Spatial Constraints: The Archaeology of Coastal Shapes [1]

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Art in Nature is rhythmic and has a horror of constraint.
~ Robert Delaunay

And the arbitrariness of the constraint serves only to obtain precision of execution.
~ Igor Stravinsky

Introduction

The purposes of this chapter are to introduce “spatial constraint theory” to archaeology and to suggest that it is relevant to understanding prehistoric adaptations in coastal areas.

Historical Background

In the 1960’s when I was first introduced to archaeology and anthropology, I read the Kulturkreislehrer (Kluckhohn 1936) as historical documents. Being of a mathematical bent some of the work of Graebner (Graebner 1911) and their archaeological counterparts fascinated me.

Of course, the quantitative geographers and ecologists were important in thinking about the location of both cultural and natural sites. I sat in on a seminars by visiting professors Robert MacArthur (MacArthur 1984; MacArthur and Connell 1966; MacArthur and Wilson 1967) and George Gaylord Simpson(Simpson 1965; Simpson 1967) at the University of Arizona in the late 1960’s I read E. C.Pielou (Pielou 1969; Pielou 1977; Pielou 1991), and was greatly influenced by Peter Haggett’s (Haggett 1965; Haggett and Chorley 1970) books and articles on locational analysis as well as Chorley’s books (Chorley 1973; Chorley and Haggett 1968; Chorley and Haggett 1970) and articles on modeling. Many years later (the spring and summer of 1996) I had a chance to spend several months with Peter Haggett at the Institute for Advanced Study in Bristol where he was the director. My interests in such topics were reawakened.

Spatial Analysis

The early work from the 1960's has been built upon and superceded by new developments through the last decades emphasizing statistical characteristics, choice, temporal changes and autocorrelation (Bartlett 1975; Cliff and Ord 1973; Cormack and Ord 1979; Golledge and Rushton 1976; Rogers 1974). Others focused on quantitative methods. (Fischer and Getis 1997; Fotheringham, et al. 2000; Fotheringham and Rogerson 1994) In 2001, a summary article by Fisher (Fischer 2001) brought many of these together in a single table reprinted here.

Table 1. Popular techniques and methods in spatial data analysis

Object Data	***Exploratory spatial data analysis***	***Model-driven spatial data analysis***
Point pattern	• Quadrat methods • Kernel density estimation • Nearest neighbor methods • K-function analysis	Homogeneous and heterogeneous Poisson process models and multivariate extensions
Area data	• Global measures of spatial associations: Moran's *I*, Geary's *c* • Local measures of spatial association: G_i and G_i^* statistics, Moran's scatter plot	• Spatial regression models • Regression models with spatially autocorrelated residuals
Field data	• Variogram and covariogram • Kernel density estimation • Thiessen polygons	• Trend surface models • Spatial predicition and kriging • Spatial general linear modeling
Spatial interaction data	• Exploratory techniques for representing such data • Techniques to uncover evidence of hierarchical structure in the data such as graph-theoretic and regionalization techniques	• Spatial interaction models • Location-allocation models • Spatial choice and search models

Since 2001, exploratory analysis, Bayesian statistics and applications to such areas as ecology, traffic, crime, and urban planning have become important (Andrienko, et al. 2006; Fortin and Dale 2005; Longley, et al. 2003; MacNab 2004; Majumdar, et al. 2004).

Time is fundamental as well as space. A good summary of the analytical relationships among spatial and temporal issues is provided by Cassetti (Cassetti 2001). Many studies analyze, model, or reconstruct changes across both space and time. Frequently, they rely upon diffusion, osmosis ,migration processes, and flows. One may analyze space from the perspective of time or time from the perspective of space. So Casseti divides spatio-temporal analysis into canonical models that emphasize the spatial variation of temporal change and compartmental models where interactions such as flows" link sub models referring to spatial entities such as regions or countries".

Many of these developments are the result of huge GIS industry. From a series of small university laboratory innovations in the late 1950's and early 1960's, the GIS industry has grown to a technology that is seen in almost every country and in almost every governmental and business enterprise. It was estimated to be worth more than a 3.6 billion dollars by the end of 2006[2]. Early proponents using spatial analysis and GIS included Duane Marble, Richard Tomlinson, and Hugh Calkins as well as others (Marble and Northwestern University Evanston Ill. Transportation Center. 1967; Marble and Anderson 1972; Marble, et al. 1968; Marble, et al. 1984; Marble and International Geographical Union. Commission on Geographical Data Sensing and Processing 1984; Marble, et al. 1980; Tomlinson, et al. 1976). A good historical overview

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[2] http://www.geospatial-solutions.com/geospatialsolutions/article/articleDetail.jsp?id=366737

from 1960 through the 1990s is the Centre for Advanced Spatial Analysis time line of GIS[3]. Today, GIScience complements GISystems in many arenas. The former emphasizing theory, methods, and solutions to particular problems including such examples as spatial interpretation and interpolation, discontinuous and patchy data, geometric and temporal modeling, topological equivalency, boundary recovery and tetrhedralization to name a few. The latter seems to be dominated by three large software systems. ESRI's ARC focuses mostly on end-user applications and is a favorite of academics for research. INTERGRAPH appears frequently in very large scale and infra-structure developments. Both are commercial with high end systems being expensive. GRASS is open access software and is favored by those who prefer to do their own programming.

