained in terms of the spatiotemporal "influence" an action performed at a location has over all locations in the proximity. According to this idea, the degree of influence between neighbouring social actions depends on the knowledge each agent has of neighbouring agents, the spatial or temporal distance between social agents at different locations and the frequency and nature of interactions between agents at different locations. *Distance* is defined as the difference between the values of any property at two (or more) spatial/temporal locations (Gattrell 1983). The concept of *Distance* is seen as a causal mechanism, because we usually assume that "everything is related to everything else, but near things are more related than distant things" (Tobler's law)(Barceló and Pallarés 1996, 1998).

What we are looking for is whether what happens (and *happened*) in one location is the cause of what happens (or *will* happen) in neighbouring locations (Barceló 2002). The analysis then pretends to examine if the characteristics in one spatiotemporal location have anything to do with characteristics in a neighbouring location, through the definition of a general model of spatiotemporal dependencies. Once we know whether social actions at neighbouring locations are similar or not, we should explain why the location of social actions is homogeneous or heterogeneous in the area defined by the performance of those actions. The characteristics of space as a dimension, rather than the properties of phenomena, which are located in space, are of central and overriding concern (Clark 1982).

Causality at the archaeological level

We cannot see in the present a series of actions performed in the past. We can perceive only a reduced subset of their material consequences. This means that we are studying a *double causality* chain. We do not have direct evidence for social actions performed in the past, however, through time social actions have produced as a consequence some observable modifications on natural things, and some of these modifications have been preserved until today. Although we do not know what actions have produced what material consequences, we can relate the variability of material consequences of social action with the variability of social actions through time and space.

The nature of the archaeological problem is that we do not know how social actions produce their material effects, and hence, we cannot predict a social action given the presence of its effect. The only chance we have to solve this problem is relying in the observed regularity of material outcomes of social action, and using it, in an heuristically way to build an input-output mapping, where initial state of the problem is the input (archaeological description of a material consequence of a social action), and its solution (the causing social action) will be the output. This task is best described as *inverse engineering* (Pizlo 2001). Inverse problems are among the most challenging in computational and applied science and have been studied extensively. Although there is no precise definition, the term refers to a wide range of problems that are generally described by saying that they are problems where the answer is known, but not the question. Or where the results, or consequences are known, but not the cause.

"Cause" can be defined as "the way an entity becomes what it is" (Bunge 1980); we can also say that a cause is the set of conditions, which determine the existence of any entity or the values of any property. In our case, the "cause" of the archaeological site is the way some group of people performed at different places and at different moments some social actions, which interplayed with other social actions and natural process generated at neighboring places and moments, until the formation of a complex system. Nevertheless, there is not any direct, mechanic or necessary connection between cause and effect. There are many actions and processes; both social and natural having acted during and after a primary cause, and also primary causes act with different intensities and in different contexts, in such a way that those effects may *seem* unrelated with causes. Some times, the social action is performed in one location, but the expected effect is not observable here and then, because the same action may not produce always the same archaeological features at the same location. Events are never produced isolated from other events. It is the spatial and temporal location of a nearly infinite quantity and diversity of related or unrelated events, which modifies the expectable consequences and effects of causal actions.

An additional difficulty is that the material record recovered at a site is not a direct consequence of a single social action. Regardless of how much evidence is present, the archaeologist cannot read directly from the archaeological record the formation process of an archaeological site as the consequence of a social process or sequence of social actions. Loss, discard, reuse, decay, and archaeological recovery are numbered among the diverse formation processes that in a sense, mediate between the past behaviours of interest and their surviving traces. They make archaeological assemblages more amorphous, lower in artefact density, more homogeneous in their internal density, less distinct in their boundaries, and more similar (or at least skewed) in composition. Furthermore, some post-depositional disturbance process may increase the degree of patterning of artefact disturbances, but towards natural arrangements (Ascher 1968, Carr 1984).

The practical solution to this paradox is to consider that *cause* or *determination* can be defined as a probability function between social action (*production, distribution, use*) and material appearance (*shape, size, content, composition, texture, location*).

