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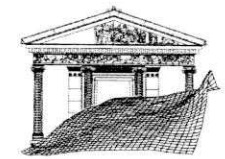

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Moving without destination. A theoretical, GIS-based determination of routes (optimal accumulation model of movement from a given origin)

Introduction

In many archaeological contexts, the analysis of movement is a very difficult task, since the identification of direct material evidence of ancient routes is not always possible. The use of GIS tools has introduced new approaches, and a good number of experiences are already available (for example, Harris 2000). In this short text we will present a methodological proposal to analyse the possible influence of routes and paths in the location of archaeological settlements, from the basis of cost maps.

The general aim here is to explore to what extent communication (understood as actual nearness, as accessibility) is an ultimate criterion for locational decisions. Our aim is not simply to explore direct relations between archaeological settlements in terms of cost, but to analyse the proximity between archaeological sites and optimal areas to conduct movement[1] (in terms of cost).

Methodology

Our proposal consists of representing the accessibility to the territory from a given departure point but without any particular destination, from a determination of optimal routes to guide movement. That is to say: given a starting point in an area, such as a settlement, to determine in which directions and through which points movement would be easiest. The proposal tries to complement both the determination of "natural pathways" (determined after friction surfaces, Bellavia 2002) and the calculation of "optimal pathways", with a determined origin and destination.

The main problem with the calculation of natural pathways is their tendency to different forms of environmental determinism, as long as neither an origin nor destination are defined, understood as socially conditioned geographical positions. In the case of the optimal routes between two points, quite the contrary happens: the optimal routes are conditioned by both the origin and destination points, that are assumed *a priori* to be necessarily connected.

[1] This work has been developed as part of the research projects "Autopista ao Pasado: Investigación e Protección do Patrimonio Arqueolóxico nun Proxecto de Obra Pública (ACEGA D+I)", PGIDIT04CCP606003PR Plan Galego de I+D 2002-2005 and "Da Protohistoria á Romanización: interacción cultural e dinámica do territorio no Norte da Provincia de Pontevedra" PGIDIT05PXIA23601PR Plan Galego de I+D 2002-2005.

What we are proposing here is not an alternative to those procedures, but an additional one aimed at estimating the setting of optimal routes from a number of given origins (typically, settlement sites), independently taken and disregarding neither specific destinations nor the position of the remaining points. This means that, given a set of settlement sites in an area, we should be able to analyse the relation between their locations and the optimal routes leading from each one of them, in order to explore to what extent those routes are channelling movement to specific points or directions or to what degree they connect sites. We must make it clear that we will not deal with questions concerning the calculation of cost surfaces, a question which has been widely discussed up to now (for instance, Van Leusen forthcoming) and certainly will be in the future. That is not one of the goals of this text, and our proposal will start with cost surfaces previously determined for every settlement, since the criteria employed to do it is now irrelevant.

The proposed methodology can be applied through different GIS systems. What is needed is only the ability to calculate cost maps and flow accumulation models. We have employed ArcGIS 9, so some technical specifications included will be referred to this software.

A flow direction model (Flow direction command-line in ArcGIS) represents the theoretical direction of the accumulation, and is usually employed to determine hydrological models after an aspect map previously calculated from a DEM. However, we will use it in a different way here. To calculate flow direction we will use, as the input surface, a cost map instead of an aspect. In this way, we will drive the cells with a higher cost value towards those with a lower one. For example (Fig. 1), after determining the cost map for a position (archaeological site) on the top of a steep sloped ridge, lowest value cells will be those on the top of the ridge, where slope values are lower[2].

After the cost map we can calculate the flow direction for every cell, so that cells with higher cost values are oriented towards those with lower values. This way, the cells at the slopes (higher cost values) will flow to the cells on the top of the ridge (lower cost values); in their turn, cells on the ridge watershed will flow to the point of origin, since distance is always a primary cost factor (the lower the distance, the lower the cost).

The MADO model

Once set, we will use the flow direction model to calculate what we have designated MADO (Spanish acronym for Modelo de Acumulación del Desplazamiento Óptimo desde un origen, "Optimal accumulation model of movement from a given origin"). The procedure consists simply in the use of an algorithm to calculate accumulation areas (such as Flow Accumulation in ArcGIS), typically used to determine hydrological models; we will use the previously calculated flow direction map as the input image. To follow the example, MADO will have higher values on the top of the ridge than at the slopes, and cell values will also increase as we approach the origin site along the top of the ridge.

[2] Assuming, in this concrete example, that topography is the only friction factor.

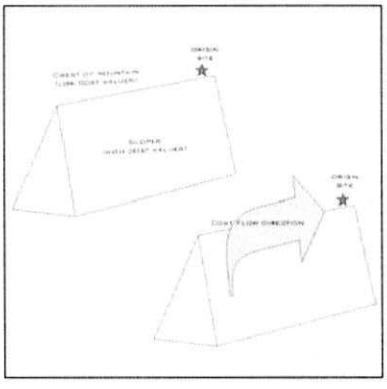

Fig. 1 – Flow direction for a single settlement (star) calculated from a cost surface.