Spatial Analysis in Archaeology

Archaeology has always had a strong spatial component. It derives from several sources. One has been the long-term recognition of the importance of provenience. Even before the 18th century the spatial locus of prehistoric and historic finds were thought to be important. Provenience verified reality and authenticity. Later, it was understood that context and provenience could provide dating, reconstruction and the answers to the questions of what, when, where and why as archaeology moved through stages of evolutionism, diffusionism, cultural historicism, processualism, and post-processualism (Trigger 2006; Willey and Sabloff 1980). Another direction was from ethno-archaeology –examining activity areas (Kent 1984; Kent 1987), domestic space (Gamble and Boismier 1991; Kent 1990) (Ogundele 2005)as well as cultural landscapes both secular and religious (Ceruti 1999; Rossignol and Wandsnider 1992).

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[3] http://www.casa.ucl.ac.uk/gistimeline/

Some of the seminal studies were Binford's (Binford 1978; Binford 1991) studies in the arctic and temperate areas.

The third direction would be from archaeological cognition (Renfrew and Zubrow) supplementing and reinforcing ethno-archaeology and vice-versa. This direction is concerned with how prehistoric individuals thought not from a post processualist interpretation but from a more behavioral and neuro-scientific view of cognition. Such studies as Costoloupous's on the spatial impact of changing memory capacity (Costopoulos 2001) , Audouze on food sharing or education (Audouze 1999; Audouze 1991), Shapiro's spatial grammars after Glassie (Shapiro 2005) and Plank's architectural and linguistic integration(Plank 2004) would be examples. Indeed, it would be nice to be able to take the work of Mark with the Hopi and Zuni or the cross-cultural classification of types of terms used for different landscapes and features and be able to move it backwards through time (Mark 2007).

However and more particularly, spatial analysis has had a long history in archaeology. General studies date back to the 1970's and 1980's (Clarke 1977; Hodder 1978; Hodder and Orton 1976). There were early modeling studies (Paynter 1982) and analyses of inter and intra spatial relationships (Hietala and Larson 1984). Although earlier studies exist, beginning slowly in the 1970's the interest in the spatial characteristics of the prehistoric landscape rapidly increased through the 1980's and 1990's and continues up through the present with what seems to be an inexhaustible range of prehistoric and archaeological landscape studies. A very small, typical but non-representative [in any statistical sense] sample are cited here as examples (Attema 2002; Barker 1981; Barker, et al. 1995; Cherry, et al. 1991; Cremeens and Hart 2003; Grinsell and

Fowler 1972; Hauser 2007; Kelso, et al. 1990; Metheny 2007; Mithen 2001; Reeves-Smyth and Hamond 1983; Taylor, et al. 1998; Trément, et al. 2000; Trinkley, et al. 1992; Ucko and Layton 1999; Wagstaff 1987; Wiseman and Zachos 2003)

As in the case of geography, Geographic Information Science and Geographic Information Systems have had a major impact on the discipline (Richards 1998). The changes in two decades have been very significant from the early introductions in the late 80's and early 90's (Aldenderfer and Maschner 1996; Allen, et al. 1990) to the state of the art today (Allen, et al. 1990; Conolly and Lake 2006). Two processes should be noted. One is as the software improved and became easier to use as well as cheaper the use of GISystems as part of the standard toolkits and procedures for excavations and surveys became de rigueur. Concomitantly, the use of GISystems changed from specialists to almost all field and analytical archaeologists (Bintliff, et al. 2000; Doolittle, et al. 2004; Gaffney and Stan*ci*c 1991). The second process that has been only slightly slower has been the use of GIScience to determine spatial relationships that were indiscernible in the prehistoric record such as interpolated land ownership patterns, religious, viewsheds, or soundsheds. (Estrada Belli 1999; Galloway 2006; Lock and Stan*ci*c 1995)There have been a large number of predictive models for site type and site location that have revolutionized contract archaeology in the last ten years (Henry, et al. 2004; Mehrer and Wescott 2006). In short, it is an important part of the historical arts and sciences (Galloway 2006; Knowles 2002)

Spatial Constraints: Theory and Practice

There has been a considerable literature on spatial constraint theory from geography (Frank 2006), querying strategy(Goldstein 1996), databases (Gaede 1996; Kuper and Wallace 1996), artificial cognition (Allen 2007; Loula, et al. 2007), reverse engineering (Menon, et al. 1997), spatial layout (Baykan, et al. 1991), dynamics (Chin, et al. 1992; Schott 1989; Zhao and Badler 1989), flows , and temporal problems (Chin, et al. 1992; Schott 1989; Zhao and Badler 1989). As one can see it generally has developed in computer science and cognitive science departments.