In this way, a depositional set may be thought of as a mathematical set, the organization of which is the end product of structural transformations operating upon a previously structured set (Estévez 2000, Mameli, Estévez and Barceló 2002). These changes and transformations in the original patterning of archaeological data are not a simple accumulation process from low entropy sets to higher entropy patterns (disturbed deposits), but a non-linear sum of quantitative changes, which beyond a threshold, produce a qualitative transformation. Archaeological assemblages should be regarded as statistical aggregates of individual elements, because they interact with various agents of modification, with considerable potential for variation in the traces they ultimately may bear. In this way, changes in the density probability function of artifact locations are related with changes in the probability value of a social action being performed at a specific location. The approach here relies on a prior hypothesis of spatial smoothness (see also Barceló & Pallarés 1996, 1998), which considers that two neighboring observations are supposed to have been more likely originated from the same group than two observations lying far apart. The question is how the locational differences among the effects of cause *C* have determined or conditioned the locational differences among the effects of cause *B*. This property has also been called *locational inertia*: it is a time-lag effect that activities experience in the adjustment to new locational influences (Wheeler et al. 1998).

We need to evaluate the presence and significance of a number of possible influences and complications in the spatiotemporal variability of social action based on the spatiotemporal variation in the data. Archaeological features vary in some more or less continuous and frequently complex way throughout. Their variation is typically the result of a combination of geological, biological and social processes, each with its own spatiotemporal variation in scale and complexity. The formation processes that have combined over many hundreds or thousands or even millions of years to produce the complexity of the archaeological site are so many and so varied in scale and influence that the changes in archaeologically visual features (shape, size, composition, texture, location) are not determined univocally by social action (production, distribution and use). But there is some probability that in some productive, distributive or use contexts, some values are more probable than others. In other words, changes in the probability of the performance of a social action determine changes in the probability value of the spatial variability of material effects, not only of the same action, but also of other actions performed at the same place at different moments.

The many dimensions of archaeological spaces

The aim is to develop an understanding of the general principles which determine the spatial and temporal location of those observable properties of material effects *caused* by social actions, on the basis that the specific relationship between cause and effect is not deterministic, but stochastic. The basic assumption is that an archaeological site is not randomly organized, nor it is the result of a single sequence of actions alone. Spatiotemporal variation of any archaeological feature cannot be completely random; it has after all resulted from a number of individually more or less determinate processes.

This is the obvious result to the fact that social action is never performed in a spatial vacuum. We have seen that it is necessarily related to other social and natural events which generate in their turn a *discontinuity* in physical space, when the causative actions or formation process acting on neighboring locations are different. This discontinuity is the consequence of interfacial boundaries or contacts (Rao 1972, Lüth 1993, Groshong 1999), which are the place where two different formation processes seem to join or to differentiate. In other words, social action variability with respect to distance is statistically measurable only within a finite *region* defined by some interfacial boundaries, which are in their turn the consequence of some discontinuities in the spatiotemporal variation of other archaeological features. The importance of observable discontinuities in physical space to archaeological characterization lies in the fact that they frequently influence the spatiotemporal variation of other social actions and natural events. Consequently, the spatiotemporal structure of archaeological sites depends very much on where and how other social and natural events generate a complex topology of discontinuities in physical space.

In this way, we can prove that any archaeological feature has a spatially indeterminate source of variation in a mathematical sense, but regionally dependent. Within such a region there should be some statistical relationship between the difference in value of a regionalized feature at any pair of points and their distance apart, and at greater distances the differences should be statistically independent of each other. This is the underlying supposition of spatial analysis in different disciplines (Houlding 2000, Fotheringham *et al.* 2000, Haining 2003).

This assumption means that where physical space is undifferentiated, the effects of social action cannot be asserted. We are able to define social action only in terms of its observable effects, that is, in terms of observable spatial modifications generated by social action. It is only when physical space (ground surface) has been modified as a result of human agency, that we can speak about an archaeological site (Barceló *et al.* 2003, 2005).

It is of paramount importance then to describe not only the presence or absence of such discontinuities, but specially the physical and mechanical attributes that control their visual features (shape, size, texture, composition and location). After all, such discontinuities should be explained as the qualitative nature of observable changes in the physical space generated by social action, and their properties also explain how they influence the spatiotemporal location of other actions.