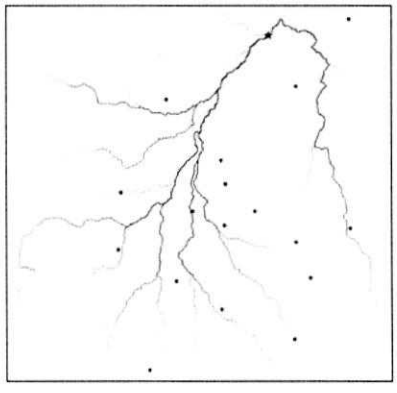

Fig. 2 – MADO. Flow accumulation calculated from a flow direction (the star represents the origin site).

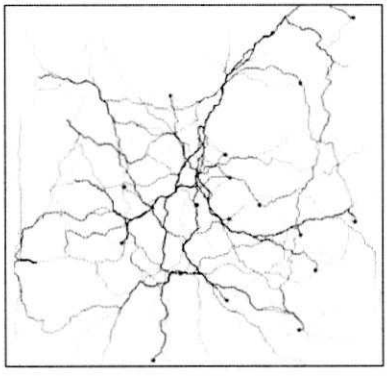

Fig. 3 – Sum of MADO calculated from every single settlement (dots) in the map.

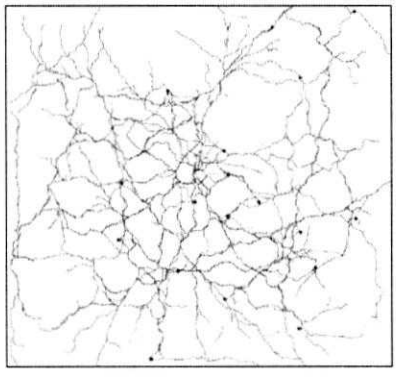

Fig. 4 – Boolean reclassification of Fig. 3.

MADO can be briefly defined as the representation of an accumulation model of lowest cost movement calculated from a given origin and without specific destination points (Figs. 2-4). Once calculated, the resulting image can be reclassified in order to remove low values (non relevant points) and to extract a new image where the highest value cells will indicate areas of potential routes. Despite the apparent complexity, MADO can be useful for different questions. Since destination points are not taken into account for the calculation, and given a suite of settlement sites in an area, this can be a good way to analyze the arrangement of optimal routes starting from every individual site and exploring to what extent these routes are linking settlements into a pathway network. It can also be useful to compare the reliance of "optimal pathways" between two previously defined points.

An interesting experiment is to calculate MADO for every individual site in a given series, to obtain a full range of values that represent the best or worse cability for movement of every position. Since that calculation is based on a flow

algorithm, the result will always be a sort of trend, track map. If we determine isochronal lines from every site, we will be able to establish their vicinity to those "flow tracks" in terms not of linear distance but of actual accessibility. This could be compared to the results of a typical analysis of optimal routes calculated from a previous setting of both an origin and a destination points.

Although MADO clearly has applications for analysing accessibility, it also poses some problems. As we move away (in terms of cost) from the starting point, absolute cell values decrease, since they are not only depending on friction. That makes it difficult to set a general-purpose translation of MADO values into a hierarchy of optimal routes. This problem does not have a straight forward solution, although we can suggest two possibilities. The first one is very simple: to sum up all the MADO for a given series of settlements of a same area. In that way, cells closer to every starting point (settlement) will retain higher values, but values will tend to get balanced between all sites.

The second possibility consists of performing a Boolean classification of a MADO, in order to remove (set to 0) all low values, while considering as valid (set to 1) high values, in order to get a non-hierarchical route network. The problem here is how to define a threshold to set out low and high values. Since MADO values depend to a great extent on the number of cells of the DEM, it is not possible to set a general reference value, as it will always depend on a combination of the extent of the area and the resolution of the DEM. However, it will always be possible to find significant relations between MADO values and actual route networks (either present or historical), so an approach is possible to the relation between the "value" of movement and its materialization (providing that our interest is to explore the processes of formation of tracks).

Conclusions

In any case, it is quite wrong to present the problem in terms of setting significant reference values from a qualitative (absolute, general) point of view. That is why we will focus on the determination of a threshold between low and high values from a specific (and simple) statistical analysis of every single MADO. A MADO image will consist of a huge range of values, with a very uneven distribution, the majority being in the low part. Having that in mind, the first statistical indicator can be the use of the mean value as a reference threshold. In that way, we will get a network which is still complex but manageable. A further refinement will come from the use of the standard deviation, which will complement the representativeness of the mean.

Once calculated the single MADO for a number of points (settlements) in an area, and reclassified into Boolean images, we will be able to sum all up and to get a hierarchical map of routes for the area. Higher values will represent those points where more routes converge, and subsequently could be interpreted as highly probable locations for tracks or paths with regard to the points used as nodes for calculation.

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