As Frank (Frank 2006) has pointed out the relationships between extended objects that is non-point like objects need to be created as an extension of the relations among points. Peuquet and Zhan suggest visual interpretation that is essentially a conic system (Peuquet 1987) . Another by Papadias and Sellis (Papadias and Sellis 1992) is based upon bounding rectangles which is related to GIS buffering. Similarly Frank has suggested several sets of spatial relationships (Figure 1).

Spatial constraints may be qualitative, quantitative and or material (Gross-Amblard 2006). One way to conceive of spatial constraints is to consider them from the perspective of spatial reasoning. One may conceive of a spatial constraint network—that is a qualitative graph---where the nodes represent objects and the arcs represent spatial relations. Inserting a new object or a new relationship between two objects in the network impacts not only the original objects but because of the composition, the insertion yields additional constraints. (Frank 2006) One might think about a simple prehistoric example where one node is individuals, another fire pits, another middens and what happens if new object such as a coast wall are inserted.

Others augment these generalities. Working downward from broader to more specific. In general, the greater the constraints the more precise is the execution and the better the predictability. This is because there are fewer choices. Some constraints will slow motion or create a change in direction. Others will block motion completely e.g. a cave wall. In a three or four dimensional system, spatial constraints may be the result of the actor being able to move only in two dimensions.

Constraints are based on the ability of the mover to sense the constraint or the constrainer to sense the mover. In some sense constraints are based upon the constraining phenomena signaling that it is constraining. Furthermore, frequently it is necessary for the phenomena doing the constraining and the phenomena being constrained to signal each other. Namely, signals must be sent that one is constraining and that one is approaching the constraining phenomena. In addition, there are issues of reducing constraints. To what degree are the "once constrained" able to figure out a way to not constrain themselves.

Movement is not an uniform phenomena under constraining systems. In some cases the amount of constraining resistance will vary creating preferred directions. There will be preferred movements—for example in a cave situation there may be general rules that people will prefer to move away from the dark to the light. In general, if one is unable to go directly to the goal, it is preferable to move parallel to the general direction of the goal than in any other direction. In some cases moving in one direction will be more difficult than moving in the opposite direction even over the same spatial transect. Easy modern examples are going downhill on a ski slope in contrast to uphill on skis. Or scrambling over a talus slope where the rocks are more ragged on one side than the other. Sometimes moving to the goal will be more difficult if one leaves the path for there may be greater constraints to returning to the path than may be to getting to the original goal.

Constraints may change over time. They may be periodic in space, in time, or both. Furthermore, they may evolve singularly or together. The constraints themselves may change in a periodic manner. For example, the shape of the coast may vary over space being convex and then concave. The coast may change during periods of deposition or erosion[4]. Or it might be even more dynamic -similar to a wave phenomena where the constraining barrier is related to the tide. Or the spatial constraint networks may evolve over time until a threshold is reached and then there is a fixed pattern indefinitely (Jean-Francois Condotta 2006□) .

Constraints may be realized proactively or reactively. Constraints may be junctive or disjunctive (Baykan and Fox 1997) by which is meant that when there are two or more criteria which are creating the constraints they may be junctive (and) or disjunctive (or). These constraint systems

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[4] Furthermore, one is familiar with the importance of isostasy in the northern hemisphere. The growth of glaciers will cause the earth to sink and conversely there is isostatic rebound when the glaciers melt. In fact in many places such as Northern Finland the evolution of the coastal landforms is a function of eustasy, uplift rates and tectonic factors that sculpt and modify coastal landscapes. The Bothnian Bay, at the northern end of the Bothnian Gulf, was freed from the ice about 9300 years ago. After the weight of the ice was lifted, the earth's crust began to rebound. This rebound, which still continues at a rate of 7,5–9mm/year, is faster along the shores of the Bothnian Bay than anywhere else in Fennoscandia (Eronen 2005)
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are far more general than simply human motion. For example they could be used for lithic tool production. For example assume a type of lithic production (Levalloisian) is a process in which strikes are created using a mallet, a core, and an intervening bone or horn tool. The production tools need should satisfy the following two criteria. First, they should be able to withstand the forces they are going to be subject to and second the tool shapes should be such as there is no tool part interference. These would be junctive constraints –in that both need to met.