A spatiotemporal discontinuity cannot be defined only in terms of their boundaries (Barceló *et al.* 2003) They should be analyzed as the measured changes in value in the spatiotemporal variability of an archaeological event We may concentrate on the two main features of social spatial dynamics to understand the formation mechanisms of spatiotemporal discontinuities: These characteristics are:

- the statistical changes in physical space *as a result* of social action (S_i)
- the qualitative changes in physical space *as a result* of social action (Q_i)

S_i is any material outcome of social action which can be sampled or measured in terms of numerical values exhibiting a variation: geomechanical properties, mineral grades, soil morphological features, material accumulations like the frequency of a pottery type, the frequency of bones, etc. Q_i are observable characteristics of the archaeological space that have a finite number of possible descriptive values, and uniform value within finite, irregular regions. Those qualitative properties are associated with discrete archaeological areas with distinct boundaries (a wall, an occupation floor, a pit, etc.).

The statistically induced modifications in physical space can be understood in terms of the perception of concentrated and disperse patterns of material consequences of social actions. Statistical events in archaeological space are then usually referred as accumulation or aggregation episodes, in which the probability that a social action occurs is related to its dimensions. In other words, the more frequent the refuse materials at a specific place (location), the higher the probability that a social action was performed in the vicinity of that place.

Social action and natural events also generate qualitative visual modifications. Ground surface is modified positively and/or negatively, both by human action and/or by bio-geologic processes. In the case of positive modifications generated by human action, we have the building of vertical structures: walls, columns, arcs, barrows or by bio-geologic processes; in the case of negative structures we have holes, caves, quarries, trenches and pits). In some cases, we can also refer to "horizontal" modifications: occupation floor, roads, tracks, etc. The apparently amorphous accumulations of sediment or stones resulting from the collapse of a wall are also phases in an archaeological spatiotemporal trajectory. All of these are physical modifications, which should be used as additional dimensions of archaeological spatial variability.

Both variables are intrinsically related, especially in the way successive qualitative modifications and statistical accumulations proceed through time and space. We should take into account that certain archaeological components are accumulated upon a pre-existing original ground (a surface), whereas others are deposited in slopes of posteriors contacts. In that sense, spatial variation of a quantitative variable is invariably influenced by secondary properties and characteristics of the host ground surface, which may be qualitative in origin. These properties have unique, independent spatial variation in their own, often subject to abrupt spatial discontinuity caused by structural deformations; as a result the statistical properties of social action are likely to include similar discontinuities in its variation

The underlying idea is that changes in the topology of archaeological space determine changes in the statistical properties of the archaeological record. Both are a consequence of the particular interplay between natural and social events across space and time, and both are the evidence we use to define *social activity area* in terms of the probability of an unobserved action, which has caused the spatial distribution of observable material effects. Assuming that spatiotemporal discontinuities are a function of the probability an action was performed at that location, we can say that any distinct region in archaeological space defined by the topological and statistical properties of a social action acts as an attractor for the material consequences of the same or any other action spatiotemporally related. Furthermore, if we observe inside the attraction basin for a social action the material effects of other actions, we can conclude, that some social actions *attract* other social actions.

Understanding the past in the present

In this paper an archaeological site has been considered as the result of successive and overlapping modification steps (both qualitative and statistical in nature). Therefore, we may define archaeological space as a sequence of finite states of a temporal trajectory, where an original entity -physical space, that is, ground surface- is modified successively, by accumulating things on it, by deforming a previous accumulation or by direct physical modification (building, excavation) (Barceló *et al.* 2003, 2005).

Actual technology of GIS software does not allow this kind of investigation. These computer programs are for the most part passive repositories of data, with a limited functionality for answering locational questions. What we need is not a database of archaeological data linked to bidimensional representations of physical space (maps), but an explanatory model of the dynamics of dialectical formation process, both at the micro and the macro level.

This can be computed alternatively by estimating different spatial probability density functions for each material outcome associated with different social actions. The starting point is completely different from current GIS programs. Mathematically, the spatiotemporal probability of a social action is represented as a five-dimensional vector.

$S_i\ (Q_i,\ t,\ x,\ y,\ z)$

Here, the average density of observed changes in physical space (S_i: probability of social action) is related to spatial position -Cartesian spatial coordinates (x, y, z: North, East and Elevation, or latitude, longitude, and height)-, temporal position (t), and the form and arrangement of physical space *as a result* of another, spatially related qualitative event (social or natural) (Q_i). In this model, Cartesian coordinates represent the outcomes of geological and social processes that lead to the configuration of the ground surface where we have observed some statistical patterning (or *accumulation*) of the material outcomes of social action (Si).