Turning to some constraining conditions regarding people who settle on coasts. In theory people move into a coastal area and are compliant in all directions. However, there are preferred and non preferred directions of motion at a given time point. The coast creates spatial constraints on human movement physically, perceptually, and culturally. These may include issues of dry and wet, non-boat and boat, the sacred and profane, and simply pressure. The coast may act as a barrier or part of a box in which the human activity is similar to Brownian motion. The more circumscribed the coast, the smaller the box or correlatively the faster the movers are moving the greater the pressure caused by a similarly curved coast.

Simulation and Analysis

In order to examine the impact on spatial constraint on prehistoric populations along a coast, I have created a set of experiments. A number of simulations were done. Sets of coasts of different shapes were created. There were three shapes. They are an arc shape, an extended arc, and a flat arc. They were conceived as being a more or less standard coastal curve, a much deeper large coastal curve, and a flat almost straight line beach and coastal curve. Other shapes could be created. For example, a small mouthed but large bodied “coastal lake”.

For the purpose of these studies, the coast is seen to be a true barrier. One could simulate that a certain proportion of the movement was on boats. However, for simplicity in this first study it is assumed that people will not pass from the coast into the ocean. Into each coastal area, the same numbers of people were introduced in the same manner for the same length of time. These people then moved in a periodic manner. One type of periodic movement was that they could move towards the interior or toward the beach and coast. This would be moving back or forth along the South-North axis. A second type of periodic motion was moving back and forth along the West-East axis. The third form would be in both directions[5].

Table 2 shows the location by figure number of the results from these simulations where "2u" should be read figure 2 upper graph and "3l" should be read figure 3 lower.

Table 2

Direction/Coastal type	Arc	Extended Arc	Flat Arc
Vertical-South/North	2u,3u,5u	6u	7u,7l
Horizontal/West-East	2l,3l,5l	6l	7u,7l
Combined/All	4		

[5] The author wrote the simulation programs from scratch using a series of generalized subroutines. In other words, I built subroutines that could be combined into different simulations that created the shapes of the coastal areas, created initial individuals and their locations, created their introduction into the coastal area, created the functions by which they move, created their interaction relationships, created the methods of monitoring, and created methods of visualization. The linear and bipolar distributions reflected whether at the very first movement into the coastal area the people were located along a line or whether they were located in a "V". The periodic movements were based on a variety of sine and cosine functions. The programs use C++ and Octave as their base.

Figure 2a is a schematic showing the parts of the results of the simulation. One should note the location of water, the coast, the “mouth of the coastal area” and the deep part of the coastal area that is near the coast itself. Figure 2b upper shows the locations of people as they move periodically North to South and back North again and then North South again. The upper left and the upper right diagrams have identical periodicity functions but in the case of the upper left simulation the entry domain is linear while in the case of the upper right simulation the entry domain is bimodal. In other words, there are two simulations with slightly different characteristics as the population first enters the coastal area but essentially similar following the same periodic movements moving in and out of the internal area of the coast. The lower graphs are similar except the periodic motion of the people is from West to East and East to West and back again. The entry domain is linear in the lower left and bimodal in the lower right.

The results are interesting. For all four diagrams there are clear patterns created. For the upper and lower left graphs, there is a line of circles across the entrance of the coastal area, a larger circle below and then some outliers. They are also bilaterally symmetrical around a north –south axis. The upper graph is slightly more patterned than the lower graph in that there are slightly fewer outliers on in the deepest part of the coastal area and along the edge. For the upper and lower right graphs the only clear pattern is the bilateral symmetry around the South-North axis. For both there is a clear line of activity around the entrance to the coast –the interior and in the lower a central activity area. Conclusions that might be fairly reached are that linear entry provides more repetitive organization than the bimodal, all provide significant activity at the interior entrance to the coast and that there are round activity areas near the interior entrance of the coast for both South-North , and East West periodic motion.

Figure 3 shows the results of four more complicated periodic movement patterns in the same coastal situations as figure 2. The movement patterns are more complicated in the sense that the periodic movement consists of the combination of two interacting periodic movements acting at the same time in the same oscillating direction within the coast. The strong degree of activity at the interior entrance to the coast continues in all four simulations. The distribution in the left upper i.e. South-North motions are considerably more patterned than in the other simulations in this figure or the previous figure. The bipolar entry rights upper and right lower still are primarily patterned in bilateral symmetry around the south-north axis. However, there is more patterning particularly at the interior entry to the coast in the right upper. One begins to see six almost circular "activity" areas. Finally, it is clear that the South-North motions result in considerably more activity deeper within the coast than West-East in figure 3 than figure 2.