To adequately represent the socially generated discontinuities in physical space, we must consider a semi-infinite continuum made up of discrete, irregular, discontinuous geometrical shapes (surfaces, volumes) defined by characteristics which in turn influence the variation of an archaeological or geological feature. The idea is that such discontinuities are related to visual interfacial boundaries, which are dynamically constructed, and hence conformable through space and time. They can be considered as *space and time shape-and-extent constrained deformable regions*, which influences the way additional features locate in space and time. Within them, there should be some statistical relationship between the difference in value of the dependent regionalized variable which defines the discontinuity at any pair of points and their distance apart (Houlding 2000, p. 5). Therefore, it seems possible to measure the presence/absence of degrees of spatiotemporal continuity in the local values that adopt the statistical and qualitative properties that characterize the material consequences of the causal action. Each one of these discrete units, will correspond to a transition, and can be defined as that limit that indicates an interruption or variation in the causal process.

Just as a theory of time must articulate raw duration into stretches of time (intervals) and their endpoints (events), so a theory of space will articulate raw extension into chunks of space and their boundaries (Galton 1997). Within this spatiotemporal theory, a *phase* has been defined as a homogenous region in space delimited by a well-defined discontinuity or boundary (Barceló *et al.* 2003). We may assume that events are single outcomes of social action within a *phase*, and exhibit a statistically measurable degree of continuity within it.

We need a minimum of six dimensions to adequately represent the dynamic character of spatial discontinuities. And this is something that GIS programs are not designed to solve. What we need is some way to define a mapping from time to positions (Galton 1997): for each time t we should specify the position of the observed material outcomes of social action or the natural event having influenced on the social action at t. This simple statement actually conceals a multitude of complexities.

The observation of a socially generated change in the statistical or qualitative properties of physical space is an *event*. It is represented by one real vector variable r of four dimensions, which may be considered as coordinates of an abstract n-dimensional space named the *phase space*. As we have seen, those dimensions refer to the ground surface where the event takes place (Cartesian coordinates), and the attraction basin of related social actions (a partition of archaeological space in terms of S_i and Q_i alternatively.

The particular relations between events can be described by a function $r(t)$, according to which the events trace out a continuous curve in the phase space named a *phase curve* or *trajectory*. The set of all possible spatiotemporal changes is named the *phase flow*.

In this way we can represent archaeological dynamics as a continuous trajectory across space and time in the sense that to change from one position to another, the material outcomes of social action have to pass through intermediate positions. Our problem is that the dimensionality of these *trajectories* is too high to be adequately represented using first-order equations

$\delta\,\rho\,/\,\delta\,t = v(r,t)$

The alternative way implies to explore the dynamics of the archaeological space by means of the elaboration of a visual model that qualitatively represents socially generated discontinuities across physical space in terms of spatiotemporal states, events and transitions. That is to say, we should build a multidimensional visualization model of the changes of state in the space and through the time (Barceló 2001).

The best way is by imposing a temporal slicing on discrete partitions of the archaeological space representing areas of different probability (Barceló and Vicente 2004). Since we have defined the archaeological events in term of the temporary location of the changes of state between space locations, the intention of such a slicing will be to visually represent the transitions between events.

This implies to decompose the model into a number of submodels, each for a time slice:

$W(\mathrm{t}=1,x,y,z)$

$W(\mathrm{t}=2,x,y,z)$

$W(\mathrm{t}=3,x,y,z)$

$W(\mathrm{t}=4,x,y,z)$

In that sense, a *temporal stack* is a display of multiple temporally differentiated 4D scalar maps in a single window. Stacks can be viewed from different perspectives, treating the layers of the stack as another spatial dimension. For instance, the figure shows a 4D representation of an archaeological time step. Here grey level is used to represent different W values at different x,y,z coordinates. Let W' be the value at a position in the array defined by $t = t'$, $x=x'$, $y = y'$, and $z = z'$. This datum will be rendered in the data view as a colored pixel. The grey level is defined by a data-to-grey mapping, or grey table, and the position of the pixel in the window is defined by a data-to-view coordinate mapping.

If we have sampled 3 temporal periods, each containing, for instance a 10 x 100 x 200 x 200 data array, we can integrate all data into a single volumetric set with 3 x 10 x 100 x 200 x 200 array, where 3 is the number of temporal steps (slices), 10 the number of values of the W characteristic, and 100 x 200 x 300 the dimensionality of the 3D grid where spatial values vary.

A series of cross-sectional surfaces of this type is referred to as a volumetric dataset or simply as a dataset. Such a data set is represented by a series of volumes, each containing a similar n-dimensional data array. Collectively, these files are interpreted as a single array of $n+1$ dimensions.

Processing a volumetric dataset begins by stacking the slices of a given dataset in computer memory according to the *interpixel* and *interslice distances* so that the data exists in a "virtual" coordinate space which accurately reflects the real world dimensions of the originally sampled volume. The next step is to create additional slices to be inserted between the dataset's actual slices so that the entire volume, as it exists in computer memory, is represented as one solid block of data. The number of slices needed to fill in the blanks is based on the dataset's interpixel and interslice spacing and the slices needed are created through interpolation.

The visual model allows an interpretation of the spatiotemporal variability of the material consequences of social action in terms of discrete, contiguous, irregular surfaces, with uniform value throughout each volume. They are not a representation of a physical container for archaeological material, but a partition of archaeological space in terms of spatiotemporal discrete units where the probability of a deposition or post-deposition event is the highest. In this sense, it is a multidimensional probability map.

Now that we have created a geometric model that represents the spatiotemporal probability of the different social actions computed from the spatiotemporal variability of their material outcomes, we can compute some basic statistics for the model, including intensity, extent and directionality. The last one is particularly interesting because it is a good explanation of the propensities and probable influences acting among possible locations.

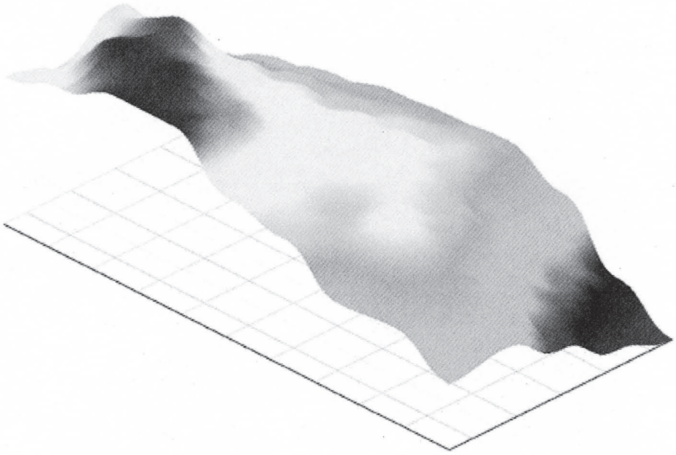

Fig. 1 4D representation of an archaeological time step

Conclusions

In this paper, I have argued that archaeological events are actions (social and/or natural) that generate modifications in the values of the statistical and qualitative properties of physical space.

A visual model has been created to analyze regularity or lack of regularity in the pattern of spatiotemporal changes of the material consequences of these actions. The objective has been to determine a meaningful relationship between difference-in-values (variance in the *quality* of social action) and difference-in-location (variance in spatiotemporal changes). This relationship, if it exists, is essentially a measure of how the material outcomes of social action vary across time and space. Intuitively we expect any such relationship to show that variance in the social action consequences increases as distance increases. In other words, we expect social events close together to have relatively small differences, and those further apart to have relatively large differences. At greater distances, both in time and in space, as the sample become independent of each other, we expect the variance of the samples to oscillate about some constant value.

The dynamics of this process has been represented in terms of transitions or phases (secondary properties of physical space). In this way:

- from the statistical analysis of the variability of texture or differences of composition it emerges a pattern of second-order *discontinuities*
- from the statistical analysis of the variability of shape and size between spatiotemporal consecutive discontinuities it emerges a pattern of gradients, determining the presence and extent of discrete units in archaeological space-time
- the phase flow of the archaeological space emerges from the regularities at the level of