The fourth figure consists of four periodic movements in which the periodic movement is in both directions simultaneously. All four figures (left and right, upper and lower) show significant patterning. The upper results are simple single combinations of the South-North and West-East periodic motions. For these upper pictures, the previously heavy activity at the interior mouth of the coast has now moved further north and is actually in front of the coastal mouth. There is less activity at the entrance. In fact, the circular patterning moves further south. In the middle of the upper left figure there are three circular patterns in the middle of the coastal area. The lower figures both left and right are the result of both South–North and West-East movements created recursively. By recursive of course what is meant is that the function is self defined which results in a repetition in a self similar way. An easily understood example is the “old fashioned” barber shop or some more modern elevators that have mirrors on opposite walls. So as one looks into one mirror ones sees the reflection of the other one and vice versa going on to infinity. This is a recursive function. Figure 4 lower shows the coast with both South-North and West-East periodic movements combined and defined so that they would be recursive. The result is that the interaction is moved far more into the interior of the coastal area[6]. The linear entry (lower left) is far more patterned than the bipolar entry (lower right). In short, both the single combinations and the recursive combinations changes the locus of the first interactions (outside the mouth and into the center of the coastal area.)

Figure 5 shows the distributions of the results of the periodic motions if the motions are nested and are self-reifying…i.e. they are fractals (Zubrow 2007). The four images are left upper and right upper are South –North oscillating motions based upon fractals while the left and right lower are West-East oscillating movements. The entrance of the coast is where the motions begin again for all four sub-figures. The entrance of the left upper coast has nine circular activity areas if you count the partial ones on the sides of the coast. There is also a pattern in the center of the coast that consists of three nested elongated ellipses whose axis is West-East. The bipolar entry (right upper) continues to be less patterned and bilaterally symmetrical around the South – North axis. It also does not completely utilize the entire depth of the coast –stopping all motion about 2/3 of the way into the coastal area. The lower figures, West-East motion, are generally similar to their South-North counterparts. However, a difference is noted. In figure 5 the right

[6] By which is meant that the activity is closer to the coastline itself.

lower shows more use of the closer parts to the coast and in comparison to the line of circular activity areas at the interior entrance to the coat, there are two distinct circular areas in the north central part of the coast in the right lower picture and there is a far greater concentration of motions at the interior front of the coast and in the center than in any of the other diagrams.

Figure 6 shows the result of extending the coastal area –i.e. making much longer coasts. In addition, the periodic motions are extended to reflect the larger size. The upper left shows a pattern that is familiar. There is concentration in the entrance, six plus activity circles and then in the center and depth of the coastal area three nested circular activity areas. In the upper right, the three nested circular activity areas have extended to take up almost the entire coast.

However, what is far more surprising takes place in the lower figures where the West-East periodic motions are taking place. In these cases both left and right lower all the activity is taking place in the part area closest to the coast.   On the left with the linear entrance it is very patterned while the right is less patterned but does have three small circular activity areas in the part of the area closest to the coast.

Figure 7 has in the upper diagrams two simultaneous motions at the same time. On the upper left there are two South-North oscillating motions, on the upper right there are two West-East motions. Considerable activity for each of these takes place in front of the coasts -more than in any previous diagram. On the upper left there really is not any patterns in the same sense as we have seen before while the one on the right has a clear complicated pattern. There appear to be a triangle of two circular activity areas and one slightly more rectangular one closer to the coast itself.

In the lower diagrams the left lower or South-North and West-East recursive function of oscillating motion shows even more activity before the interior mouth of the coast. There does not seem to be much patterning. In the final diagram, where there is a recursive oscillating South-North and West East function, all the activity takes place right near the apex of the coast. There are three activity areas.

The simulation shows that in general that linear entry creates more patterned interaction than the bipolar entry. South-North motions generally are more patterned than West-East motions. There are generally more changes in the amount of coastal area used within the coastal areas in West-East movements than South-North. The combination of West-East and South-North movements whether with or without recursion change the amount of coastal area used both inside and outside the coastal area significantly as does extending the walls or changing the shape. Changing the motion to a fractally based motion does not have a significant impact.

Conclusions

This paper has reviewed both the history and present use of "spatial analysis" and then its use in archaeology. It has introduced the rapidly developing field of "spatial constraint theory" and suggested some uses in archaeology. In particular, it has argued for spatial constraint theory's relevancy to understanding prehistoric use and adaptation to coastal areas. A simulation study use different types of a) entry into areas, b) directions of periodic oscillating motions (South-

North, East-West, and in combination, c) different shaped coasts, and d) different types of oscillating periodic motions based upon simple, extended, fractal, and recursive functions was undertaken. The simulation shows significant differences in patterning caused by type of entry and increased patterning in interactions created by periodic movements that are vertical to the coastal mouth (South-North). Oscillating periodic movements that are horizontal to the coastal mouth (West-East) vary the amount of coast use both inside and outside the front of the coast as does oscillating movements resulting from the combination of directions without or with recursion.

Obviously, spatial constraint need not be derived only from physical or environmental factors. Ritual frequently requires constrained periodic spatial movement. For example, one might think about people attending a Christian Church and each leaving their seat and moving forward to receive Communion and Holy Sacrament. One could use spatial constraint theory to see what primary and ancillary interactions are possible. This could be done with other ethnographically more relevant examples. I also believe that one might be able to look at the distribution pattern of the artifacts and the coastal boundaries and probably infer backwards to the spatial constraints. Both of these however raise a series of theoretical and methodological problems that cannot be dealt within this relatively short chapter.

If nothing else, this chapter shows that to understand the distribution of settlements and artifacts within and around coasts, the constraint of human movement by the shape of the coast will need to be understood. The use of “spatial constraint theory” should help.

Figures:

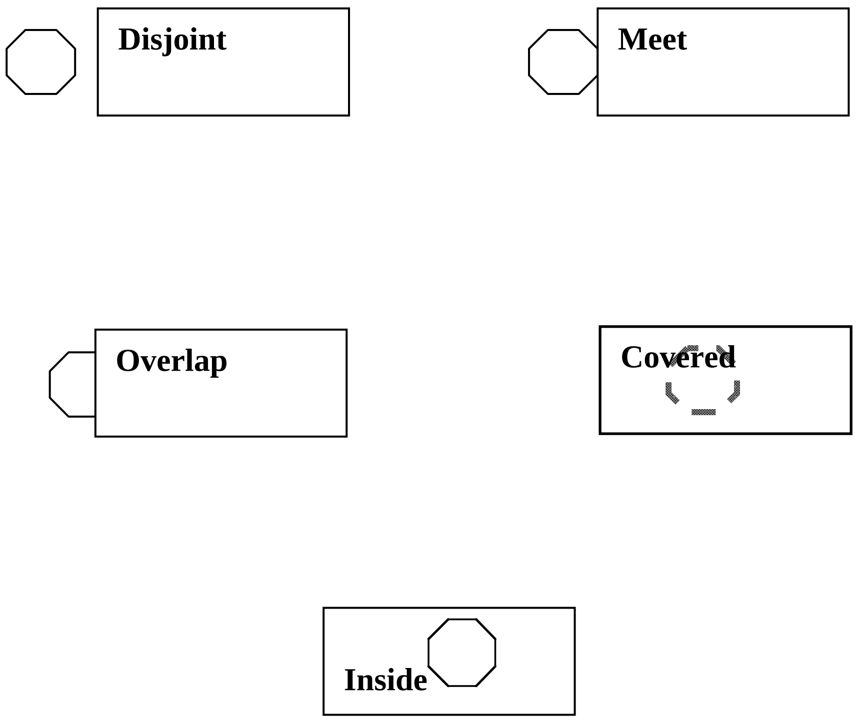

Figure 1. Spatial relationships redrawn from Frank.