Fig. 2 A 5Dimensional representation of an archaeological phase flows

the discrete spatiotemporal units functionally differentiated

The concepts of *attraction* and *accumulation* allow the study of social space in dynamic terms, that is, taking into account that social action caused quality changes in time and space. Each localized event in space and time, be it an individual, a collective action, or a series of actions, develops together with its environment as a complex network of bi-directional relationships at multiple levels, conditioning the performance of the action and successive actions performed in the neighborhood. On the one side, it materializes a complex field of attraction, radiation, repulsion, and cooperation around this activity, producing the necessary energy for the functioning and even the existence of the social system. On the other side, activities localized around this activity influence it through different interaction channels. What we are really studying is the directionality of social action, and this can be done by means of the analyses of *locations as places of attraction or accumulation*. Our objective is then to analyze how the statistical and qualitative outcomes of social action "vary significantly from one spatiotemporal location to another". Formation process and accumulation effects appear in some locations and not in other because of their position relative to some other location for another process or a reproduction of the same process. An explanatory model then should pretend to understand whether the characteristics in one location (for instance a wall, or an activity area) have anything to do with characteristics at a neighbor location (for instance an accumulation of pottery or lithics, or bones) through the definition of a general model of spatiotemporal dependence. In other words, our main objective should be how distinct formation process has influence over spatiotemporal discontinuities observed through the site.

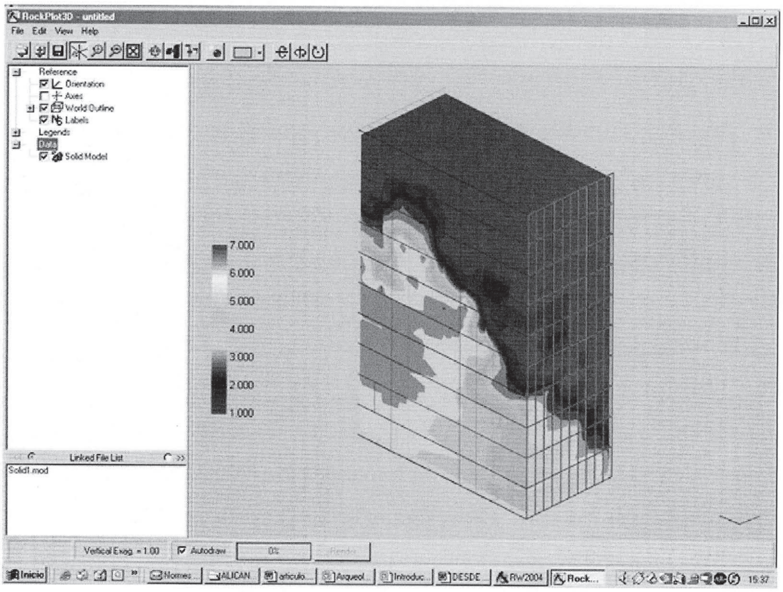

Fig. 3 A volumetric representation of a multidimensional archaeological trajectory in the phase space.

The goal of archaeological research should then be to find the hidden relationship between space-time and constituent events of an archaeological site formation process. This approach defines archaeological space as a sequence of finite states of a temporal trajectory, where an entity (ground surface) is modified successively *determined* by social action, and *conditioned* by natural events.

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考古学の多次元空間分析 −GISパラダイムをこえて−

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この論文では、「遺跡は社会的行動と自然的過程が、複雑・動的・弁証的感性で関連する、１つの複雑な相互連関機構である」と定義される。同時に、時空間のレベルにおいては、考古学的な形成過程の説明的モデルが提示される。目的は、社会活動によって形成された物質的結果の観察可能属性の時空間的な位置を決定する、一般原理の理解を発展させることである。最も基本的な想定は、「遺跡は不規則的に編成されるのではなく、また偶然だけの結果によるものでもない」ということである。考古学的空間の位相変化が、考古学的記録の統計属性の変化を決定する。例えば、時空間的な断絶が、ある行動がその場所で行われた、という可能性を示す１つの機能であると想定すると、どのようにして考古空間における異なったパーティションが同様のあるいは他の時空間的連関を持つ行動に対するアトラクター（※動的システムの固定点）として理解しうるのか、を示唆することになる。

私が研究しているのは、社会的行動の時空間における方向性について、である。そしてその目的は、社会的行動の統計的あるいは質的な結果が、どのように「ある時空間から他の時空間へ変動するか」を分析することである。編成過程と累積効果は、ある場所において、そしてその他の場所ではない場所で現れる。なぜなら、それらのポジションは別のプロセスや同様のプロセスの再生産のための他のポジションと連関するためである。私は、ある場所における特質によって、時空間的依存の一般モデルの定義を通じて、近隣の場所における特質にも関係があるかどうかについて理解できるのではないかと考えている。