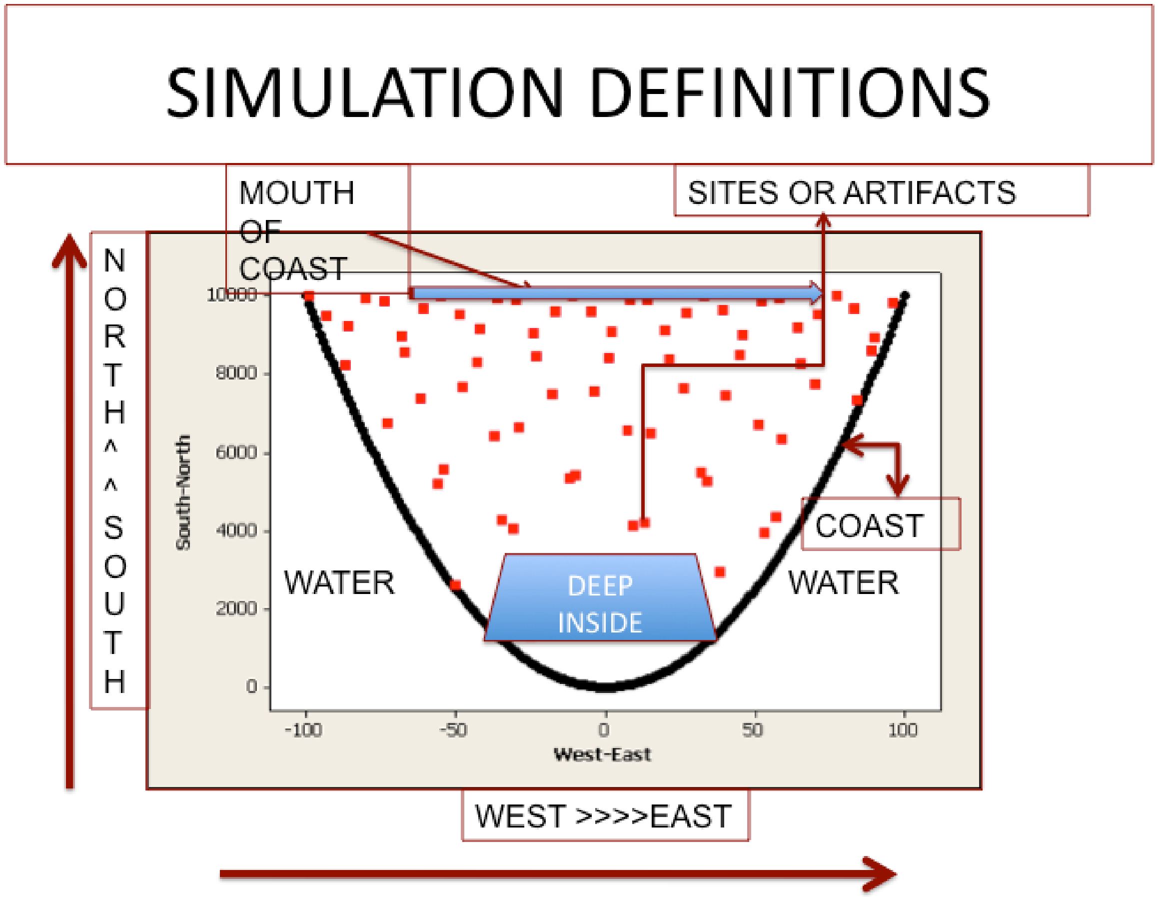

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Figure 2a: Layout of the Simulation Results

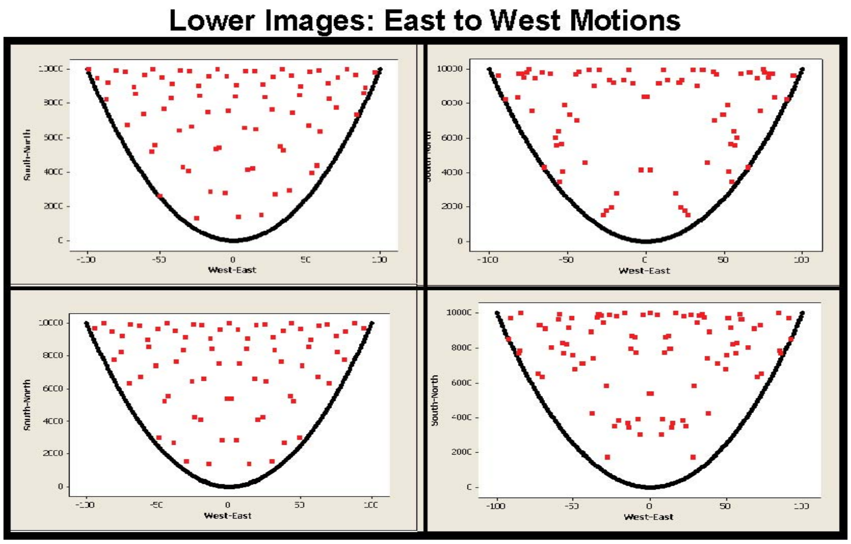

Figure 2b Four Simple Periodic Movement Patterns Spatially Constrained by Coasts: Upper Images: South to North Motions; Lower Images: East to West Motions

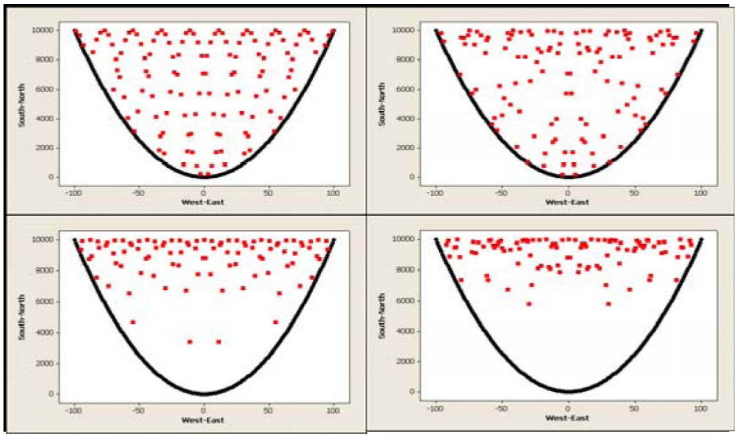

Figure 3. Four More Complicated Movement Patterns Spatially Constrained by Coasts: Upper South-North Motions Lower West- East Motions.

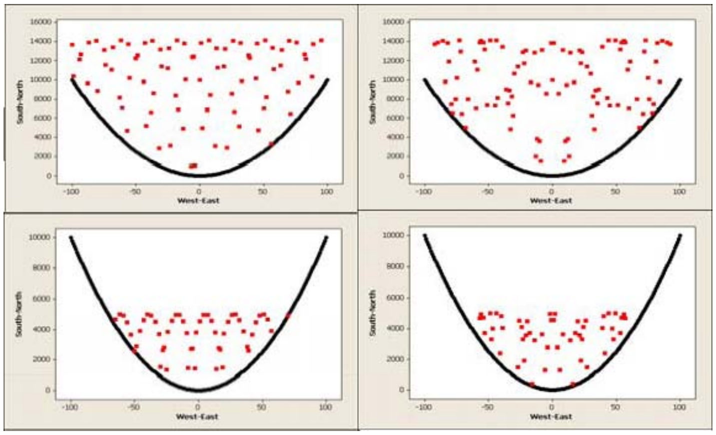

Figure 4. Four Periodic Movement Patterns Spatially Constrained by Coasts in Which both South-North and West-East Movements are Taking Place Simultaneously: Upper: Single Combination Motions, Lower: Recursive Combination Motions.

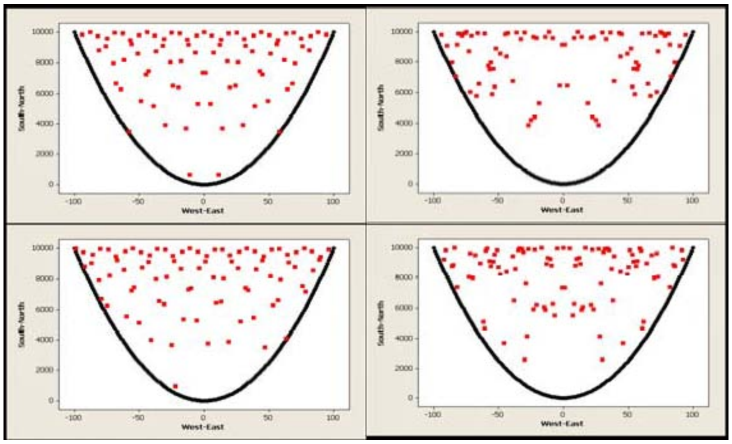

Figure 5. Four Periodic Movements Spatially Constrained by Coasts Based Upon Scalar Movement Patterning From Fractals: Upper South-North Motions: Lower West-East Motions

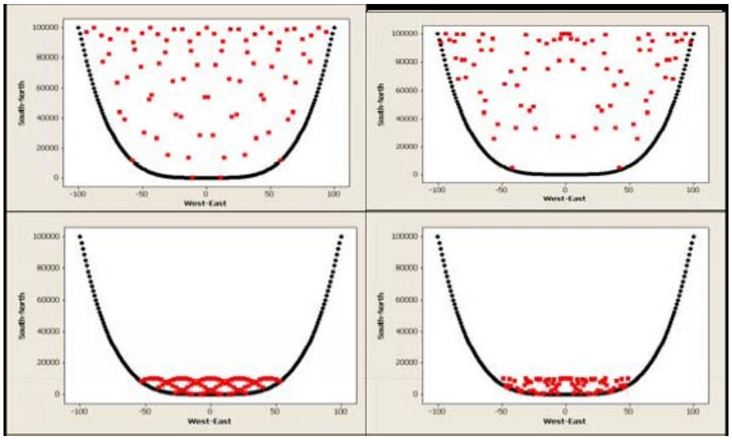

Figure 6. Four Periodic Movements for Extended Coasts with Multiple Movements Simultaneously: Upper: South-North Motions; Lower: West-East Motions

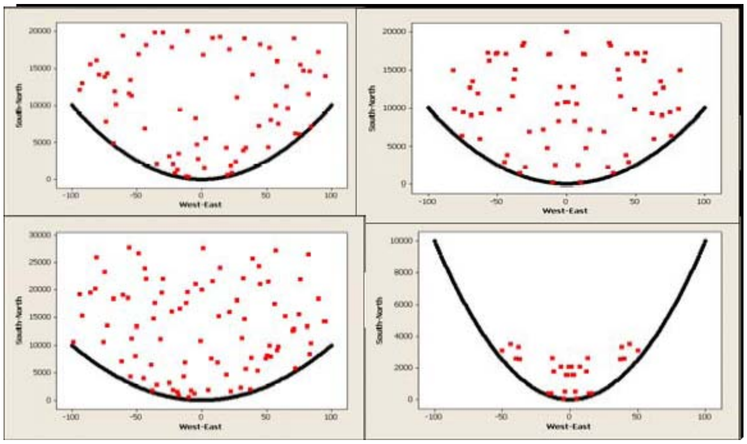

Figure 7. Four Periodic Movements for Extended Coasts Multiple Functions Simultaneously; Upper Left: Two South-North Motions; Upper Right: Two West-East Motions Lower Left: South-North and West-East Motions; Lower Right: South-North and West-East Recursive Motions

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